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16. Abstract

Electronic vehicle identification (EVI) is already an important component of electronic toll collection. Universal EVI would provide the opportunity for transportation agencies to introduce ITS features such as in-vehicle information systems. In this project three areas were researched: (1) Current and promising technologies for vehicle identification, especially those already being deployed for toll collection, (2) Incorporation of national and state standards, legislative initiatives, and public response into TxDOT planning, and (3) Costs, benefits and implementation requirements for EVI.

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ELECTRONIC VEHICLE IDENTIFICATION: APPLICATIONS AND IMPLEMENTATION CONSIDERATIONS

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Products

Information from Products 3 and 4 have been incorporated into this final report. Chapter 5 contains material from Product 3, while material from Product 4 can be found within chapter 6.

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ABSTRACT

As road pricing begins to supplant the gas tax as a mechanism for funding the U.S. transportation system, the need for electronic vehicle identification (EVI) is increasing. EVI is already an important component of electronic toll collection, the preferred practice among toll authorities in the U.S. and internationally. In addition, a host of potential applications in Intelligent Transportation Systems (ITS) will depend on EVI. Universal EVI would provide the opportunity for transportation agencies to introduce ITS features such as vehicle-roadside communication and in-vehicle information systems. Motivated by these considerations, the Texas Department of Transportation (TxDOT) requested the Center for Transportation Research (CTR) to evaluate EVI technologies and to examine the requirements for implementation. In this project three areas were researched:

1. Technology: Current and promising technologies for vehicle identification, especially those already being deployed for toll collection.
2. Organization: Incorporation of national and state standards, legislative initiatives, and public response into TxDOT planning.
3. Implementation: Costs, benefits, and implementation requirements for EVI.

In synthesizing the interactions of these three areas, CTR also developed a timeline of technological opportunities, and outlined a business model for implementing EVI.

CHAPTER 1: INTRODUCTION

1.1 Scope

TxDOT Needs: As road pricing begins to supplant the gas tax as a mechanism for funding the U.S. transportation system, the need for electronic vehicle identification (EVI) is increasing. EVI is already an important component of electronic toll collection (ETC), the preferred practice among toll authorities in the U.S. and internationally. In ETC systems, account holder vehicles generally carry an electronic tag, thereby automating the recognition and billing process. However, non-account vehicles create complications: they must stop and pay cash, or, failing to do so, their license plate is photographed and read, then the owner is identified and billed. Besides slowing down traffic, non-automated tolling is relatively expensive, and erroneous billings are possible.

Fitting every vehicle with an electronically readable identifier, such as in the vehicle registration tag, would significantly improve the efficiency of both tolling and Intelligent Transportation Systems (ITS). A host of potential ITS applications in transportation system management depend on being able to detect when and where vehicles are in the network. Universal EVI would provide the opportunity for transportation agencies to introduce ITS features such as vehicle-roadside communication and in-vehicle information systems. Motivated by these considerations, the Texas Department of Transportation (TxDOT) requested the Center for Transportation Research (CTR) to evaluate technologies for EVI and to examine the requirements for implementation.

Research Areas: For this project CTR conducted research in three areas:

4. Technology: Current and promising technologies for vehicle identification and registration, especially those already being deployed for toll collection.
5. Organization: Incorporation of national and state standards, legislative initiatives, and public response into TxDOT planning.
6. Implementation: Costs, benefits, and implementation requirements for EVI.

In addition, in order to synthesize the interaction of these three strands CTR developed a matrix timeline of technological opportunities, and outlined a business model for implementing EVI.

1.2 Research Approach

Requirements: The research problem statement prepared by TxDOT addressed the concerns of two of its headquarter Divisions: the Texas Turnpike Authority Division (TTA)'s plans for future toll collection, and the Vehicle Title and Registration Division (VTR)'s options for vehicle registration and database sharing. Therefore, CTR's research plan attempted to meet both of these strategic needs. As shown in Table 1.1, CTR developed a set of research requirements based on TxDOT needs, and identified appropriate research products to inform policy-making within TxDOT.

Table 1.1: TxDOT Needs and Research Requirements

TxDOT needs	*Research requirements*	*Desired products*
1. Tolling technology, 1-5 years, 6-10, 10+ years 2. Standards and practices driving Texas decisions	Synthesize state of the art in toll collection, standards, and ITS integration	P1. Best practices in toll collection
	Develop a tolling technology matrix timeline	
3. Functional requirements and expectations of ETC 4. Advantages/ disadvantages of different systems 5. Reliability 6. Performance measures	Analyze performance and expectations of toll collection technologies • Accuracy, cost, etc. • Support requirements • Commercial uses • ITS functions	P2. Analysis of toll collection systems
7. Feasibility of EVI 8. Obstacles 9. Cost	Analyze requirements for EVI • VTR needs • Database sharing	P3. Cost and return on investment
	Analyze economics of EVI • Costs and benefits	
10. Acceptability by public 11. Timeline 12. Long-term best value	Outline a policy on driver data collection and sharing • Enabling legislation	P4. Implementation plan for EVI
	Develop outline business model and recommendations	

1.3 Research Tasks

Nine research tasks were completed in this project. Each task had defined objectives and outputs, which fed into subsequent tasks in a critical-path fashion. The tasks are described below.

Task 1. Leverage industry resources

The objective of this task was to establish a direct link between this research and active practitioners in the toll-road industry and the ITS arena. A panel of experts was established to provide industry expertise. Members included executives from TransCore, Zachry Corp., and DMJM Harris, who all donated their time to this effort. The panel gave CTR access to a broad range of experience, technical expertise, standards and specifications, committees, task forces, and decisions, which in turn provided valuable data to TxDOT. The output of this task was perspective and insight on national and international tolling and ITS developments that guided the entire research effort.

Task 2. Synthesize state of the art in toll collection

The objective of this task was to develop a synthesis of tolling developments in the U.S. and internationally, interoperability, overarching standards, national ITS architecture, and national and state implementation activities. Over 100 documents (see References and Bibliography) on the subjects of tolling and ITS were reviewed. Utilizing contacts provided by the expert panel, CTR obtained information from individuals and groups, e.g., IBTTA, ITS-A, AAMVA, etc., with special knowledge of operating and emerging systems. The results provided an up-to-date status on plans, initiatives and best practices to integrate toll collection with other ITS activities, including vehicle registration, both nationally and internationally. The output of this task was Research Product P1, a synthesis of best practices in toll collection, and a set of early recommendations.

Task 3. Develop a tolling technology matrix timeline
The objective of this task was to integrate technological developments with TTA and VTR plans. Utilizing the expertise of the TxDOT project panel, CTR conducted a situation review of TTA and VTR technology plans. The results of Task 2 also fed into this task. In addition, CTR recognized that the promulgation of standards such as DSRC will influence technology development, while legislation will affect technology penetration. CTR therefore conducted an analysis of trends over the next 5, 10, and 15 year windows, examining technology, standards, ITS integration, legislation, and TxDOT plans. Expectations of future technologies were also assessed, such as prospects for Global Positioning systems (GPS), Global Navigation Satellite Systems (GNSS), and automated vehicle systems. All of these results were integrated in a matrix timeline of technology development to illustrate the interactions of the above factors in 5-year time increments through 2020, and thus graphically portray the forces driving Texas decision making over that period. These results were submitted as part of 0-5217 Product P2.

Task 4. Analyze performance and expectations of toll collection technologies
The objective of this task was to provide a comprehensive analysis of toll collection technologies, including strengths and weaknesses, performance measures and standards, downstream uses, and potential ITS functions. CTR collected and analyzed published data and standard measures of the performance, accuracy and cost of ETC technologies. This analysis included an assessment of the advantages, disadvantages, and support requirements for various technologies. Task 2 fed into this task. These results were submitted as part of 0-5217 Product P2. In addition, CTR compiled an opportunity review, examining potential uses of tolling technology and data collection/sharing capabilities. Downstream commercial uses and support of ITS functions were the two main areas of focus. The potential for toll tags for EVI was a major component of this analysis. The end result of this task was a ranking of technologies based on assessment of their potentials, and recommendations for the most promising opportunities. These results fed into Task 5.

Task 5. Analyze organizational requirements for electronic vehicle registration
The objective of this task is to analyze VTR operations and the potential for an electronic vehicle registration device. Through interviews with VTR staff CTR conducted a systems analysis of VTR needs and concerns. CTR also interviewed key personnel in other

agencies interacting with VTR to evaluate their concerns. The feasibility of database sharing was also considered. Through interviews with VTR and other consultants CTR analyzed opportunities for connections between tolling databases and VTR databases, and for improvements. During this exercise VTR hired a consultant to manage its database update efforts. CTR therefore provided its recommendations to the VTR panel overseeing the consultant's work.

Task 6. Conduct a cost/benefit analysis of EVI

The objective of this task was to analyze the economics of EVI. The results of Task 5 fed into this task. CTR collected data on costs, including deployment of roadside readers and enforcement systems. Similarly, potential benefits of vehicle identification for traffic management were factored in. The result was a statement of costs and benefits of EVI under various deployment scenarios, which was submitted in 0-5217 Product P3.

Task 7. Review legislative needs and policy on driver data collection and sharing

The objective of this task was to outline a policy on collection of driver data via electronic tags. The results of Task 5 fed into this task. In order to advance EVI, three planks were identified as necessary: legislation, policy, and public acceptance. CTR conducted a review of legislation, specifically what information can be collected, and permissible use. CTR outlined a policy to address concerns over privacy with regard to what data is collected, what uses they may be put to, and who will have access. The output of this task was a draft policy on EVI data, which was included in Research Product P4.

Task 8. Develop outline business model and recommendations

The objective of this task was to develop an outline business model for EVI. CTR developed scenarios for implementation of EVI. Because of the cost, deployment scenarios were considered in relation to TxDOT long-term policy on transportation system management and tolling. Other considerations included violation enforcement and potential public backlash. Benefits of EVI and opportunities for privatization were also considered. All of these analyses formed the basis of an outline business plan and recommendations for implementation of EVI, which were included in 0-5217 Product P4.

Task 9. Prepare research reports and products

This task covered the preparation of all research products and reports. The four research products generated in this project are:

1. 5217-P1 *Toll Collection Technology and Best Practices*. May 2006.

2. 5217-P2 *Electronic Vehicle Identification: Industry Standards, Performance, and Privacy Issues.* August 2006.

3. 5217-P3 *Electronic Vehicle Identification: Benefit and Cost Analysis.* May 2007.

4. 5217-P4 *Electronic Vehicle Identification: Outline Model for Implementation.* August 2007.

Based on all information acquired during the course of the project, this final technical report was prepared, documenting all results from Tasks 1 through 8. This final report also includes appropriate excerpts from project products, which will guide TxDOT with regard to implementing EVI. Key research results and recommendations are also documented in a separate, brief summary report.

1.4 Report Outline

This chapter covered the scope of the research and a summary of the work that was performed. Chapter 2 presents a discussion of tolling technologies and best practices, and an assessment of trends in tolling technology. Chapter 3 provides a review of the standards for ETC technologies, and the linkage between EVI and ITS. Chapter 4 examines the potential for introducing EVI through the vehicle registration process, and the legal issues of EVI. Chapter 5 discusses the costs and benefits of EVI under different implementation scenarios. Chapter 6 outlines a policy on EVI data and business models for implementation. Chapter 7 provides a summary of findings, conclusions, and recommendations. Appendix A is a discussion of possible EVI funding opportunities.

CHAPTER 2: TOLLING TECHNOLOGY AND BEST PRACTICES

2.1 Introduction

Tolling as a method of financing major transportation system expansion and enhancement is becoming more common in the United States. However, neither the traveling public nor transportation agencies want vehicles to stop or slow down to pay at a toll facility. To this end, several technologies, collectively called Electronic Toll Collection (ETC), have been developed in the last 15 years, allowing drivers to move in and out of toll systems without delay. Open Road Tolling (ORT), with toll collection fully automated, is now the preferred practice, being more efficient, environmentally friendly, and safer than manual toll collection.

In this chapter, tolling technologies and practices are discussed. Ultimately, vehicle identification/registration systems used in tolling have the potential to go beyond that function to include other desirable transportation system management functions. Therefore, likely developments and enhancements are reviewed, along with potential tie-ins to other Intelligent Transportation Systems (ITS) deployments.

2.2 Evolution of Tolling

In this section the rationale for tolling is presented, followed by a perspective on stages in the evolution of tolling.

2.2.1 Objectives of Tolling

There are three main reasons why tolling, or road pricing, is implemented (Wikipedia: Road Pricing, 2006):

- *Finance/Revenue Generation*: To recoup the costs of building, operating and maintaining the facility. Road pricing is becoming a more appealing means of funding transportation, because revenues from federal and state gas taxes have not kept up with growth in demand for infrastructure. Moreover, toll financing allows projects to be built sooner instead of waiting for tax revenues to accumulate.
- *Demand Management*: To moderate the growth in demand on the transportation system, and to encourage more use of public transportation and carpooling. For example, vehicles are charged to enter inner London, England, as a way of regulating the demand in the region.
- *Congestion Management*: To place a price on limited roadway space in proportion to demand. In this application the toll increases with the level of congestion. In the absence of such pricing, drivers do not appreciate the costs they impose on others as a result of the congestion they cause.

2.2.2 Stages of Tolling

Direct payment for use of transportation routes is expected to become more pervasive over time. Four stages are envisioned as shown in Table 2.1, beginning with corridor tolling and cordon tolling, then area-wide or vehicle-miles-traveled (VMT) tolling, and ultimately an integrated system management strategy (Deloitte Research Public Sector Study, 2003). Each stage improves system efficiency over the previous one, but also has higher complexity. Each stage also requires certain conditions before implementation. Only the first two strategies, corridor tolling and cordon tolling, have been widely implemented, with ETC being a necessity to move to the next two stages. The third stage is now being pilot tested in a few areas, while the final stage, an integrated system, lies in the future.

Table 2.1: Stages of Tolling

Tolling strategy over time	**Objectives**	**Complexity / efficiency**	**Required conditions**
1. Corridor tolling	Repayment for facility	Low	Road must be exclusive to those who pay
2. Cordon tolling	Demand management	Medium	Public trust that benefits will outweigh costs
3.Area-mileage tolling	Revenue generation	High	Uniformity/interoperability
4. Integrated system management	Demand/ congestion management	Very high	Flexibility across modes; access to information

- *Corridor Tolling*: This is the most common form of tolling, in which a driver pays a fee to use a specific stretch of roadway or bridge. Included in this category are High Occupancy Toll (HOT) lanes, lanes designated for multi-passengers but which single-occupant vehicles can use if they pay a toll. The primary objective of the toll is to repay the cost of building and operating the facility. Complexity can be as low as having the driver stop and pay cash on entry or exit, although most systems are implementing ETC. However, the corridor is likely to be underused compared to alternative non-tolled routes and may not relieve congestion in a region. The road must be exclusive to those who pay, otherwise users do not feel compelled to pay and the program may not earn adequate revenue.
- *Cordon Tolling*: This is a charge for entering a specific area. The primary objective is to control the number of vehicles entering. Every entry point must be equipped with means of identifying vehicles and ensuring that they pay, have paid, or will pay. To be an effective strategy, the public must be convinced that benefits (improved mobility, lower pollution, etc.) will be realized fairly quickly. An efficient public transportation system across the cordon is essential for this strategy to be effective.

- *Area-wide Mileage Tolling*: This is a mechanism whereby vehicles are charged based on VMT—a road user fee. An example of this system is the German truck toll, in which all trucks are required to pay tolls based on the distance traveled inside Germany. In some respects this strategy is analogous to the U.S. gas tax, in that, theoretically, each vehicle pays based on miles driven. The primary objective is to generate revenue for the transportation system and, to a lesser degree, to regulate the amount of driving. The complexity of distance-based tolling is relatively high and requires uniform application area-wide, as well as interoperability across borders.
- *Integrated System Management*: In this visionary concept, the demand for transportation would be managed through information: users would have a choice of modes and routes and an array of ways to pay for a trip. The charge would incentivize the most efficient mode choice and the market would drive the provision of capacity. Highly complex systems, such as roadside-vehicle-traveler communications would be needed, but system usage would be highly efficient. Required conditions include market flexibility and access to information.

2.3 State of Practice in Tolling

The majority of toll transactions are now electronic. For example, Dallas' North Texas Turnpike Authority (NTTA) collects about 68% of its 780,000 daily toll transactions from 640,000 toll tag accounts. 54% of Houston's Harris County Toll Road Authority (HCTRA) daily 800,000 toll transactions come from some 1.3 million EZ-TAG accounts.

2.3.1 Overview of Current Practice

Electronic Tolling: Electronic Toll Collection (ETC) has two hardware components: a radio frequency identification (RFID) transponder (tag) on the vehicle, and a reader mounted on a gantry (Figure 2.1). Each tag has a pre-programmed ID, and returns a unique signal when queried by a radio beam from the reader. In addition to the roadside-vehicle interaction, "back office operations," i.e., systems that process data and manage accounts, are a critical component of ETC. RFID was developed by the U.S. military to identify friendly craft and to track supplies, and was commercialized by Amtech in the 1980's, starting with tags on Class I rail equipment. In 1989 Amtech undertook to install a complete ETC system for NTTA, assuming all the risks of that deployment.

Figure 2.1: Toll Tag Reader

Video Tolling: Non-tag holders can be tolled using automatic vehicle identification (AVI). License Plate Identification/Recognition (LPI/R) software with Optical Character Recognition (OCR) is used to "read" license plates and thus bill vehicle owners (video-tolling or V-tolling). OCR was originally developed to read targets for air-to-ground missiles. V-tolling has significantly higher costs per transaction than transponder tolling: $2.25 per transaction vs. 10-20 cents (Opiola, 2004), and the potential for misreads. Universal EVI would make V-tolling unnecessary.

No Cash Lanes: Newer toll roads are being built without manual toll collection lanes. For example, the new 407ETR in Ontario, Canada, is 100% ETC. The 407ETR is owned by Cintra, the company selected by TxDOT to develop the first phase of the Trans Texas Corridor. However, about 20% of the transactions on 407ETR are V-tolled using Cintra's own AVI program. The company claims over 99% accuracy in electronic tag reads and about 90% accuracy in camera reads (Bejar, 2002). Cintra's database of license plates includes adjacent U.S. states, allowing billings to visitors as well as locals.

Open Road Tolling (ORT): Existing toll systems are eliminating toll booths in favor of full ETC systems or open road tolling at highway speed. In 1998, HCTRA retrofitted its 9 mainline toll plazas for ORT. Westpark Tollway in Houston is fully ORT. ORT allows more entry/exit points on a toll facility and maximizes benefits to drivers, but it can also be plagued by violators. Enforcement of truck weight limits is also a concern.

2.3.2 Tolling Technologies

In this section, technologies that are being deployed to support ETC are discussed in more detail. Electronic toll collection requires two components in order to complete a transaction: vehicle identification and billing. The latter function is mainly a database exercise, in which the vehicle ID is tied to its owner via a database of account holders or through vehicle registration records. Vehicle identification is the more complex component of electronic tolling.

Vehicle Recognition/Classification: Vehicle identification may be accomplished through in-road or overhead sensors, cameras, roadside/vehicle communication, or combinations of these. Where vehicles are charged differently according to class, vehicle classification is part of the process. Since multi-axle vehicles are typically charged higher toll rates than cars, vehicle classification is a requirement for ETC. Figure 2.2 illustrates some of the technologies used for electronic vehicle recognition and classification.

In-road Sensors: Sensor systems may be subsurface, roadside or overhead. Inductive sensors embedded in the road surface can determine the presence of a vehicle. For example, Westpark Tollway, HCTRA's newest section, has inductive loops embedded in the zone between gantries to collect information on vehicle position, speed, classification, and delineation. Treadles register a count of the number of axles as a vehicle passes over them and, with offset-treadle installations, also detect dual-tire vehicles.

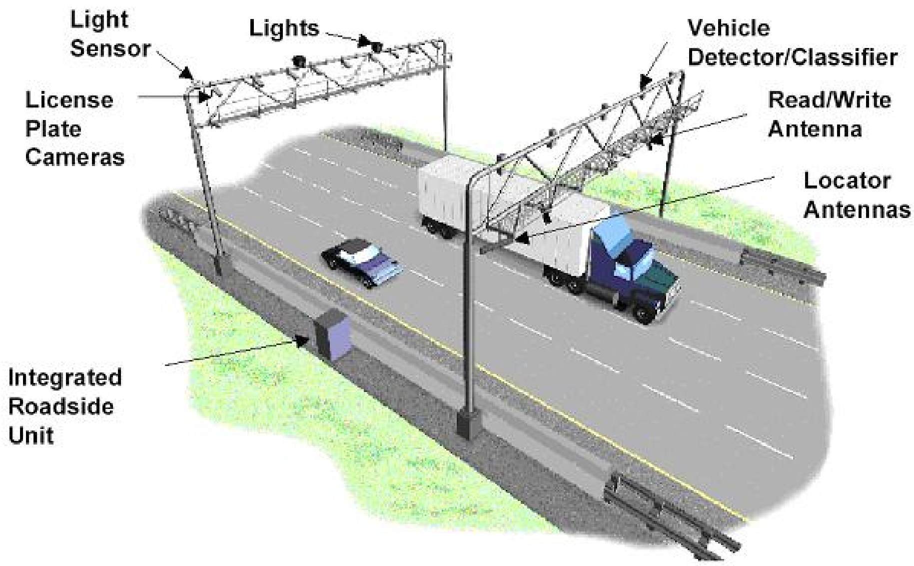

Figure 2.2: Electronic vehicle identification

One example of an in-road sensor system is Traffic Reporting and Control (TRAC), which combines state-of-the-art inductive loop detection with advanced signal processing (Smith, ITS Decision, 2002). The whole classification process takes 0.1 seconds. The TRAC system is packaged within a standard inductive loop detector, which:

- Identifies vehicles in twenty-three classes
- Accurately detects single-loop speeds
- Measures vehicle length and number of axles
- Provides point, toll segment, and toll regional view of traffic flow
- Provides web access to all data.

However, in-road sensors typically cannot recognize the identity of each vehicle for billing purposes.

Roadside Sensors: Roadside sensors include radar and laser profilers. Light-curtain laser profilers (Figure 2.3) record the shape of the vehicle, which can help distinguish trucks and trailers. Sensors can also detect gaps between vehicles to provide information on the number of vehicles crossing a location. Again, such sensors rarely are capable of identifying vehicles for billing.

Cameras: In addition to their widespread use in traffic monitoring, cameras are used for vehicle identification, typically as a means of enforcement. As a vehicle approaches the camera, a trigger is activated, resulting in a photograph being taken of the vehicle license plate. The plate is then electronically read through Optical Character Recognition, and the owner is found by searching vehicle registration records. This technique of license plate identification/recognition (LPI/R) has been gaining support because it registers visual evidence of violations, e.g., running a red light. LPI/R is also used as a backup system in tolling to bill non-account holders.

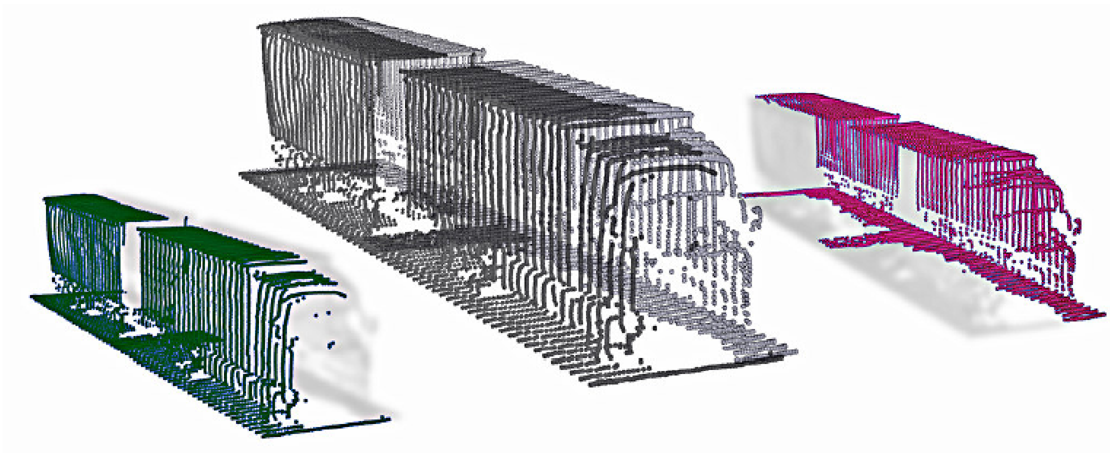

Figure 2.3 Light curtain laser profilers used in Germany (Vitronic brochure, 2004)

LPI/R manufacturers have touted additional uses for their technology other than for tolling. In commercial vehicle operations or secure-access control, a vehicle's license plate can be checked against a database of acceptable ones to determine whether a truck can bypass a weigh station or a vehicle can enter a restricted area. At international border crossings, license plates can be checked against a database of hot cars to locate stolen vehicles and plates or those registered to fugitives, criminals, or smuggling suspects. For example, the Mexican state of Jalisco recently instituted a vehicle sticker ID system with printed optical characters to help in identifying stolen vehicles.

LPI/R can be used to issue violations to speeders or simply to offer speeding drivers a reminder by displaying a plate number with the vehicle's speed on a variable messaging sign. It can facilitate emissions testing by recording a plate's alphanumeric sequence while automatically analyzing tailpipe effluents, or it can help identify and fine violators. LPI/R also can monitor the time it takes vehicles to travel from one point to another, keeping traffic management centers apprised of transit times along busy streets and highways.

An example of a video vehicle identification system is TollChecker, the automatic toll charging mechanism for trucks on German highways (Vitronic brochure, 2004).

- The TollChecker captures 3-dimensional data and reads license plates regardless of lane changes and the speed of the vehicle.
- The TollChecker identifies the class of the vehicles and ascertains whether each has to pay a toll, and whether each has paid the correct amount.
- All the data for trucks that have paid the toll or vehicles that are not required to pay the toll are deleted immediately.

- It works in conjunction with both global positioning systems (GPS) and Dedicated Short Range Communications (DSRC).

Key features of the TollChecker:

- Single gantry solution: set up requires only 15 minutes shut down of lane and no sensor loops are needed.
- Determination of weight/axle count/trailer detection: can measure accurate length, height, width, etc.
- Supports advanced enforcement such as online communication for special bookings.
- Safety:
    - Fully ORT compliable
    - No visible lighting to distract driver, even at night.
- International license plate recognition.
- Seamless integration with GPS and DSRC.

Despite its wide use, LPI/R has some shortcomings:

- Poor image resolution, usually because the plate is out of focus.
- Blurry images, particularly motion blur, most likely at higher vehicle speeds.
- Poor lighting and low contrast due to overexposure, reflection, shadows, or plate background color or style.
- An object obscuring (part of) the plate, quite often a tow bar, or dirt on the plate.
- A different font, as in out-of-state plates and vanity plates.
- Different plate styles, as in Federal vehicles.
- Circumvention techniques (such as reflective plates)
- The need to refer non-reads to a human, and the resultant extra cost.

Transponders: Transponders have become the most common form of vehicle identification. In this technology, a radio-frequency identification (RFID) chip is embedded in a unit ("tag") in the vehicle. As the tag passes under a gantry with a mounted transmitter, it responds to radio signals. Laser and infrared signals have also been tested but the radio frequency spectrum provides the greatest level of accuracy. However, some windshields coated with metal do not allow the electronic tag to be read. The percentage of cars with such windshields is very low and is thought to affect only about 0.5 percent of all vehicles. RFID has found applications in many industries, including tracking trucks and containers at ports, and in warehousing. Wal-Mart, the world's largest retailer, requires all its major suppliers to use tags to track their goods (Journal of Commerce, Jan. 2004).

Programmability: Electronic tags can be classified according to the degree to which they can be programmed (Smith, ITS Decision, 2002):

- Type I: The chip does not have any processing capabilities and the information on it is fixed (read only)—usually just a hard-wired identification number.
- Type II: These chips have an updateable area which can be used to encode information such as time and point of entry.
- Type III: These tags contain a microprocessor. They can be used to communicate such information as account balance, and driver and vehicle information to roadside or overhead sensors. Type III tags are also called "smart" tags.

The selection of tag type is important, especially if information must be written to it at highway speed. For example, write-back is used on the Florida Turnpike to record the entry point on the tag for toll computation at exit, but speed is restricted to less than 30 mph.

Power: Tags can also be classified by power source (Smith, ITS Decision, 2002):

- Passive: Passive RFID tags have no internal power supply. Incoming radio frequency signals are detected by the antennae, which power up the tag and transmit a response. Having no onboard power supply means that the tag can be very small, although the amount of data stored in them is also very small.
- Semi-Passive (or Semi-Active): these tags are similar to passive tags but have a battery which allows the tag to be constantly powered. Semi-passive tags respond faster and have a stronger reading than passive tags.
- Active: These tags may be connected to the vehicle power source. They are able to store more information and also receive and store additional information sent by roadside communications units. They also have a much greater range.

Passive (no-battery) tags have a lower cost and longer life, but require that the reader transmit energy. Many of the earlier transponders were active-type (with battery), and have now reached the end of their life. A thin printable battery is being offered for sticker tags (Precisia.com, July 2004). Such batteries could give tags LED display capabilities for expiration date, balances, and other uses.

2.3.3 ETC Deployment in the U.S.

ETC Initiatives: ETC is paving the way for deployment of Intelligent Transportation Systems (ITS) in the U.S. In 1996, the U.S. Department of Transportation (US DOT) outlined a vision to achieve a complete ITS infrastructure in the country's seventy-five largest metropolitan areas within 10 years. As of 2004, according to US DOT, sixty-two of seventy-five metropolitan areas had met the US DOT's goals for ITS deployment, largely by implementing ETC.

At the 2006 Transportation Research Board Annual Meeting, a major theme of discussion was ETC implementation and the interest shown by private firms. The ETC market is expected to experience double-digit growth in the next decade and increasingly, investors see infrastructure tolling as a business opportunity.

