Review of Existing Literature and Deployment Tracking Surveys

Decision Factors Influencing ITS Adoption

www.its.dot.gov/index.htm
Final Report— April 2012
Publication Number: FHWA-JPO-12-043

U.S. Department of Transportation
Research and Innovative Technology Administration

Produced by James Pol
ITS Joint Program Office
Research and Innovative Technology Administration
U.S. Department of Transportation

Notice

Cover photo: Abstract Speed Motion in Highway Tunnel/Thinkstock

Technical Report Documentation Page

1. Report No.
FHWA-JPO-12-043

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Review of Existing Literature and Deployment Tracking Surveys:
Decision Factors Influencing ITS Adoption

5. Report Date
April 2012

6. Performing Organization Code

7. Author(s)
James Bunch, Vaishali Shah, Carolina Burnier, Drennan Hicks, Greg Hatcher, Liz Greer, William Ball, Katie Fender

8. Performing Organization Report No.

9. Performing Organization Name And Address
Noblis
600 Maryland Ave., SW, Suite 755
Washington, DC 20024

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-11-D-00018

12. Sponsoring Agency Name and Address
ITS-Joint Program Office
Research and Innovative Technology Administration
1200 New Jersey Avenue, S.E.
Washington, DC 20590

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code
HOIT-1

15. Supplementary Notes
James Pol, COTR

16. Abstract

ITS is at cross-roads with deployment of first generation ITS technologies “at a saturation point” for mature ITS applications, especially in the large metropolitan areas across the United States. Understanding the motivating factors for adopting a technology that supports multimodal operations and for continuing its use and increasing deployment is therefore critical for the continued evolution and deployment of the next generation of ITS and especially for moving to a connected vehicle and multi-modal information and coordinated operations system envisioned for the future.

The purpose of this report is to provide a foundation that captures the state of knowledge for motivating factors influencing ITS adoption, maintenance, and growth. This report highlights the issues and insights that could be drawn from the previous funded research and additional sources, and the questions, gaps, and needs that remain. This foundation, or benchmark of knowledge, will be used to help direct and focus the subsequent tasks of the Longitudinal Study of ITS Implementation.

Analysis of the theory of innovation presented a number of implications for successful adoption and diffusion of new ITS technologies:

- Innovators/Early Adopters do not necessarily make good references or examples to convince the early majority to adopt a technology, because they are not considered “peers” by the majority of adopters.
- As the technology matures and is mainstreamed, the focus of the design should change from technology centered to consumer/needs centered products. ITS that may appeal to pioneers and large systems may not be attractive to (or needed by) smaller agencies.
- Peer networks and social systems along with their communication channels are very important when promoting imitator-driven technology adoption.

17. Key Words
Intelligent Transportation Systems, factors influencing ITS adoption and deployment, technology diffusion, longitudinal study

18. Distribution Statement

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
81

22. Price

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

Preface/Acknowledgements

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) is placing increasing emphasis on transferring ITS technology from research to deployment, and on accelerating the rate of ITS technology adoption. The JPO technology transfer efforts are aimed at accelerating deployment of both current and near-future technologies, such as connected vehicles. As part of these efforts, the JPO has sponsored research studies intended to improve the state of knowledge regarding the underlying characteristics and factors for technology adoption and deployment. This report is a deliverable from the early stage of the most recent of these studies, the Longitudinal Study of Implementation: Decision Factors and Effects (started in January 2012).

The Longitudinal Study of Implementation will assess and build upon the body of existing work related to decision factors influencing ITS adoptions, growth, maintenance or decline within the public and private sectors. The Longitudinal Study will go beyond the current state of knowledge through an interview-based approach to further analyze decision factors; a post-hoc analysis of studies and performance data comparing current performance and benefits with previous deployments, costs, and benefits information at early ITS deployment sites; and a workshop and analysis of how to present cost and benefit information in a manner that is most useful and meaningful to all the relevant stakeholders. The study team (a team consisting of staff from Noblis, Cambridge Systematics, American Transportation Research Institute (ATRI), and Merriweather Advisors) will review published evaluation reports from major model deployments and determine a set of interview questions that focus on implementation decision factors. The study to shall team conduct interviews and perform post-hoc analysis on available archived data to determine if continued implementation produced measurable effects.

This Review of Existing Literature and Deployment Tracking Surveys serves as the first step in conducting the Longitudinal Study of Implementation. A key goal of this report is to identify from existing literature the motivating factors that influence how and why transportation agencies adopt, expand, maintain, contract or discontinue technology applications. A second key goal of this review is to highlight the gaps and needs in knowledge for ITS adoption, expansion, maintenance, and decline. The third goal is to identify new adopters and others within the expansion, maintenance, or decline phases for ITS. This set of agencies will serve as a starting point for subsequent tasks within the Longitudinal Study.

Table of Contents

List of Tables

List of Figures

Executive Summary

ITS is at cross-roads with deployment of first generation ITS technologies “at a saturation point” for mature ITS applications, especially in the large metropolitan areas across the United States. Understanding the motivating factors for adopting a technology that supports multimodal operations and for continuing its use and increasing deployment is therefore critical for the continued evolution and deployment of the next generation of ITS and especially for moving to a connected vehicle and multi-modal information and coordinated operations system envisioned for the future.

An important consideration as we move to the next generation of ITS, and particularly to connected vehicles, is that deployment of an ITS technology or service will increasingly require concomitant decisions by several different stakeholders including the developers and manufacturers of a technology or service, public sector and private service deployers, and the consumers and users of a service. For example, deployment of Vehicle to Infrastructure safety applications will require decisions by the auto manufactures to develop and install the in-vehicle equipment, the public sector to provide roadside equipment, and the owners/drivers of the vehicles to pay for the vehicles or purchase and install aftermarket equipment. These developments highlight the importance of a systems approach and systems thinking when evaluating new ITS systems and how they may be adopted and deployed. The traditional linear model of innovation to deployment by a single agency or entity no longer holds. The traditional model of linear innovation reflected technical change in a linear process from invention to innovation to adoption and diffusion and similarly a linear connection from technology provider to user. A single agency or entity was often the steward of this adoption and diffusion. For today’s second, third, and next generation of ITS, innovation occurs in a far more complex environment with multiple entities requiring coordination for adoption and intermediate as well as end users. Furthermore, the technology change can be an evolving process with multiple connected layers of capabilities.

> *For today’s second, third, and next generation ITS, innovation occurs in a more complex environment, with multiple actors, requiring coordination for adoption and a focus on intermediate as well as end users.*

The purpose of this report is to provide a foundation that captures the state of knowledge for motivating factors influencing ITS adoption, maintenance, and growth. This report highlights the issues and insights that could be drawn from the previous funded research and additional sources, and the questions, gaps, and needs that remain. This foundation, or benchmark of knowledge, will be used to help direct and focus the subsequent tasks of the Longitudinal Study of ITS Implementation.

Analysis of the theory of innovation presented a number of implications for successful adoption and diffusion of new ITS technologies:

- Innovators/Early Adopters do not necessarily make good references or examples to convince the early majority to adopt a technology, because they are not considered "peers" by the majority of adopters.
- As the technology matures and is mainstreamed, the focus of the design should change from technology centered to consumer/needs centered products. ITS that may appeal to pioneers and large systems may not be attractive to (or needed by) smaller agencies.
- Peer networks and social systems along with their communication channels are very important when promoting imitator-driven technology adoption.

Four major documents were reviewed in detail to identify best practices for technology, assess the ITS market and the factors that influence ITS adoption and deployment. These four documents are:

- An Analysis of the Factors Influencing ITS Technology Adoption And Deployment (Pace, David, et al., 2011)
- ITS Technology Adoption and Observed Market Trends from ITS Deployment Tracking: Final Report (Hagemann, Garrett, et al., 2010)
- Deployment of ITS: A Summary of the 2010 National Survey Results (Gordon, et al., 2011)
- Marketing ITS Infrastructure in the Public Interest (Lappin, et al., 1998)

In general, the four major studies and the search of the ITS Knowledge Resources yielded many of the same of the decision factors affecting current ITS deployment. Looking at them by factor type, for application factor, the perceived benefits of ITS technologies, degree of integration with existing systems, and price were the leading factors cited in the studies and reports reviewed. For implementer characteristics, the most frequent factor cited was usage by a neighboring agency, supporting the finding of the Pace paper that most state agencies are imitators, rather than early adopters (Pace, et al., 2011). The User/Market factors highlighted were the user's attitude toward and acceptance of technology, as well as the user's understanding of its potential benefits and risks. In terms of the external environment, agency budget, the need to prepare for a major event or construction project, and the presence of an external funding source were most frequently cited as key decision factors influencing deployment of ITS technologies. This last factor was the only area in which the studies appeared to contradict each other, with implementers in the Gordon et al. paper citing funding and grant availability as a key factor, while Pace et al. found the presence of earmarks had no effect on ITS deployment. The basis for this apparent contradiction is explored in Chapter 3.

Analysis of the decision models presented in this report when compared to the findings from the literature and background sources related to ITS implementation revealed the following major research gaps and needs that should be further explored in this study:

- The impact that the performance of the system has on downstream decisions to expand, maintain, or contract ITS implementations, whether measured or qualitatively assessed. For example, if an agency is willing to invest in system performance monitoring and evaluation, is there a greater likelihood that the system will be supported, maintained, and even expanded?
- The transferability of the decision factors from traditional ITS applications and technologies to a connected vehicle environment.
- The importance of communication channels and implications for knowledge and technology transfer strategies.

- Most of the research regarding decision factors focuses on the initial deployment decision and does not account for the future decisions that must be made regarding expansion, maintenance, or contraction of the system.
- The influence that the *change* in the relevant decision factors has on the downstream decisions to expand, maintain, or contract their ITS implementations.
- Little is known regarding the most important decision factors (and their relative priority) considered for a system replacement with a newer, next-generation technology.
- The relative importance of the many decision factors is not well understood. It is also unknown how these factors might work together to influence ITS adoption and deployment.
- The impact of agency characteristics such as agency size and overall budget on the decision processes is not well-established.
- The extent of differences in the decision factors between the various ITS application areas and their corresponding organizations.
- Gathering an understanding of the most important information needs of agencies to facilitate decision-making in the ITS marketplace.

Next Steps

The findings of this research will be directly used in the development of survey instruments and questionnaires for task 3 interviews and the gaps and needs will be addressed to add to the body of knowledge. In addition, the deployment survey analysis has identified a potential list of agencies to follow up with as good candidates for the interview task, because they highlight recent decisions to deploy, expand, maintain, or contract their ITS implementations.

1 Introduction

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) is placing increasing emphasis on transferring ITS technology from research to deployment, and on accelerating the rate of ITS technology adoption. More recently, the JPO expanded and broadened its technology transfer efforts to accelerate deployment of both current and near-future technologies, such as connected vehicles. The Longitudinal Study of Implementation will provide an important foundation for these JPO efforts. The overarching goal of the Longitudinal Study is to accelerate deployment of ITS by identifying the information and support that stakeholders and decision-makers need, and by providing up-to-date cost and benefit information in a manner useful to these groups.

The Longitudinal Study aims to builds upon a body of existing work related to decision factors influencing ITS adoptions, growth, maintenance or decline within the public and private sectors. The Longitudinal Study will also go beyond the current state of knowledge through an interview-based approach to further analyze decision factors; a post-hoc set of studies reviewing deployments, costs, and benefits at early ITS deployment sites; and a workshop and analysis of how to present cost and benefit information in a way that best informs and influences decision-makers.

This Review of Existing Literature and Deployment Tracking Surveys serves as the first step in conducting the Longitudinal Study of Implementation. A key goal of this effort is to identify among existing literature the motivating factors that influence how and why transportation agencies adopt, expand, maintain, contract or deselect technologies. A second key goal of this review is to highlight the gaps and needs in knowledge for ITS adoption, expansion, maintenance, and decline. The third goal is to identify new adopters and others within the expansion, maintenance, or decline phases for ITS. This set of agencies will serve as a starting point for subsequent tasks within the Longitudinal Study.

In conducting this review, we build upon previous JPO-sponsored work performed by a number of organizations. This review considers and offers special attention to materials that express technology deployment to support transit and truck operations, public safety, and maintenance and construction operations, especially in areas that extend beyond the market areas covered in the background material. We explore models of technology adoption, and examine the applicability of the Bass model of technology diffusion. We employed the ITS Benefits, Costs, and Lessons Learned Databases and the Transportation Research Board's TRID database to conduct the literature review.

This review is organized as follows. The subsequent Chapter 2 explores the theory of innovation from literature at large and applies it to the ITS industry. Chapter 3 provides a summary of the factors identified from a review of literature to influence the adoption of ITS and its subsequent growth, maintenance, decline or decommission. Chapter 4 delves into the ITS Deployment Tracking Surveys from 2007 and 2010 to identify agencies that exhibit these various stages in ITS deployment with the backdrop of agency growth, maintenance, and contraction. Finally, Chapter 5 summarizes findings and highlights key gaps in knowledge for the adoption and subsequent growth, maintenance, decline or cancellation of ITS technologies

2 Innovation Theory

This chapter provides an overview of the full technology life cycle from initial identification of needs, through Research and Development (R&D), growth, maturity, saturation, and decline, integrated with theory on the innovation diffusion and adoption process. Special attention is paid on how various models such as the Bass Diffusion Model fit within the overall cycle, and the innovation/adoption process of organizations. This overall framework provides:

- A foundation for the overall Longitudinal Study effort that helps identify the gaps and needs in knowledge regarding the factors and process ITS adoption and deployment to be explored in Task 3.
- Implications that inform the ITS Program on the effective mix of policies and actions which help promote the development, adoption, and widespread deployment of next generation ITS systems and applications.

This chapter begins with a synthesis of the findings from the Innovation Theory review as they relate to ITS deployment. Next, an overview of the Technology Innovation/Product Life Cycle is provided, followed by a discussion of the diffusion and adoptions of innovations, and the Innovation Adoption Decision Process for Organizations. The chapter concludes with a discussion of the implications for the next tasks of the Longitudinal Study and potentially the overall ITS Program.