There have been several recent high profile infrastructure privatization initiatives:

- The $2 billion lease of the Toronto 407ETR by the joint venture team Macquarie Infrastructure Group of Australia and Cintra of Spain.
- The $3.8 billion lease of the Indiana Toll Road by the same joint venture.
- The recent $1.83 billion Chicago Skyway lease by the same joint venture.
- The announcement by Harris County officials, Texas, that they will study the sale or lease of the 83-mile system of the Harris County Toll Road Authority for a deal potentially worth up to $7 billion.
- The Cintra bid of $7.2 billion for six segments of the Trans Texas Corridor (TTC-35).

ETC Technology Providers: Major providers of ETC technology include ACS, InTrans, Mark IV, Raytheon, Siemens, SIRIT, TransCore, and United Toll Systems. For example, SIRIT managed the integration of the California system, and is now performing similar services for Colorado's E470 toll road and its new addition Northwest Parkway. TransCore is the largest ETC provider in the U.S.

TransCore's Technology: The toll tag has evolved from a boxy transponder to a windshield sticker. TransCore has developed SeGO®, a paper-thin, low-cost, battery-less tag operating at 5.9 GHz with a read range of 1000 feet and 1024-bit read/write memory. SeGO has write-back at 80 mph (TransCore, 2005). SeGO is an upgrade to eGO, which operates at 915 MHz and has a range of 31.5 feet. Almost one million eGo tags are already in use. Features include locking individual bytes, laser etching, custom programming, and disabling upon removal. Georgia's State Road and Tollway Authority (SRTA) is upgrading to eGO (SRTA, 2005). Compatibility between old and new tags is a concern. The TransCore tag reader reads multiple protocols, thus allowing migration from older tags (TransCore, 2005). The U.S. Bureau of Customs uses TransCore's RFID tags in its SENTRI "trusted vehicle" program at U.S. land borders. TransCore also performed the border system integration (Elias, 1998).

TxTAG: In 2004 TxDOT's Texas Turnpike Authority Division (TTA) announced that TransCore's SeGO transponder was selected to provide interoperability among existing and proposed Texas toll systems (Russell, Nov. 2004). This printable tag, brand named TxTAG, culminated more than two years of effort by Team-Tx, a statewide group of toll industry experts.

TxTag

Public Acceptance: ETC has stimulated a boom in the demand for toll tags. James Ely, executive director of Florida's Turnpike, said that their SunPass accounts increased from

1 million to 1.4 million within a year, now accounting for 50% of transactions. Florida's goal is to have 75% ETC by 2008 (IBTTA, 2004). However, the growth in tag accounts in Florida can also be attributed to a toll differential: 6¢/mile for tag holders versus 7.5¢/mile for cash customers. Generally, the public objects more to inconvenience in paying tolls than to the principle. With ETC there is considerable scope for experimentation in road pricing, e.g., variable tolls.

Violators or Customers? Scofflaws, rental cars and tractor-trailers present special problems for all-electronic tolling systems. On January 14, 2005, the Houston Chronicle reported that officers on the Sam Houston Tollway pulled over a driver who used the ETC lane without a tag. A database check found she owed $17,651 in fines! Ironically, she worked for a collections agency. On the 407ETR in Toronto, Cintra had to litigate a dispute with the Ontario government, claiming that 16,000 toll violators owed US$12 million and should not receive license renewals.

However, toll operators are beginning to view ORT users without tag accounts as a class of customers, not violators. NTTA in Dallas and 407ETR in Toronto offer anonymous accounts. TxDOT's intent is to increase use of toll tags, and reduce the need for violation procedures. At a cost of about $9 each for TxTAG, options for distribution include grocery stores, gas stations, vending machines, mass mailing, etc. TxTAG accounts work like a pre-paid phone card, with starting accounts as low as $20. TxDOT also would like to encourage toll road use, proposing techniques such as:

- Unregistered accounts
- On new tollroads, offering free tags for a period
- Introductory offer of a tag with $20 credit on it to get motorists to try the new pike
- Sending first time violators a tag instead of a fine notice (Powell, 2004).

Rental Tags: The rental car industry is considering renting out toll tags to its customers (*NY Times* article, 01.10.06). They have found that rental car customers do not mind paying tolls, but do object to having to wait in line to pay them because the car does not have a tag. Budget Rent-A-Car gives the option of renting a transponder for 99 cents a day, tolls not included.

Consumer Friendliness: Motorists are demanding consumer-friendliness and flexibility from transportation agencies. At the same time many toll authorities are increasing the functionality of their systems, including retail applications, in their quest for greater market share (Marketresearch.com, 2005). For example, there are promising technologies for billing:

- A smart-card interface on the toll tag, or self-swipe of a credit card similar to gas pumps, can allow tolls to be deducted without the need to keep customer accounts.
- Cell phone accounts. Cell phones now have automatic location technology to assist in emergency services dispatch in many areas of the U.S. Nearly every motorist in the U.S. has a cell phone. A wireless provider could, with the agreement of the motorist, provide data to the toll company on trips made on the toll facility (Samuel, 2000).

2.4 Best Practices in ETC

In this section, two examples of best practices in ETC are presented.

2.4.1 Toronto 407ETR in Canada

The Toronto 407ETR is one of the most sophisticated toll roads in the world in terms of ETC (Figure 2.4). Tolling is entirely electronic, and there are no manual tolling lanes or booths (407 ETR, FAQ). Tolls are based on the number of kilometers traveled. The 407ETR ETC technology combines transponders with video enforcement. The tag readers poll the vehicle as it approaches the gantry to triangulate vehicle trajectory, get the best read, and minimize errors.

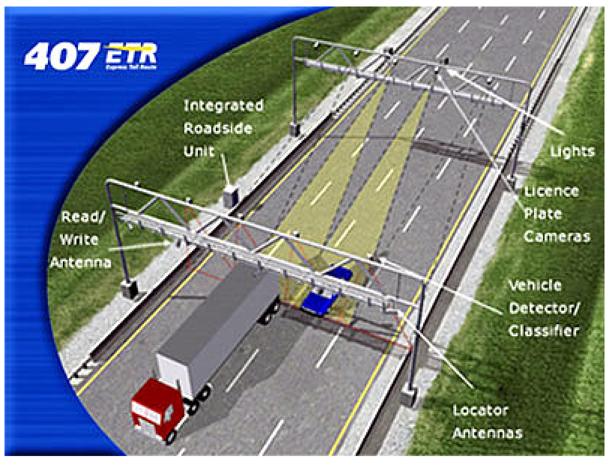

Figure 2.4 ETC on the Toronto 407ETR Highway

There are two types of transponders in use in the system: one for regular vehicles and the other for vehicles with a gross weight over 5 tons. Transponders are the property of the 407ETR and are leased for Canadian $2.15 per month or $21 per year. Using a transponder saves the customer the $3.50 video toll charge per trip. All vehicles using the 407ETR are required to be registered with the 407ETR authorities. If a person is not registered and drives on the 407ETR, the license plate number is taken and sent to the Ministry of Transportation in order to get vehicle information and classification for billing purposes. Scofflaws may have their vehicle registration revoked. If a vehicle is not registered, public sources are used to find addresses.

The customer information collected and retained on records includes:

- Name
- Mailing address
- E-mail address
- Telephone number

- Vehicle plate number
- Driver's license
- Transaction history

The 407ETR does not share information with third parties except:

- If it is a legal requirement.
- In a serious emergency situation.
- Collection agencies for the purpose of collection on past accounts.
- Commercial reasons, such as surveys, etc.

The following types of vehicles are exempt from tolls:

- Law enforcement
- Fire fighting
- Ambulances/medical services
- National defense
- Diplomatic vehicles

Some other facts about the 407ETR are (TollRoad News: IBTTA Conference, 2005):

- 77 percent of transactions are now by transponder (up from 65 percent in 2000)
- 650,000 transponders support about 230,000 transactions per day
- the customer service center has 140 seats (versus forty at privatization)
- customer service calls have declined from a peak of 160,000 per month in 2003 to 70,000 in April 2005
- Optical Character Recognition (OCR) software, roadside processing, and cameras and their housings are being upgraded
- all vehicles owned by the toll agency, including ice and snow units, are being tracked by GPS and their movements are being logged to improve efficiency and provide better evidence in case of criticism or lawsuits
- problems with vehicle classification (based on laser profilers) are being addressed
- images of non-payers are being kept longer to establish a databank
- police working on enforcement now have transponder readers in their vehicles
- roadside signs warning that rear license plates must be visible have reduced violations by plate obscuration
- training and better equipping of police have increased prosecutions
- safety has been addressed by improving traction at several places and accidents have been reduced.

The Toronto 407ETR has an impressive collection rate. A concerted, multi-faceted effort at cracking down on violators over 4 years has seen the percentage of "unbillables" go from about 8 percent in 2000 to about 3.1 percent in 2004. There is also discussion of switching from the current system of flat rates per-km to differential toll rates in different segments of the 41-interchange pike, with higher per-km tolls for the busier sections.

2.4.2 London Cordon

A best practices example of video tolling is the London Congestion Charge Scheme (Wikipedia: London Congestion Charge, 2005). The program requires motorists entering the 22 km^2 of the Central London area (Figure 2.5) to pay a fee. Singapore was the first city to adopt congestion charging in 1998, followed by others including Bergen and Trondheim, but as of 2006, London is the largest city to do so. The organization responsible for administering the charge is Transport for London (TfL).

London currently relies exclusively on LPI/R technology for vehicle identification. There are 230 CCTV-style cameras, which are able to monitor approximately 98 percent of all vehicles inside the zone. One hundred eighty of these cameras are lined along the edge of the congestion zone. Fifty others are placed within the zone to capture the vehicles not picked up by cameras at the edge or those vehicles moving exclusively within the zone. Mobile camera units are also deployed within the zone. The video streams are transmitted to a central data center, where a computer system equipped with OCR software detects the registration plate of the vehicle. A second data center provides a backup location for image data. This list is then compared with a list of cars whose owners/operators have paid to enter the zone. Those that have not paid and are seen are fined.

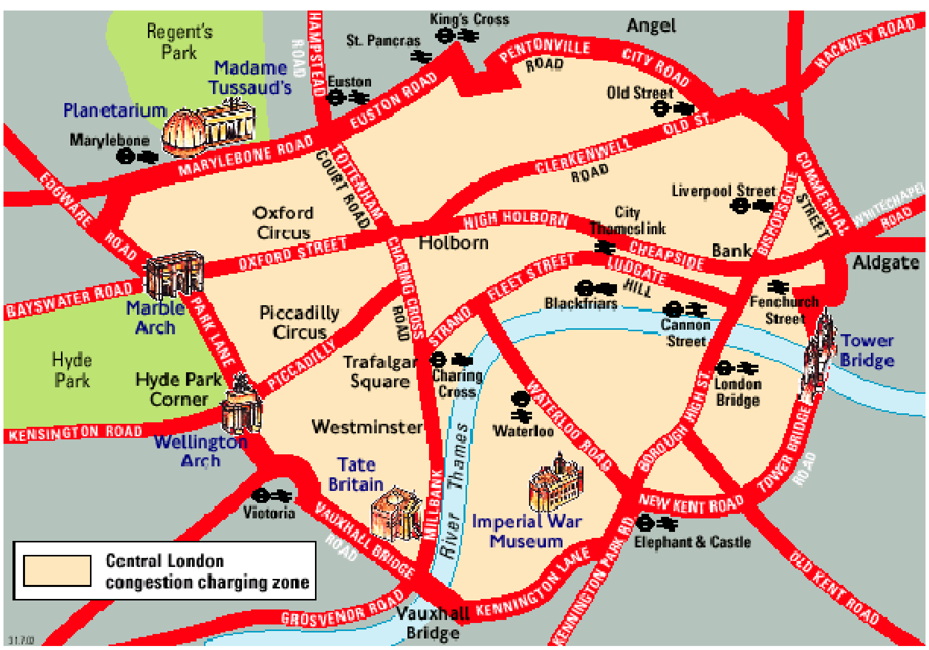

Figure 2.5: The city of London, England, showing the toll cordon

The daily fee of £8 must be paid by the registered owner of a vehicle that enters, leaves, or moves around within the Congestion Charge zone between 7 a.m. and 6:30 p.m., Monday to Friday. If the charge is not paid by 10 p.m. on the day of travel, the charge is increased to £10 to cut the number of last-minute payments. Failure to pay by midnight results in a fine of at least £50. Businesses are given a special rate of £5.

The main aims of the project were to:

- reduce congestion by reducing the number of private vehicles entering the city and encourage the use of public transport, bicycles, etc.
- make the distribution of goods and services more reliable, sustainable, and efficient.
- improve journey time reliability for car users.
- make radical improvements in bus services.
- generate revenues to improve the transport in London more generally.

According to a study commissioned by the TfL, 6 months after the scheme was implemented traffic delays had decreased 30 percent inside the congestion zone (Transport for London report, 2003). Time spent traveling under 10 km/hour was reduced by 25 percent, and trip time reliability increased about 30 percent. About 60,000 fewer car movements were entering the charging zone daily. Of those 60,000, 50-60 percent had switched to public transport, 23-30 percent diverted around the zone, and 15-25 percent switched to carpooling, bicycles, or mopeds. The congestion charging program is expected to earn revenues of 80-100 million pounds in future years. London is considering adding transponders for a wider toll cordon.

2.5 Considerations in Implementing ETC

2.5.1 Benefits and Costs of ETC

ETC Benefits: ETC provides significant benefits to toll operators and motorists when compared to manual toll collection. Oklahoma Turnpike, one of the first to use high-speed toll plazas, saw a 90% reduction in collection costs on ETC lanes. The Tappan Zee Bridge in New York saw a 250% increase in vehicle throughput, with large time savings for drivers, less fuel consumption (6-12% reduction), and lower emissions (FHWA, 2005). Payments are also more convenient, with options for prepaid accounts, credit card auto-pay, and accounts accessible via 800-number or website.

Among the benefits of ETC are:

- ETC lanes improve the speed and efficiency of traffic flow and save drivers time. Manual toll collection lanes handle only about 350 vehicles per hour (vph), and automated coin lanes handle about 500 vph. An ETC lane can process 1200 vph, with ORT lanes allowing up to 1800 vehicles per hour (Tri-State Transportation Campaign, 2004).

- As a result of better flow, congestion is reduced, fuel economy is improved, and pollution is reduced.
- Increased revenue: time savings, faster throughput, and better service attract more customers, thus increasing revenue.
- Reduced accident rates/ improved safety because of less slow-and-go driving.
- Increased efficiency of roads because of better distribution between tolled and non-tolled routes.

Two benefits of open-road tolling are especially noteworthy (Tri-State Transportation Campaign, 2004):

- Safety benefits: Generally, ORT facilities are nearly accident-free. ORT allows vehicles to travel at normal highways speeds, avoiding dangerous stop-go traffic and sudden merges, and eliminating the danger of drivers jockeying for lane position. ORT can also cut down on the distractions toll payers face while driving, such as fumbling for change or having to slow down or stop to pay the toll.
- Economic Benefits: Delays cause losses to both the driver and the overall economy. Drivers suffer direct costs of increased fuel consumption and vehicle wear and tear owing to idling and stop-and-go movement, as well as indirect costs of stress. Valuable time is spent in traffic instead of productive work. Delays also drive up the cost of shipping goods—a cost usually passed on to the consumer. ORT reduces delays and thus provides economic benefits.

Costs of ETC: There are several costs in implementing an ETC system. Among the major costs are:

- Toll Agency Costs: According to a 2002 study by the California Center for Innovative Transportation, the cost per transaction of an ETC system is between $0.05 to $0.10 (Smith, ITS Decision, 2002). A manual toll cost per transaction is $0.35 to $0.45. Not only are the costs per transaction usually lower in an ETC system, the number of transactions is far higher than in a manual system. Additionally, the number of people required to operate an ETC system is far fewer than required for a manual toll collection system. Overall costs per transaction, therefore, shrink significantly.
- Costs to the User: Most systems which have implemented ETC require motorists to buy or rent the equipment. In addition to the cost of the system, the motorist is also required to pay a security deposit, keep a minimum balance in his account, and, in some cases pay a monthly fee for the ETC equipment. Some systems also require motorists to keep a credit card balance.
- Initial Sunk Costs: The initial costs of implementing ETC or converting a manual toll facility into an ETC can be quite high. There are also significant operational and maintenance costs to an ETC system that are difficult to predict or to figure into present worth calculations.

2.5.2 Limitations of ETC

ETC technology has some limitations that must be considered in the context of implementing universal EVI.

Tag Read Accuracy: Accuracy in reading tags is a concern. One estimate suggests that up to 20% of customers don't mount their tags properly, resulting in about 10% not being read (IBTTA, 2004). In effect 2% of total tags end up being V-tolled. However, toll operators do not provide data on the percentage of vehicles not billed, since they are not eager to advertise the likelihood of getting a free pass.

Camera Misreads: Misreads of license plates are also an issue. The heart of an LPI/R system is its recognition engine and embedded algorithm, which varies with different providers. License plate styles and fonts differ across jurisdictions and are changed over time, and, in addition, the same plate numbers are used by many states, making LPI/R a continuing challenge. Hyder Consulting of UK found that LPI/R error rates are in the range of 15 to 35% (Opiola, 2004). ABC 13 News in Houston reported on September 24, 2002 that HCTRA billed Ramiro Garza for using the EZ-TAG lane without a tag. Garza denied the charge. His plate is 3ZHP44, and the photograph of the plate looks like 3ZMP44.

Data Security: The federal Graham Bailey Leach Act regulates toll data privacy, but increased read and write range of RFID toll tags could allow hackers to access toll data from roadside hotspots. New standards are being developed to address toll data security concerns.

Database Issues: Many state vehicle registration databases contain large numbers of obsolete data on owners and addresses. In some states there is no legal requirement for motorists moving addresses to notify the state motor vehicles division. Better ways of locating vehicle owners, possibly a national database, are needed. Commercial databases are one possibility for addressing deficiencies in state registration databases.

Implementation and Operation Challenges: Some challenges will have to be overcome in order to fully implement ETC:

- Insufficient knowledge of ETC technology by consumers who fear their movements will be ‘tracked.’
- Political disinclination, also mainly because of ignorance about ETC technology, as well as a desire to avoid antagonizing voters who have a misguided notion of ETC.
- Interoperability issues between different systems, which raise costs.
- Reconstruction of highways to include ORT lanes, to build gantries, or to dismantle existing manual toll collection booths.
- Non-paying users—because of minor shortcomings of ETC technology, some users may slip through the system without paying.

2.5.3 Comparison of Technologies

Of all current toll technologies, RFID tags have the highest accuracy, while camera/ plate reader systems have the lowest accuracy and highest cost, according to a World Bank study (World Bank, 2006). Table 2.2 shows the accuracy levels and transaction costs of current toll technologies. In addition, the vehicles per hour (VPH) processed by each technology are shown, with RFID able to handle 1800-2400 VPH, i.e., free flow conditions, with 99.25 percent accuracy and lowest cost per transaction. Clearly, electronic vehicle identification can now be conducted at highway speeds with very high accuracy.

Table 2.2: Current Toll Technology Costs and Accuracy Levels

(World Bank, 2006)

Toll options	**Toll Volumes (VPH)**	**Cost per Transaction ($)**	**Accuracy (%)**
Manual	250–350	0.35–0.45	98.0
Automatic Coin Machine with barrier (five coins)	450–550	0.28–0.35	98.5
Automatic Coin Machine without barrier (one coin/token)	500–700	0.28–0.35	95.0
Voucher Script	500–900	0.37–0.48	98.5
Automatic Number Plate Recognition (ANPR)	600–1000	2.25	85.0
Smart Card	700–900	0.10–0.19	99.5
RFID: Dedicated lane with barrier	900–1100	0.10–0.19	99.96
RFID: Free flow lane	1800–2400	0.07–0.15	99.25

2.5.4 Enhancements

Interoperability: A major concern regarding electronic tags is the degree to which they are interoperable with tags from other regions. Integration of toll systems allows tag holders to move seamlessly between systems. Italy and Japan have always had interoperable toll systems, and the rest of Europe and Australia are also following that trend. Most U.S. states, including Florida, Illinois, and Georgia, are implementing interoperability.

Table 2.3 shows current tag operations in the U.S. and those that provide interoperability. California's system is already fully interoperable. In the northeast U.S. E-ZPass is widely used, and Virginia, New Hampshire and Maine are now joining in. Dallas' NTTA accepts Houston's EZ-TAGs, and in October 2003 Houston's HCTRA began accepting NTTA toll tags in 20 special lanes marked with the TxTAG logo.

Table 2.3: Toll Tag Systems in the U.S. and Interoperability

(Source: Wikipedia)

Jurisdiction	Tag System	Interoperable with:
California	Fastrak	
Colorado	EXpressToll	
Florida	SunPass	
Florida- Lee County	LeeWay	SunPass
Florida- Key Biscayne	C-Pass	
Florida- Orlando	E-PASS	SunPass
Florida- Osceola County	O-PASS	SunPass
Georgia- Atlanta	Cruise Card	
Illinois	I-Pass	E-ZPass
Kansas	K-Tag	
Massachusetts	Fast Lane	E-ZPass
Minnesota	MnPass	
Oklahoma	Pikepass	
South Carolina	PalmettoPass	
Texas- Dallas	TollTag	TxTAG, EZ TAG
Texas- Houston	EZ TAG	TxTAG, TollTag
Texas	TxTAG	EZTAG, TollTag
U.S. Northeast	E-ZPass	
Virginia	Smart Tag	E-ZPass

Universal Tag: American Traffic Solutions plans to introduce the PlatePass®, which it says will do away with having to carry multiple tags for different systems (*NY Times* article, 01.10.06). The idea is that the customers would have information stored in the PlatePass database. American Traffic would then share that data with toll authorities across the U.S. Customers will be able to drive through any ETC lane without the use of a transponder. Instead of registering them as violators, system would scan the PlatePass, look up the customer on the database and charge the owner's credit card.

2.6 Upcoming Tolling Technologies

Some technologies are currently being considered as possible alternatives to transponders and video tolling, and may find applications in area-wide mileage tolling programs and in integrated system management, including:

- Odometer Tolling
- Vehicle Positioning Systems
    - Satellite Tolling
    - Cell Phone Tolling

The state of Oregon is studying system-wide, per-mile tolling using Global Positioning Systems (GPS) or odometer reading. GPS tolling is already in partial implementation in several countries across Europe. Phone tolling is another ETC option which has possibilities but has not been tested.

2.6.1 Odometer Tolling

Oregon Pilot Test: The Oregon Department of Transportation (ODOT) is conducting a pilot project on odometer tolling (Oregon Department of Transportation, 2005). In 2001, the Oregon State Legislature created the Road User Fee Task Force (RUFTF) to look at means to raise revenue as a replacement for Oregon's gas tax. RUFTF looked at twenty-eight different options and focused on a distance-based charge on the number of miles traveled in Oregon. The Road User Fee Pilot Program was created to examine the technical and administrative feasibility of implementing a per-mile fee. The program uses on-board mileage-counting equipment to keep track of the number of miles traveled. Based on the results of the pilot test, ODOT will draft legislation to be put before the state legislature in 2009.

Pre-pilot Trial: During the fall of 2005, a *pre-pilot* program of twenty volunteers started the program to work out any unexpected issues that could occur. Volunteers' cars were equipped with on-board mileage-counting equipment (Figure 2.6). In spring 2006, 280 volunteers in Portland had the equipment added to their vehicles. For a period of one year, volunteers paid a fee equal to 1.2 cents a mile and no gas tax. Two service stations in the Portland area were equipped with mileage reader devices and pilot participants were asked to fill their vehicles at these participating service stations when convenient. While the vehicle was refueled, the on-board mileage counter communicated with the mileage readers placed at the pumps. When the purchase was totaled, the gas tax was deducted automatically and the road user fee added automatically.

Figure 2.6: On-board mileage-counting equipment in the Oregon Pilot Project

Mileage Categories: A federal requirement of the Pilot Program was to test the ability to count separately the miles traveled during rush hour within a congested area. Some of the pilot volunteers were placed in a rush hour pricing group to test this concept. Because the pilot was a test, many policy options remain for decision-makers, such as charging a lower rate-per-mile for vehicles that achieve a certain fuel efficiency, for motorists that avoid rush hour zones, or for those participating in other environmentally-friendly activities. The road user fee program did not track, store or collect private information. There was a switching device that counted the number of miles the vehicle traveled. The device could not record the location of the vehicle except when the vehicle passed through certain designated rush-hour zones. The device counted only the number of miles traveled within the zone, not the time of day, location in the zone, or even the day. There was also a GPS receiver in the cars that simply told the electronic odometer whether to count the miles as *in state* or *out of state*. This was to prevent volunteers from being charged for miles driven outside the state.

Privacy Measures: No location data was transmitted anywhere or stored in onboard device or elsewhere; because vehicle location data was not collected, it could not be accessed. The only data collected and transmitted was the mileage, which was sent to the gas pump reader through a radio frequency that could only travel about 8 to 10 feet. As the driver fueled up, the VMT was calculated and the gas tax was deducted. Clearly, Oregon has concerns about the possibility of a public backlash over driver privacy.

Technology Phase-in: The Oregon Road User Fee concept recommends that only new vehicles be equipped with the on-board technology. All of the technologies being used in the pilot program are already being manufactured in cars today. Some automobile manufacturers have already announced that key components will be standard equipment on all models within the next few years. The Federal Highway Administration (FHWA) and transportation standard organizations are working to adopt universal standards for the same technologies being used in the pilot program. In the near future, therefore, it is very likely that a state adopting a GPS-based mileage fee would not need to require additional hardware to be installed in vehicles. Some sort of software upgrade seems more likely.

Future Policy Decisions: With the Road User Fee Pilot Program, Oregon is not looking to raise revenue but to examine options for future transportation revenue. Any future policy decision Oregon may make on the mileage fee does not necessarily translate into adopting congestion pricing. The results of the pilot study were not available for inclusion in this report.

2.6.2 Cell Phone Tolling

System Outline: Cell phone tolling is a concept that has potential for mileage-tolling. In one version, a chip similar to a cell phone chip would be installed in a vehicle (i.e., every car carries its own cell phone), and frequent communication between cellular towers and the chip would determine how far the car has moved and would assess a toll. Given the near total coverage of cell phone signals in urban (and congested) areas of the U.S. and the deployment of GPS capabilities in cell phones for 911 phone locating, this technology appears to be technically feasible. It is likely to be less expensive than satellite-based systems because the infrastructure needed (cell phone towers) already exists. In addition, installing a cell phone chip in a car will likely be less expensive than installing a GPS unit capable of picking up satellite signals.

Viability: One proof of viability of the concept is in a recent marketing campaign by telecommunications firm Sprint to help parents keep track of their children. The service lets parents look at maps on their cell phones to locate their children, who also carry cell phones. Sprint's service shows data such as street addresses to which a child is in close proximity and the estimated accuracy of the reading, which could range from a radius of 2 yards around the child to hundreds of yards.

Other Applications: There is also an experiment in Missouri, using cell phones to monitor traffic congestion. Conducted by the Canadian firm, Delcan, the operation uses the frequent signals relayed between the cell phones and cell phone towers to map traffic flows and congestion patterns. With adaptations, this technology can be used to charge a VMT toll. TxDOT's Traffic Operations Division will issue a request for proposals in January 2008 for a pilot test in the Waco district for mapping traffic speeds.

Creating the Market: Clearly, this ability to track a cell phone position must be marketed carefully to avoid a backlash among cell phone users, hence the initial focus on traffic congestion and paranoid parents. At the same time, cell phone companies are already entering the market for driver services such as subscription packages for traffic and weather reports and emergency assistance such as OnStar®.

2.6.3 Satellite Tolling

Promise: Satellite tolling would use a satellite-based vehicle-tracking system to determine exact vehicle location while using mobile communication technology to compute toll charges. Each vehicle would carry an on-board unit (OBU) to record the vehicle's movements by periodically downloading satellite time-stamped location coordinates. Satellite tolling is considered the most promising technology for ETC because it allows for accurate, distance-based tolling. It is also flexible, allowing for time- and location-variable tolls.

Satellite tolling is touted to become the preferred method of ETC, especially in Europe. Germany is already testing a freight tolling system. The European Commission has proposed to implement full ETC by 2010. The European Space Agency (ESA) is funding Mapflow, an Irish technology provider, to study the feasibility of pan-European tolling. Cost, accuracy and complicated back office operations are concerns (ESA, Jan 2005).

Advantages: Advantages of satellite tolling include:

- <u>Faster, hassle free and less paperwork:</u> GPS tolling will involve less paperwork and lower transaction costs than other forms of tolling. All a driver has to do is drive through a toll station and his driving distance and toll information can be uploaded into the system automatically through wireless connection. If the driver has a prepaid account, the toll charge can be deducted automatically.
- <u>Ancillary services could be provided through transponders and GPS:</u> In addition to toll collection, GPS deployment will allow other information and services to be

passed along to the driver. For example, the driver will be able to receive real time weather and traffic information. In case of an emergency, his position and situation can be accurately monitored.

- Negates the necessity of investing in expensive roadside infrastructure: Once the infrastructure is in place, there are few costs involved in the operation of a GPS-based tolling system
- More flexibility in variable tolling: Tolls could be levied differently based on road traveled, time traveled, and so on. For example, a vehicle traveling on a busy road during rush hour would be tolled more than a vehicle traveling a country road.
- Built-in OBUs: Currently, vehicle owners have to buy or rent OBUs for GPS tolling. In the near future, all new vehicles are likely to come with OBUs as a standard feature.