2.1 Synthesis

The theoretical perspective is important due to the changing nature of next generation ITS. The first generation of ITS (ITS1.0) prior to the year 2000 has been characterized as leveraging of “one way” technologies primarily based on infrastructure. Around 2000, ITS 2.0 based on collaborative or “two-way” communications technologies began to emerge. ITS 3.0 began to emerge in 2004/2005 utilizing automated vehicle operations and automated, interactive system operations and system management (Sorensen J., 2011). The next horizon of ITS (ITS 4.0) envisions connected systems incorporating personal mobile devices, vehicles, infrastructure and information networks for multi-modal system operations as well as personal contextual mobility solutions. Crowdsourcing and smartphone data integration for systems operations, use of “big data” for systems monitoring, context/location aware traveler information and predictive analytics, continued connected vehicle, smart mobile device, and infrastructure development, integrated systems operations (ICM)

> *Innovators/Early Adopters do not necessarily make good peer references for the Early Majority. Consider pilot or demonstration projects targeted to locations that are technically close to the majority.*

and smart real time parking are just a few of the emerging next generation ITS applications predicted in the near term (Sorenson, 2012). On the horizon is the creation of integrated "smart cities" where transportation is just one of the overall systems monitored and managed in a coordinated "smart" environment. The question becomes how will we get there and who will lead (Frost & Sullivan, 2011; Zielinski, S. 2010).

An important impact of the first generation ITS technologies reaching maturity in many market segments is a shift in the nature of the decision to adopt innovations in ITS and emerging technologies. The decision is no longer ITS/No ITS. Compatibility with existing ITS and its remaining useful life or potential obsolescence are now important factors. What type of change and benefits will the new technology provide? Will they be "incremental" enhancements to existing ITS, or "disruptive" changes providing totally new services or benefits? Will they replace or coexist with existing ITS?

The background material supports the view that ITS is at cross-roads with deployment of mature first and second generation ITS technologies and applications "at a saturation point," especially in the large metropolitan areas across the United States. As we move to ITS 3.0 and beyond to connected vehicles, the development and successful deployment of ITS technology is becoming increasingly interdependent, requiring parallel decisions by several different actors, including the developers and manufacturers of a technology or service, the public sector and other deployers of the service, and the consumers and users of the service. Moreover, as the ITS technology or service is deployed and operated over time, performance Measures of Effectiveness (MOEs) can be observed and conditions or factors may change. Figure 2-1 depicts this new environment:

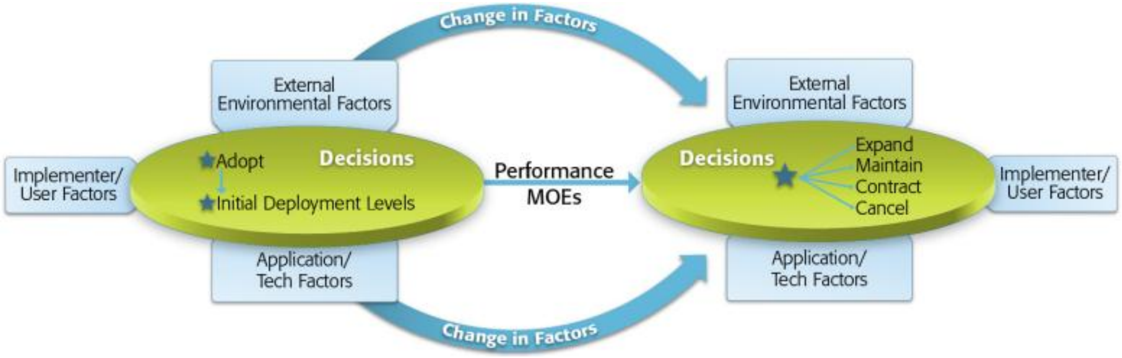


Figure 2-1: Decision Factors Affecting ITS Deployment Can Change Over Time

2.1.1 Insights Relevant to Future ITS Deployment

The analysis of the theory of innovation presents a number of implications for successful adoption and diffusion of new ITS 3.0 and beyond technologies, as listed below:

- Innovators/Early Adopters do not necessarily make good references or examples to convince the early majority to adopt a technology, because they are not considered "peers" by the majority of adopters.

- As the technology matures and is mainstreamed, the focus of the design should change from technology centered to consumer/needs centered products. ITS that may appeal to pioneers and large systems may not be attractive to (or needed by) smaller agencies.
- Peer networks and social systems along with their communication channels are very important when promoting imitator-driven innovation.

2.2 The Technology / Product Life Cycle

In order for an agency to adopt and deploy an innovation/technology, it must first be invented, made market ready, and commercialized. For users to continue to use a product it must remain useful and have benefits that outweigh its costs. New innovations may overtake them. Products may be discontinued or be no longer supported. Ultimately they become obsolete and users may be forced to move to new products to replace them. Understanding this overall technology/product lifecycle helps identify how the Department can most effectively support development, deployment, and use of the next generation of ITS.

As shown in Figure 2-1, a technology/product's development, rise, and fall can be viewed as a two-part process (Halsnæs, K. P. et al., 2007, p. 152). Part 1 is the process of conceiving, creating, and developing new technologies or advancing the technological frontier, and Part 2 is the process of diffusing or deploying these technologies. There is a significant "gap" or "valley of death" that must be navigated if an innovation/technology is to reach maturity, as discussed in detail later in this chapter.

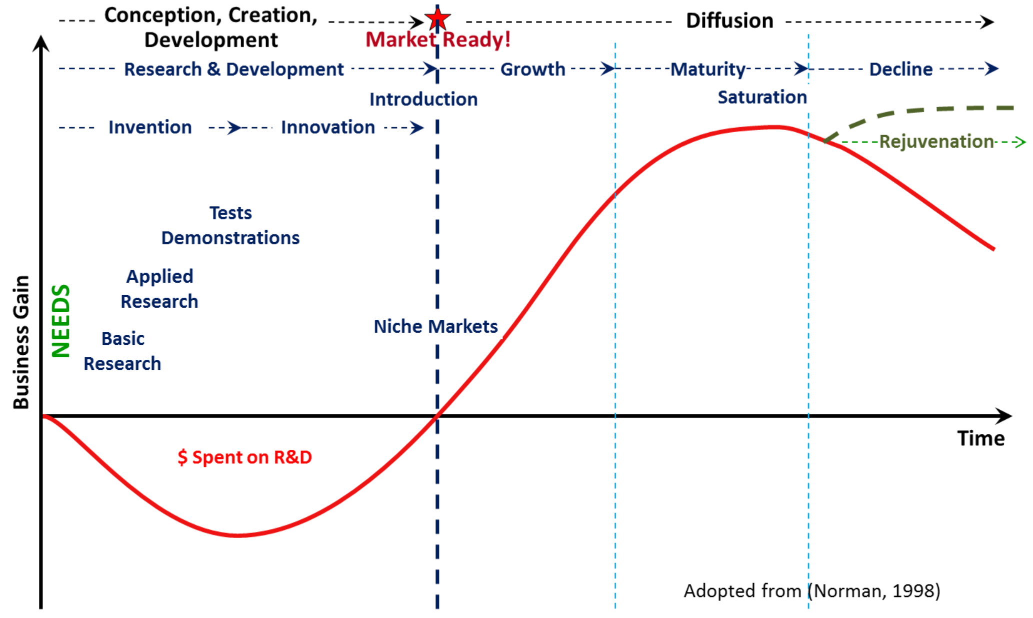


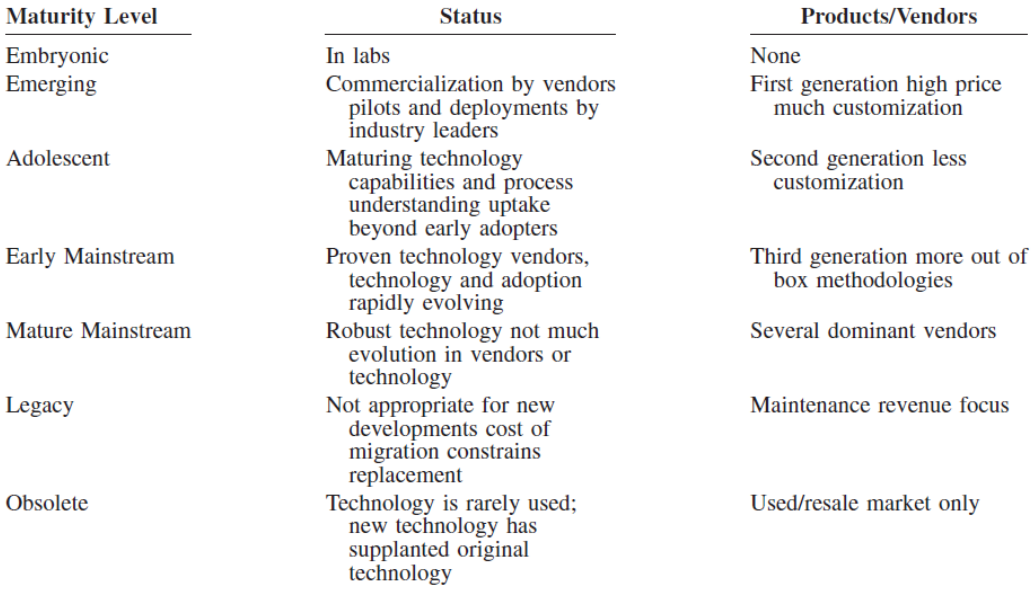
Figure 2-1 The Technology / Product Life Cycle

The full technology product life cycle extends to include the maturation and decline of the innovation, with one focused on the physical and technological aspects, and the other focused on the user acceptance and market aspects of a product. The life cycle phases are defined as: Development, Growth or Ascent, Maturity, and Decline (Rodrigue, J.P. et al, 2009). Others have added based upon their focus different phases such as the Introduction of the product, emergence of Niche markets, Saturation, and Rejuvenation or Termination (NetMBA, 2012; Halsnæs, K., P. et al, 2007, Tutor2net, 2012). Eventually, all technologies reach a period of decline as new innovations provide features and benefits they do not have or they are no longer supported by their producers.

The initial conception, creation, and development is often described as consisting of “Invention” or the first practical demonstration of the idea, and “Innovation” which is the first commercial application of the idea (Foxon, T.J., 2003). This overall phase encompasses basic or pure research, technology demonstrations, tests and demonstrations to potential purchasers, and commercialization (Rogers, E.M. 2003; Grubb, M., 2004). During the R&D and early introduction innovations will have a period of monopoly where the developers are the sole producers of the product. However, as it enters commercialization and the growth phase, competitors start to copy and/or improve on the product (Rodrigue, J.P. et al., 2009). The “public” nature of ideas is one barrier to investments in initial research and development that often has to be overcome for technologies where the public benefits they produce are greater than can be internalized by initial developers.

As shown in Table 2-1, Gartner’s Maturity Levels capture the relationships between the maturity of the technology, its status, and the product and vendors that produce it. This analysis shows the implied evolution of the innovation throughout its lifecycle, and the interplay between the maturity and the dedication of new development resources. As new innovations emerge, legacy systems continue to remain because of the costs associated with making the transition. At some point systems become obsolete, and use diminishes and suppliers stop providing support for it.

Table 2-1 Gartner’s Maturity levels (Fenn, 2010)



Maturity Level	Status	Products/Vendors
Embryonic	In labs	None
Emerging	Commercialization by vendors pilots and deployments by industry leaders	First generation high price much customization
Adolescent	Maturing technology capabilities and process understanding uptake beyond early adopters	Second generation less customization
Early Mainstream	Proven technology vendors, technology and adoption rapidly evolving	Third generation more out of box methodologies
Mature Mainstream	Robust technology not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Technology is rarely used; new technology has supplanted original technology	Used/resale market only

The type of innovation also impacts how long it takes the technology to move through the cycle, how it is developed, and its acceptance and adoption by potential users (Foxon, 2003). Incremental, or continuous, innovations improve the functionality and efficiency, or reduce costs of existing products or processes. They may be the result of insights gained by learning by doing (producers) or learning by using (users) rather than from a specific R&D effort. They are also typically dominated by the large entrenched leaders in the market place.

Radical innovations provide new services or products that previously did not exist and may be aimed at users not currently served by existing products. The Apple iPad is an example. These innovations often come from specific R&D efforts, or small start-ups with new ideas outside mainstream industry. A radical/transformative technology or product can be followed by incremental models/versions extending the life of the technology.

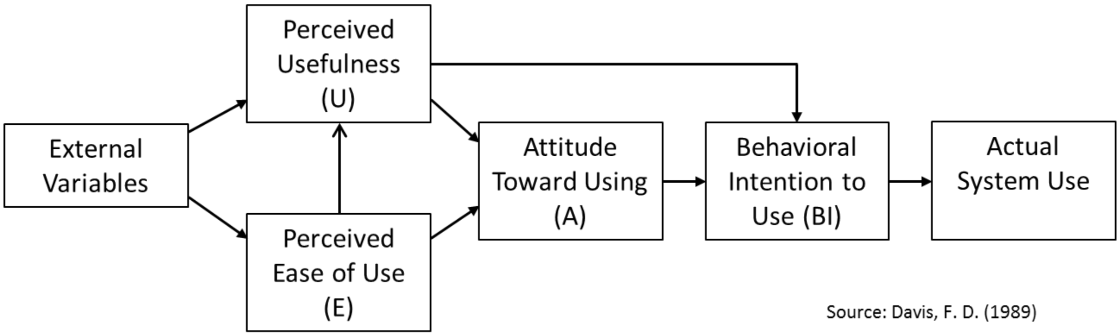
As discussed later, Christensen defines Sustaining versus Disruptive innovations based upon how they impact the marketplace. Sustaining innovations are aimed at the existing mainstream and support the status quo. Disruptive innovations often have high initial marginal costs, but focus on providing new services to market segments not served. This protects them from the overall market and allows them to evolve to the point where they often supplant current products and companies that produce them.

Since ideas and innovations often build upon each other, many innovations are also “path dependent” and are the result of networks and environments that reinforce their development (Foxon, T.J., 2003). Many new products that came out of Silicon Valley since the 1980s are the result of this path and interrelated system of innovations that exists there.

As innovations and technologies emerge and are market ready they must still be adopted and deployed by users. This diffusion and adoption is the subject of the next section.

2.3 Adoption and Diffusion of Innovations

The Technology Acceptance Model (TAM) (Davis, 1989) and its extension the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) provide a basis for examining the diffusion of innovations. The TAM provided the important concept that when users are presented with a new technology they will accept it and use it based upon their perceptions. As shown in Figure 2-2, external factors influence an innovation’s perceived usefulness and ease of use, leading to a user’s attitude toward using the product and their intention to use it. Many factors and constraints may intervene and consequently intentions may not lead to actual use.