Disadvantages: Disadvantages of satellite tolling include:

- Phase-in period: At present, an OBU has to be installed for a vehicle to use GPS tolling. It is expected that it will be another 10–15 years before non-OBU equipped vehicles are phased out.
- Interference in certain situations: At present, GPS is not entirely reliable because there can be situations where satellite signals are lost (such as in *urban canyons*, or heavily forested roads, and during lightning storms). The technology, however, is getting more accurate and these problems are expected to be resolved, for the large part, by upcoming satellite deployments.
- Public reluctance of being tracked: GPS is, in fact, a passive system and cannot track individuals themselves. Just because someone carries an active receiver does not mean his every move can be followed. This only becomes possible once positional information is forwarded to a third party. For use in road pricing, where a vehicle's movements are built from satellite-navigation data, the data needs to be passed to roadside beacons or reported over cellular phone networks.
- Start-up costs: Some of the start-up costs such as distribution of OBUs and installation of payment booths may be expensive. The German TollCollect system, for example, went well over budget. Once installed, however, it is not as expensive to maintain as other forms of toll collection methods.
- Need to provide transponders and OBUs at a cost of up to $350 per OBU. These costs will go down, however, with mass use. In the meantime, deployment is proceeding in the trucking industry because of the desirability of tracking shipments.
- Manual system may be needed despite GPS: This is perhaps the greatest obstacle for GPS tolling. There may still be the need for manual lanes despite the use of GPS. This is because the out-of-state vehicles may not have GPS units. One solution would have drivers inform the toll stations in advance that they are planning to come through and pay for their tolls online beforehand. This solution also has some potential problems. First, the driver would have to know the exact

route he would be traveling. This could be a problem for out-of-state drivers who are not familiar with the roads. Also, all of them might not have access to computers to book online. Such a system is also very rigid. A driver might change his travel plans and travel on another day or take another route. Manual tolling might also have problems with the driver paying the toll for one trip and using it for two or more trips. Manual tolling has to give the driver a time window to take into account contingencies such as traffic jams, rest stops, flat tires etc. A driver might still be able to use that time window to make more than one trip. There might also be language difficulties in the U.S. for visitors from Mexico trying to book manual tolls over the phone.

- User anonymity is difficult to guarantee: This is the case with many other ETC technologies.

Improvements: Satellite technology is improving rapidly. With the launch of the European Galileo system (beginning in 2008), the technology will improve further. Galileo is the next generation of satellites and will overcome most of the shortcomings of the current GPS system, being more accurate and reliable. It will also be interoperable with existing systems, allowing for greater access and backup ability. The project is being managed by the European Commission and European Space Agency. Galileo will include thirty satellites by the end of 2010 and will be compatible with the U.S. GPS and Russian Glonass systems. It will reportedly be more accurate than current GPS, with real-time positioning down to less than a meter. It will also be guaranteed to operate under all but the most extreme circumstances.

Galileo: The Galileo system will work as shown in Figure 2.7 (BBC: Europe's Galileo Project). The procedure is as follows:

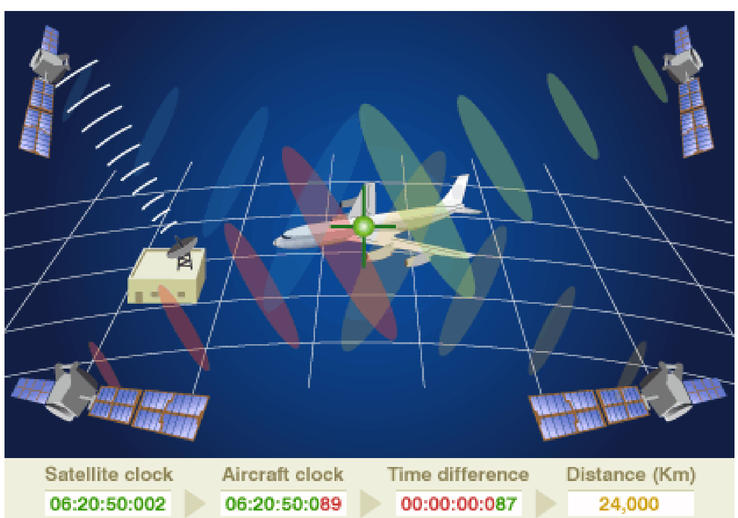

Figure 2.7 The Galileo Satellite system for Global Positioning

- Satellite navigation systems determine a position by measuring the distances to at least three known locations—the Galileo satellites.

- The distance to one satellite defines a sphere of possible solutions; the distance to three defines a single, common area.
- The accuracy of the distance measurements determines how small the common area is and thus the accuracy of the final location.
- In practice, a receiver captures atomic-clock time signals sent from the satellites and converts them into the respective distances.
- Time measurement is improved by including the signal from a fourth satellite. *Galileo time* is monitored from the ground.

2.6.4 Application of GPS Tolling in Germany

Overview of Toll Collect: The German federal government has introduced a distance-based truck toll for all heavy commercial vehicles and vehicle combinations with a permissible total weight of 12 tons or more (Toll Collect website FAQ, 2005). The road toll covers over 12,000 km of German highways and is applicable to German and foreign road users alike. Toll Collect, a private company, was awarded a contract by the German federal government to develop a toll system capable of calculating and collecting road use charges based on the distance traveled. In addition, the Toll Collect system ensures that the collection of road tolls does not disrupt traffic flow. Toll Collect is a form of open road tolling and does not require vehicles to slow down or stop or restrict them to a designated lane.

Participation: The automatic log-in is based on a combination of the Global System for Mobile communications (GSM) and GPS systems. In order to use the automatic log-on service, the driver must get an On-Board Unit (OBU). With the aid of GPS and other positioning sensors, the OBU automatically determines the number of miles driven on the toll road, calculates the toll amount to be paid, and transmits the information to the Toll Collect computer center. The driver is not required to book the route himself, as all the key data is stored in the OBU.

In order to participate in the automatic log-in, the transport company and the truck must register with Toll Collect. After registration, the truck receives a vehicle card for the truck, on which the most important vehicle information is stored. Then an OBU is installed in the truck. The OBUs are the property of Toll Collect and are free to registered users. After the termination of the contract, the OBU must be handed back to Toll Collect. There are two types of OBUs available, the slot-mounted OBU (in the DIN slot) and the surface-mounted OBU (on the dashboard). Only one OBU can be used per vehicle, and the vehicle's license plate information is stored in the individual OBUs during installation.

The alternative to the automatic log-in is the manual login. Under this system, users must prepay for the use of a planned toll route. The drivers can log in either at a toll station terminal or over the Internet.

Logging In: Truck drivers can log-in manually at toll station terminals in one of the 3500 registration points in Germany and neighboring countries. It is possible to log-in in German, English, French and Polish. The log-in procedure at a toll station terminal is similar to purchasing a ticket. The driver enters all the relevant vehicle information, departure time, starting point and destination. The toll station terminal then calculates the shortest route within the toll road network. The user can accept this route or choose an alternative one by entering other waypoints. The user then confirms the route, selects the desired payment method, and receives a login receipt upon payment. This ticket should be kept in the vehicle. The receipt contains:

- vehicle information
- selected route
- length of the route
- amount of the toll
- a sixteen-digit login number
- the period of validity

Registration with Toll Collect is not required to log-in at a terminal.

Payment: There are several alternative ways in which toll fees can be paid:

- LogPay plan (direct debit)
- Fuel Card payment
- Credit account payment
- EC card payment
- Credit card payment
- Cash payment

Enforcement: There are four levels of enforcement for the system:

- Automatic enforcement: Around 300 fixed overhead gantries are used to enforce compliance. The gantries span the entire road and determine whether a passing vehicle is required to pay the toll and if the toll has been duly paid. Each vehicle is recorded by a detection and tracking unit, which classifies the vehicle and determines whether it is required to pay a toll. Classification is done by scanning the vehicle three-dimensionally to check the contour of the vehicle, which determines whether it is required to pay a toll and also determines how many axles it has. If no toll is due, the data is immediately deleted.

- Stationary team controls: The Federal Office for Goods Transport (Bundesamt für Güterverkehr, BAG) employees engage in stationary enforcement on parking lots in the vicinity of the control bridges.

- Mobile team enforcement: BAG has approximately 300 control vehicles throughout Germany 24 hours a day to provide mobile toll enforcement.

- Company-level enforcement: BAG employees perform company-level enforcement by randomly checking freight transport companies on site to determine if they have paid the required toll.

Data Protection and Security: The German government is responsible for the truck toll system and Toll Collect is a subcontractor for BAG. As the client, BAG defines the requirements to be implemented and issues instructions. The data protection policy is continuously coordinated with BAG and the Federal Commissioner for Data Protection and Freedom of Information (Bundesbeauftragter für den Datenschutz und die Informationsfreiheit, BfDI), which are the oversight authorities.

Permission to process data for the toll system is provided primarily by the BfDI and the Truck Toll Regulation. However, the provisions not only permit data processing, but at the same time prescribe strict earmarking for specific purposes and short deletion deadlines for the operator. This data is processed by the operator, acting on behalf of the BAG, "strictly in accordance with data protection guidelines and exclusively for the statutorily prescribed purpose of toll collection."

Vehicle information is recorded at the control bridges in accordance with the legislative guidelines. The drivers cannot be recognized in the photos. When vehicles are determined not to be required to pay the toll, the photo is not evaluated with respect to the plate number, but is deleted immediately. Personal data is transmitted to the extent "necessary to fulfill statutory toll collection purposes or to perform tasks set forth in the contract with the user." Toll Collect Short Message Service (SMS) messages are encrypted and the communications partner is authenticated. A closed (end-to-end) security chain is always formed with cryptographic functions to prevent the manipulation of data and any "listening in" on information.

It is not possible to access and read information in an OBU. Modified single in-line memory module (SIMM) cards designed solely for data communication are used, and speech communication is also not possible. Only authorized service stations have the capability to work on terminals. Reading out data from an OBU requires an access code, which may not be given to third parties. If an attempt is made to manipulate an OBU or if it is stolen and re-installed, the control technology will automatically recognize this.

Performance: Here are some facts and figures about the German system after one year of operation (Kossak, A.TRB 2006):

- About 500,000 trucks equipped with onboard units (160,000 foreign).
- About 110,000 companies with about 735,000 trucks registered.
- 1,931 workshops licensed for OBU service (435 in foreign countries).

- Shares of booking alternatives: 86 percent OBU, 14 percent POS/ Internet.
- About 1 million tolling transactions per day.
- About 1 million toll bills dispatched; rate of complaints/appeals: 0.7 percent.
- About 23 billion vehicle-kilometers in 11.5 months/35 percent by foreign trucks.
- 2.86 billion € revenue ($3.45 billion) in 12 months > expected: 3 billion €.
- Toll-violator-rate: < 2 percent.
- System availability: > 99 percent; demanded by contract: 95 percent.
- No traceable increase of freight-charges.
- No traceable impact on consumer prices.
- No significant impact on the structure of the logistic industry.
- No significant shift from road to rail or inland waterways.
- A reasonable number of trucks use/used alternative toll-free routes.
- Tendency to buy trucks with higher environmental standards.
- No significant shift from heavy trucks to light trucks.
- Significant tendency to a higher average load factor.
- Truck-kilometers without cargo on Autobahns decreased by 15 percent.

2.7 Trends and Initiatives

ETC has become the flagbearer for deployment of Intelligent Transportation Systems (ITS). ETC technologies, namely in-road systems, video systems, and electronic tags, are competing among themselves for the expected growth in ITS. Rules for the ITS Deployment Program are defined in TEA-21 Section 5208. Private sector involvement is encouraged. This program may provide an opportunity to assist in funding EVI deployment (See Appendix A).

2.7.1 Trends

More In-vehicle Features: According to *The Economist* magazine, several changes are likely to occur with the implementation of ETC (*The Economist* 06.10.04). Future vehicles are likely to include a standard OBU with multiple capabilities:

- Give real-time information on traffic and weather conditions as well as toll rates and conditions on roads
- Inform the driver about gas stations, shopping, restaurants etc
- Upload diagnostic data about the car

- "Smart box" would automatically transmit location of vehicle
- Emergency request could be triggered at airbag inflation
- Number and location of passengers, e.g., in buses
- Real-time traffic data would guide others away from emergency or accident scenes
- Future systems could warn of road dangers and take control of the vehicle, e.g., limiting speed
- Car insurance premiums charged by distance
- OBU could be a virtual back seat driver, giving instructions (e.g., if driver crosses over onto different lane, exceeds speed limits)

Automatic Dispatching and Monitoring: About 7500 taxis in Singapore have been equipped with GPS in recent years. GPS provides spatial coordinates of these taxis and their positions are sent to a central dispatch center. When a customer calls for a taxi, the request is sent to all taxis within a 2 km radius of the customer. If a taxi driver accepts the fare, he alerts the call center. The benefits of this system for the taxi driver are shorter cruising times, while the customer benefits from shorter waiting times and quieter taxi rides because of the absence of in-taxi communication with the dispatch center.

Speed Detection: The PoliScan from the German firm Vitronic is a system for digital speed detection and recording (Vitronic PoliScan website). This system can simultaneously record and measure several vehicles in parallel lanes.

- The PoliScan uses a high-resolution digital camera to take an overview picture of the vehicle, including the driver. It identifies vehicles by license plate recognition and the license numbers are cross-checked with a database. The data are then encrypted and stored digitally.
- In contrast to laser-based systems, the speed measurement is target selective, enabling the monitoring of multiple lanes simultaneously.
- Digital image recording is possible regardless of weather conditions.
- The data from PoliScan can be transmitted immediately to relevant traffic control officers who can then stop offenders.
- PoliScan can either be used as a moving or a stationary device—it can be put on the back of a police van or mounted on an overhead gantry.
- Information for vehicles raising suspicions can be given to the proper authorities, and information for those vehicles causing no alarm can be deleted.

Emissions Inspection: Mark IV Industries, one of America's leading electronic technology firms, is actively looking at Automated Vehicles Emissions Inspections (AVEI). At present Mark IV has wireless technology that is capable of transferring diagnostic engine data from a vehicle's on-board interface to the roadside. Thus, toll transponders can double as emissions readers. This technology would allow people to drive through an emissions inspection checkpoint and have the condition of their cars assessed right away instead of having to wait in line. The basic idea is to replace the manual inspections with wireless, electronic data extractions from vehicles' on-board computers using transponders.

Mark IV believes there would be several benefits for enforcement, including faster, more thorough and more uniform inspections, increased customer satisfaction, and better utilization of staff resources. Consumers would also benefit because inspections would be uniform and less time-consuming. It would also be more cost-efficient and provide a cleaner environment. Features of the AVEI would include:

- Transponder linked to vehicle computer
- Drive-through inspection booths with electronic readers
- Real-time data extraction
- Software for analyzing and determining pass/fail
- Financial settlement
- Open road speeds
- Possibility of manual override by staff at the booth.

In March 2005, Mark IV conducted an experiment of this technology in New Jersey, with officials from the NJ Department of Environmental Protection and NJ Motor Vehicle Commission present (Manuel, P. Mark IV IVHS). In the experiment, the following were demonstrated:

- Accuracy: At vehicle speeds up to 100 mph, the capture rate was 99.99 percent +.
- Range: demonstrated at 125 ft and 75 ft.
- Vehicle position
- Private memory pages
- Read-write transponder technology (i.e. type II)

Roadside Beacons: In this application, beacons are buried under the pavement and the transponder picks up the signals as vehicles pass along. The signals can transmit a wide variety of data ranging from traffic reports ahead, weather information, blind curves ahead, and so forth. It can also be used in toll collection. As the vehicle passes the beacon, its information is recorded in the on-board transponder/unit in the car. The data can later be uploaded to calculate the tolls to be paid. This system can also work well in areas like cities and tunnels where GPS signals are weak or inaccurate.

Driver Information: "Otto" is a 5.9 GHz Dedicated Short Range Communication (DSRC) device from MARK IV designed to provide warnings or alerts to drivers, allowing them to take evasive actions, as well as providing real-time information such as weather conditions, congestion, and traffic accidents. On-the-go communication between vehicles could significantly increase highway safety. Otto uses digital radio technology to pass information over distances of up to 1 km between roadside communicators and the on-board imbedded DSRC device on the vehicle. The technology uses Wireless Access in a Vehicular Environment (WAVE).

Next Generation Transponders: The Austrian firm EFKON is developing an OBU that is essentially a computer capable of communicating with a regional server (EFKON Multi-Lane Sensor). It will also include capabilities to communicate with the road, other vehicles, and the driver. EFKON's current transponders allow communication at high speeds, even while changing lanes and overtaking. Some of the solutions require minimal infrastructure, and some are completely infrastructure-free. EFKON offers three groups of "MultiLane Free Flow Systems:"

- Traditional gantry–based systems
- Semi-autonomous toll systems with minimized infrastructure (ECOTOLL®)
- Autonomous wide area pricing systems

These systems are used in the following basic applications:

- wide area truck tolling (lorry road user charging) systems
- tachograph based charging schemes
- highway or other discrete tolling systems
- toll enforcement systems and audit systems
- traffic counting
- shadow tolling systems
- section speed control systems
- customer specific

Multi-Use Payment: Future uses for the electronic tag may also include the universal tag, which can be used for multiple purposes (e.g., on subways and other public transit systems, as well as for purchases in stores and restaurants). Although the universal tag is not widespread in the U.S., there is a multi-use payment system in use that makes transit payment more convenient. Payment for bus, rail, and other public or private sector goods and services can be made using transit fare cards at terminal gates or at check-out counters and phone booths of participating merchants located near transit stations. Multi-use systems may also incorporate the ability to pay highway tolls with the same card. Table 2.4 shows U.S. metropolitan areas with multi-use payment systems.

Table 2.4: U.S. Metropolitan Areas with Multi-Use Payments
(Source: US DOT 2004)

Metropolitan Area	State	Number of Agencies	
		Surveyed/ Returned Survey	*With Shared Transit Fare Payment/ Toll Collection*
Albany, Schenectady, Troy	NY	1 / 1	1
Baltimore	MD	3 / 3	1
Chicago, Gary, Lake County	IL	11 / 11	1
Dallas, Fort Worth	TX	6 / 6	1
Greenville, Spartanburg	SC	3 / 3	1
Harrisburg, Lebanon, Carlisle	PA	1 / 1	1
Los Angeles, Anaheim, Riverside	CA	22 / 22	2
Miami, Fort Lauderdale	FL	4 / 4	1
New York, Northern New Jersey, Southwestern Connecticut	NY	22 / 21	2
Orlando	FL	1 / 1	1
Pittsburgh, Beaver Valley	PA	5 / 5	1
Richmond, Petersburg	VA	2 / 2	2
San Francisco, Oakland, San Jose	CA	17 / 17	2
Sarasota-Bradenton	FL	2 / 2	1
West Palm Beach, Boca Raton, Delray	FL	1 / 1	1

2.7.2 Initiatives

There are currently several government and private initiatives facilitating a move towards integrated transportation system management. Among the most prominent of these are the European Electronic Vehicle Consortium, the US DOT Vehicle Infrastructure Initiative (VII), and the Car2Car Consortium, composed of some of the world's leading car manufacturers. Federal funding is provided under the ITS Integration Program to accelerate the integration of ITS in metropolitan and rural areas.

Vehicle-Roadside Communication: A study conducted by the European Electronic Vehicle Consortium looks into two main approaches for achieving Electronic Vehicle Identification (EVI). The first is EVI as a stand-alone technology. This would involve having roadside gantries and checkpoints that would communicate with the vehicle. The communication methods could involve RFID, mobile communications, DSRC broadcast, infrared, or CALM (Communications Architecture for Land Mobile environment). The second approach is to have EVI embedded into in-vehicle telematics, that is, cars will come with standard built-in telematics supporting EVI (EVI Consortium, 2004).

Vehicle Infrastructure Initiative (VII): This is an initiative undertaken by the U.S. Department of Transportation to deploy advanced vehicle-vehicle and vehicle-infrastructure communications that keep vehicles from leaving the road and enhance safety movement through intersections (US DOT, ITS: Vehicle Infrastructure Initiative, 2005). This wireless communication is supported by DSRC.

The VII aims for the coordinated deployments of communication technologies:

- In all vehicles by the automotive industry, and
- On all major U.S. roadways by the transportation public sector.

Data transmitted from the roadside to the vehicle could warn a driver that it is not safe to enter an intersection. Vehicles could serve as data collectors and anonymously transmit traffic and road condition information from every major road within the transportation network. Such information would provide transportation agencies with the information needed to implement active strategies to relieve traffic congestion.

The VII vision for US DOT is that every car manufactured in the U.S. would be equipped with a communications device and a GPS unit so that data could be exchanged with a nationwide, instrumented roadway system. According to US DOT, a well-functioning vehicle-to-vehicle and vehicle-to-roadside communications system could halve the 43,000 deaths that are caused by vehicles leaving the road or traveling unsafely through intersections. In addition, traffic delays could also be cut down significantly.

Protection of privacy is paramount. The intent is that general data collected by the public sector would be anonymous and used only for safety purposes and for efficient management of transportation operations. It is expected that this technology will facilitate a number of uses that drivers may choose, such as electronic toll collection or telematics services for which some private information might be required. For those services, the intent is that the owner or driver would have to "opt in" and give permission for that information to be shared.

A VII consortium has been established to determine the feasibility of widespread deployment and to establish an implementation strategy. The consortium consists of the vehicle manufacturers already involved in the IVI, American Association of State Highway and Transportation Officials (AASHTO), ten State Departments of Transportation, and US DOT.

Car2Car Consortium : Europe's top car manufacturers have combined forces in the Car2Car Communication Consortium (C2CCC) to develop a standard for communications between cars and infrastructure facilities (Auto-Intell News, Dec. 14, 2004). C2CCC is a non-profit organization initiated by vehicle manufacturers, which is open for suppliers, research organizations and other partners (Car2Car Communication Consortium, 2005). C2CCC is dedicated to the objective of further increasing road traffic safety and efficiency by means of intervehicle communications. The members at present include: Audi, BMW Group, DaimlerChrysler, EPA, Fiat, Honda, IHP, NEC, Opel, Philips, Renault and Volkswagen.

The mission of the consortium is to create and establish an industry standard for car to car communications based in wireless local area network (LAN) components. Although this is primarily an initiative for the European market, there is a push to make this Car2Car standard interoperable worldwide. The radio system for the Car2Car Communication is derived from the standard IEEE 802.11, also known as Wireless LAN. As soon as two or more vehicles are in radio communication range, they connect automatically and establish an ad hoc network (Figure 2.8). As the range of a single Wireless LAN link is limited to a few hundred meters, every vehicle is also a router and allows sending messages over multi-hop to farther vehicles. The routing algorithm is based on the position of the vehicles and is able to handle fast changes of the ad hoc network topology.

Figure 2.8 Car-to-car ad hoc networks

The timeline for Car2Car wireless implementation is as follows:

July 2005:	Basic concept, first prototype
January 2006:	Research and Development (R&D) guidelines, recommendations
December 2007:	Draft of full specification, demonstrators, interoperability field trial
December 2008:	Specifications as input to standardization
December 2010:	Frequency allocation

In the U.S., DaimlerChrysler is working on the vehicle-vehicle and vehicle- infrastructure short range communications system. As a result of these technological improvements in passenger vehicles expected over the next few years, it is foreseeable that cars will also come equipped with OBUs, which can be used for tolling purposes.

2.7.3 Integration of Trends and Technologies

In the Crystal Ball: Since the future financing of transportation infrastructure will be through some form of road pricing, tolling technology is likely to lead the way in roadside-vehicle communications deployment in the U.S. Figure 2.9 is a prognostication of future trends in tolling technology. The horizontal axis is a rough timeline, predicting a shift from corridor and cordon tolls to universal mileage tolling by 2025. This trend will affect the market share of competing tolling technologies.

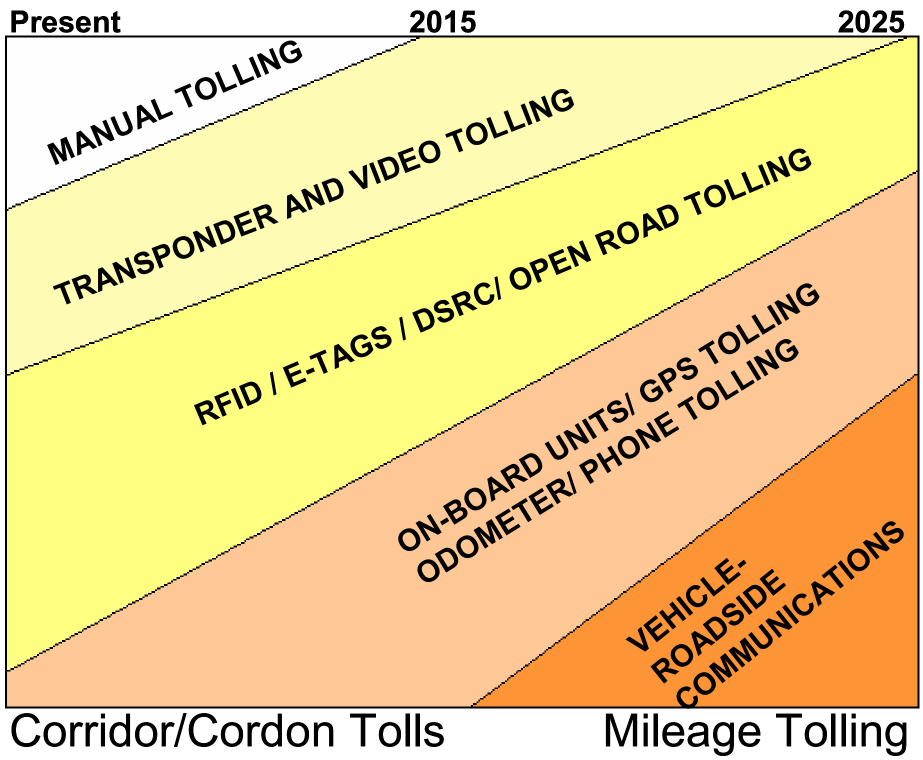

Figure 2.9 Tolling Trends and Technologies

Market Share: It is anticipated that manual tolling will be obsolete in the U.S., probably within 5 years. RFID tags, which currently account for 40-60 percent of toll transactions in the U.S., are expected to fully replace the 15-25 percent of toll transactions done manually, and thus will dominate the U.S. toll market over the next 20 years or so. Deployment of Dedicated Short Range Communications (DSRC) connected to the computer bus of a vehicle will create more options for EVI and ITS. Tags, however, require significant roadside infrastructure to accomplish area-wide tolling. Cell phone and satellite/GPS tolling will gradually create a niche in the market as more vehicles come with manufacturer-installed on-board units (OBU), and in the longer term as costs come down, may replace RFID. However, RFID through DSRC is expected to form the backbone of transportation communications infrastructure in the U.S. for the near future.

2.8 Chapter Summary

Tolling Technology: In this chapter, technologies and practices for tolling were presented. The motivations for tolling were reviewed, and the stages in the evolution of tolling were discussed. Benefits and costs of ETC were presented, followed by a review of current deployment of ETC in the U.S. Mature ETC technologies were discussed, including sensors, video-tolling systems, and RFID transponder systems. Examples of best practice in the application of these technologies were evaluated. Next, some ETC technologies with the potential for implementation in the near future were presented, namely odometer, phone, and GPS tolling. Tie-ins to Intelligent Transportation Systems (ITS) deployments and an ultimate integrated transportation system were discussed.

Trends: It was seen that the next stage in the evolution of tolling is likely to be a mileage-based system, i.e., the driver pays periodically for miles driven in a region. While odometer, phone, and GPS systems all have the potential for mileage tolling, RFID tags with DSRC are likely to be the dominant tolling technology in the U.S. for some time. Right now truck manufacturers are embedding DSRC tags in all their vehicles, and some car manufacturers have started as well. It is likely that these will be linked to vehicle recognition systems within the next decade. These developments provide a basis for implementation of EVI. In the next chapter, standards for tolling technologies and ITS will be discussed.

CHAPTER 3: STANDARDS FOR ETC TECHNOLOGIES AND ITS

3.1 Introduction

At the 2005 International Bridge Tunnel and Turnpike Association (IBTTA) conference in Toronto, there was widespread agreement that tolling in the future is likely to make use of multiple technologies, including Dedicated Short Range Communications (DSRC) transponders, satellite-fed location finders (i.e., GPS), and cameras for enforcement. Ed Regan, head of Wilbur Smith's Traffic and Revenue Department, believes that within 10 to 15 years there will be widespread road pricing throughout the U.S., with distance- and location-based road use charges (RUC) or tolls displacing fuel taxes.

Tolling technology has proven to be the most successful deployment of Intelligent Transportation Systems (ITS) in the U.S. In this chapter, industry standards and performance characteristics for ETC technologies are presented. This is followed by a review of proposals for ITS, and a discussion of the role of EVI in future ITS.

3.2 Dedicated Short Range Communications (DSRC)

DSRC is a short to medium range wireless protocol specifically designed for high-speed vehicle-roadside and vehicle-vehicle communications. It increases the security, speed in data sharing, and read range of RFID systems. Operating in the 5.9 GHz (gigahertz) frequency, it is intended to supplement current RFID applications which share the 915 MHz (megahertz) frequency with cordless telephones, garage door openers, and many other non-licensed wireless applications. DSRC provides 75 MHz of spectrum and permits much higher data transmission rates compared to the 915 MHz frequency which has only 12 MHz of spectrum available. Other users of the 5.9 GHz frequency include military radars and satellite communications systems.

3.2.1 Bandwidth Allocation

The 5.7 to 5.9 GHz (gigahertz) range of the radio spectrum has been designated by the International Telecommunications Union radio standards subcommittee (ITU-R) for industrial, scientific, and medical (ISM) uses. Figure 3.1 shows the bandwidth allocations in different parts of the world. Japan uses the 5.7 GHz bandwidth, while Europe uses 5.8 GHz. In the U.S., DSRC operates on two different levels: 915 MHz (megahertz) and 5.9 GHz. In 1999, the Federal Communications Commission (FCC) allocated the 5.9 GHz radio spectrum for vehicle-vehicle and vehicle-roadside communications in the U.S.