Source: Davis, F. D. (1989)

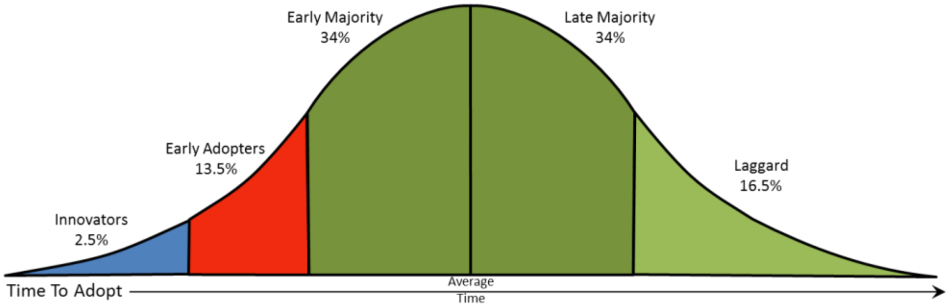
Figure 2-2 The Technology Acceptance Model

The UTAUT provides additional details and factors to the TAM. It posits that four key constructs are direct determinants of user intention and behavior: performance expectancy, effort expectancy, social influence, and facilitating conditions. User characteristics of gender, age, experience and voluntariness of use are posited to mediate the impact of the four key constructs first on the user's intention and then on their behavior. Validation of the UTAUT in a longitudinal study found that it explained up 69 percent of the intention and usage of information technologies (Venkatesh, et al., 2003).

The idea that perceptions of the innovation matters and that these are influenced by the adopter's characteristics, the external conditions, and social influence is important to keep in mind since it leads to the importance of both communications channels and social "peer" networks in the diffusion of innovations.

2.3.1 Diffusion of Innovations

The Diffusion of Innovation theory first introduced by Everett Rogers postulates that innovation factors impact a user's perception of the innovation prior to adoption of the innovation. These factors then affect the rate of adoption of the innovation. Rogers categorized adopters of any new idea or innovation as innovators (2.5 percent), early adopters (13.5 percent), early majority (34 percent), late majority (34 percent) and laggards (16 percent). Rogers estimated these proportions based on a normal Bell-curve. This categorization has become known as the "Technology Adoption Lifecycle" or the Innovation Adoption Curve and is shown in Figure 2-3.

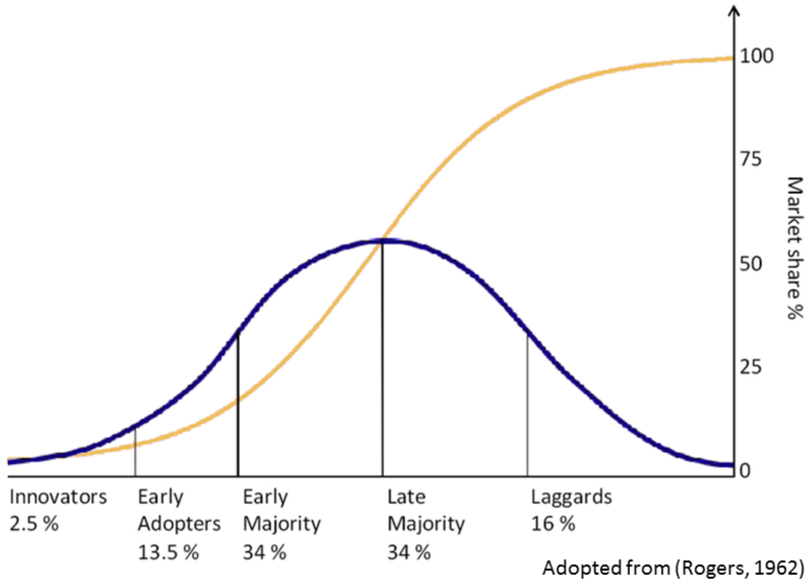


Adopted from (Rogers E.M., 200)

Figure 2-3 Adopter Categorization On The Basis of Innovativeness: "Technology Adoption Lifecycle"

The rate of adoption forms the Diffusion of Innovations (DOI) model, an "s-shaped curve," as shown in Figure 2-4. The graph shows a cumulative percentage of adopters over time – slow at the start, accelerating as adoption increases, then leveling off until only a small percentage of laggards have not adopted. (Rogers, 1983.)

The TAM attributes and DOI characteristics provide a theoretical basis for the decision factors considered in this literature review. The actual decision factors cited in the studies reviewed were categorized according to three main areas: implementer/user factors, technology factors, and external environmental factors.



Adopted from (Rogers, 1962)

Figure 2-4 Diffusion of Innovations Model

2.3.1.1 Implementer/User (Adopter) Factors

Implementer/user factors are those that are intrinsic to the agency or individual using the technology. They capture the “Attitude toward using” and “Behavioral Intention to Use” of the TAM model. Factors such as risk tolerance, degree of technical sophistication, and the influence of peer networks are all implementer/users factors and would determine agency’s status as innovators, early adopters, early and later majority, or laggards. The U.S. DOT may wish to explore the influence of these factors when designing future deployment tracking surveys.

2.3.1.2 Technology (or Application) Factors

Technology factors are those that describe the technology or innovation being considered for adoption. Individual ITS technologies can be characterized as incremental or radical, disruptive or sustaining. For example, electronic tolling might be considered disruptive technology since it created a new market landscape and funding mechanism. In addition, decision factors such as inter-operability and integration with existing systems technology factors often cited by agency staff in their decision to deploy ITS. Price is also a large factor, and it is heavily impacted by the level of adoption of the technology.

2.3.1.3 External Environmental Factors

External environment factors are those extrinsic to the implementer or user considering the technology, such as government policies and priorities, as well as the factor most frequently cited by purchasers, budget and funding opportunities. Studies suggest that government Research and Development (R&D) funding be used to bridge the gap to market commercialization of a portfolio of technologies, especially those with high development costs as well as high potential public benefit (Kohler and Frencia, 2011.) However, with the exception of Pace, et al. the literature is lacking in measures of effectiveness of specific funding mechanisms with those aims.

2.3.2 Crossing the Chasm

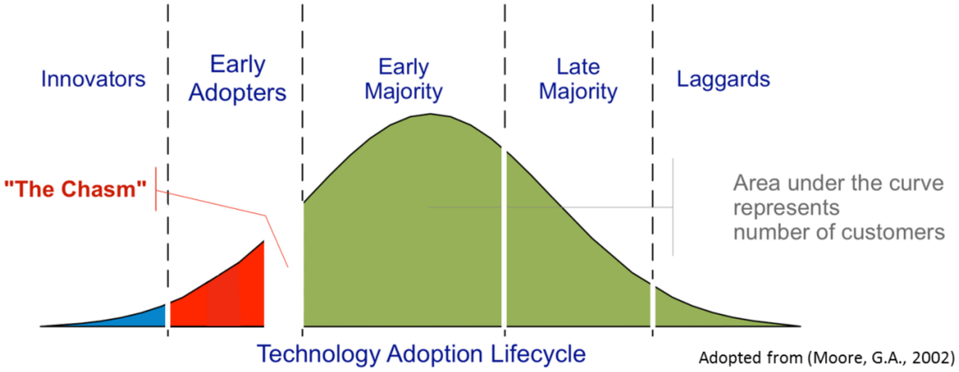


Figure 2-5 The Chasm between Adopter Categories

In 1991 Geoffrey Moore added a new concept to the Technology Adoption Lifecycle and diffusion theory, that there exists a gap or “chasm” between any two of the adopter groups that must be crossed if a technology/innovation is to continue to be adopted. This is illustrated in Figure 2-5. Moore focused on how marketing strategies need to change across the lifecycle. Each adopter group has different motivations and looks at potential innovations through their unique perspectives which may require different marketing. The gap “symbolizes the dissociation between the two groups – that is, the difficulty any group will have in accepting a new product if it is presented in the same ways as it was to the group to its immediate left (Moore, 2002). Three of the gaps are relatively minor, or “cracks” in the bell curve. However, a “chasm” exists between the Early Adopters, and Early Majority that must be overcome if the innovation is to reach the mainstream.

An example of a funding strategy that successfully addressed the chasm within the ITS program is the 511 planning assistance grants that were given to states to help them plan out their 511 traveler information deployment programs. This assistance program provided Federal funding to public agencies to develop regional and statewide plans for implementing 511 traveler information services, and/or to help defray the costs of telephone service providers in converting traveler information telephone numbers (FHWA, 2001). Those agencies who applied were eligible for up to $100,000 with a state/local financial matching requirement. While the innovators and early adopters may not have needed these grants, the grants stimulated many (early and late majority) states who might otherwise have delayed to move forward with their 511 system deployment plans. In total, 46 states or districts received some form of financial assistance through this program, and the deployment of 511 is now considered to be mainstreamed across most states and many major metropolitan areas. Over 40 active 511 systems are currently in operation across the United States (FHWA, 2011).

The gap between the innovators and the early adopters occurs when a “hot technology product cannot be readily translated into a major new benefit.” The gadget lovers think the technology is cool and invest the time to understand it, but others wonder what to do with it. Showing that the new technology provides new capabilities never before possible (the killer app) is one way to overcome this “crack.”

The “crack” between the Early Majority and the Late Majority results from the two groups willingness to invest time in becoming technically competent with the innovation. By this time the market for the product has been established and it has become part of the mainstream. The Early Majority is typically more comfortable with change and technically adapt and will “invest” in its use, the Late Majority is much less willing to do so. Consequently, to overcome this “crack” it needs to become increasingly easier to adopt and use. It must become a “commodity.”

The last “crack” is between the Late Majority and the Laggards. Laggards simply don’t want anything to do with the innovation or new technology of concern. Therefore, it is unlikely that marketing or demonstrations of benefits will ever convince them to make a change. However, external factors such as new regulations, or obsolescence of a product that they do use may force them to adopt or change. A recent example is the Digital TV Transition which ended analog transmissions and forced many to buy DTV converters or switch to cable or satellite service providers. Proposed Federal Motor Carrier Safety Administration (FMCSA) regulations to mandate electronic onboard recorders (EOBRs) on all trucks would force laggards to adopt the EOBR technology.

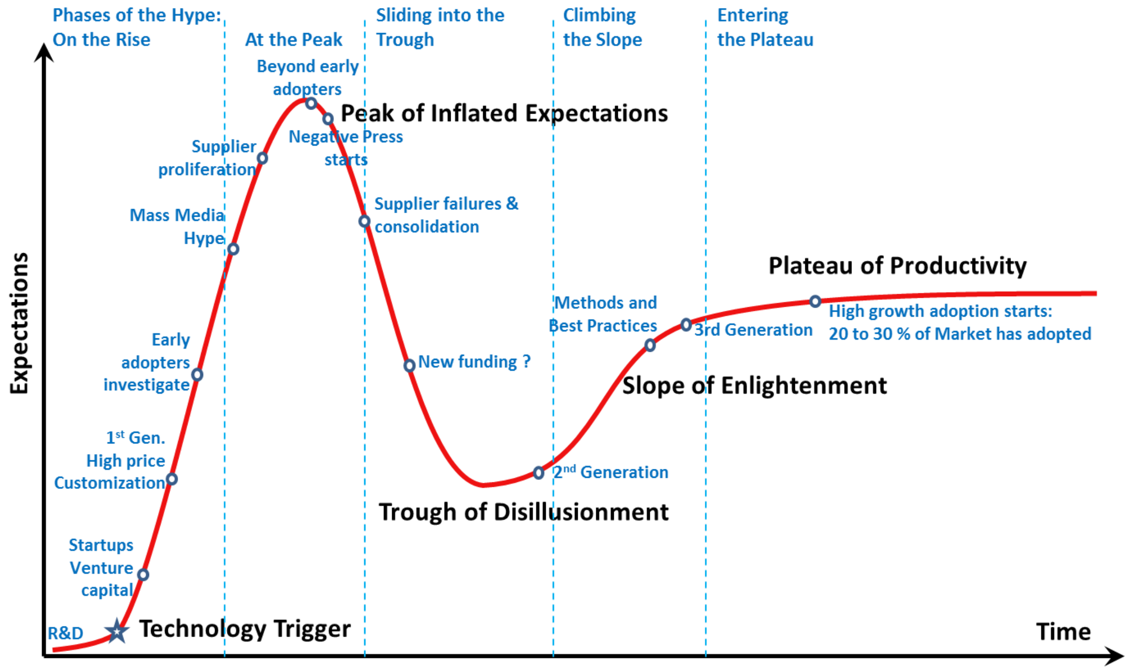
The chasm between Early Adopters and the Early Majority is the result of how each views the purpose behind innovation and considers their peers. Early Adopters are looking for radical and discontinuous “change agents” to give them a competitive advantage over others. They want to be first and thus are usually willing to “test” new products and bear the burden of learning and/or ironing out the wrinkles of early models. The Early Majority on the other hand are focused on productivity improvements to improve existing operations and do not want to disrupt their organization. They are not attracted to radical changes or new systems and are typically unwilling to debug experimental products or prototypes. Often they also look at their peers as members of the community that they can learn from and not cut-throat competitors. They would like to see the benefits and impacts on their systems before they adopt. These differences cause a Catch 22. “The only suitable reference for an early majority customer, it turns out, is another member of the early majority, but no upstanding member of the early majority will buy without first having consulted with several suitable references” (Moore, 2002).

It should be noted that the “chasm” applies for the most part to disruptive or radical innovations that are discontinuous in nature. Adoption of incremental or continuous innovations (that do not cause a significant behavioral change) such as annual software updates may not produce significant gaps in the bell curve.

2.3.3 The Need for Technologies to Evolve Throughout the Lifecycle

Both firms and technologies need to evolve throughout the cycle. The different perspectives and motivating factors between the “High Technology” Innovators/Early Adopters and the Early Majority and beyond also lead to differences in how the technology needs to evolve in order to succeed (See Norman D.A, 1998a & 1998b). High technology consumers are interested in more technology and better technical specifications. They want the new technology and will pay for it often overlooking instability or difficulty in use. They are also often attracted to bells and whistles and gadgetry. Technology dominates over user convenience and features for these groups. The later adopters of the Early Majority and beyond, however, typically are focused on how the product meets their utilitarian needs. They are seeking efficiency, pleasure, and convenience through a “consumer commodity. This requires a shift to human centered design often without the “excess technology” or enhanced features that attract the earlier groups.

2.3.4 The Gartner Hype Cycle



Adopted from (Fenn, J. 2010)

Figure 2-6 Gartner Hype Cycle (Phases of the Hype)

The Hype Cycle shown in Figure 2-6 is framework that Gartner Research uses to follow the path that expectations surrounding an innovation/technology typically takes from its introduction or “Technology Trigger” in the market place to maturity and wide spread adoption (Fenn, J. 2010). It is based on the idea that most technologies will progress through the pattern of over enthusiasm, disillusionment, then practical expectations and implementation. It also intrinsically assumes that an innovation/technology will evolve through several generations as it matures (see Figure 2-6).