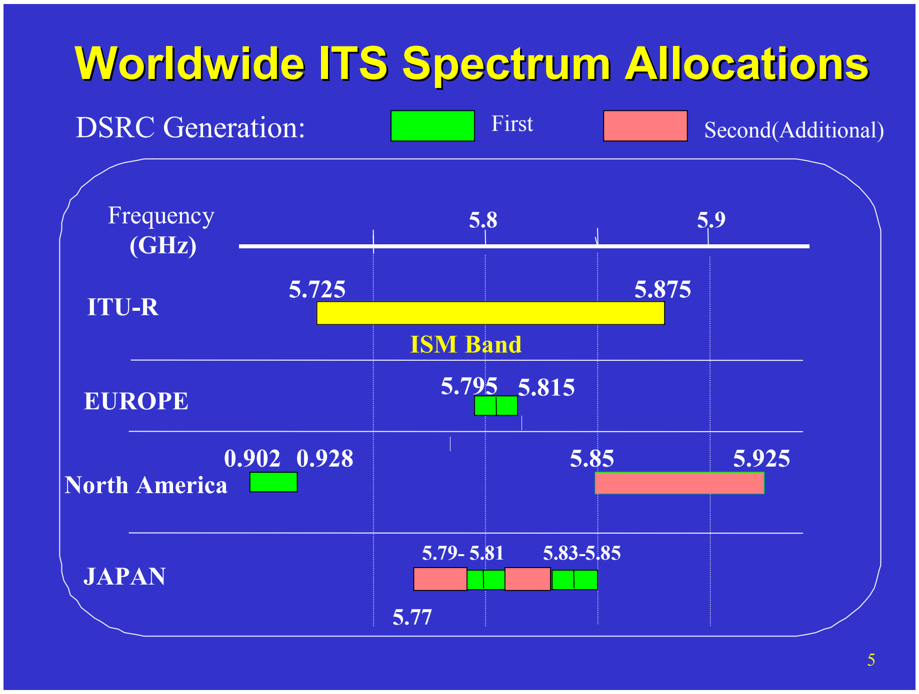

Figure 3.1: Current Worldwide DSRC Bandwidth Allocations
(Source: Armstrong, 2002)

3.2.2 Comparison of Communications Technologies

Among the considerations in selecting a communications technology, range, data rate, directionality, and cost per data unit are critical aspects. Table 3.1 shows a comparison of various radio spectrum communications technologies in terms of range, data rate (Mbps = megabits per second, kbps = kilobits per second), directionality, and rough cost per bit of data transfer. DSRC has the advantage for surface transportation applications because of data rates and cost per bit of data. Line of sight is typically not a severe constraint for roadside installations.

Table 3.1: Comparison of Radio Communication Technologies
(Source: IEEE, 2005)

	DSRC	FM Radio	Cellular Phone	Satellite
Range	1000 meters	Hundreds of kilometers	Kilometers	Thousands of kilometers
Data Rates	6 to 27 Mbps	>10 kbps	Present: >10 kbps Future: 2-3 Mbps	--
Directionality	Line of sight	Area	Area	Area
Cost (per bit)	Low	Low	$	$$$

The accuracy of DSRC has been validated in many studies. For example, DSRC vehicle positioning accuracy is ±1.5 m or better, according to research in Japan (ACHSRA, 2003). The testing was conducted with vehicles cruising at up to 120 km/h, and it also measured the influence of nearby vehicles. In addition, processing speed was tested. The sensor, mediated by the road-to-vehicle communications device, had a lag time of 20 ms or less for completion of processing by an OBU. Other tests have confirmed DSRC data transmission accuracy, even at vehicle speeds as high as 120 mph.

3.2.3 Performance of 915 MHz versus 5.9 GHz

The 5.9 GHz band level has several advantages over 915 MHz. The primary one is range: the ability to facilitate higher data rates, lower signal loss, and more accuracy over longer ranges. Table 3.2 shows the capabilities of the two bands.

Table 3.2: Comparison of 915 MHz Systems to 5.9 GHz Systems

(Source: IEEE, 2005)

	915 MHz Systems	**5.9 GHz Systems**
Range	< 30 meters	up to 1000 meters
Data Rate	0.5 Mbps	6 to 27 Mbps
Intended Use	Designed for ETC, but can be used for other applications	Designed for general Internet access, can be used for ETC.
Channels	Single unlicensed channel	7 licensed channels
Implementation	Requires special (custom) chip set and software	Uses open off-the-shelf chip sets and software

Effect of Range on Performance: Figure 3.2 illustrates the effect of range on data transfer rate and shows the performance envelope of the 5.9 GHz band compared to 915 MHz. The 5.9 GHz band includes the capability to transfer data via the Internet, allowing a *seamless integration of transportation applications with information applications*.

Applications: The 915 MHz standards were completed several years ago, and are primarily used in household applications and ETC. They can no longer sustain the demands of new applications. The 915 MHz range was the initial spectrum for toll tags in the 1990s and will be phased out as those older tags are replaced. The new set of 5.9 GHz DSRC standards supports a larger variety of applications, including advanced vehicle control, traveler information, increased freight/cargo transport support, transit, parking, and traffic management. Also, traffic safety messages will receive priority over other messages and transactions so they are delivered rapidly. These advantages, in turn, make possible the deployment of new applications, including (Mark IV, 2005):

- In-vehicle public safety warnings and alerts
- Asset tracking and new e-commerce financial services
- Vehicle-to-roadside applications, such as traffic signal prioritization
- Vehicle-to-vehicle communication for safety applications
- Internet data packet hopping
- Roadway maintenance probes

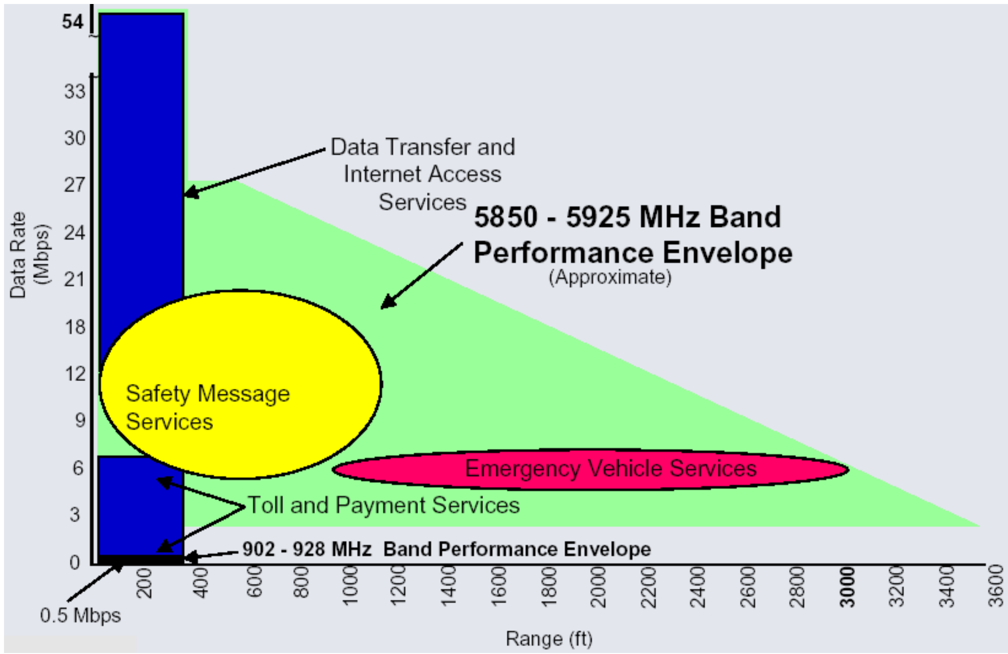

Figure 3.2: 5.9 GHz Performance Envelope (Source: IEEE, 2005)

3.3 Standards Development

Standards: Standardization plays a very important role in any large-scale deployment. A national deployment requires interoperability of equipment and systems coming from many different manufacturers, hardware/software certifications, compliance testing measures, and security measures. Standards are developed through industry consensus, and define how components operate within a consistent framework. The National Transportation Communications for ITS Protocol (NTCIP) is a family of standards that provides both rules (protocols) and the vocabulary (objects) for ITS and ETC technologies. NTCIP is a joint product of the National Electronics Manufacturers Association (NEMA), AASHTO, and the Institute of Transportation Engineers (ITE).

The standards for 5.9 GHz DSRC are being developed primarily by the American Society for Testing and Materials (ASTM) and the Institute of Electrical and Electronics Engineers (IEEE) committees, with additional elements being developed by the Society of Automotive Engineers (SAE), the American Association of State Highway and Transportation Officials (AASHTO), and the International Standards Organization (ISO). ITS America, an ITS industry forum, is providing the primary interface with the FCC. The following is a list of the companies participating in the effort at this time (IEEE, 2005).

1. 3-M
2. AASHTO
3. ACUNIA
4. AmTech
5. ARINC
6. Armstrong Consulting

7. Atheros
8. CalTrans
9. Daimler-Chrysler
10. DENSO
11. GM
12. GTRI
13. Highway Electronics
14. Hitachi
15. IDmicro
16. IMEC
17. Intersil
18. ITS-America
19. JHU/APL
20. King County Metro Transit
21. MARK IV
22. MiCOM Spa
23. Michigan State DOT
24. Mitretek
25. Motorola
26. Nissan
27. N.Y. Thruway Authority
28. OKI Electric
29. PATH
30. Raytheon
31. Sirit
32. Sumitomo Electric
33. TechnoCom
34. Toshiba
35. Transcore
36. Visteon
37. Washington State DOT
38. Wi-LAN

3.3.1 IEEE Standards

The IEEE standards aim to address the lack of high-speed communications between vehicles and service providers and the lack of homogeneous communications interfaces between different automotive manufacturers (US DOT, 2006A). The architecture, interfaces, and messages defined in the IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) support the operation of secure wireless communications between vehicles and infrastructure, as well as between vehicles. Applications will utilize these standards to provide, for example, services to drivers, roadway operators, facility operators, and maintenance personnel.

IEEE 1609 for WAVE, approved by US DOT in 2004, consists of four standards:

1. ***IEEE P1609.1—Resource Manager:*** This describes the key components of the WAVE system architecture and defines data flows and resources at all points. It also defines the command message formats and data storage formats that must be used by applications to communicate between architecture components, and it specifies the types of devices that may be supported by the OBU resident on the vehicle or mobile platform.
2. ***IEEE P1609.2—Security Services for Applications and Management Messages:*** This defines secure message formats and processing. This standard also defines the circumstances for using secure message exchanges and how those messages should be processed based upon the purpose of the exchange.
3. ***IEEE P1609.3—Networking Services:*** This defines network and transport layer services, including addressing and routing, in support of secure WAVE data exchange. It also defines Wave Short Messages, providing an efficient WAVE-specific alternative to IPv6 (Internet Protocol version 6), which can be directly

supported by applications. Further, this standard defines the Management Information Base (MIB) for the WAVE protocol stack.

4. ***IEEE P1609.4—Multi-Channel Operations:*** This provides enhancements to the IEEE 802.11 Media Access Control (MAC) to support WAVE operations.

3.3.2 ASTM Standards

ASTM is developing ***E2213-03- Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems—5 GHz Band DSRC Medium Access Control (MAC) and Physical Layer (PHY) Specifications***. ASTM E2213-03 provides wireless wide-bandwidth, high-speed communications over short distances between information sources or transaction stations on roadside units (RSU) and OBU, between OBU, and between portable units and OBU. The communications generally occur over line-of-sight distances of less than 1,000 meters.

ASTM E2213-03 is based on and refers to computer industry IEEE standard ***IEEE 802.11—Wireless LAN Medium Access Control and Physical Layer specifications High-Speed Physical Layer in the 5 GHz band***. This standard defines the operating parameters required to implement a high-speed data transfer service in the 5.9 GHz Intelligent Transportation Systems Radio Service (ITS-RS) band.

ASTM E2213-03 describes the requirements and procedures to provide for the privacy of user information being transferred over the wireless medium and authentication of the DSRC-conformant or IEEE 802.11-conformant devices. The standard is intended for equipment manufacturers and system integrators but may also be of interest to regulatory agencies, research consultants, and turnpike agencies. The high speed, assured data-delivery nature of this standard fully supports public safety applications and private enterprise delivery of information to vehicles. In October 2004, the Federal Communication Commission (FCC) approved ASTM standard E2213-02 for DSRC in the 5.9 GHz frequency band.

3.3.3 Electronic Payment Systems (EPS) Standards

OmniAir, a tolling industry consortium, is pursuing an EPS National Interoperability Specification (NIS). The EPS NIS will provide a uniform financial transaction process and network interface protocols from On-Board Units (OBU) to Road Side Units (RSU) to service provider to clearinghouse to issuer (IBTTA, 2005). Security of transactions is an essential element of EPS, and public key certificates will be used for this purpose. Figure 3.3 illustrates the anticipated EPS transaction sequence.

Governing principles for EPS for 5.9 GHz include:

- Nationwide interoperability
- Integration into new vehicles
- Simultaneous operation with legacy systems

- Two-way exchange with user for ordering-based systems:
    - OBU sends billing information
    - RSU optionally writes a tag.

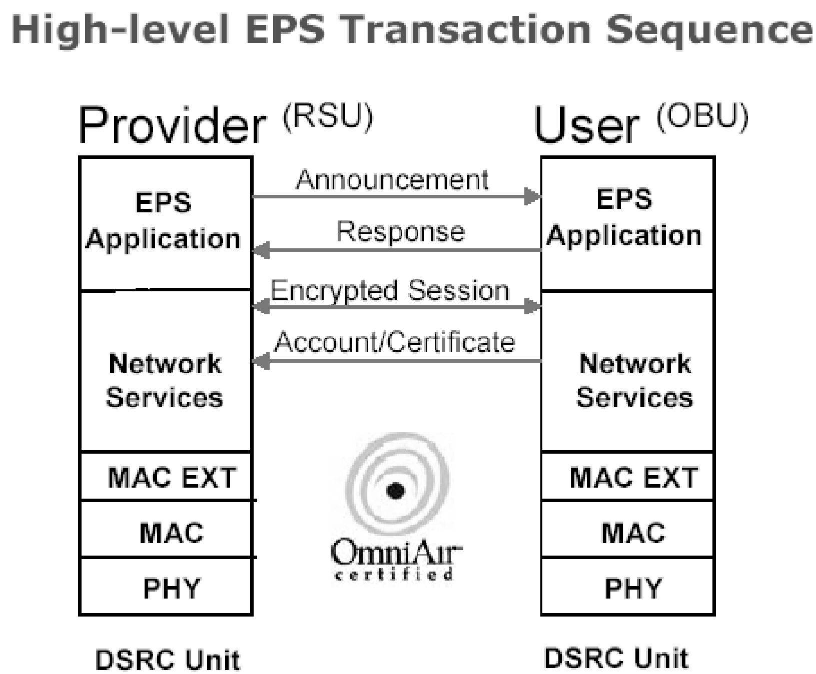

Figure 3.3: OmniAir Electronic Payment Service Transaction Process (IBTTA, 2005)

The National Interoperability Specification has been in development since mid-2004. At present, given that the protocol stack standards are stable, the following detailed application standards need to be developed:

- OBU to RSU
- RSU to Clearinghouse
- Inter-Clearinghouse
- Security Model.

3.3.4 Future Standards

Standards development is a long process. It has taken more than 6 years to put together the draft standards for 5.9 GHz in the U.S., and the work is not yet completed. Development of DSRC and GPS standards in Europe is still ongoing. Given the level of effort required, it is unlikely that complete standards will be developed anytime soon to facilitate a tolling industry switchover from DSRC to another technology. Newer technologies will have to demonstrate superior performance and cost before they can be considered viable replacements.

3.4 Role of EVI in ITS and Transportation System Management

This section describes the role of EVI in an integrated transportation management system. Vehicle credentialing, possibly via EVI, will be an essential component of future ITS. Already, in some northeastern states PrePass integrates truck credentialing with toll collection. However, developments will be constrained by the need for integration with existing infrastructure and TxDOT operations.

3.4.1 ITS Architecture

At present, the US DOT and several state departments of transportation (DOTs) are in the process of designing and implementing an all-inclusive, interconnected regional transportation system management network that incorporates travelers' needs, vehicle needs, and roadside requirements. The idea is that every user on the transportation system will be interconnected, resulting in greater safety, efficiency, and maximization of utility for the traveler and transportation system alike (PennDOT, 2005). This system is referred to as ITS Architecture. Figure 3.4 shows a partial diagram of ITS architecture.

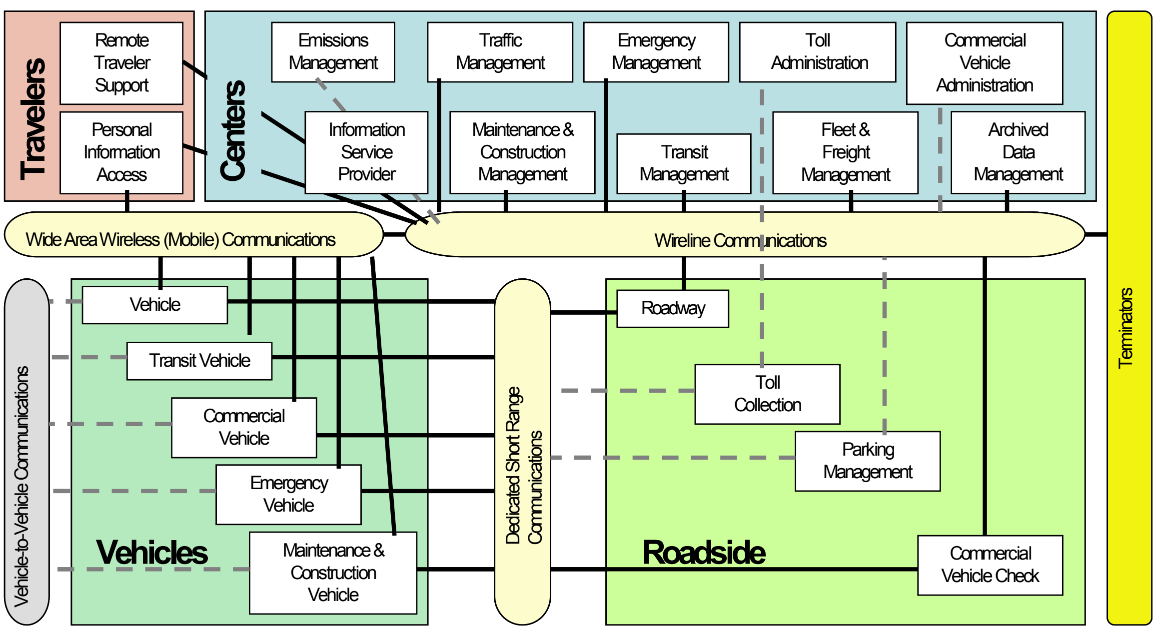

Figure 3.4: Partial "Sausage Diagram" for ITS Architecture
(Kimley-Horn & Assoc., 2005)

Travelers: Two subsystems, *Personal Information Access*, and *Remote Traveler Support*, would provide the capability for travelers to receive traffic information at home, on portable devices, or at en-route locations such as transit stops. The system would also support public safety monitoring, using surveillance equipment, and emergency notification within public areas. Tracking vehicle location is an essential requirement for collecting and distributing information.

Vehicles: This system would provide vehicle-vehicle and vehicle-roadside communications to support efficient, safe, and convenient travel. For the *Vehicle* subsystem, functions would reside in on-board units (OBU), and will eventually include automated vehicle operation. The *Transit Vehicle* subsystem would include signal prioritization functions, while the *Commercial Vehicle* subsystem would include cargo contents information, vehicle and driver safety data, and communications with inspection facilities. The *Emergency Vehicle* subsystem would provide coordination among police, fire, incident response, and medical services and would include signal preemption. Feedback processing would assist in re-routing traffic around incidents. The *Maintenance Vehicle* subsystem would provide location and condition information as well as environmental sensors for reporting infrastructure condition and weather. Each vehicle would require an ID and the means to continuously monitor its location and condition.

Roadside: This system would monitor and control traffic through vehicle identification, credentialing, and pricing, and would manage the performance of roadside elements. The *Roadway* subsystem would include monitoring of infrastructure and would deploy automated systems for de-icing or closing flooded lanes. Work zone surveillance would include driver warnings and violation enforcement. Safety features would include collision avoidance. The *Parking* subsystem would support electronic payment of parking fees, monitoring of lot usage, feedback to approaching vehicles, and dynamic pricing of parking. The *Commercial Vehicle Check* subsystem would support credentialing, safety and emissions inspections, weigh-in-motion, and pre-clearance at interdiction points. The *Tolling* subsystem would allow ORT, interoperability, feedback of account status, and transaction records. The Roadside system would require that the movements of each vehicle be recorded, and that an accountholder be identified for payments.

Centers: The Transportation Management Centers would provide the data processing required for ITS. The *Archived Data* subsystem would capture and maintain data. The *Information Service Provider* subsystem would collect, process, store, and disseminate transportation information to system operators and the traveling public. The information would be provided to the traveler through the Traveler system and various Vehicle subsystems through communications links. The *Emergency Management* subsystem would coordinate the activity of incident response services, including selection of responders, routing, and traffic control.

The *Traffic Management* subsystem would communicate with the Roadway subsystem to monitor and manage traffic flows. Incidents would be detected and the information provided to the Emergency Management subsystem, travelers, and third party providers. The subsystem would coordinate traffic information and control strategies with neighboring jurisdictions and with rail operations. The subsystem would also support demand management policies such as managed lanes. The *Transit Management* subsystem would manage transit fleets and coordinate with other modes and services, including providing customer information. The *Maintenance and Construction*

Management subsystem would manage construction and maintenance activities through continuous monitoring of infrastructure conditions and assignment of resources.

The *Freight Management* subsystem would provide information to commercial operators and researchers on routing/restrictions, and cargo/driver conditions. In addition, it would support connections to financial institutions and regulatory agencies, allowing seamless transactions. The *Commercial Vehicle Administration* subsystem would support credentialing, permitting, taxation, and safety regulation. The *Emissions Management* subsystem would monitor emissions and provide feedback on demand management needs. It would also flag emissions violators while providing automated inspections by data extraction from a vehicle's OBU. The *Toll Administration* subsystem would provide general payment administration capabilities and support the electronic transfer of funds from the customer to the transportation system operator. All of these subsystems would require electronic vehicle identification and user/account holder recognition/registration.

3.4.2 Expectations of ITS

Tolling is just one of the many functions ITS is expected to support. Apart from potential ITS uses in Figure 3.4 seen earlier, additional applications include:

- Monitoring travel times and congestion
- Feeding customized information to motorists
- Violations (emissions, registration, etc.): compliance can be checked at road speed.
    - Identifying emissions or registration violators
    - Warning speeders automatically
    - Notifying truckers of load-zoned or restricted lanes
- Security: When deployed at strategic points, including state borders, EVI can aid in homeland security.
    - Controlling access to secure areas
    - Pre-clearance (green line) at border crossings or other interdiction points
    - Spotting stolen or wanted vehicles.
- Commercial applications: tolling is increasingly a financial transaction similar to other purchases. For example, Spanish tollroads have organized to have banks manage ETC accounts and issue transponders (IBTTA, 2004). This is a short step to integrating tolling accounts with drive-through shopping and credit card accounts. Currently California is conducting a test with fast food giant McDonald's.

Potential uses for data from a vehicle's computer accessed by a DSRC reader include:

- Accident records: a vehicle's condition before crash could be obtained.
- Vehicle occupancy on HOV lanes: the computer senses occupancy for seatbelt warnings and to deploy airbags.

- Truck tolling based on tire pressure monitored by the vehicle computer.

Electronic vehicle identification is a requirement to realize the full benefits of ITS.

3.4.3 Timeline for ITS and EVI

Table 3.3 illustrates a possible timeline for development and implementation for the standards discussed in this chapter, and the integration of ITS. It is likely that the trend of using EVI for commercial vehicle credentialing will encourage the introduction of EVI systems in selected regions of the U.S. in the 2010-2015 timeframe

Table 3.3 Trends in ITS and EVI Implementation

Driving forces	Timeframe: Present -2010	2010- 2015	2015- 2025
Technologies	• Phase out of manual tolling and 915 MHz tags • Domination of toll market by 5.9 GHz DSRC tags • Growth of EVI for commercial vehicle credentialing • ITS deployment	• Mileage tolling using DSRC • Growth of tolling via GPS/cell phone • Completion of ITS deployment • Introduction of EVI in some U.S. states	• Satellite/GPS for mileage tolling • ITS integration
Standards	• Implementation of 5.9 MHz DSRC standards • Interoperability of toll tags within regions	• All toll tags interoperable in U.S. • Worldwide DSRC standards	Standards for GPS in traffic management

3.5 Chapter Summary

In this chapter, the status of standardization in ETC was reviewed. In addition, the role of EVI in an integrated system for transportation management was outlined. It was seen that DSRC standards are moving forward rapidly, and that ITS depends on universal EVI. In the next chapter the role of vehicle registration systems in EVI will be explored.

CHAPTER 4 EVI THROUGH VEHICLE REGISTRATION

4.1 Introduction

Two considerations for EVI implementation are obvious: the laws and rules under which TxDOT operates, and concerns about privacy. In this chapter concepts are explored that would allow vehicles to be identified electronically via the vehicle registration process. In addition, legal issues, privacy concerns, and enabling legislation are reviewed.

4.2 Vehicle Registration

Vehicle identification assists in verifying that vehicles using the public roads meet legal requirements, namely, roadworthiness, insurance status, etc. The most common form of vehicle ID is the license plate. State DOTs maintain a database of license plate numbers and relevant owner information within a Department of Motor Vehicles (DMV).

4.2.1 Registration and Titling

It is a legal requirement in the U.S. for most types of motor vehicles to be registered with a state DOT or DMV if they are to be used on public roads. The DOT records the vehicle's details (make, model, vehicle ID, etc.), details of the party currently responsible for the vehicle (name, address, and other contact information), and the registration expiration date. The state DOT provides a unique number on specified license plates that must be displayed on the vehicle. In addition, most DOTs now provide a sticker showing the expiry month/year of registration, plus other data, and require that the sticker be visibly displayed, either on the plate or inside the windshield. Linking the vehicle ID to its owner and contact information is a necessity to ensure financial responsibility.

Vehicle Titling: Issuing vehicle titles (proof of ownership) is another function of state DOT registration offices. A vehicle owner files proof of purchase documents (bill of sale from dealer, signed transfer of title from previous owner, lien release from financial institution, etc.) and receives a certified title document. Figure 4.1 illustrates the registration and titling process at TxDOT's Vehicle Title and Registration Division (VTR).

Vehicle Title Information: The American Association of Motor Vehicle Administrators (AAMVA) is a non-profit organization that develops programs in motor vehicle administration, police traffic services and highway safety. One of the issues they are looking at is the National Motor Vehicle Title Information System (NMVTIS). The NMVTIS—legislation invoked by the US DOT Anti Car Theft Act of 1992—allows state titling agencies to verify the validity of the owners' documents before it grants titles. Not only will law enforcement officials be able to obtain information on any vehicle, they will also get junkyard and salvage yard information related to the vehicle. Potential consumers would also get data on odometer readings, title history, and vehicle history, allowing them to make more informed decisions about purchases and insurance. If the car has an OBU, this information would be stored on it and could be downloaded directly.

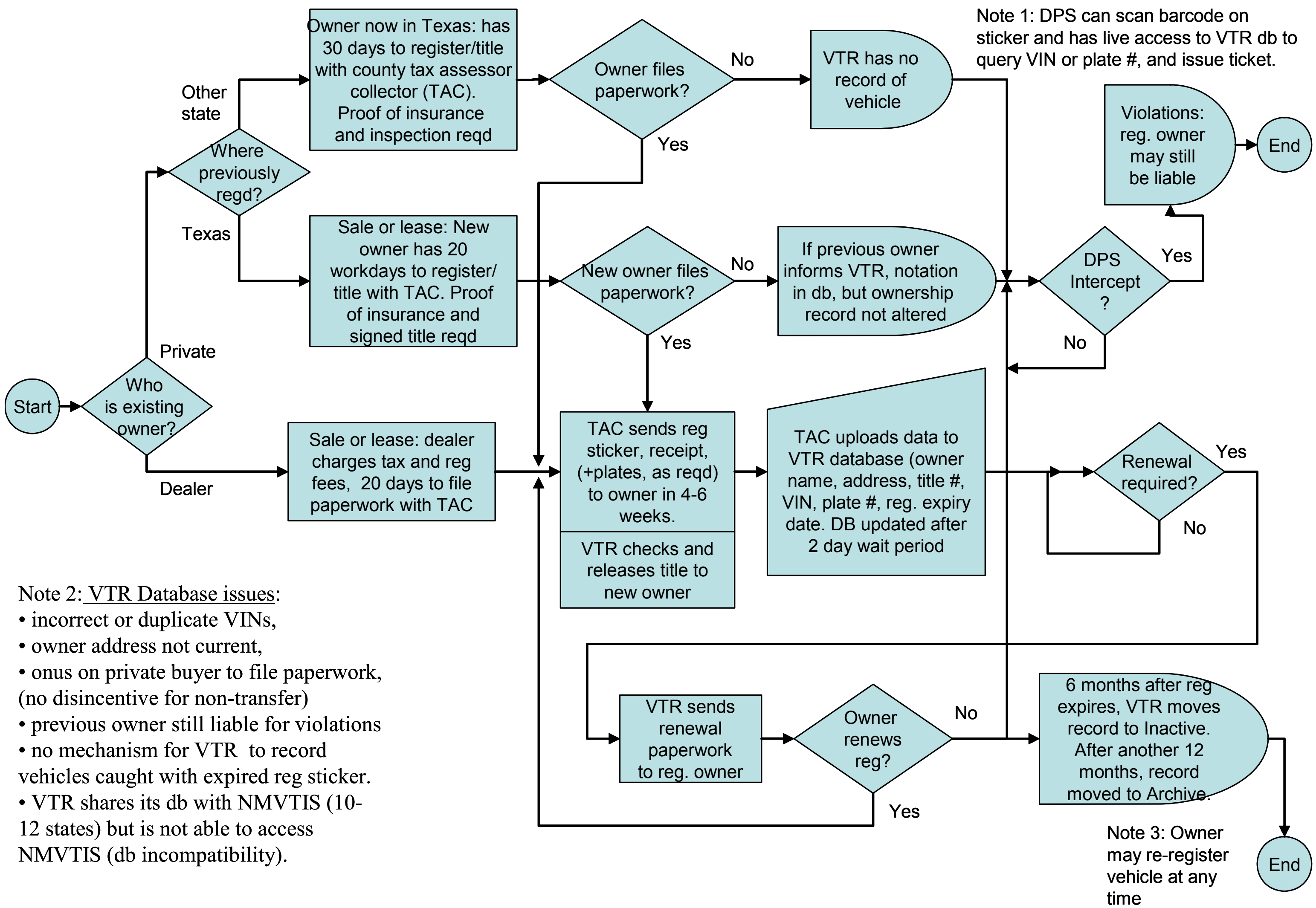

Figure 4.1 Vehicle Registration and Titling Process at TxDOT's VTR

Vehicle Identification Number (VIN): Vehicle data sharing among state DOTs is an issue. However, each manufactured vehicle in the world has a unique ID. The VIN is a combination of numbers and letters imprinted by vehicle manufacturers on the engine, frame, and other parts of a vehicle. Newer vehicles have a 17-character VIN consisting of:

- 1st character: Identifies the country in which the vehicle was manufactured. For example: U.S.A.(1 or 4), Canada(2), Mexico(3), Japan(J), Korea(K), England(S), Germany(W), Italy(Z)
- 2nd character: Identifies the manufacturer. For example; Audi(A), BMW(B), Buick(4), Cadillac(6), Chevrolet(1), Chrysler(C), Dodge(B), Ford(F), GM Canada(7), General Motors(G), Honda(H), Jaguar(A), Lincoln(L), Mercedes Benz(D), Mercury(M), Nissan(N), Oldsmobile(3), Pontiac(2 or 5), Plymouth(P), Saturn(8), Toyota(T), VW(V), Volvo(V).
- 3rd character: Identifies vehicle type or manufacturing division.
- 4th to 8th characters: Identifies vehicle features such as body style, engine type, model, series, etc.
- 9th character- Identifies VIN accuracy as check digit.
- 10th character: Identifies the model year. For example: 1994(R), 1995(S), 1996(T), 1997(V), 1998(W), 1999(X), 2000(Y), 2001(1), 2002(2), 2003(3), etc.
- 11th character: Identifies the assembly plant for the vehicle.
- 12th to 17th characters: Identifies the sequence of the vehicle for production as it rolled off the manufacturer's assembly line.

On the Internet there are several sites that allow a VIN to be entered and return vehicle data. In effect, a national database of VINs exists. The VIN can serve as a common link among databases without compromising the private data stored in each.

VTR Restrictions: Release of VTR records is restricted by state and federal laws such as the Driver's Privacy Protection Act (DPPA). VTR keeps records of personal information (names and addresses of owners & lienholders) and non-personal information (vehicle data, registration and title status). The law permits release of personal information only if the requester certifies that they have a defined permissible use, while non-personal information may be released to anyone. Use in connection with the operation of a private toll transportation facility qualifies as a permissible use of VTR's personal and non-personal information records. VTR provides Texas toll systems with a weekly update of its database of plate numbers and registered owners.

4.2.2 Database Enhancements

Online Registration: Use of automated ways to transact business is a growing trend. In 2001, TxDOT's Vehicle Titles and Registration Division (VTR) started online registration of motor vehicles. Users in participating counties can renew their vehicle registration via the Internet. The county tax collector's office (point-of-sale or POS) verifies payments, then prints and mails the registration renewal stickers. Information required for vehicle registration include county of residence, address, credit card number, license plate number, last 4 digits of the VIN, and insurance information. Registration information from VTR's mainframe Registration and Title System (RTS) is exchanged with a webserver, Texas Online (TxO), and the user's browser. TxO communicates with credit card providers to transfer funds to the county's bank account. The county also maintains a local database of registration data, payments, and refunds.

Database Sharing: The database structure to handle online transactions is illustrated in Figure 4.2 (BearingPoint.com, 2003). Registration information from VTR's mainframe Registration and Title System (RTS) is exchanged with the webserver, Texas Online (TxO), and the user's browser. TxO communicates via E-pay with credit card providers to transfer funds to the county's bank account. The county also maintains a local database of registration data, payments, and refunds. There are several points of possible integration between VTR databases and tolling databases, supporting the implementation of EVI systems.

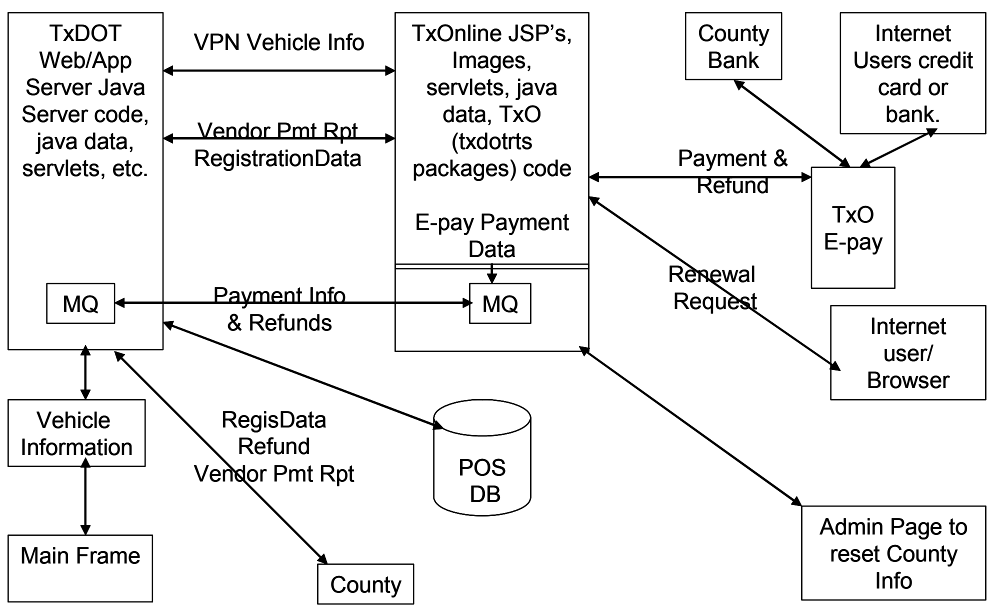

Figure 4.2: Online Registration Communication Structure (BearingPoint.com)

Distributed Networks: In implementing EVI, center-to-center communications will be a challenge, as will enforcement, including the role of the Texas Department of Public Safety (DPS). The Trans Texas Corridor will be wired for ITS and open road tolling. All corridors will have closed circuit cameras and dynamic message signs. Regional cooperation is desirable, as in the case of EZPass in the northeast and in the TxTAG program. Figure 4.3 illustrates the distributed toll collection/data sharing network proposed by TTA for the TxTAG program (Russell, 2004). Such distributed networks are a promising solution for data sharing.

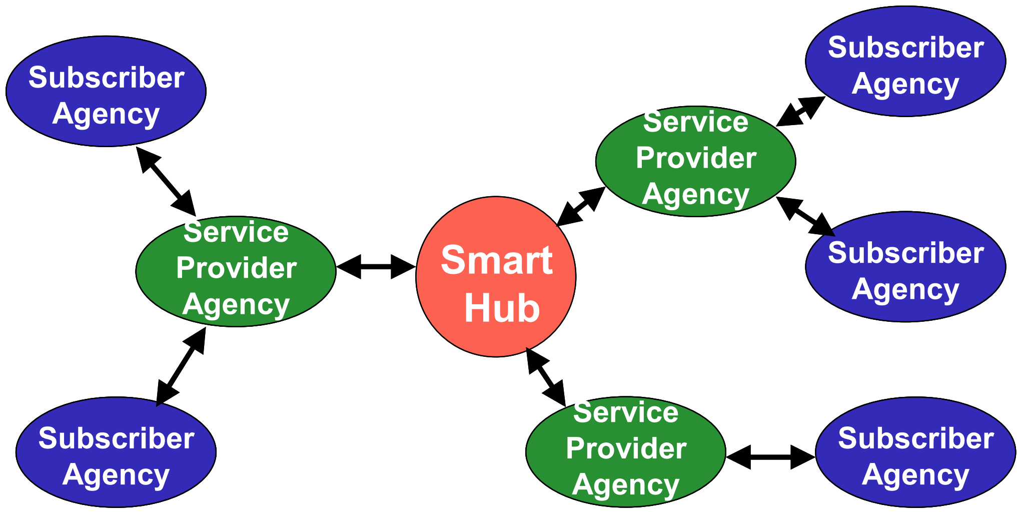

Figure 4.3: TxDOT's Proposed Distributed Toll Data Network (Russell, 2004)

4.3 Introducing EVI through Registration

The primary interest of TxDOT's VTR in this research was to examine the possibility of using smart stickers for vehicle registration. Currently, Texas registration stickers are inscribed with the last 8 digits of the VIN, the license plate number, the county of registration, and the registration expiration month/year. The same information is also printed in bar code form on the sticker to discourage counterfeiting. Texas Department of Public Safety (DPS) officers are able to scan the bar code and verify validity. They also have live access to the VTR database to check ownership.

4.3.1 Initiatives

Universal Tag? Apart from the recent implementation of bar coding, there are two initiatives regarding sticker tags. The first is a joint effort of DPS and VTR to implement recent legislation that requires vehicle/motorist insurance information to be available to DPS. The idea is that the officer can automatically verify whether the vehicle has current insurance. The second is an idea by the Texas Commission on Environmental Quality (TCEQ) to merge the emissions/inspection sticker with the registration tag. TCEQ has not yet approached VTR with its proposal.

Merging Print with Electronic: In addition to imprinting required registration information on a sticker, it may be possible to code the data onto a built-in RFID tag in the sticker, which can then be read and/or written to remotely. Currently, RFID toll tags are affixed inside the windshield and are similar to a registration sticker in appearance. A typical size is 85 mm x 76 mm (3.3 in. x 3 in.), consisting of two layers of film housing a tiny antenna connected to a chip that integrates both processor and memory. Toll tags are now paper-thin except at the chip, where they are 1 mm thick. Figure 4.4 shows a toll tag from TransCore, maker of TxTAG, now being deployed by the Texas Turnpike Authority Division (TTA).

Figure 4.4: TransCore Toll Tag: Full Size (TransCore, 2006)

Potential Candidates: There are already some companies trying to market electronic vehicle registration (EVR) tags. For example, in 2003 TransCore and 3M proposed an EVR system based on an electronic tag. Features would be similar to the SeGO tag. Vehicle compliance would be checked with readers strategically placed throughout the state (TransCore, 2004). The entire procedure would be a replica of ETC vehicle ID operations.

Initiative in China: Validation of registration, insurance, and inspection can all be accomplished by DSRC as an alternative to bar codes. RFID tags can also be printed with familiar information for normal reading. Several provinces of China now use RFID tags for vehicle registration. In 2000, TransCore entered a contract with Sichuan Province in China to implement RFID tags for vehicle registration. To begin rollout of the system, Sichuan is using 1 million of TransCore's Intellitag windshield sticker tags and several hundred universal access point RFID readers in roadside-fixed, mobile, and handheld configurations. Initially, all vehicles in Yibin City were issued tags. Wireless inquiries of passing vehicles provide vehicle registration information and status of annual vehicle inspection, vehicle emissions, taxation, and traffic record—all within 0.1 s. The technology also supports dynamic management of traffic intersections to control traffic, speed, and safety. In the future, the technology will be adapted to the growing demand for mobile commerce, such as electronic payment at gas stations.

4.3.2 Electronic Vehicle Registration (EVR) Benefits for Texas

EVR using RFID tags to replace current registration stickers would provide benefits to VTR:

- *Increase compliance and lower the cost of vehicle registration transactions.* Government agencies lose millions of dollars each year because an estimated 3 to 10 percent of vehicles are not compliant with annual registration requirements, a cost which then trickles down to taxpayers and law-abiding citizens. On the other hand, because drivers would know how easily they could be spotted by remote scanners, they would be more likely to register. Savings could also accrue if a new sticker is not issued each time registration is renewed—instead, a database update would be sufficient.

- *Improve the integrity of titlin*g. Many DOTs do not have an effective way to ensure that the new owner of a vehicle purchased in a private transaction will file the paperwork to transfer the title. Electronic monitoring would make it easier to identify vehicles that have not had a complete transfer of title if the previous owner files a notice of transfer but the new owner fails to complete the transfer.

In addition, EVR would further two other initiatives in which VTR is involved:

- *Reduce the number of uninsured vehicles.* Uninsured motorists are a significant problem for the road system. The 79th Texas Legislature passed Senate Bill 1670, which provides that the Texas Department of Insurance (TDI), in consultation with DPS, TxDOT, and the Texas Department of Information Resources (DIR) "shall establish a program for verification of whether owners of motor vehicles have established financial responsibility." The goals of this Financial Responsibility Verification Program (FRVP) are as follows: to reduce the number of uninsured motorists in this state; to have vehicles operate reliably; to be cost-effective; to sufficiently protect the privacy of the motor vehicle owners; to safeguard the security and integrity of information provided by insurance companies; to employ a method of compliance that improves public convenience; to provide information that is accurate and current; and to have the capacity to be audited by an independent auditor. Most of the bidders for the contract (TransCore is one of them) are also affiliated with the toll tag industry, so it is possible that the program will involve RFID tags. Database sharing is a major concern for the insurance companies.

- *Increase compliance with vehicle inspection requirements.* Annual vehicle inspection is required in most jurisdictions to protect public safety. A windshield sticker is issued to verify compliance. In addition, several counties require emissions inspections to screen for vehicles that pollute excessively. However, a significant segment of vehicles on the road have expired inspection stickers. Manual compliance monitoring methods are sporadic and usually depend upon other incident detection events, resulting in minimal sampling of the total vehicle population. RFID scanning would replace labor intensive and expensive manual, visual-based identification, tracking, and enforcement systems.

Furthermore, EVR would strengthen law enforcement capabilities by enabling:

- Easy access to, and sharing of, interagency information, including alerts, prior to approaching a vehicle with a history of incidents
- Automated detection of non-compliant vehicles
- Faster apprehension of dangerous vehicles.

Finally, apart from other previously discussed generalized benefits of DSRC and EVI that would be achieved through EVR, EVR would also deter motorists from being non-compliant with legal requirements. Subsequently, agencies can allocate resources to higher-priority concerns.

4.3.3 Drawbacks of EVR

There are some drawbacks associated with deployment of EVR (CUTR, 1993). Chief among them are:

- *Specialized methods, personnel, and equipment.* Deploying EVR will require a change in the way VTR operates and will require new equipment and personnel with specialized skills. Initial costs and training requirements will be significant. Databases and database security will also have to be upgraded. In addition, county offices that now handle online registration will have to be reconfigured to deal with the new tags. DPS will require different scanners than the ones now used for bar code reading. There may also be a need for additional customer service during a transition period. Establishing an acceptable level of service will be a challenge.

- *Data privacy and information exchange.* Both public and private sectors are concerned about the potential numerous uses of data obtained from roadside scanners. The public sector does not want any information generated by electronic screening to be misused. The potential for hackers to capture data or alter records must be addressed. Some private companies may be wary of losing business secrets inadvertently when they share data, while others will want to get free access to data for commercial purposes.

- *Acceptance by enforcement personnel.* Many enforcement personnel do not trust automated inspections, and believe it is necessary for officers to be seen doing their work in order to serve as a deterrent. Some jurisdictions may not be able to afford the scanning equipment or the computer systems required to provide access to statewide databases.

- *Acceptance by the public.* The public is concerned about systems that allow them to be tracked. However, significant benefits, convenience, and low cost often trump these concerns. For example, credit card use continues to grow even though the data makes it easy to trace where, when, and what business individuals transact. Regardless, an outreach program would be needed to alleviate fears of *Big Brother*.

4.3.4 Developments That Could Influence EVR

National Initiatives: Over the next five years, there are some major initiatives and legislative changes scheduled to take place that could affect EVR through their impacts on vehicle registration and licensing:

1. A national database of motor vehicle IDs, ownership, and registration address.

2. Restructuring of the REAL ID Act. The REAL ID Act of 2005 is Division B of an act of the United States Congress entitled Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Tsunami Relief, 2005. One of the recommendations of this controversial legislation is to deter terrorism by establishing national standards for state-issued driver's licenses and non-driver's identification cards.

   Title II of REAL ID—"Improved Security for Driver's License' and Personal Identification Cards"—repeals the provisions of a December 2004 law that established a cooperative state-federal process to create federal standards for driver's licenses and instead directly imposes prescriptive federal driver's license standards. After December 31, 2009, "a Federal agency may not accept, for any official purpose, a driver's license or identification card issued by a state to any person unless the state is meeting the requirements" specified in the Real ID Act. States remain free to also issue non-complying licenses and ID's, so long as these have a unique design and a clear statement that they cannot be accepted for any Federal identification purpose.

Texas Initiatives: TxDOT's VTR is creating a vision for the next 5-15 years and has hired a consultant (Dye Management) to examine its operations and recommend changes. The issues being considered include:

1. Strengthening of insurance verification/financial responsibility, perhaps requiring better proof of extended validity of insurance.
2. Plate to owner, i.e. a person owns plate numbers, attaches them to vehicles when he buys, and removes them when he sells.
3. Electronic titling, i.e., acceptance of electronic signatures, etc.
4. Standard registration fee for cars and light trucks.

At present, VTR is still examining the role of the private sector in the vehicle registration function. The Dye Management project will make recommendations. Potential areas for improvement include contracting out the customized license plate activities, streamlining the dealer title system (along the lines of how counties are contracting out some the titling work), and truck registration—especially interstate and international trucking.

Changes in technology are also being considered:

1. Web-hosted applications. Users can access public areas and transact business directly, but there will be private areas with firewall/password protection.
2. New database structure to support web-hosting. Records will be centered on individuals, not on plate numbers (i.e., a plate is assigned to a person with associated data, not vice versa).
3. Use of imaging and other technologies to reduce paper records and paper transactions.

As VTR moves to a customer-centered database service, they will collect email and phone information to simplify contacting for billing reminders. In the future they may also collect credit card information for direct billing. They will also share data with other agencies in order to ensure that billing addresses, information on drivers licenses, insurance, inspections, etc., are up-to-date.

4.4 Privacy Issues with EVI

This section addresses the privacy issues associated with electronic vehicle identification systems. There still remains a great deal of uncertainty regarding privacy issues stemming from EVI. Current laws barely address electronic privacy, and given the rapidly changing nature of technology, interpreting the law with respect to privacy is becoming more challenging.

4.4.1 Issues Regarding Electronic Monitoring

Government agencies generally support more widespread use of electronic monitoring of public activities and communications in the interest of efficiency, public safety, and security.

- *Efficiency:* Better information on the use of infrastructure allows for better management of limited resources, planning for future needs, and preventive maintenance.
- *Safety:* Remote *patrolling* using cameras and listening devices deters scofflaws in the same way regular police patrols do. Visual or audio evidence helps trace violators and increases the likelihood of conviction.
- *Security:* Criminals increasingly communicate and transfer funds electronically. Terrorists also tend to target transportation infrastructure, where people gather in large numbers, such as planes and trains. Monitoring transportation networks, analyzing unusual patterns, and profiling likely culprits are all tools for disrupting such activity.

On the other hand, civil liberty advocates and many members of the public are disquieted by *Big Brother* government. They argue that the monitoring of legal activities is equivalent to unwarranted search and seizure.

- *Civil liberties:* Surveillance chills legitimate dissent. The same technology used for monitoring terrorists and criminals can be used for tracking and persecuting people who disagree with the government.
- *Secret records:* Collecting data, e.g., where individuals have traveled or where they stopped, could be potentially embarrassing if disclosed to employers or opponents. The commercial value of such data raises the potential for corruption by officials. Identity theft is also possible.
- *Monitoring displaces scofflaws:* Violators may simply move their activities to areas where monitoring is not in place.
- *Cost:* Advanced technology is expensive and requires high skill levels for installation, maintenance, and operation. With so many social needs under-funded, monitoring of the public without due cause should not be a priority.

4.4.2 Constitutionality of Automated Enforcement

Automated enforcement programs have raised concerns about the violation of an individual's right to privacy, as inscribed in the First and Fourth Amendments of the Constitution. In addition, the programs may raise other constitutional issues, such as the right of free association (First Amendment), the right to equal protection (Fourth Amendment), right to present a defense (Sixth Amendment), and the right to due process (Tenth Amendment). Similar concerns apply to EVI. A study conducted by the University of California at Davis looked at the legal and constitutional framework regarding automated enforcement checkpoints (UCD, 2005).

Privacy: Regarding the First Amendment, no court case has yet established an individual vehicle driver's right to privacy. Legal scholars also assert that automated enforcement does not violate Fourth Amendment protections against unreasonable searches, based on Supreme Court cases that find that vehicle drivers and occupants have a diminished legal expectation of privacy.

Speedy Trial: Alleged violators have the right to be notified promptly, under the Sixth Amendment. The right to present a defense may be infringed upon when there is a time lag between the alleged violation and the receipt of a citation, because defendants may forget important details needed to defend their case, especially when they are unaware that they were caught in a violation. However, the courts have ruled that due process rights are not violated if a citation is issued within 1 year, as long as the delay is not deliberate. Still, it is in the interest of the issuing agency to be as speedy as possible, from a public acceptance standpoint.

Public Perception: Most people have the perception of privacy while driving, and consider electronic monitoring of that activity a violation of privacy. Therefore, agencies planning to deploy such systems must address those privacy concerns and market the benefits of the program before deploying it. Moreover, the program should be tailored expressly to further the efficient operations of the agency and not exceed the agency's mission. In executing the program, it is critical that targets for fines are notified as soon as possible, with clear guidelines for appeal and resolution.

4.4.3 Privacy Laws in the U.S.

While automated enforcement has been regarded as constitutional, such programs must be consistent with existing federal and state privacy laws. The following describes the most important federal laws regarding privacy.

Freedom of Information Act (FOIA) (1966): It was the Founding Fathers' view that the American government should be subservient to the individual. Thus, court rulings have generally held that the American public has the constitutional and inherent right to be allowed access to information held by the government. However, there is often a clash between the sensitivity of some government information and a private interest's desire to have access. Therefore, in 1966, Congress enacted the Freedom of Information Act (FOIA) to deal with requests for government records, consistent with the people's "right to know." The FOIA explicitly applies only to federal government agencies. These agencies are under several mandates to comply with public solicitation of information. Along with a requirement to make public and accessible all bureaucratic and technical procedures for applying for documents, agencies are also subject to penalties for hindering the processing of a petition for information. Thus, there is recourse for someone to go to a Federal court if suspicion of illegal tampering or delayed sending of records exists. However, there are nine exemptions, under which the President has unlimited power in declaring something off-limits or necessarily classified as a matter of national safety. This loophole has presented numerous problems for individuals seeking information under the FOIA.

The Privacy Act (1974): The Privacy Act of 1974 is an act regulating government control of documents that concern a citizen. It states that a person has the right to:

- see records about himself, subject to the Act's exemptions,
- amend that record if it is inaccurate, irrelevant, untimely, or incomplete, and
- sue the government for violations of the statute, including giving others access to his records unless specifically permitted by the Act.

In conjunction with the Freedom of Information Act (FOIA), the Privacy Act advanced the rights of an individual to influence personal information held by the government.

Electronic Communications Privacy Act (ECPA) (1986): The ECPA was enacted by the U.S. Congress to extend government restrictions on wire taps to include transmissions of electronic data by computer. Specifically, the ECPA was an amendment to Title III of the Wire Tap Statute of 1968, which was primarily designed to prevent unauthorized government access to private telephone communications. Later, ECPA was amended by some provisions of the USA PATRIOT Act (2001). ECPA creates standards and procedures for court-authorized electronic surveillance, regulates when electronic communication firms may release information, and provides legal protection of the privacy of stored electronic communications from outside intruders and unauthorized government officials.

At present, revisions of the ECPA are under consideration, including privacy protection for toll road customers. It should be noted, though, that in most places toll road use is essentially voluntary because toll roads usually run parallel to a free facility. Participation in an electronic toll collection system, therefore, can also be considered voluntary. Drivers who have fears about being tracked or photographed can use the free facility or pay in cash.

The Patriot Act (2001): The Patriot Act was passed by Congress in 2001 as a response to the terrorist attacks of September 11, 2001. This act has tremendous ramifications for privacy in the U.S. While the Patriot Act has ten titles and numerous sections, Title II: Enhanced Surveillance Procedures, which gives increased powers of surveillance to governmental agencies, is the most relevant with regard to the issue of privacy. In particular, there are several sections in Title II that have been criticized by civil rights and privacy groups as being too vague and intrusive (Wikipedia: USA Patriot Act, Title II).

Title II sections have the potential to affect privacy in the use of traditional information sources such as telephones, to newer communication methods such as the internet and also EVI practices. In general, opponents of the Patriot Act argue that the government is given too much unchecked power. Government authorities, they argue, do not have to show enough evidence to obtain warrants or personal information. They also argue that the new powers given to agencies are essentially violations of a person's First and Fourth Amendment rights, and that judicial oversight is almost non-existent.

Some of the sections of Title II that could affect EVI are:

- Section 203, which gives authorities the ability to share information regarding criminal activity. Opponents believe that the section will not limit disclosure solely to information relating to investigations of terrorist activities, because the term "foreign intelligence information" is too vague.
- Section 206, which allows for the roving surveillance of targets and allows a government agency to require full assistance to perform such surveillance. Opposition groups believe that this statute gives too much free rein to government authorities and that lowering standards leads to abuses of the Fourth Amendment. In the opinion of the Electronic Frontier Foundation, section 206 allows the FBI to "wiretap every single phone line, mobile communications device, or Internet connection that a suspect might be using without ever having to identify the suspect by name…for a year" (Electronic Frontier Foundation: Patriot Section 206).
- Section 212, which allows the emergency disclosure of electronic communications to protect life and limb. At present disclosure is limited to phone companies and ISP handing over a customer's personal records to authorities

when there is reasonable belief that lives are in danger, but disclosure might be expanded to include EVI data as well.

- Section 220, which gives the power to Federal courts to issue nationwide search warrants for electronic surveillance—which could possibly include warrants for EVI information. Section 220 deals with criminal cases as well as terrorism, something opponents believe should not have been specified in the Act. They believe that agencies will be able to find sympathetic judges who will issue warrants even if the warrants do not completely satisfy the strict requirements of the Fourth Amendment to the Constitution. Additionally many warrants are issued *ex parte*, which means that the party being served need not be present when the order is issued.
- Section 216, which is an expansion of pen register laws. Opponents of the law believe that pen register laws were designed to be used specifically for wiretaps and not for more modern communications modes such as the internet.

There is overwhelming consensus that appropriate safeguards and guidelines on the control and use of information must be established to protect the privacy of individuals.

4.5 Additional and Enabling Legislation

At present, most countries, including the United States, have not passed laws specifically governing the use of RFID. In many cases, existing privacy laws are interpreted to cover the use of data collected by RFID systems, as well as bar codes and other systems. Some U.S. states have considered enacting new laws that deal with issues particular to RFID, such as the surreptitious scanning of RFID tags by retailers or people with criminal intent.

State Laws: The implementation of EVI programs usually requires special amendments to state law. According to the Insurance Institute for Highway Safety, nineteen states and Washington, DC currently have some form of local or statewide enabling legislation for automated enforcement. However, long-standing programs in Arizona operate without a specific statute. Such enabling legislation is typically necessary to establish a number of important legal conditions necessary for the effective operation of EVI.

Legal Authority: States need to enact laws giving agencies the legal authority to institute EVI. An example of the lack of legal authority comes from California. Under California law, the use of camera technology in red-light and grade-crossing violations programs, and photo-radar for speeding enforcement are specifically prohibited. In effect, there is no legal authority to directly issue citations from such EVI programs. Instead, *notices* of violations can be issued to the registered vehicle owners, beginning the process of legal service for an eventual court citation.

Until the owner signs the notice of violation, the county does not have jurisdiction to issue a citation. If the alleged violator ignores the notice, staff of the agency must make a positive license photo match and submit a formal request to the court to have a citation issued. Photographs that do not match the ones on file or are blurry must be thrown out.

This procedure is labor intensive and costly. Eight of the nine defunct automated speed enforcement programs in California noted lack of legal authority as a major factor in their demise.

Requirements for Enabling Legislation: The specific elements of the enabling legislation are usually determined in cooperation with the courts, enforcement agencies, state transportation department, motor vehicle departments, and other entities whose operations may be affected by the program, such as insurance companies and vehicle user associations. The basic framework is one that typically establishes infraction types, procedures, deadlines for service of citation, liabilities incurred, and defense procedures. Authority may be delegated to a civilian contractor for some enforcement duties, penalty and fine provisions, and admissibility of evidence.

Voluntary electronic screening programs may not require enabling legislation because their rules and procedures are established through voluntary contracts among agencies, vendors, and the carriers. However, non-voluntary screening applications may require legislation that addresses a broad range of issues, depending on the type of data collected. For example, commercial vehicle screening may raise issues of business confidentiality and trade secrets.

The lack of legislation regarding electronic vehicle identification in general, and DSRC in particular, has to be addressed. Transportation system managers are planning an electronic future, in which DSRC would link all segments of transportation, as well as commercial activity; and a legal framework is necessary for the process to move forward successfully.

4.6 Possible EVR Timeline and Chapter Summary

Given the various changes that are currently occurring and are likely to occur in the future regarding EVR, a timeline was developed in this research to provide a sense of the direction of developments, and the issues that must be addressed. As was seen in Table 3.3 earlier, the primary driving forces are technology and the development of standards. Table 4.1 is based on the interactions, impacts and opportunities discussed in this chapter, and indicates the required initiatives within state DOTs, and anticipated public response.

Chapter Summary: Two considerations for EVI implementation are obvious: the laws and rules under which TxDOT operates, and concerns about privacy. Legislative changes may be required to advance EVI, specifically what information can be imbedded in the sticker, and who will have access to read data. In addition, VTR procedures may need to be enhanced. The role of DPS should also be clarified. The public will have concerns over privacy as EVI is implemented. On the other hand, public response to government actions can be more vehement than expected, as in the case of the Austin toll plan. For EVI, a TxDOT policy on collection and use of driver data via electronic tags would be advisable. If TxDOT decides to proceed with implementation, public response will need to be addressed through a public relations campaign.

Table 4.1: Possible EVR Timeline

Driving force	Timeframe: Present -2010	2010- 2015	2015- 2025
Legislation	Unsettled law regarding privacy and electronic communications. Attempts by state DOTs and Congress to enact laws.	Test cases and challenges on electronic monitoring. Supreme Court rulings.	Settled law on privacy and electronic data.
Interactions, impacts, opportunities			
Required DOT Initiatives	• Deployment of ITS in metropolitan areas • Use of tolling to expand system capacity • Interoperability of toll systems • Managed lanes and congestion pricing • Separation of trucks from cars	• Mileage tolling and variable pricing • Toll interoperability with Canada and Mexico • EVI and EVR	Integrated system management using ITS.
Public response	• Outreach programs to market the benefits of EVI and EVR. • Public opposition to *Big Brother* • Political opposition to some initiatives	Benefits of EVR in terms of convenience and lower costs start to accrue.	Public should have internalized the benefits of EVI.