The Hype Cycle includes five phases (Floor Management Network, 2012):

- **Technology trigger**. A potential technology breakthrough that triggers significant publicity. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
- **Peak of inflated expectations**. A phase of overenthusiasm and unrealistic projections during which a flurry of publicized activity by technology leaders results in some successes but also

failures as the technology is pushed to its limits. Conferences often are organized around the innovation.

- **Trough of disillusionment**. Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters. Bad press often leads to the innovation becoming out of fashion.
- **Slope of enlightenment**. More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks and benefits. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious. Commercial off-the-shelf methodologies and tools start to become available to ease the adoption/deployment process.
- **Plateau of productivity**. Mainstream adoption starts to take off. The technology's broad market applicability and relevance are clearly paying off. The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generation. The final height of the plateau varies according to whether the technology is broadly applicable or only benefits a niche market.

While the stages laid out in Moore's "Crossing the Chasm" follow the technology adoption cycle from the vendor's perspective, the Gartner Hype Cycle traces technology adoption from the adopter's or customer/buyers point of view. The trough of disillusionment coincides with the Chasm described previously between Early Adopters and the Early Majority. The Plateau is reached as the market transitions from the Early Majority to the Late Majority adopters. This provides additional insights to adopters on when they should invest in the innovation and also to developers on how to introduce/promote emerging and next generation products. If for example, the "hype" on what next generation ITS such as "Connected Vehicles" or ICM can deliver is made too soon (prior to the release of proven market ready systems) there is a chance of increasing and deepening the trough of disillusionment as agencies become wary of the next big thing being promoted by the Department.

2.3.5 The Bass Diffusion Model

The Bass Diffusion Model was introduced by Frank Bass in 1969 (Bass, 1969 and 2012) and is used to mathematically model and forecast product and technology adoption in the marketplace. The model is based on 1) the characteristics of the adopters and their propensity to innovate, and 2) the influence of two types of communications channels: Mass media and interpersonal channels. As shown in Figure 2-7, early adopters, or Innovators, obtain their information through the mass media (or hype). Imitators tend to adopt based on the experiences of their peers learned through interpersonal communications. An important component of the Bass Model is that as the markets change, the rate of new adoption at a given point in time is a function of the number of previous adoptions (Pace, et al., 2011). As the market reaches saturation an inflection point after which the rate of adoption begins to decline.

The Bass model provides comparisons between different types of products and insights on how their markets are driven. Some innovations tend to be driven by innovators, while others tend to be driven by the concerns of imitators. This has significant implications for future innovations in ITS since many of the next generation ITS are similar to large capital durable good and system investments (e.g. ATM machines, ultrasound, sustainable energy sources) and past ITS markets have been driven by Imitators. Ways are needed to either provide peer references (e.g. Crossing the Chasm), or to encourage conversion from imitation to innovation by adopters of the new technologies by sharing and reducing risk (Pace, et.al. 2011).

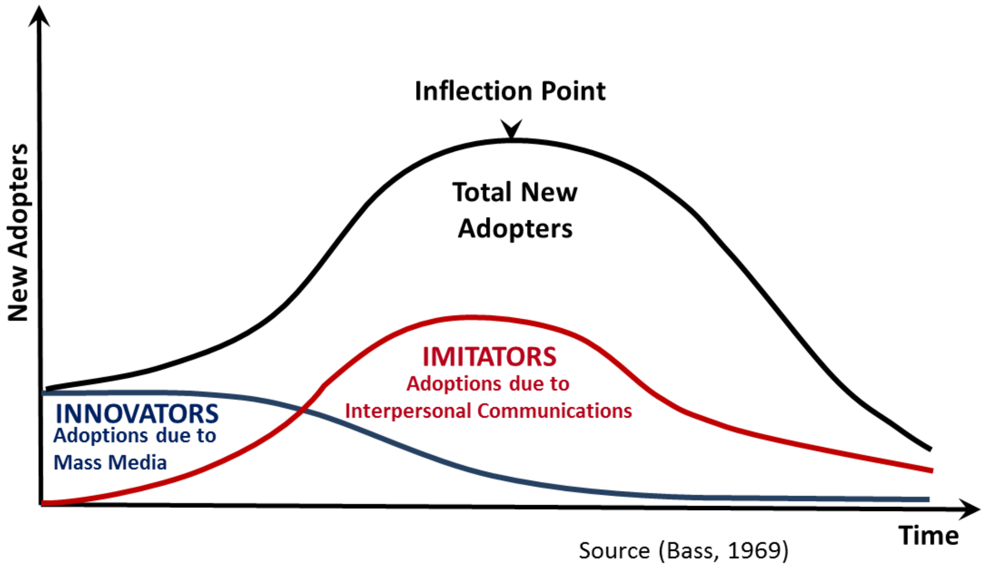


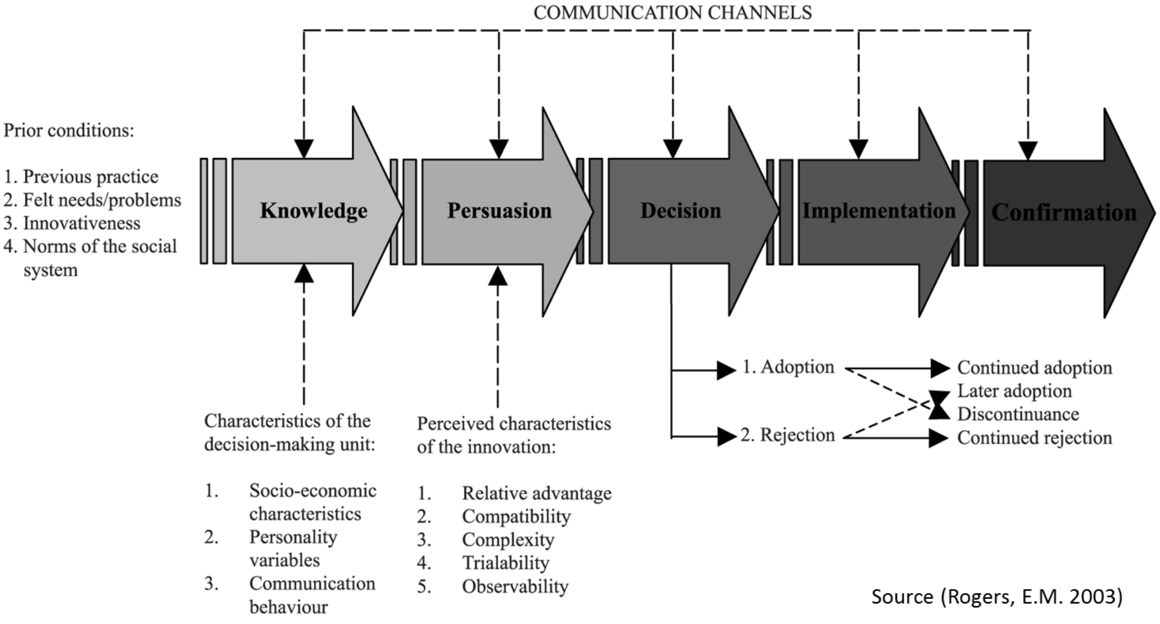
Figure 2-7 Bass Diffusion Model

2.3.6 The Innovation Adoption Decision Process

Roger's Diffusion of Innovation (Rogers, 1995), describes a five step process for the decision to adopt and use a technology by an individual. The five steps illustrated in Figure 2-8 are:

1. Knowledge – The person becomes aware of an innovation and has some idea of how it functions.
2. Persuasion – The person forms a favorable or unfavorable attitude toward the innovation.
3. Decision – The person engages in activities that lead to a choice to adopt or reject the innovation.
4. Implementation – The person puts an innovation into use.
5. Confirmation – The person evaluates the results of an innovation-decision already made.