CHAPTER 5: BENEFIT-COST ASSESSMENT OF EVI

5.1 Introduction

Among the benefits touted for EVI are improved speed and accuracy of data collection and analysis, and increased agency efficiency. EVI could be integrated into existing and proposed ITS deployment, and would capture information that could be shared with other agencies in real-time. Examples include insurance compliance, traffic conditions, and traveler information. Costs, including deployment of roadside readers and enforcement systems, must be considered.

This chapter provides an assessment of the benefits and costs of implementing EVI, focusing on the transportation-related impacts. This analysis is not intended as a comprehensive estimate of all benefits and costs, but as an indication of the relative magnitude of the impacts and an assessment of the feasibility of the concept.

5.2 Analyses by Others

DeCorla-Souza Study: In a study by Patrick DeCorla-Souza of the Transportation Research Board (TRB), the costs and benefits are analyzed for a system-wide congestion pricing program using DSRC in a Washington, D.C. case study area (TRn, 12/03/03). All vehicles would be transponder-equipped and would be scanned and charged as they passed under mainline gantries at highway speed. The study claims that, by using dynamic tolls to reduce peak-period traffic, high levels of service can be maintained. The estimates of costs and revenues (2003 $) are shown in Table 5.1.

Table 5.1: Cost and Revenue Estimates for EVI-based Congestion Pricing

(TRn, 2003)

Annualized Costs:	**$ million (2003)**
400 gantries at 3 mi apart at $60K ea.	24
DSRC equipment at $46K ea.	19
Video cameras at $24K ea.	10
System costs	17
Staff and equipment	10
Transaction costs @15c x 2.4 m trips/day for 250 days	90
Total cost per year	**(170)**
Annual Revenue:	
Total revenue for 2.4 m trips/day x 5.4 mi./trip x 14c per mi. x 250 days	450
Less 20% discount for toll-exempt vehicles	(90)
Total revenue per year	**360**
Revenue/Cost Ratio:	**2.12 : 1.00**

DeCorla-Souza's toll rates are based on the value of time savings. At a value of time of $8.40/hour (compared to $13.80 estimated for the SR 91 Express Lanes in California) and an average time savings of 1 min/mi (60 mph versus 30 mph), an average toll rate of 14¢/mi is used, resulting in a revenue/cost ratio of 2.12 : 1.00. The study shows a positive return even though the only benefit counted is the value of time savings to motorists.

Another study, conducted by the San Francisco Bay Area Toll Authority, found benefit cost (B/C) ratios as high as 14.0 for freeway ramp metering projects using EVI. Newly designed HOV toll lanes and mixed free flow lanes also showed positive B/C ratios, as listed in Table 5.2. It can be concluded that the benefits of DSRC deployment in transportation system management are likely to outweigh the costs.

Table 5.2: Bay Area Toll Authority: B/C Ratio for Projects Using EVI

Project	Benefit / Cost Ratio
Freeway Ramp Metering	14.0
New HOV Lanes	2.0
New Mixed Flow Lanes	1.2
Auxiliary Lanes	5.0

ITS Europe Study: In a study conducted by ITS Europe for the European Union (ERTICO, 2004), the payback period for EVI implementation in Europe was estimated. The worst case scenario of minimum estimate of benefits and maximum estimate of cost produced a payback period of approximately 25 years. In the best case scenario of maximum benefits and minimum costs, the payback period was 14 years, still a long period considering the 'shelf life' of new technologies. That study also noted the difficulty in translating benefits into revenue, and the risks of unknown costs, largely due to uncertainties regarding the technologies.

5.3 Assessment of Benefits

Deployment of EVI can provide benefits to managers of transportation infrastructure as well as users, translating ultimately into economic benefits and savings to the general public.

5.3.1 Benefit Classifications

For this study, the benefits associated with implementing EVI in Texas are categorized in three levels: first order or direct revenues, second order or user benefits, and third order or societal benefits. Not all of these benefits are quantified here.

- First order benefits: those applications that would directly translate into increased revenues for transportation agencies, for example, improved registration, vehicle inspection, and enforcement of road use regulations.
- Second order benefits: those applications that result in savings to users through better traffic operations, for example, time savings and fewer crashes.

- Third order benefits: benefits that redound to the wider society, for example, increased economic efficiency and reduced pollution.

It is important to note that the first order benefits carry a political risk, in that they would be achieved through more efficient monitoring of vehicles. Government agencies would need to be transparent in any decision to raise revenues through better enforcement. On the other hand, the second order benefits are likely to enjoy widespread public support, but would not translate into direct revenues to pay for implementation. The third order benefits are quite diffuse, and are neither likely to advance support for implementation nor to increase funding prospects. All benefits are annual values unless otherwise stated.

5.3.2 First Order Benefits

The ability to quickly and accurately identify vehicles operating on the transportation system would allow authorities to more easily recognize those that do not follow regulations on road use. EVI would help agencies increase conformance with legal requirements, and ensure that applicable fees are paid.

- **Improved compliance with registration**

Vehicle registration accounts for roughly one quarter of the budget for the Texas Department of Transportation (TxDOT, 2004). TxDOT's Vehicle Titles and Registration Division (VTR) estimates that 3 percent of vehicles using the roadways are not up-to-date with their registration (VTR Meeting, 2007). It is probable that 50-75% of the motorists not in compliance plan to renew their registration but have not gotten around to it. Knowing that they are more likely to be identified and fined would motivate those motorists to keep their registration current. For this analysis, an improvement in registration compliance of 25-50% will be assumed, translating into an increase in registration fees.

- **Improved compliance with inspection and testing**

All 254 Texas counties require annual safety inspections on vehicles. In addition, 17 counties require vehicle emissions testing in order to use the roadways. These counties are Brazoria, Fort Bend, Galveston, Harris, Montgomery, Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, Tarrant, Travis, Williamson and El Paso (Figure 5.1).

Emission testing plays a vital role in the urban areas of Texas in improving air quality and environmental standards (DPS, 2007). DPS could not provide a figure on non-compliance with inspection requirements, so for this analysis a noncompliance rate similar to the registration noncompliance is assumed (namely, 3%: the assumption made is that the same people who forget to renew their registration probably are just as likely to forget inspections). Therefore, again a 25-50 percent improvement is estimated upon the implementation of EVI. Not only would this increase in compliance provide air quality and safety improvements for urban areas and the state, but it would provide for an increase in revenues from inspections. A monetary value will only be calculated for the inspection revenues, not the air quality and safety benefits (which are very difficult to quantify).

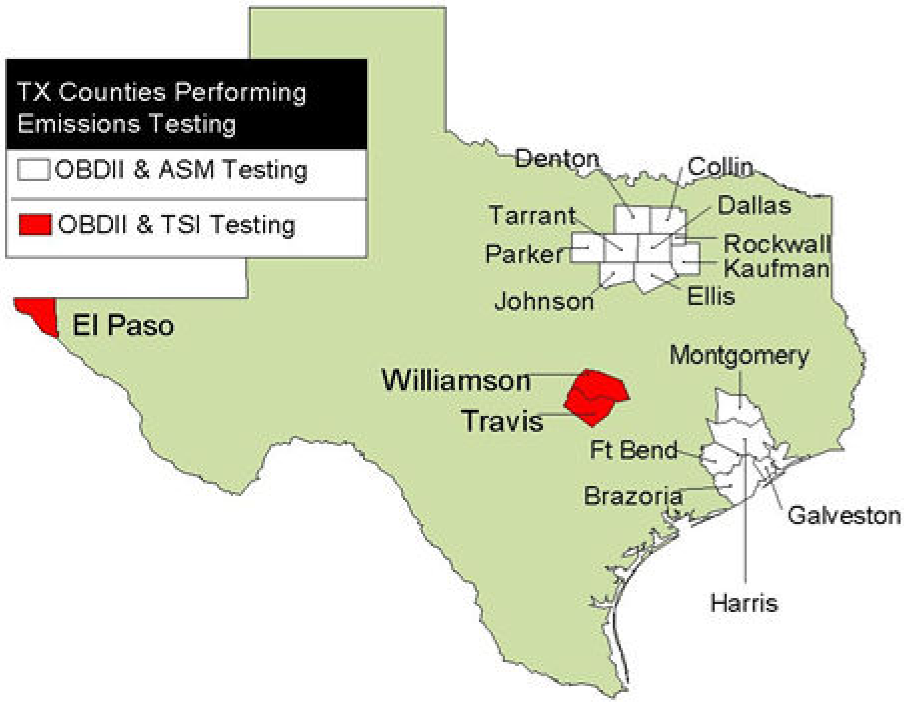

Figure 5.1: Vehicles emissions testing requirements in Texas

- **Improved compliance with road use regulations**

Generally in Texas, checks on compliance with road use regulations such as proof of insurance and licensure of drivers (including suspensions resulting from DWI offences) are only carried out when a vehicle is stopped by an authority for probable cause. EVI would allow highway patrol personnel to link scofflaws to vehicle IDs and thus locate them more easily on the roads. Failure to carry a readable vehicle ID would be a ticketable offence. Such automated enforcement does not violate Fourth Amendment protections against unreasonable searches, based on Supreme Court cases that find that vehicle drivers and occupants have a diminished legal expectation of privacy.

According to the European study done by ERTICO (2004), 35 percent of moving violations could not be prosecuted due to lack of proof resulting from low quality evidence. For example, speed checks carried out manually or by means of speed cameras have the possibility of losing proof of violation due to the poor quality of photos, escape from pursuits, or the faltering of radar equipment. It was estimated that there would be an improvement of 10-25% in compliance with road rules, including licensing and insurance, with EVI implementation (ERTICO, 2004). A similar improvement rate is assumed for Texas, resulting in increased revenues from ticketing of violations.

5.3.3 Second Order Benefits

Better monitoring of traffic would allow better information on delays and route choices to be provided to motorists. Such information would result in improved system efficiency and time savings (Walton et al., 2006). As seen earlier, EVI would improve compliance with road use regulations, reducing loss of property and life due to crashes. In addition, sophisticated applications of vehicle position/trajectory recognition would reduce the number of crashes.

- **Improved effectiveness in traffic management**

Most of the data on traffic volumes is collected from in-road sensors such as loop detectors. EVI would provide faster and more accurate data on volumes, classification, travel times, and congestion. Feeding delay information to travelers would result in traffic re-routing, leading to better utilization of the existing system. Not only would users enjoy the time savings result from higher traffic throughputs and avoided congestion, but they would also have lower fuel costs and vehicle wear-and-tear. According to a CTR study, a reduction in travel time of 1.6 percent would be observed in urban areas when a traveler information system is implemented (Walton et al., 2006). It is assumed that only urban drivers (about 50% of all VMT in Texas (BTS, 2000)) would see this benefit. Given the annual costs associated with congestion for Texas, estimated at $5,530,000,000, and for Austin, estimated at $430,000,000 (BTS, 2000), EVI would provide significant savings to road users.

- **Freight and other system efficiencies**

Currently, vehicles are identified primarily through the reading of license plates. EVI would allow faster and more accurate vehicle identification, speeding up freight inspection, weighing, and clearance at borders. Freight vehicles could also enjoy in-vehicle safety warnings and notification of load-zoned or restricted lanes. Implementing EVI would improve traffic signal coordination and prioritization, infrastructure condition and maintenance reporting, and would also lower the costs for deployment of future ITS elements. Moreover, with universal EVI, video tolling would be unnecessary. However, it is very difficult to quantify most of these improvements in system efficiency monetarily.

- **Decreased crashes**

Several studies have drawn correlations between speed compliance and the reduction of vehicle collisions. One study linked a 1 mph reduction in average speed to a 5 percent reduction in crashes (Finch, 1994). Another study claims that compliance with a 50 km/h speed limit would produce a 44 percent reduction in the total number of collisions (Gou, 2007). Australian research found that a reduction from 110 km/h to 100 km/h would result in reducing casualty crashes by 20 percent (Long, 2006). The ERTICO – ITS Europe study concluded that EVI implementation would result in a 0.1-0.5 km/h reduction in speeding violations, and a 0.3 to 1.5 percent reduction in crashes would result (ERTICO, 2004). For this analysis, a 0.2-1.0 percent reduction will be used. With this postulated reduction in collisions, road users would experience a major benefit from decreased injuries and fatalities.

- **Decreased vehicle theft**

In 2005, DPS estimated that the value of stolen vehicles in Texas was $828 million, of which 30% were not recovered (DPS, 2005). The ability to more accurately and regularly identify vehicles would lead to increased recovery of stolen vehicles and even a reduction in vehicle theft. The study conducted by ERTICO – ITS Europe estimated a 5-10% reduction in stolen vehicles (ERTICO, 2004). However, it must be noted that there are GPS tracking and other technologies for vehicle recovery, and these are likely to grow in use. Therefore, for this analysis, a reduction of 1-2% in vehicle loss will be attributed to EVI, still resulting in significant savings to motorists.

5.3.4 Third Order Benefits

Third order benefits to the wider society would result from EVI implementation, including improvements in economic efficiency, reduction in pollution, and savings on future costs. However, most of these benefits are difficult to quantify. Hence, the estimate of benefits of EVI implementation will be understated in this analysis.

5.4 Cost Assessment

Costs for deployment of EVI infrastructure can be expected to be similar to those for tolling installations, because tag readers and software would be very similar. However, costs will also depend on the functional intent, amount of coverage desired, and the design of the roadside elements. Enforcement coverage would also be an issue. It may not be cost-effective to set up a V-toll system for rare users such as out-of-state cars.

5.4.1 Overview of Costs

The following figures provide an indication of the costs of various elements of EVI infrastructure. The year 2002 cost estimates for three main toll plazas and thirteen ramp toll plazas on the Central Texas Turnpike Project SH 45 North element (now nearing completion) are shown in Table 5.3 (CTTP, 2002).

Table 5.3: SH 45N Toll System Component Cost Estimates

Toll system component	Estimate ($ m)
3 mainline toll plazas—structure	17
13 ramp toll plazas— structure	10
Prefab toll booths	2
Toll plaza footprints—sitework	1
Fiber optic network	7
Furniture and equipment	1
Toll collection software, etc.	23
Toll tags	8
Total	**69**

Annual operation and maintenance costs are not included. With an estimated 4 percent annual construction cost escalation factor and 10 percent construction contingency factor, the final year 2007 cost for the SH 45N toll collection system is expected to be around $90 million. That number still compares favorably with recent single toll plaza construction costs of $21 million in Lee County, Florida, and $25 million in York, Maine.

5.4.2 Cost Elements

The following costs are annualized values unless otherwise stated.

- **Production and Distribution Costs**

The implementation of EVI would require the manufacturing of a DSRC tag to be mounted on the windshield of all vehicles registered in the state (later on, it may be 'hard-wired' into vehicles). Distribution and installation is assumed to be similar to the current method for registration stickers and TxTag toll tags, namely, mailing the tag to the vehicle owner who then installs it himself. Implementation would take about 1 year, as registration tags are renewed. The TxTag toll tag costs $9.65 each, and this price is rapidly falling (TxTag, 2007). This is a one time cost until the tag wears out or becomes obsolete. For example, the tags originally distributed for the Dallas tollway in the early 1990's are now becoming obsolete and are being replaced with TxTags. With an assumed life of 10 years and at an interest rate of 8%, the annual cost is $1.44 per vehicle. It is estimated that about 10% of tags will be damaged or lost each year, costing $1.04 per vehicle. In addition, new tags will need to be distributed to newly registered vehicles each year. An increase of 2% a year in vehicle registration is anticipated (VTR, 2007).

- **Infrastructure Costs**

To obtain the benefits described earlier, it would be necessary to install overhead tag readers on roadways. In addition, highway patrol cars will require handheld readers to scan tags when vehicles are stopped. The current cost of hand-held readers is estimated at $2,000-$5,000. With an assumed life of 10 years and at an interest rate of 8%, the annual cost of handheld readers is about $298-$745. It is assumed that overhead readers would be installed approximately every 5 miles along the roadways in urban areas (as is the case for an experimental deployment done in Houston, Texas), and approximately every 10-15 miles in rural areas. These overhead readers are estimated at an annualized cost of $2,000-$5,000 each. Because sign structures and traffic light gantries already straddle most urban roadways, additional structures to support readers would not be needed in urban areas. Rural areas would require such structures. Structures are estimated at an annualized cost of $13,000-$19,000 each, including maintenance (ITS, 2004).

- **Maintenance Annual Costs**

Every handheld and roadside reader would require mandatory maintenance and calibration each year. The costs are estimated at $200-$500 per unit per year (ITS, 2004).

- **Annual Transaction Costs**

There is a cost associated with the task of reading the tags and processing the data in a traffic management center. For example, it is estimated that ETC transactions cost $0.07-$0.15 (CTR, 2006). Since most EVI "transactions" will not involve accessing accounts and billing customers but simply reading time stampings and processing them, it is assumed here that costs will be $0.01-$0.02 per read. Using total annual VMT of 220 billion for all of Texas and 102 billion Texas urban (BTS, 2000) and reads at 5 miles in urban areas and 15 miles in non-urban areas, 28 billion reads will be required annually to capture all vehicles. However, it is not necessary to read every vehicle to monitor the system. For this analysis, a 20% read rate will be used in urban areas and 10% in rural areas. These numbers equate to an average of about 500,000 reads per reader per year. As a comparison, the ERTICO study estimated that each reader will perform on the order of 20,000 reads per year (ERTICO, 2004).

5.5 Benefit/Cost Calculations

There are different scenarios for implementation of EVI, with different cost impacts. Deployment of readers will be expensive, and may only be feasible for specific roads or locations. Installation and operation costs will differ for overhead and roadside readers.

5.5.1 Case Study Scenarios

A range of EVI implementation scenarios are possible:

1. Full scale: Tag every vehicle and install infrastructure throughout the state.
2. Phased:
   i. By vehicle type: Begin EVI implementation with a specific class of vehicles, e.g. commercial vehicles. In fact, several private trucking companies have already installed tracking devices of various types (GPS, cell phone, RFID) to monitor cargo movement. This is a clear example of commercial need driving implementation, and it would benefit TxDOT to study this development and evaluate its potential as a PPP for EVI.
   ii. By region: Begin EVI implementation in an urban core (as for cordon tolling). This has been successfully implemented in London, and has been proposed for New York City. No such proposal has yet been floated in Texas.
   iii. By corridor: Begin EVI implementation in an urban corridor (similar to corridor tolling). The infrastructure for tolling already exists in several Texas cities, making it easier to 'tag' on to the existing system. Houston has already implemented a pilot EVI system on some of its freeways, and Austin district has submitted a proposal to FHWA to do a comprehensive trial.

To understand the possible range in the benefit/cost ratio for implementing EVI, the two extremes were analyzed. Values for the state of Texas as a whole and for a section of Interstate 35 in north Austin were calculated. The Austin section was selected in order to identify more concentrated effects. As a relative indicator of Austin's response to EVI, within 3 months of opening of the Central Texas toll roads (namely SH 45N and SH

130), over 200,000 TxTAGs were sold in the Central Texas area (personal communication from Phil Russell, director of TxDOT's TTA Division).

Corridor Characteristics: For this study, a 6.4 mile section of Interstate 35 in northern Austin between US-183 and Lamar Blvd was evaluated. The daily traffic in this segment is 230,000 (CAMPO, 2007). Since a large part of the traffic on I-35 through downtown Austin is local, it is postulated that each vehicle is making an incoming and outgoing trip daily. Therefore, about 115,000 vehicles in the Austin region can be considered to be regular users of that roadway segment.

5.5.2 Calculation Equations

The benefits and costs that were quantified for this analysis are as follows:

Annual Benefits:

Improved compliance with registration

$B_r = R_r \times \%_{nc} \times \%_i$

B_r = Benefits due to improved registration

R_r = Annual registration revenues

$\%_{nc}$ = Percent non-compliance in registration, testing and inspection

$\%_i$ = Anticipated percent improvement in registration, testing and inspection

Improved compliance with inspection and testing

$B_i = R_i \times \%_{nc} \times \%_i$

B_{ii} = Benefits due to improved testing and inspection

R_i = Annual revenues from testing and inspection

$\%_{nc}$ = Percent non-compliance in registration, testing and inspection

$\%_i$ = Anticipated percent improvement in registration, testing and inspection

Improved compliance with other road use regulations

$B_{ov} = (R_{dl} + R_s \times \%_{ls}) \times \%_{iov}$

B_{ov} = Benefits due to improved compliance with other regulations

R_{dl} = Annual revenues due to lack of drivers license, insurance or DWI offense enforcement

R_s = Annual revenues due to speed offenses and signal violations

$\%_{ls}$= Percent lost due to inability to identify offenses and violations

$\%_{iov}$= Anticipated percent improvement in identifying offenses and violations

Improved effectiveness in traffic management

$B_{tm} = CC \times \%_{itm}$

B_{tm} = Benefits due to improved effectiveness in traffic management
CC = Annual urban congestion cost
$\%_{itm}$ = Anticipated percent improvement in traffic management

Decreased road crashes

$B_{rc} = L_{rc} \times AS_r \times \%_{irc}$

B_{rc} = Benefits due to decreased road crashes
L_{rc} = Annual losses due to road crashes
AS_r = Average speed reduction
$\%_{irc}$ = Anticipated percent improvement in road casualties

Decreased vehicle theft

$B_{vt} = L_{vt} \times \%_{ivt}$

B_{vt} = Benefits due to decreased vehicle theft
L_{vt} = Annual losses due to vehicle theft
$\%_{ivt}$ = Anticipated percent improvement in vehicle theft

Annual Costs:
Production and distribution initial costs

$C_{pd} = N_v \times P_{pd}$

C_{pd} = Costs due to production and distribution
N_v = Number of vehicles registered
P_{pd} = Price of production and distribution per tag

Infrastructure initial costs

$$C_i = (N_{hr} + \frac{Mi_{hw} \times (1 - \%_{rural})}{Mi_{ru}} + \frac{Mi_{hw} \times \%_{rural}}{Mi_{rr}}) \times P_r + \frac{Mi_{hw} \times \%_{rural}}{Mi_{rr}} \times P_s$$

C_i = Costs due to infrastructure
N_{hr} = Number of hand held readers needed
Mi_{hw} = Miles of highway
Mi_{ru} = Miles per reader needed, urban areas
Mi_{rr} = Miles per reader needed, rural areas
$\%_{rural}$ = Percent of highway miles in rural areas
P_{rh} = Price per reader, handheld
P_{ro} = Price per reader, overhead
P_s = Price per structure

Maintenance costs

$$C_m = (N_{hr} + \frac{Mi_{hw} \times (1 - \%_{rural})}{Mi_{ru}} + \frac{Mi_{hw} \times \%_{rural}}{Mi_{rr}}) \times M_r$$

C_m = Costs of annual reader maintenance

N_{hr} = Number of handheld readers needed

Mi_{hw} = Miles of highway

Mi_{ru} = Miles per reader needed, urban

Mi_{rr} = Miles per reader needed, rural

$\%_{rural}$ = Percent of highway miles in rural areas

M_r = Annual maintenance cost per reader

Annual transaction costs

$$C_t = (N_{hr} + \frac{Mi_{hw} \times (1 - \%_{rural})}{Mi_{ru}} + \frac{Mi_{hw} \times \%_{rural}}{Mi_{rr}}) \times N_t \times P_t$$

C_t = Costs annually due to reader transactions

N_{hr} = Number of hand held readers needed

Mi_{hw} = Miles of highway

Mi_{ru} = Miles per reader needed, urban

Mi_{rr} = Miles per reader needed, rural

$\%_{rural}$ = Percent of highway miles in rural areas

N_t = Number of annual transactions per reader

P_t = Price per transaction

Annual production and distribution increase costs

$$C_{apd} = N_v \times P_{pd} \times (1 + \%_{inc})^t - N_v \times P_{pd} = C_{pd} \times (1 + \%_{inc})^t - C_{pd}$$

C_{apd} = Costs annually for production and distribution increases

N_v = Number of vehicles registered

P_{pd} = Price of production and distribution per tag

$\%_{inc}$ = Anticipated percent increase in registered vehicles per year

C_{pd} = Costs due to production and distribution

t = Program time in years

Benefits Summation

$$B = (B_r + B_i + B_{ov} + B_{tm} + B_{rc} + B_{vt}) \times t$$

Costs Summation

$$C = C_{pd} + C_i + (C_m + C_t) \times t + \left[C_{pd} \times (1 + \%_{inc})^t - C_{pd}\right]$$

5.5.3 Values for Calculation

Table 5.4 shows the values that were used for the two case studies to input into the previous equations in order to determine benefits and cost values for analysis. The sources of these values are also given. The 'Worst case values' shown are those that lower the benefits and increase the costs, and will be used later in the sensitivity analysis.

Table 5.4: Values used in calculations, and sources

Variable	Texas	I-35	Source	Worst-Case Value
R_r	$1,377,726,866	$7,898,603	VTR, 2007 / $\%_{TX}$	
$\%_{nc}$	3%	3%	VTR, 2007	
$\%_{i}$	50%	50%		25%
R_i	$165,231,000	$947,281	Combs, 2007 / $\%_{TX}$	
R_{dl}	$67,000,000	$384,116	DPS, 2004 / $\%_{TX}$	
R_s	$7,415,000	$42,511	Combs, 2007 / $\%_{TX}$	
$\%_{ls}$	35%	35%	ERTICO, 2004	
$\%_{iov}$	25%	25%	ERTICO, 2004	10%
CC	$5,530,000,000	$31,727,318	BTS, 2000 / CAMPO, 2007*	
$\%_{itm}$	0.8%	1.6%	Walton, 2006	
L_{rc}	$19,761,000,000	$113,291,173	NHTSA, 2005 / $\%_{TX}$	
AS_r	0.1	0.1	ERTICO, 2004	0.05
$\%_{irc}$	2%	2%	ERTICO, 2004	
L_{vt}	$827,818,781	$4,745,942	DPS, 2005 / $\%_{TX}$	
$\%_{ivt}$	2%	2%	ERTICO, 2004	1%
N_v	20,059,065	115,000	VTR, 2007 / CAMPO, 2007	
P_{pd}	$2.48	$2.48	TxTag, 2007	
N_{hr}	1,711	2	DPS, 2003	
Mi_{hw}	79,535	6.4	TxDOT, 2004	
Mi_{ru}	5	5		
Mi_{rr}	15	15		10
$\%_{rural}$	62%	0%	TTI, 2002	
P_{rh}	$298	$298	ITS, 2004	$745
P_{ro}	$2,000	$2,000	ITS, 2004	$5,000
P_s	$13,000	$13,000	ITS, 2004	$19,000
M_r	$200	$200	ITS, 2004	$500
N_t	500,000	500,000	estimate	
P_t	$0.01	$0.01	estimate	$0.02
$\%_{inc}$	2%	2%	VTR, 2007	
$\%_{TX}$	-	0.57%		

Many values for the I-35 case required extrapolation from State of Texas values. This calculation was done by using a comparative percentage of users, $\%_{TX}$.

$$\%_{TX} = \frac{N_V^{I35}}{N_V^{TX}} = 0.57\%$$

* Explanation for calculation of I-35 annual congestion cost

$$CC^{I35} = \frac{TC^{I35} \times Mi_{hw}^{I35}}{DVMT^{AUS}} \times CC^{AUS} = \frac{230{,}000 \frac{veh}{day} \times 6.4\ mi}{19{,}950{,}000 \frac{veh \cdot mi}{day}} \times \$430{,}000{,}000\ per\ year$$

5.5.4 Case Study Results

Use of the values from the previous section and the calculation equations yields the values in Table 5.5 for specific benefits and costs for statewide implementation.

Table 5.5: Results for statewide implementation

Variable	Description	Texas	Percentage
B_r	Improved compliance with registration	$20,665,903	*15%*
B_i	Improved compliance with annual inspection and testing	$2,478,465	*2%*
B_{ov}	Improved compliance with other road use regulations	$17,398,813	*12%*
B_{tm}	Improved effectiveness in traffic management	$44,240,000	*31%*
B_{rc}	Decreased crashes	$39,522,000	*28%*
B_{vt}	Decreased vehicle theft	$16,556,376	*12%*
B_{annual}	**Estimate of annual benefits**	$140,861,556	
C_{pd}	Production and distribution costs	$49,746,481	*33%*
C_i	Infrastructure annualized costs	$46,027,652	*31%*
C_m	Infrastructure maintenance costs	$2,208,621	*1%*
C_t	Annual transaction costs	$48,666,667	*32%*
C_{apd}*	Production and distribution increases costs	$3,871,400	*3%*
C_{annual}	**Estimate of annual costs**	$150,520,821	
	B/C ratio	**0.94**	

Overall, the annual benefits for the state of Texas are slightly less than the costs, and the **B/C ratio is 0.94**. However, it must be stressed that not all the benefits identified are quantified here. Of those quantified, 15% come from improved registration collections, and just 2% from improved inspections. Improved compliance with road use regulations and decreased vehicle thefts each contribute 12%. The largest contributions come from improved traffic data (31%) and from decreased crashes (28%). These percentages would change somewhat depending on assumptions in calculating the benefits and how much of the benefit is attributed to EVI. However, they do indicate the relative impacts of EVI on transportation, and can be used to focus on specific aspects of implementation and on gaining public support.

The annualized costs are almost equally distributed among tag distribution, infrastructure (hard) and transaction (soft) costs. A large part of these costs will be incurred initially in establishing the system, meaning that funding for the system will need to be upfront. In all likelihood, given the low B/C ratio, deployment would have to be phased.

The relevant results for the 6.4 mile segment of Interstate Highway 35 through Austin are as shown in Table 5.6:

Table 5.6: Results for selected I-35 Austin corridor implementation

Variable	Description	I-35 Austin	Percentage
B_r	Improved compliance with registration	$118,479	*11%*
B_i	Improved compliance with annual inspection and testing	$14,209	*1%*
B_{ov}	Improved compliance with other road use regulations	$99,749	*9%*
B_{tm}	Improved effectiveness in traffic management	$507,637	*48%*
B_{rc}	Decreased crashes	$226,582	*21%*
B_{vt}	Decreased vehicle theft	$94,919	*9%*
B_{annual}	**Estimate of annual benefits**	$1,061,575	
C_{pd}	Production and distribution costs	$285,200	*63%*
C_i	Infrastructure annualized costs	$9,192	*2%*
C_m	Infrastructure maintenance costs	$1,600	*0%*
C_t	Annual transaction costs	$138,000	*30%*
C_{apd}*	Production and distribution increases costs	$22,195	*5%*
C_{annual}	**Estimate of annual costs**	$456,187	
	B/C ratio	**2.33**	

Compared to the figure for the entire state, the annual benefits for this segment are greater than the costs, and the **B/C ratio is 2.33**. Of the benefits quantified, 11% come from improved registration collections, and just 1% from improved inspections. Improved compliance with road use regulations and decreased vehicle thefts each contribute 9%. The largest contributions come from improved traffic data (48%) and from decreased crashes (21%). Again, these percentages would change somewhat depending on assumptions in calculating the benefits and how much of the benefit is attributed to EVI.

The annualized costs are largely from tag distribution (63%), and transaction costs (30%). Because some of the hard infrastructure already exists in urban regions, those costs are low.

5.6 Sensitivity Analysis

Because there is a range in the assumed values for the benefit and cost calculations, the 'worst case values' shown earlier were used to lower the benefits and increase the costs. The objective was to assess the effect of the assumptions on the computed values. The relevant numbers for the two cases are shown in Table 5.7:

Table 5.7: B-C Ratios: Worst case scenario

Variable	Texas	%	I-35	%
Improved compliance with registration	$10,332,951	*11%*	$59,240	*8%*
Improved compliance with annual inspection and testing	$1,239,233	*1%*	$7,105	*1%*
Improved compliance with other road use regulations	$6,959,525	*8%*	$39,899	*5%*
Improved effectiveness in traffic management	$44,240,000	*49%*	$507,637	*66%*
Decreased crashes	$19,761,000	*22%*	$113,291	*15%*
Decreased vehicle theft	$8,278,188	*9%*	$47,459	*6%*
Estimate of annual benefits	$90,810,897		$774,631	
Production and distribution costs	$49,746,481	*21%*	$285,200	*47%*
Infrastructure annualized costs	$71,913,175	*30%*	$22,980	*4%*
Infrastructure maintenance costs	$6,343,415	*3%*	$4,000	*1%*
Annual transaction costs	$105,200,000	*44%*	$276,000	*45%*
Production and distribution increases costs	$3,871,400	*2%*	$22,195	*4%*
Estimate of annual costs	$237,074,471		$610,375	
B-C Ratio	**0.38**		**1.27**	

As expected the benefit/cost ratios decrease, to **0.38** and **1.27** respectively. However, the urban case still remains favorable, indicating that even under adverse scenarios, it is worthwhile to consider deployment of EVI in urban areas. Deployment of the tags is a significant cost, but can be passed on to vehicle owners, as the cost per tag is small compared to the current annual registration fee of about $70.

5.7 Chapter Summary

In this chapter the benefits and costs of implementing EVI were presented. The costs examined were those for the infrastructure required to install and operate the system, while the benefits evaluated were those that can be reasonably quantified and directly attributed to the implementation. Benefits to the transportation system were categorized in three levels: first order or direct revenues, second order or user benefits, and third order or societal benefits. Not all of these benefits were quantified. As a result, the B-C ratio estimates are extremely conservative. Other impacts that would benefit the wider society were not quantified, since the objective was to assess the relative magnitude of benefit and cost components and evaluate how those would influence implementation. Two assessments were presented, one for the state of Texas as a whole, and the other for a segment of Interstate Highway 35 in Austin, Texas.

CHAPTER 6 EVI DATA POLICY AND OUTLINE BUSINESS MODEL

6.1 Introduction

In this chapter an implementation model for EVI is outlined. First, the environment for implementation is discussed, focusing on a policy for managing EVI data. Then business models for implementing EVI are reviewed. Finally, a timeline is presented that integrates technological developments, legislation, and EVI services.

6.2 EVI Policy Considerations

6.2.1 Motivations for EVI

Public demand for information: With data processing capabilities increasing rapidly, it is now feasible to analyze huge amounts of data and create value-added information. The transportation sector, especially state departments of transportation, has lagged behind other fields in this regard. The public is becoming used to receiving a variety of information on the fly, and it is frustrating to travelers that even as they are able to receive text, audio, and video from anywhere in the world via wireless internet, they cannot get information on congestion in their immediate locale.

How EVI can help: EVI has the potential to revolutionize traffic information systems. Being able to detect where and when every vehicle is moving is comparable to having a 'high definition picture' of the transportation system, making it possible to deploy a host of services, such as in the following areas.

Travel and Traffic Management. These services would process EVI data to provide information to roadside display devices as well as in-vehicle devices. Information packages would include:

- Pre-trip travel information
- Ride matching and reservation
- En-route driver information
- Route guidance and traveler services information
- Parking information
- Traffic control
- Incident management
- Travel demand management.

Public Transportation Management. These services would support the operations of public transit organizations by processing EVI data on transit vehicles. Aspects of the transit system ranging from operations to maintenance and security would be covered, including:

- Personalized public transit
- En-route transit information
- Public travel security
- Fleet management

Commercial Vehicle Operations. These services support the goal of improving the efficiency and safety of freight operations, and will benefit both the economy and the trucking industry. The foundation for all the commercial vehicle operations user services is the exchange of information on the driver, the tractor, the trailer, and the cargo. EVI data on commercial vehicles would be processed to support:

- Commercial vehicle administrative processes
- Fleet and freight management
- Automated roadside safety inspection
- On-board safety and security monitoring
- Hazardous materials security and incident response
- Commercial vehicle electronic clearance, including border crossings

Emergency Management. Emergency management and public safety (police, fire, and emergency medical services) agencies would use these services to improve their management of and response to emergency situations ranging from traffic incidents to disasters to evacuations. EVI data on emergency vehicles would be processed to support:

- Emergency notification and personal security
- Emergency vehicle management
- Disaster response and evacuation.

Advanced Vehicle Safety Systems. These services contribute to the goal of improving safety and transportation system efficiency, and will rely on additional sensors deployed in the infrastructure. EVI data may be processed to support:

- Safety readiness
- Pre-crash restraint deployment
- Vision enhancement for crash avoidance
- Longitudinal, lateral, and intersection collision avoidance
- Automated vehicle operations.

Maintenance and Construction Management. These services address the monitoring, maintaining, improving, and managing of the physical condition of the roadway, associated infrastructure equipment on the roadway, and the available resources necessary to conduct these activities. EVI data would support:

- Projection of future maintenance needs
- Scheduling of maintenance and construction
- Messages and construction warnings to motorists.

Information Management. These services relate to processing system usage data and planning for future demand in capacity and support services. EVI data would be a trove of information for planning.

Electronic Payment. This aspect would facilitate payments for services while in vehicle, ranging from tolls, fares, and parking, to drive-through purchases and information service payments. Seamless communication between roadside and vehicle is expected to support deployment of many other services, both within and outside the transportation arena.

6.2.2 EVI Technology Selection

EVI applications: In order to derive the main technical requirements for the EVI device to be installed in vehicles, a subset of the most crucial EVI applications have to be selected in order to focus on public agency business needs. Value-added downstream services that can be derived from EVI should be left to the private sector.

Table 6.1 provides a comparison of five EVI technologies, with their capabilities scored by CTR to reflect how well they address the specific business needs of TxDOT, such as traffic management, safety, etc. The technical aspects of these technologies were presented in Chapter 2. A scoring of 1 indicates limited capability, ranging to 4 for full capability (in some cases not yet available but promised when that technology is fully deployed). This assessment is for comparative purposes only and is not intended as an exhaustive evaluation of the individual technologies.

Table 6.1: Comparison of Five EVI Technologies

	Available Options				
TxDOT Business Needs	**Loops/ Sensors**	**Video**	**Tags**	**GPS**	**Cell Phone**
1. Improved Traffic Management					
Information on speed	1	1	4	4	2
Information on volumes	3	3	4	4	3
Information on delays					
-accidents	1	1	2	4	2
-incidents (weather, debris)	1	1	1	4	2
-congestion	1	1	2	4	2

TxDOT Business Needs	Available Options				
	Loops/ Sensors	Video	Tags	GPS	Cell Phone
Commuting Patterns					
-peak volumes	2	3	3	4	3
-traffic generators	1	3	3	4	3
-destinations	2	3	3	4	3
-mix of vehicles	2	4	4	4	4
Total:	**14**	**20**	**26**	**36**	**24**
2. Safety Benefits					
Fewer road casualties	2	2	2	3	2
Speeds	2	2	2	3	2
Signals	1	2	2	3	1
Total:	**5**	**6**	**6**	**9**	**5**
3. Improved Compliance					
Titling and registration	2	3	4	4	2
Emissions	2	4	4	4	3
Insurance	1	2	4	4	2
Theft	3	4	4	4	3
Total:	**8**	**13**	**16**	**16**	**10**
4. Increase in Revenue					
Improved registration process	2	2	3	4	2
Improved emissions testing coverage	3	3	3	4	3
Improved vehicle identification	3	3	3	4	3
Efficiency of vehicle identification	2	2	3	4	2
Total:	**10**	**10**	**12**	**16**	**10**
5. Further Downstream Uses:					
Pre trip travel information	1	1	2	4	2
En-route driver information	2	1	3	4	1
Route guidance	2	2	2	4	2
Ride matching and reservation	2	2	2	4	2
Traveler services information	2	2	3	4	2
Incident management	2	2	2	4	2
Traveler demand management	2	2	3	3	2
En-route transit information	2	2	3	4	2
Comm. vehicle elec. clearance	2	3	3	4	2
Automated roadside safety insp.	2	3	3	4	2
Onboard safety and sec. monitoring	2	2	2	4	2
Comm. vehicle admin process	2	2	3	3	2
Hazmat sec. and incident response	2	2	3	4	2

TxDOT Business Needs	Available Options				
	Loops/ Sensors	**Video**	**Tags**	**GPS**	**Cell Phone**
Freight mobility	2	2	3	4	2
Emer. notification and pers. security	2	2	2	4	3
Emergency vehicle management	2	2	2	4	3
Disaster response and evacuation	2	2	2	3	2
Maint. and construction ops.	2	2	2	2	2
Total:	**35**	**36**	**45**	**67**	**37**
Grand Total:	**72**	**85**	**105**	**144**	**86**
Average Utility:	**1.89**	**2.24**	**2.76**	**3.79**	**2.26**

This assessment indicates that loops and sensors, with an average utility score of 1.89, have limited to medium capability for EVI. Video, with an average score of 2.24, has medium to fair utility. Tags, with an average score of 2.76, have fair to good utility. GPS, with an average score of 3.79, has good to almost full capabilities, but it must be noted that many GPS capabilities may not be widely available for another 10 years. Cell phone technologies, with an average score of 2.26, are marginally better than video, and somewhat less capable than tags.

Table 6.2 takes into account the availability of standards, legislation, use in practice, and experience in administration of each of those five technologies to provide an assessment of availability to deploy at this time.

Table 6.2: Availability of Different EVI Technologies

	Loops	**Video**	**Tags**	**GPS**	**Cell Phone**
Standards	√	√	√	~	√
Legislation	√	√	~	~	×
Deployment	√	~	~	×	√
Administration	~	~	~	×	√
Score	**3.5**	**3.0**	**2.5**	**1.0**	**3.0**
Utility x Availability	**6.71**	**6.72**	**6.90**	**3.79**	**6.78**

√ = 1 Available at present
~ = 0.5 Some availability at present
× = 0 Not available at present

By this assessment, loops are scored at 3.5, video at 3.0, tags at 2.5, GPS at 1.0 and cell phones at 3.0. Multiplying utility by availability gives an indication of feasibility for the intended purpose. By this measure, loops score 6.71, video scores 6.72, tags score 6.90, GPS scores 3.79, and cell phones score 6.78. The scores are close enough that all except GPS can be considered equally feasible; however, it is clear that tags and GPS have the most potential for future improvements. Given that the full capabilities of GPS will not emerge until some point in the future, tags appear to be the most feasible technology for EVI at this time.

6.2.3 Constraints on implementing EVI

Legality: The primary question regarding EVI is whether it is legal. An agency needs either express authority or implied authority to undertake a given action. A legal statute grants express authority. Implied authority means the act in question is necessary to achieve the express purpose or objective of the statute. For example, a state DOT may have implied authority to take actions that contribute to the safe operation of the highway system.

DOTs generally have broad expressed authority to perform planning, construction, operation, and maintenance of roads. However, it is not always clear how far implied authority extends regarding activities such as monitoring safety and congestion. Most DOTs have been able to establish traffic management centers and intelligent transportation systems (ITS) under the implied authority of managing congestion. From this perspective EVI, being an essential component of future ITS deployments for congestion management, falls within the implied authority of DOTs. Moreover, given that the majority of the benefits of EVI serve public purposes, the public sector needs to play the lead role in EVI deployment.

Privacy: An electronic vehicle ID is in essence no different from a license plate number. The latter is required to assist in identifying a vehicle, and ensuring that it meets legal requirements for using the public roads, namely, registration status, roadworthiness, insurance status, etc. Linking the vehicle ID to its owner and contact information is a necessity to ensure financial responsibility. State DOTs maintain a database of vehicle IDs and relevant owner information within a department of motor vehicles (DMV) for that very purpose, but have strict rules on sharing that data.

Linkage of license plate to vehicle owner data is widely used for interdiction. For example, some local jurisdictions have deployed systems that photograph the license plates of vehicles that break traffic laws and mail the owner a fine notice. Toll agencies use the same technique to bill non-account vehicles. To contact the owner, the billing agency must gain access to the DMV database, and this use is legally allowed. Vehicle owners frequently challenge this use on privacy grounds, but courts have consistently ruled that privacy rights are diminished in public spaces.

Similarly, recording vehicle movements by camera for traffic management purposes is not a violation of privacy. The main difference between EVI and video identification is the linkage between capturing the vehicle ID and accessing the owner information. Video requires optical character recognition (OCR), an expensive and error-prone process, to read license plates. EVI would simplify the process significantly, making it a simple database exercise. It is precisely this ease of accessing owner data that raises privacy concerns. Hence, for the non-anonymous category of EVI applications, a careful investigation is required and a set of rules have to be derived in order to guarantee privacy protection.

It is clear that sensitive information should not be available through the vehicle-roadside link. A firewall should be established between the vehicle ID reader system and the vehicle owner database. The latter information should remain in the hands of a trusted party, such as the DMV. Use of the data should be independently audited for the public. The principles of an EVI data policy are presented next.

6.3 Essential Elements of a Policy on EVI Data

Before implementing EVI, TxDOT needs to establish a comprehensive policy on the acquisition and use of EVI data.

6.3.1 Scope of policy

In the EVI system envisioned, an electronic tag will supplement or replace the registration sticker of each vehicle. The tag will hold the same information as the registration sticker (make, model, registration number, partial VIN, etc.). Roadside readers will allow TxDOT to collect information including location of the vehicle and timing of movements. EVI data will allow TxDOT to implement more efficient traffic management and other services. TxDOT's EVI data policy should include, as a minimum, the following six items:

- TxDOT principles
- Compliance with Federal and State laws on privacy
- Data subjects
- Information collection
- Data recipients, and
- Information sharing.

6.3.2 TxDOT principles

The policy should include a statement of basic principles observed by TxDOT. For example:

- TxDOT and its affiliates and agents respect and are fully committed to protecting individual privacy. In order to serve its customers better, TxDOT needs to implement a thorough and comprehensive system to gather and process data on the vehicles that use the transportation system.

- TxDOT will comply with principles of good practice with regard to the collection and dissemination of that data. All the information TxDOT obtains will be:
  1. Obtained and processed fairly and lawfully
  2. Used only for specified purposes
  3. Adequate and relevant but not excessive
  4. Accurate and up-to-date
  5. Held for no longer than necessary
  6. Accessible to all data subjects
  7. Subject to appropriate security measures.

6.3.3 Compliance with Federal and State Laws on Privacy

A common concern regarding electronic monitoring of vehicle movements is that it gives the government the ability to enforce laws through "hidden electronic policing." However, automated enforcement has been consistently found to be constitutional. In addition, TxDOT's policy must be consistent with existing federal and state privacy laws. Following are the most important federal laws regarding privacy (discussed in detail in Chapter 4) that the EVI data policy must comply with:

- Freedom of Information Act (FOIA) (1966): In 1966 Congress enacted the Freedom of Information Act (FOIA) to deal with requests for government records, consistent with the people's "right to know." The EVI data policy will fully comply with FOIA and allow authorized parties access to the data.
- The Privacy Act (1974): The Privacy Act regulates how the government can disclose, share, provide access to, and keep the personal information that it collects. The Privacy Act does not cover all information collected online.
- Electronic Communications Privacy Act (ECPA) (1986): The ECPA creates standards and procedures for court-authorized electronic surveillance, regulates when electronic communication firms may release information, and provides legal protection of the privacy of stored electronic communications from outside intruders and unauthorized government officials.
- The Patriot Act (2001): Title II: Enhanced Surveillance Procedures, which gives increased powers of surveillance to governmental agencies, is the most relevant with regard to the EVI data policy. Note: Information collected from vehicle-vehicle and vehicle-roadside communications fall under the purview of the Patriot Act.

6.3.4 Data Subjects

The EVI data policy must safeguard information on all the subjects in the system. The main subjects for data collection will be vehicles moving on the transportation system, and by extension, the registered owners of those vehicles. The data subjects for the EVI data policy can be categorized as follows:

- Customers and clients
- Fleet owners and coordinators
- Other users of the transportation system
- Complainants, correspondents and enquirers
- Offenders and suspected offenders.

6.3.5 Information Collection

Under the EVI data program, TxDOT will collect and use various types of vehicle and personal information to serve customers, save time and money, and better respond to customer needs by providing additional services. Information will be used for the purposes intended, for the purposes required under the law, or to address security threats.

The data collected under the new policy will be used according to strict guidelines. By providing personally identifiable ownership information during vehicle registration, customers grant TxDOT consent to use this information, but only for the primary reason customers are giving it, namely, to establish ownership of a vehicle using the transportation system. TxDOT will ask customers to grant consent before using customer's voluntarily provided information for any secondary purposes, other than those required under the law.

The data to be collected may be categorized in the following ways:

- *Identification Information:* information from vehicle registration and ownership that identifies a customer, such as name, address, telephone number, email address, etc.
- *Application Information*: information the customer provides to TxDOT such as credit card accounts.
- *Information from Outside Sources*: information from outside sources regarding insurance, driving records, etc.
- *Other General Information*: information from internal and external sources, such as customer history and vehicle ownership history.
- *Automatic Online Collection*: where vehicle registration is done online, this policy will comply with TxDOT website policies. For example, the TXDOT website states:

- We collect information about your visit that does not identify you personally.
- We can tell the computer, browser, and web service you are using.
- We also know the date, time, and pages you visit.
- In the event of a known security or virus threat, we may collect information on the web content you view.

- *Transaction and Experience Information*: information about geographical position and time of travel sorted by vehicle identifier.

6.3.6 Data Recipients

There are various recipients for the EVI data collected and processed under this policy. The chief recipients will be drivers themselves. There are also other parties who are legitimate claimants of EVI data. The primary data recipients include:

- Data subjects themselves
- Local governments
- Other government agencies
- Ombudsmen and regulatory authorities
- Data processors
- Police forces
- Survey and research organizations
- Other entities with approval for an authorized use.

Information sharing: The EVI data policy will cover the management and sharing of information. There are several situations in which TxDOT might have to share vehicle and personal information:

- Within TxDOT
- With companies that work for TxDOT
- With third parties
- In other situations
- Using online services

Managing information within TxDOT: TxDOT is made up of a number of entities (such as the VTR division and the Texas Turnpike Authority division). TxDOT may share any of the categories of EVI data among its entities. For example, sharing information could save customer time in other transactions because the customer may not need to furnish the same information twice. Sharing information also allows TxDOT to use information to identify any unusual activity and then contact the vehicle owner if necessary.

Managing information with companies that work for TxDOT: TxDOT will inform the customer in the event of sharing any vehicle and customer information with any companies that might be working for TxDOT. For example, if TxDOT has data contractors, all those nonaffiliated companies receiving customer information from TxDOT are contractually obligated to keep the information TxDOT provides to them confidential, and to use the customer information only to provide the services TxDOT asks them to perform.

Disclosing information in other situations: TxDOT might also have to disclose any of the categories of EVI data to law enforcement officials and similar organizations when required or permitted by law. For example, information may be disclosed in connection with a subpoena or similar legal process, fraud prevention or investigation, risk management and security.

Disclosing information to third parties: TxDOT will not sell personal and vehicular information to third parties without individual consent. The types of information TxDOT discloses should depend on the service (for example to insurance companies) and in some cases the choices the individual has made. TxDOT will not disclose vehicle and personal information other than in accordance with this policy. In general, that means that the individual must consent to the disclosure in advance. Consent may be obtained in several ways, including:

- In writing
- Verbally
- Online by clicking a button
- Through the use of a dialing string or button on a wireless device or handset
- At the time of initiation of a particular service offering, when customer's consent is part of the required terms and conditions to use that service

For example, consent to disclose vehicle and personal information can be implied simply by the nature of the request, such as when a customer asks TxDOT to transfer ownership of a vehicle to another person. The first owner's address is disclosed as part of the service and the customer's consent is implied by use of the service.

TxDOT may have to share personal information with third parties as necessary to complete a transaction, perform a service on TxDOT's behalf (such as enhancing TxDOT's ability to serve customers better), or perform a service that the individual has requested. When the third party acts solely on TxDOT's behalf, TxDOT will not allow them to use vehicle and personal information for other purposes. For example, TxDOT may have vendors process and print a billing statement on its behalf. They can only use the personal information TxDOT gives them to produce the billing statement.

In the event of a merger, acquisition, sale of company assets, or transition of service from a TxDOT contractor to another entity, as well as in the event of insolvency, bankruptcy, or receivership in which personal information would be transferred as one of the business assets of the company, TxDOT data will not be disclosed without the agreement of TxDOT.

Sharing information with other government agencies: TxDOT may share vehicle and personally identifiable information with the federal government and other state governments or other local governments as needed for legitimate government functions. By providing vehicular and personally identifiable information, customers grant TxDOT consent to use this information, but only for the primary reason customers are giving it. Also, laws may require TxDOT to share collected information with authorized law enforcement, homeland security, and national security agencies. TxDOT will ask customers for consent before using voluntarily provided information for any secondary purposes, other than those required under law.

6.4 Outline Business Model for EVI Implementation

6.4.1 Environment for implementation

Scope: At least three different scenarios for EVI deployment could be considered:

1. Phased deployment by date, e.g., mandatory on all new vehicles from a certain date on, and retrofitting of existing vehicles as they come up for registration renewal.
2. Phased deployment by vehicle class, e.g., start with commercial vehicles, then public vehicles, etc.
3. Phased deployment by jurisdiction, e.g., start with urban counties, then adjacent counties, etc.

Each of these scenarios requires legislative action(s) at the state level, and cooperation at the national/federal level, e.g., a directive to auto manufacturers to make the VIN electronically accessible.

Stakeholders: There will be very different perspectives among various stakeholders on almost all aspects of EVI. If EVI is proposed as a public sector requirement and possibly made mandatory equipment in motor vehicles, it has to be justified only and solely by the public sector needs. The development of the telematics value-added services should be left to the private industry (with proper precautions regarding safety, etc.). Coordinating the perspectives of the potential stakeholders can be done by:

- defining the participants' roles and expectations,
- identifying the issues requiring the most coordination, and
- creating a management structure to resolve conflicts and carry out this coordination.

Functional requirements: In order to allow the key benefits of EVI to function in a national context, a consensus among the relevant public authorities in the different states is needed on a set of common functional requirements for the EVI device and the communication means. Examples of such functional requirements are the maximum distance at which the device can be read by the reader equipment, the reliability of the data transmission required for enforcement purposes, etc. Also, the extra functional requirements induced by the selected value-added services need to be identified. National and worldwide standards for dedicated short range communications (DSRC) were reviewed earlier in this report.

Financing: Infrastructure, or the lack of it, determines the types of EVI system services that can be provided. It was seen earlier that annualized infrastructure costs for EVI for the entire state of Texas are estimated at about $46 million, annualized equipment costs are about $54 million, annual transaction costs are about $49 million, and annual maintenance costs are about $2 million, totaling about $150 million annually. Because these are annualized values, in reality the initial expenditure will need to be around $1 billion. In the current public infrastructure financing climate, public-private partnerships (PPP) for EVI deployment should be considered.

Some private partners will only be willing to participate if the data are already available to support their application or device. Other private partners may actually be attracted to areas that lack infrastructure. In such a situation, the appropriate EVI system business plan may be a turn-key approach where the private sector designs and constructs the infrastructure. If a region lacks both infrastructure and the resources needed to construct it, the agency may want to consider having the private sector select its own monitoring techniques to meet the needs of its customers, one of which would be the public sector.

The potential for revenue from the private sector is determined by the size of the EVI system market. A crucial consideration is whether the EVI system market is mature enough to generate significant revenue for public sector use anytime soon. Barter arrangements of goods and services can also be considered because many public agencies face restrictions on cash payments. Similar arrangements have been used in shared-resource projects involving telecommunication installations in publicly controlled right-of-way. The desire for revenue must be balanced against the transportation policy-related benefits of EVI. Ultimately, larger issues such as the development of national standards to ensure interoperability and the emergence of the wider information services industry will affect the growth of the EVI system market.

6.4.2 Public-Private Partnerships (PPP)

Given the challenges involved, a private-public partnership is suitable for the deployment of a successful and feasible EVI system.

PPP projects offer a number of advantages, including:

- ***Acceleration of infrastructure provision***—PPPs often allow the public sector to translate upfront capital expenditure into a flow of ongoing service payments. This enables projects to proceed when the availability of public capital may be constrained (either by public spending caps or annual budgeting cycles), thus bringing forward much needed investment.

- ***Faster implementation***—the allocation of design and construction responsibility to the private sector, combined with payments linked to the availability of a service, provides significant incentives for the private sector to deliver capital projects within shorter construction timeframes.
- ***Reduced life cycle costs***—PPP projects that require operational and maintenance service provision provide the private sector with strong incentives to minimize costs over the whole life of a project, something that is inherently difficult to achieve within the constraints of traditional public sector budgeting.
- ***Better risk allocation***—a core principle of any PPP is the allocation of risk to the party best able to manage it at least cost. The aim is to optimize rather than maximize risk transfer, to ensure that best value is achieved.
- ***Better incentives to perform***—the allocation of project risk should incentivize a private sector contractor to improve its management and performance on any given project. Under most PPP projects, full payment to the private sector contractor will only occur if the required service standards are being met on an ongoing basis.
- ***Improved quality of service***—international experience suggests that the quality of service achieved under a PPP is often better than that achieved by traditional procurement. This may reflect the better integration of services with supporting assets, improved economies of scale, the introduction of innovation in service delivery, or the performance incentives and penalties typically included within a PPP contract.
- ***Generation of additional revenues***—the private sector may be able to generate additional revenues from third parties, thereby reducing the cost of any public sector subvention required. Additional revenue may be generated through the use of spare capacity or the disposal of surplus assets.
- ***Enhanced public management***—by transferring responsibility for providing public services, government officials will act as regulators and focus upon service planning and performance monitoring instead of management of the day to day delivery of public services. In addition, by exposing public services to competition, PPPs enable the cost of public services to be benchmarked against market standards to ensure that the very best value for money is being achieved.

Issues and Concerns about PPPs: Issues such as exclusivity are often major legal hurdles for agencies deploying PPP. The following are some of the provisions that must be negotiated:

1. General legislation allowing or restricting private sector involvement
2. Existence and legal basis of cost recovery mechanisms
3. Ability to provide guarantees

4. Property issues of land and infrastructure
5. Land acquisition
6. Planning permission requirements
7. Licenses
8. Need for project specific statutory requirements
9. Transparency of laws
10. Administrative coordination
11. Dispute settlement provisions
12. Forms of possible state financial support
13. Competition and antitrust regulations
14. Potential impact of employment and social security laws
15. Currency and profit repatriation rules
16. Public sector borrowing restrictions
17. Tax and accounting liabilities
18. Adequacy of selection and procurement procedures
19. Legislation governing project agreements and operational issues
20. Property law
21. Intellectual property law
22. Transfer of know-how and technologies
23. Adequacy of oversight and monitoring provisions and authority to regulate services

6.5 Business Models

There are primarily five models of PPPs illustrating how a business plan can be structured. The models, which entail increasing levels of private-sector control, are:

1. Public-centered operations,
2. Contracted operations,
3. Contracted fusion with asset management,
4. Franchise operations, and
5. Private, competitive operations

All the models provide the same basic services and involve the same basic participants. What differs is who performs the consolidation or fusion of the information, who pays for that function and who provides the subsequent data feed for getting the information out to the public. These models are illustrative. There are many variations of each with many options. All five share these common assumptions:

- significant data collection takes place in the public sector,
- the private sector collects at least some data and these data are available with the main data fusion process, and
- the public sector provides some data free to the public;
- the private sector performs most of the data dissemination and is assumed to generate revenue unless otherwise noted.

6.5.1 Public-Centered Operations

This business model gives the public sector the greatest measure of control, helping direct its benefits toward meeting public policy goals, but generates the least amount of revenue while requiring the greatest amount of public expenditure.

In this arrangement, public agencies enter into service contracts with private sector companies for the completion of specific tasks. Service contracts are well-suited to operational requirements and may often focus on the procurement, operation, and maintenance of new equipment. Service contracts are generally awarded on a competitive basis and extend for short periods of time of a few months up to a few years. They allow public agencies to benefit from the particular technical expertise of the private sector, manage staffing issues, and achieve potential savings. Nonetheless, with service contracts, management and investment responsibilities remain strictly with the public sector. While they afford certain benefits, service contracts cannot address underlying management or cost issues affecting poorly run organizations.

This approach best fits situations where the ultimate purpose is to meet the region's public policy goals. This example assumes the state DOT has the expertise and interest to control a significant portion of the EVI System and it operates the data fusion process. But any other agency could, potentially, perform that. In this example, however, the public sector often decides to disseminate as much data as possible to help meet public policy goals. This reduces the market potential for the private companies.

This business approach requires a considerable level of technical expertise within the public sector agency that performs the fusion process. However, it allows business relationships between the public and private sectors to be very simple. (Basically all that is required is a letter of agreement stating that the DOT authorizes the private sector to access the data and that the public sector bears no responsibility for keeping the system operating to meet private sector needs.)

The **advantage** of this approach is that the public sector is directly responsible for the systems that affect its operations. This gives it the greatest measure of control in making changes to directly meet its needs. It is the most politically feasible, and typically has higher political support than other business plans.

The primary **disadvantages** of this approach are that most public sector agencies lack the technical skills and staffing to efficiently perform many of the fusion-related tasks. In addition, in this case of EVI, large quantities of data are given freely to the public. This limits much of the revenue potential, which discourages the private sector from contributing funding to expand the market. An agency that wants to control EVI but that has no money and little infrastructure should not pursue this type of model.

6.5.2 Contracted Operations

This business model allows the public sector to maintain overall control but provides improved access to the private sector's technical expertise and staffing.

The major difference between this approach and the Public Centered option is that the data fusion process is contracted to the private sector—possibly through a turn-key agreement or with the private sector owning the data fusion software. The public sector, however, still provides large amounts of traveler information to the general public. So aside from the data fusion service, the potential for revenue for the private sector is limited.

The **advantage** of this business approach over the Public Centered approach is that it allows the public sector to access the technical skills of the private sector while still maintaining control over the data fusion process. When writing the data fusion contract, the DOT has the freedom to specify the constraints it believes are important for operation of the system.

As with the Public-Centered approach, the primary **drawback** of this business approach is that this mechanism is costly to the public sector (which must still fund the data fusion contract). Moreover, the opportunity for private sector revenue generation may be limited because of the high level of free information.

6.5.3 Contracted Fusion with Asset Management

This business model uses the same basic business structure as Contracted Operations but has different emphases. The first is a significant reduction in the amount of information given to the public. The second is the addition of an "asset manager" function besides the data fusion function. Asset management combines product development, marketing, and sales functions.

In this arrangement, public agencies utilize management contracts to transfer responsibility for asset operation and management to the private sector. These comprehensive agreements involve both service and management aspects and are often useful in encouraging enhanced efficiencies and technological sophistication. Management contracts tend to be short-term, but often extend for longer periods than service agreements. Contractors can be paid either on a fixed fee basis, or on an incentive basis where they receive premiums for meeting specified service levels or performance targets. Nonetheless, responsibility for investment decisions remains with the public authority.

Operation and management contracts often provide a good opportunity to encourage greater private sector involvement in the future. They are particularly appropriate in sectors undergoing transition from public ownership where existing regulatory and legal frameworks may not allow greater private participation. They can be helpful in generating trust between the public and private sectors in markets where there has been little experience with PPPs. They also provide a means for private companies to test the waters in potentially risky markets with limited risk exposure. While operation and management contracts should be expected to improve service quality, they cannot be expected to improve service coverage or encourage tariff reform.

The asset manager's responsibilities include:

- working with the data fusion provider to create data products that meet user requirements, and
- selling those public sector data products to clients, creating new services that can use these data products and maximizing the revenue generated and shared, from these products.

The asset manager also may work with the lead public agency to bring new agencies on board and add new data collection devices to the system to increase the value of the public sector's data. The goal of this model is to increase the revenue generated for public sector use. The asset manager is needed specifically to undertake the task of finding and exploiting new uses (and revenue sources) of the available public sector data.

6.5.4 Franchise Operations

This business model makes use of the private sector's technical skills and marketing capabilities. In this example, the public sector essentially removes itself from the data fusion process. In return for exclusive access to the public sector's data, the private sector company that is fusing the data agrees to provide that data back to the public sector free of charge— the company also sells the data to other private sector partners.

To help create a revenue stream, the public sector cuts back on the availability of free information. With this approach, costs to the public sector are reduced considerably as is operating complexity, while the potential for private sector revenue is maximized. Under this approach, the public has to pay for much of the information and the public sector agencies are totally reliant on the private sector for the fused data.

Leases provide a means for private firms to purchase the income streams generated by publicly owned assets in exchange for a fixed lease payment and the obligation to operate and maintain the assets. Lease transactions are different from operations and management contracts in that they transfer commercial risk to the private sector partner, as the lessor's ability to derive a profit is linked with its ability to reduce operating costs, while still meeting designated service levels. Leases are similar to operations and management contracts in that the responsibility for capital improvements and network expansion remains with the public sector owner. However, in certain cases the lessor may be responsible for specified types of repairs and rehabilitation.

Under the right conditions, private companies entering into lease agreements might also make targeted capital improvements in order to improve operating efficiencies and profit levels. However, responsibility for planning and financing overall investment and expansion programs remains with the public sector owner. Lease agreements can be expected to extend for a period of five to fifteen years. They are suitable only for infrastructure systems that generate independent revenue streams, and are often used in the public transportation and water sectors. Traditional procurement can also be used to cover the design and build functions either bundled or separately. As with the earlier examples, ownership of assets remains with the public body and the private sector is responsible only for well-defined tasks adopting limited responsibility.

One **advantage** of this approach is that it reduces the cost to the public sector considerably. It also provides incentives for the private sector to provide services that generate revenue, which can then be used to expand the system. In addition, it takes maximum advantage of the private sector's ability to implement innovative technologies to expand the market. If the private sector can make a substantial profit (and this approach maximizes that likelihood), this approach also provides the best opportunity for generation of revenue that can be applied toward public sector data collection costs. (Revenue sharing would have to be incorporated into the business arrangement between the public sector and the private data fusion company.)

A **disadvantage** of this approach is that the general public has to pay (sometimes indirectly, such as by listening to advertising) for much of the information that it would get for free under either of the first two business approaches. Another disadvantage is that the public sector must rely on the private sector for the fused data that it needs to enhance transportation system management. A third disadvantage is the risk of creating a monopoly if the system turns out to be lucrative. This would increase costs to consumers and decrease the private sector's incentive to innovate. Finally, the public sector assumes somewhat more risk because if the private sector company abandons this market (because it cannot generate sufficient revenue), the data fusion and downstream functions will cease to exist.

6.5.5 Private, Competitive Operations

This business model maximizes the competition within the market, aiming to lower consumer costs and maximize private sector innovation. This approach assumes the public sector makes its data available to more than one company willing to provide data fusion services. It can be provided free or for a fee. The companies then add value according to their own business approaches and resell the data to the public and other information service providers.

This model is used by the National Weather Service to provide access to publicly collected weather information. Agencies purchase data and information from competing private sector firms, depending on which company best meets the needs of travelers or businesses. The advantage is that the competition should intensify the companies' incentives to provide better, lower-cost services. However, if the market is not large enough to sustain multiple companies, the revenue stream may be too small to achieve the growth needed to bring about better, lower-cost services.

The **advantage** of this business approach is that the competition it fosters among private sector companies should intensify these companies' incentives to provide better, lower cost services. This should result in higher levels of consumer satisfaction, information dissemination, and public access to information. The **disadvantage** of this approach is that if the market is not large enough to sustain multiple companies, the revenue stream may be too small to achieve the necessary market growth and to support the design and deployment of new and better information services. Another result could be a loss of competition as one or more companies leave the marketplace for more profitable endeavors, resulting in a de facto monopoly.

6.6 Applicability of Business Models and Chapter Summary

Earlier, in Chapter 4, a timeline was presented to illustrate the evolution of ITS technologies, standards, and legislation, required DOT initiatives, and the expected public response. Table 6.3 provides the same information along with available services and suitable business models for their provision.

For the core services that EVI would support, a public-centered operations business model is adequate. This model is expected to become untenable within 5 years as the public demands additional services. For an expanded set of travel information services, a contracted operations business model is suitable, perhaps for another 5-10 years. But developments in freight mobility and the demands of homeland security, coupled with increasing GPS capabilities, will make the contracted fusion with asset management a viable business model for EVI within 10-15 years.

Chapter Summary: In this chapter an implementation model for EVI was outlined. First, the environment for implementation was discussed, focusing on a policy for managing EVI data. Then business models for implementing EVI were reviewed. Finally, a timeline was presented that integrates technological developments, standards, legislation, required DOT initiatives, public response, EVI services, and applicable business models for EVI.

Table 6.3: EVI Timeline Matrix (2 pages)

Forces	Timeframe: Present -2010	2010- 2015	2015- 2025
Technologies	• Phase out of manual tolling and 915 MHz tags • Domination of toll market by 5.9 GHz DSRC tags • Growth of EVI for commercial vehicle credentialing • ITS deployment	• Mileage tolling using DSRC • Growth of tolling via GPS/cell phone • Completion of ITS deployment • Introduction of EVI in some U.S. states	• Satellite/GPS for mileage tolling • ITS integration
Standards	• Implementation of 5.9 MHz DSRC standards • Interoperability of toll tags within regions	• All toll tags interoperable in U.S. • Worldwide DSRC standards	Standards for GPS in traffic management
Legislation	Unsettled law regarding privacy and electronic communications. Attempts by state DOTs and Congress to enact laws.	Test cases and challenges on electronic monitoring. Supreme Court rulings.	Settled law on privacy and electronic data.
Interactions, Impacts, Opportunities			
Required DOT Initiatives	• Deployment of ITS in metropolitan areas • Use of tolling to expand system capacity • Interoperability of toll systems • Managed lanes and congestion pricing • Separation of trucks from cars • Outreach programs to market the benefits of EVI and EVR	• Congestion pricing • Mileage tolling and variable pricing • Toll interoperability with Canada and Mexico • EVI and EVR	Integrated system management using ITS.

Forces	Timeframe: Present -2010	2010- 2015	2015- 2025
Public response	• Public opposition to '*Big Brother*' • Political opposition to some initiatives	Benefits of EVI in terms of convenience and lower costs start to accrue.	Public should have internalized the benefits EVI.
Business Models			
Services	-titling and registration* -electronic payment services* -traffic control -commercial vehicle electronic clearance -emissions testing and mitigation* -personalized public transit -automated roadside safety inspection*	-pre-trip travel information -en-route driver information -route guidance -ride matching and reservation* -highway-rail intersection -public transportation mgmt -en-route transit information -traveler services information* -incident management -travel demand management -public travel security	-archived data* -longitudinal collision avoidance -lateral collision avoidance -intersection collision avoidance -vision enhancement for crash avoidance -on-board safety and security monitoring -pre-crash restraint deployment -automated vehicle operations* -maintenance and construction -commercial vehicle administrative processes -hazardous materials security and incident response -freight mobility -emergency notification and personal security* -emergency vehicle management* -disaster response and evacuation operations
PPP Model	**Public Centered Operations**	**Contracted Operations**	**Contracted Fusion with Asset Management**

* Non-anonymous category of EVI applications

CHAPTER 7 CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

Vehicle Registration: It is a legal requirement in the U.S. for most types of motor vehicles to be registered with a state DOT or DMV if they are to be used on public roads. The state DOT records the vehicle's details and provides a unique number on specified license plates that must be displayed on the vehicle. The DOT also maintains a record of the party currently responsible for the vehicle (name, address, and other contact information), and the registration expiration date. Linking the vehicle ID to the owner is necessary to ensure financial responsibility.

Scannable Stickers: In addition to license plates, most DOTs provide a sticker showing the expiry month/year of registration, plus other data, and require that the sticker be displayed, either on the plate or, more commonly, inside the windshield. Registration stickers may also contain encoded data readable only by scanners carried by public safety officers. Such encoding has two purposes: to ensure that the sticker is not fake, and to allow the officer to quickly upload the data for a database check on the vehicle.

There are initiatives in Texas and elsewhere to introduce 'smart' tags with additional features, such as insurance verification and RFID. The objective of EVI is to deploy unique identifiers for individual motor vehicles that can be accessed without having to approach the vehicle. RFID tags are already serving this role in electronic toll systems.

Tolling, ITS and EVI: Tolling technologies are paving the way for implementation of Intelligent Transportation Systems (ITS). Tolling is evolving from corridor and cordon systems to a mileage-based system, i.e., the driver pays periodically for miles driven in a region. While odometer, phone, and global positioning systems (GPS) all have the potential for mileage tolling, RFID tags are likely to be the dominant tolling technology in the U.S. for some time. Right now truck manufacturers are embedding such tags in all their vehicles, and some car manufacturers have started as well. It is likely that these will be linked to vehicle recognition systems within the next decade.

Vehicle Computers: EVI is already a reality for most newer-model vehicles courtesy of on-board units (OBU). In its most basic form, an OBU is a computer platform that continuously monitors and optimizes vehicle performance. For maintenance and repair, the OBU data (including the vehicle identification) is accessed electronically.

Transportation Applications: Inevitably, more and more applications are being added to OBUs, and performance monitoring can now be done wirelessly. Also using wireless, fleet operators are able to capture and analyze individual vehicle data via roadside communications. The rapid take-up of these platforms is driven by commercial value-added services and new transportation business models. Universal EVI has potentially significant applications for transportation system management.

7.2 EVI Benefits and Costs

Current situation: The public is becoming used to receiving a variety of information instantaneously, and it is frustrating to travelers that even as they are able to receive text, audio, and video from anywhere in the world via wireless internet, they cannot get information on congestion in their immediate locale. EVI has the potential to revolutionize traffic information systems. Being able to detect where and when every vehicle is moving is comparable to having a 'high definition picture' of the transportation system, making it possible to deploy a host of services. EVI would provide benefits to transportation system managers, users, and the general public.

Agency Benefits: EVI benefits to managers of the transportation system include:

- Better data for managing operations through monitoring of travel times and congestion. For example, in Houston, tag readers mounted on gantries on freeways scan toll tags to record travel time.
- Better information for travelers, resulting in traffic redistribution and higher throughputs, leading to better utilization of existing systems.
- Better traffic signal coordination and prioritization
- Better reporting of infrastructure condition and maintenance
- Higher compliance with safety and regulatory requirements
- Lower costs for deployment of future ITS elements.

Traveler Benefits: Likely traveler benefits include:

- Customized information on traffic conditions, e.g., in-vehicle feeds
- Time savings from higher traffic throughputs and ability to avoid congestion
- Lower fuel costs, pollution levels, and vehicle wear-and-tear.

Freight Benefits: Likely commercial vehicle operator benefits include:

- Better information on travel times and preferred routes, including notification of load-zoned or restricted lanes
- In-vehicle safety warnings and alerts
- Pre-clearance (green line) at border crossings, inspection and weigh stations, or other interdiction points
- Asset tracking and e-commerce services.

Benefits to the General Public: The general public likely would obtain the following additional benefits:

- Higher compliance with insurance and safety requirements

- Location of stolen or wanted vehicles
- Controlled access to secure areas
- Deferred need for expansion of the system because of better utilization of existing assets.

Cost-Benefit Analysis: In this research, an analysis of the costs and benefits of implementing EVI was conducted. It was found that the annual benefits for the state of Texas are less than the costs, and the B/C ratio is in the range of 0.94 to 0.38. It must be stressed that not all the benefits were quantified. Of those calculated, 19-29% would come from enhanced governmental revenues. Benefits to road users, namely improved traffic data, fewer crashes, and better recovery of stolen vehicles would contribute 71-81% of benefits. For an urban case in the Austin area, the B/C ratio is in the range of 2.33 to 1.27. Enhanced governmental revenues would provide 14-20% of the benefits. Road user benefits would constitute 80-86% of those calculated. These percentages indicate the relative impacts of EVI on transportation, and can be used to focus on specific aspects of implementation and on gaining public support.

The costs for the system include tag distribution, infrastructure (hard) and data processing (soft) costs. For a statewide program, tag costs would be in the range of 23-36% of the total. Infrastructure costs would be 32-33% of total, while data processing costs would be 32-44% of total. For an urban program, tag costs would be 51-68% of total, infrastructure costs would be 2-5% of total, and data processing costs would be 30-45% of total. A large part of these costs will be incurred initially in establishing the system, meaning that funding for the system will need to be upfront. Appendix A summarizes Federal funding sources. In all likelihood deployment would have to be phased.

7.3 EVI Requirements

EVI deployment scenarios: At least three different scenarios for EVI deployment could be considered:

1. Phased deployment by date, e.g., mandatory on all new vehicles from a certain date on, and retrofitting of existing vehicles as they come up for registration renewal.
2. Phased deployment by vehicle class, e.g., start with commercial vehicles, then public vehicles, etc.
3. Phased deployment by jurisdiction, e.g., start with urban counties, then adjacent counties, etc.

Each of these scenarios requires legislative action(s) at the state level, and cooperation at the national/federal level, e.g., a directive to auto manufacturers to make the VIN electronically accessible.

EVI technologies: EVI is already being implemented through toll tags and OBUs, but the expectation is that it will grow steadily, especially as added-value services enter the scene. In this research, an estimate was made of the current feasibility of five different technologies for EVI: loop detectors, video, tags, cell phones, and GPS. On a scale of 16, loops score 6.71, video scores 6.72, tags score 6.90, GPS scores 3.79, and cell phones score 6.78. The scores are close enough that all except GPS can be considered equally feasible, but it is clear that tags and GPS have the most potential for future improvements. Given that the full capabilities of GPS have yet to emerge, tags appear to be the most feasible technology for EVI at this time.

Vehicle ID: From a technical perspective deploying EVI is straightforward: it would be a relatively simple matter to code the universal vehicle ID number (VIN) into new vehicle OBUs. For non-OBU-equipped vehicles, an in-vehicle transponder with the VIN hard-coded would be sufficient. Toll tags already have the capability to encode data. Issues such as tampering and disabling of the device will have to be addressed.

Readers: Roadside or overhead readers would be required to read the vehicle IDs at road speed. Again, toll tag readers are already performing this function. However, most toll systems require a trigger to activate the reader; for example, an in-road loop detector is needed to "spot" oncoming vehicles. More sophisticated scanning systems will be required to deal with high-volume roadways. Electronics manufacturers are already showcasing laser profilers and other spotters, but the desirable solution should allow a single device to detect and record each passing vehicle. Microwave readers show promise in this respect. Security and encryption of data transfers is also critical.

Standards: Standardization of onboard identifiers and overhead readers is in progress, as discussed in detail in Chapter 3. For example:

- A provisional standard already exists for VIN coding (ENV ISO 14816 – Road Traffic and Transport Telematics—Automatic Vehicle and Equipment Identification—Numbering and Data Structures, and more particularly Coding Structure 5, which is the VIN as defined in ISO 3779/3780. The vehicle manufacturer is responsible for the uniqueness of the VIN.)
- The communications protocols between the transponder/computer platform and the reader equipment are in development [CEN, ETSI and ISO related working groups especially in the field of Dedicated Short Range Communications (CEN TC 278 WG 9)].

7.4 Legal Issues

Privacy Concerns: Two considerations for EVI implementation are obvious: the laws and rules under which TxDOT operates, and concerns about privacy. Legislative changes may be required to advance EVI, specifically what information can be embedded in the sticker, and who will have access to read data. The role of DPS should also be clarified. The public will have concerns over privacy as EVI is implemented. For EVI, a TxDOT policy on collection and use of driver data via electronic tags would be advisable. If TxDOT decides to proceed with implementation, public response will need to be addressed through a public relations campaign.

EVI Data Policy: An electronic vehicle ID is, in essence, no different from a license plate number. EVI simplifies the task of linking a vehicle to its owner, so extra care is needed in preserving EVI data privacy. TxDOT's EVI data policy should include, as a minimum, the following six elements:

1. TxDOT principles
2. Compliance with federal and state laws on privacy
3. Definition of data subjects
4. Definition of scope of information collection
5. Definition of data recipients, and
6. Limitations on information sharing.

The role of VTR: VTR is the custodian of vehicle ownership data in Texas, and will have to play a strong role in maintaining the integrity and privacy of that data. At present, VTR is reviewing its registration and titling operations to streamline its processes. Initiatives include expanding web-hosted applications and reconfiguring its database structure. These developments will be affected by a federal initiative to create a national database of motor vehicle IDs, ownership, and registration addresses.

7.5 Business Models for Implementing EVI

Public-private partnerships (PPP): In the current public infrastructure financing climate, PPP will be essential for implementing EVI. PPP projects offer a number of advantages, including:

- Acceleration of infrastructure provision
- Faster implementation
- Reduced life cycle costs
- Better risk allocation
- Better incentives to perform.

Some private partners will be willing to participate only if data are already available to support their application or device. Other private partners may actually be attracted to areas that lack infrastructure. In such a situation, the appropriate EVI system business plan may be a turn-key approach wherein the private sector designs and constructs the infrastructure. If a region lacks both infrastructure and the resources needed to construct it, the agency may want to consider having the private sector select its own monitoring techniques to meet the needs of its customers, one of which would be the public sector.

Business models: There are primarily five models of PPPs. The models, which entail increasing levels of private-sector control, are:

1. Public-centered operations,
2. Contracted operations,

3. Contracted fusion with asset management,
4. Franchise operations, and
5. Private, competitive operations

All the models provide the same basic services and involve the same participants. What differs is who performs the consolidation or fusion of the information, who pays for that function, and who provides the subsequent data feed for getting the information out to the public.

EVI Timeline Matrix: Tolling is likely to become the norm for financing the transportation system in the future. RFID tags will replace manual tolling in the U.S. within a few years and will therefore be the preferred technology for tolling. As toll tags become more commonplace, traffic management applications for toll tag scan data will increase. For example, DOTs will start introducing systems to monitor travel times and other operations. Such benefits of EVI will drive deployment. As the benefits become clearer, users will want the technology. For example, trucking companies that have equipped some of their fleet with transponders report that those drivers seem to enjoy higher status and are more likely to remain employed with that company.

Considering the various changes that are currently occurring and are likely to occur in the future regarding EVI, a timeline was developed in this research to provide a sense of the direction of developments, and the issues that must be addressed. The primary driving forces are technology, the development of standards, and legislation. These forces create impacts upon the general public and opportunities within state DOTs to provide enhanced services utilizing different business models. It was found that Public-Centered Operations are applicable to current services, but, within 5 years, Contracted Operations will be a preferred business model for implementing EVI. In 10 years, as ITS integration becomes a reality, Contracted Fusion with Asset Management will be the most suitable business model.

7.6 Recommendations

Given the foregoing findings, the following recommendations are provided:

1. Legislation to codify agency authority and procedures is desirable. Cooperation will be needed among DOTs, vehicle user associations, insurance companies, legislators, enforcement agencies, and the courts. It is necessary to establish the legal authority to conduct the program, and to determine the types of liabilities incurred, deadlines for resolution, and defense/resolution procedures. Moreover, the program should be limited to the agency's mission.

2. EVI has the potential to enhance governmental revenues by making violators more easily identifiable. However, there are political risks associated with taking this route, which could potentially doom the implementation. Even though EVI is legal, public concerns over privacy make it necessary for DOTs to develop a public

relations campaign to market the benefits before initiating programs. The marketing should focus on the user benefits of the EVI. It was seen that those are large enough to justify the investment, especially in urban areas. As benefits become clearer in the pilot regions, resistance is expected to decrease.

3. Develop a comprehensive EVI data policy. For the non-anonymous category of EVI applications, a careful investigation is required and a set of rules have to be derived in order to guarantee privacy protection. It is clear that sensitive information should not be available through the vehicle-roadside link. A firewall should be established between the vehicle ID reader system and the vehicle owner database. The latter information should remain in the hands of a trusted party, such as the DMV. Use of the data should be independently audited for the public.

4. A phased deployment starting with areas where benefits are most likely, namely, selected urban areas, will allow the program to pay for itself. Given the good B/C ratio for urban areas compared to statewide deployment, it would make sense to begin deployment in urban areas. In fact, the benefits of improved traffic management alone are large enough to justify urban deployments, rendering moot the issue of having to raise revenues by targeting violators. Furthermore, because the major urban areas of Texas already have toll systems that use RFID tags, deployment can begin by installing the readers on non-toll roads, and equipping the traffic management centers to process the data. In this regard, it should be noted that the Houston district is already using tag readers to estimate traffic speeds, and the city of Austin is proposing to do the same. As the identified benefits begin to materialize, the next phase would be to equip all vehicles in urban counties with the tags, then eventually all counties. The final stage would be installation of readers in rural segments, if overall benefits justify the cost.

5. Deployment should be flexible to technology changes and to customer needs, with appropriate business models. EVI technology is developing rapidly, with DSRC and GPS replacing video and in-road detectors. However, cost is a factor. The scope of deployment would be limited only by financing and willingness of the private sector to partner. For the core services that EVI would support, a public-centered operations business model is adequate. This model is expected to become untenable within 5 years as the public demands additional services. For an expanded set of travel information services, a contracted operations business model is suitable, perhaps for another 5-10 years. But developments in freight mobility and the demands of homeland security, coupled with increasing GPS capabilities, will make the contracted fusion with asset management a viable business model for EVI within 10-15 years.

To implement universal electronic vehicle identification, a number of strategic decisions will have to be made regarding scope of deployment and technical specifications as well as societal issues such as privacy and security, which will involve multiple stakeholders. It is anticipated that the implementation of EVI will take several years and will be an incremental process. EVI implementation has already begun in the form of electronic toll tags and OBUs, but the expectation is that it will grow steadily, especially when added-value services emerge. It would benefit TxDOT to monitor initiatives in vehicle credentialing especially in the trucking industry, as that may provide opportunities to partner with the private sector in EVI deployment.

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APPENDIX A: FEDERAL FUNDING FOR ITS

The Transportation Equality Act (TEA-21), a major piece of legislation provided to fund the federal Intelligent Transportation Systems program, dealt primarily with research, training, and standards development. It was succeeded, in 2005, by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which sets out the parameters for federal transportation funding until 2010.

Transportation Equity Act-21

As per TEA-21, a total of $1.282 billion in contract authority was provided for FYs 1998-2003 to fund the Intelligent Transportation Systems (ITS) program (US DOT TEA-21 Factsheet). Of this total, $603 million was targeted to research, training, and standards development. Programs to accelerate integration and interoperability in the metropolitan and rural areas and to deploy commercial vehicle ITS infrastructure were established and funded at $482 million and $184 million respectively.

In addition to the funds authorized specifically for ITS, ITS activities were eligible under other programs. Both NHS and STP funds could be used for infrastructure-based ITS capital improvements, and CMAQ funding could be used for the implementation of ITS strategies to improve traffic flow that contributes to air quality improvement. Transit-related ITS projects are defined to be capital projects and are therefore eligible for related funding.

The legislated purposes of the program were, among others, to expedite integration and deployment, improve regional cooperation and operations planning, develop a capable ITS workforce, and promote innovative use of private resources.

SAFETEA-LU

SAFETEA-LU is the most recent legislation enacted for U.S. transportation funding, governing the federal surface transportation spending through 2010 (Wikipedia: SAFETEA-LU). Signed into law in 2005, it is a $286.4 billion measure containing a host of provisions designed to improve and maintain the transportation infrastructure in the U.S., especially the highway and interstate road system

Basic points in SAFETEA-LU regarding ITS (US DOT SAFETEA-LU Implementation: ITS and Operations):

- Strong support for ITS R&D.
- ITS Deployment mainstreamed.
- Significant focus on congestion mitigation, including:
    - Congestion management
    - Real-time information
    - ITS

- Incorporation of system management and operations.

ITS R&D

- Research and Development
    - Program reauthorized and expanded.
    - $550 million over 5 years.
        - Road weather—$20 million
        - I-95 Corridor—$35 million
        - Rural and Interstate Corridor Communications Study—$3 million
    - New advisory committee required.
    - New 5-year program plan required.

ITS Deployment Funding

- Mainstreamed throughout Federal-aid program; including high priority projects.
- Eligible under National Highway System (NHS), Surface Transportation Program (STP), and Congestion Mitigation and Air Quality (CMAQ).
- Categorical National Environmental Policy Act (NEPA) exclusion.
- ITS Deployment funds in 2005 only.
- $100 million, over 4 years, for Commercial Vehicle Information Systems and Networks (CVISN) deployment.

Congestion Management—Pricing

- Continues Value Pricing Program
    - $59 million in new funding, including $12 million for projects not involving tolls.
- New Express Lanes Demonstration Projects
    - Allows tolling of new or existing lanes to reduce congestion and/or improve air quality.
    - Fifteen projects, no separate funds.
    - DOT to establish interoperability requirement for automatic toll collection.
- High Occupancy Toll (HOT) Lanes Mainstreamed
    - Requires States to certify that they will monitor operational performance, enforce High Occupancy Vehicle (HOV) restrictions, and address seriously degraded operations.

Congestion Management—Research

- Surface Transportation Congestion Relief Solutions
  - $36 million over 4 years for research.
  - $3 million over 4 years for training and technical assistance.
  - Focus on:
    - Congestion management system effectiveness
    - Congestion measurement and reporting
    - Effective congestion relief strategies
- Future Strategic Highway Research Program (SHRP)—SHRP II
  - $205 million over 4 years for research.
  - Managed by National Academy of Sciences.
  - Four focus areas, including:
    - Improving reliability

Real-Time Information:

- Real-Time Systems Management Information Program
  - Establish capability in all States to provide real time:
  - Sharing of information
  - Monitoring of traffic conditions
  - Purpose—ease congestion, improve response to severe weather, accidents, and other incidents; and enhance security.
  - Eligible for funding under NHS, STP, and CMAQ.
  - Must be part of regional ITS architectures.
  - DOT to establish data exchange standards within 2 years.

- Transportation Technology Innovative Demonstration Program
  - Two-part extension and expansion of Intelligent Transportation Infrastructure Program established by Transportation Equity Act for the 21st Century (TEA-21).
  - $2 million per city available to support deployment of traffic monitoring infrastructure and commercialization of data.
  - Twenty-two new cities + thirteen original cities that have not received prior funding are eligible.
  - Part I: Existing contract with Mobility Technologies will be completed as planned (eleven additional cities).

  - Part II: Create and complete new program to use any unobligated and any new appropriated funds.

Implications of SAFETEA-LU on ITS and Operations

- More funding for ITS and Operations.
- Maintains strong ITS R&D program.
- Increases focus on congestion relief.
- Puts strong focus on managed lanes and pricing.
- Establishes nationwide requirement for real-time information systems.
- Advances system management and operations.