Diffusion of innovation theory suggest that the innovation-decision depends heavily on the innovation-decisions of the other members of the social system, especially at the Knowledge and Persuasion stages. From the beginning, one's knowledge of the new technology depends on the communications channels and behavior employed.



Source (Rogers, E.M. 2003)

Figure 2-8 The Innovation Decision Process

Looking at the five characteristics of innovations that influence an individual's decision to adopt or reject an innovation, we see that the last two, Trialability and Observability, and possibly Complexity (depending on how one learns) are highly dependent on engagement with social system members. The five characteristics are:

- Relative advantage-Does it represent a significant improvement over previous technologies?
- Compatibility- Can it be assimilated into my life?
- Complexity – How difficult is it to learn to use?
- Trialability-Can I easily try it out?
- Observability-Is it visible to others?

The innovation-decision is made through a cost-benefit analysis where the major obstacle is uncertainty. People will adopt an innovation if they believe that it will, all things considered, enhance their utility. They must believe that the innovation may yield some relative advantage to the idea it supersedes. But how can they know for sure that there are benefits? Communication from trusted opinion leaders are very important for informing adoption decisions as well as the individual's personal risk preferences (Orr, 2003).

2.4 Implications

As the background material has shown, ITS is at cross-roads with deployment of mature first and second generation ITS technologies and applications "at a saturation point," especially in the large metropolitan areas across the United States. Moreover, as we move to ITS 3.0 and beyond to connected vehicles, the development and successful deployment of ITS technology is becoming increasingly interdependent, requiring parallel decisions by several different actors, including the developers and manufacturers of a technology or service, the public sector and other deployers of the service, and the consumers and users of the service. For example, transit information applications for mobile phones require the development and implementation of the mobile application (often by the private sector), the preparation of the scheduling and routing information and creation of the open data system and interface by the transit agency, and the use of mobile devices and purchase/installation of the application by the consumer. Connected Vehicle-to-Infrastructure (V2I) safety applications will require decisions by the auto manufactures to develop and install the equipment, the public sector to provide roadside equipment, and the owners/drivers of the vehicles to pay for the vehicles or purchase and install aftermarket equipment. The traditional linear model of invention followed by research and development of the technology (innovation), independent adoption and deployment by a public agency, then continued operation and maintenance rarely holds. These developments highlights the importance of a systems approach and systems thinking when looking at new ITS systems and how they may be adopted and deployed.

This analysis of the theory of innovation presents a number of implications for successful adoption and diffusion of new ITS 3.0 and beyond technologies. The first insight is that Innovators/Early Adopters do not necessarily make good references or examples to convince the early majority to adopt a technology, because they are not considered “peers” by the majority of adopters. The need to provide peer “Early Majority” examples so other Early Majority organizations may consult and reference them has significant implications for the ITS Program R&D and pilot/demonstration efforts. There is a risk that if locations/agencies that are significantly more technically advanced than others are chosen, they are likely to be perceived as too different to be relevant by others to be good models.

Innovative strategies are needed to help bridge the divide (or chasm) between the early adopter and the early majority agencies. The example cited in this chapter was the development and funding of a FHWA 511 planning assistance grants program that assisted successful applicants in the planning and initial conversion costs of their 511 traveler information programs.

As the technology matures and is mainstreamed, the focus of the design should change from technology centered to consumer/needs centered products. ITS that may appeal to pioneers and large systems may not be attractive (or needed) by the average / smaller agency.

As discussed above, peer networks and social systems along with their communication channels become very important when promoting imitator-driven innovation. The Department must analyze the communication channels for sharing information on what is the “norm” and the benefits/costs of different innovations if it seeks to influence adoption.

3 Literature Review

This review of literature begins with a detailed scan of four key documents that identify factors influencing ITS adoption and the state of ITS deployment. The first three were initially identified in the RFTP. The initial scan revealed a fourth document relevant to identifying factors associated with the adoption and continued deployment of ITS and technology in general. The four documents listed below were reviewed in detail to identify best practices for technology, assess the ITS market and the factors that influence ITS adoption and deployment. These four documents are listed below:

- An Analysis of the Factors Influencing ITS Technology Adoption And Deployment (Pace, David, et al., 2011)
- ITS Technology Adoption and Observed Market Trends from ITS Deployment Tracking: Final Report (Hagemann, Garrett, et al., 2010)
- Deployment of ITS: A Summary of the 2010 National Survey Results (Gordon, et al., 2011)
- Marketing ITS Infrastructure in the Public Interest (Lappin, et al., 1998)

This review examines a number of additional resources including findings from 31 major evaluation reports, 12 state reports, and a keyword review of the Benefits and Lessons Learned database within the Knowledge Resources. Findings from these sources and the four key documents are summarized in the subsequent section, 3.1 Summary of Decision Factors Influencing ITS Deployment. The list of major evaluation and state reports reviewed is presented in Appendix B. Section 3.2 highlights key findings from the Pace et al. report, while Sections 3.3-3.5 summarize relevant material from the Hagemann, Gordon, and Lappin reports, respectively. Section 3.6 highlights selected material from the ITS Knowledge Resource keyword review and the 12 state reports.

In addition, separate reviews of decision factors considered by the commercial vehicle industry and the connected vehicle industry are included in Sections 3.7 and 3.8. These analyses surfaced decision factors that are sufficiently distinct that they are presented in their own sections. Further, in 2010, the ITS Professional Capacity Program (PCB) Strategic Plan (Greer, et al., 2011) leveraged multimodal public and private sector stakeholder to highlight challenges to ITS adoption and the potential of leveraging technology transfer tools to accelerate the adoption of newer technologies. Findings from this effort are summarized in Section 3.9. Finally, in April 2012, a European consortium completed and published a set of 8 reports on “Innovation Processes in Surface Transportation,” which is a broad effort analyzing innovation across decades for public and private sector entities within road, maritime, rail, inland waterways, and intermodal transportation. This work has insight directly valuable to this existing effort. Study highlights and from this effort are summarized in Section 3.10. Overall selected findings are summarized in the below three paragraphs.

In general, the four major studies and the search of the ITS Knowledge Resources yielded many of the same of the decision factors affecting current ITS deployment. Looking at them by factor type, for application factor, the perceived benefits of ITS technologies, degree of integration with existing systems, and price were the leading factors cited in the studies and reports reviewed. For implementer/user characteristics, the most frequent factor cited was usage by a neighboring agency, supporting the Pace paper conclusion that most state agencies are imitators, rather than early adopters. In terms of the external environment, agency budget, the need to prepare for a major event or construction project, and the presence of an external funding source were most frequently cited as key decision factors influencing deployment of ITS technologies. This last factor was the only area in which the studies appeared to contradict each other, with implementers in the Gordon et al. paper citing funding and grant availability as a key factor, while Pace et al. finding the presence of earmarks had no effect on ITS deployment.

Questions have been raised about whether directed funding programs such as competitive grant programs and earmarks actually provide the desired catalyst effect of spurring state and local deployments in particular area or for a particular purpose. A review of transportation earmarks by the U.S. DOT Inspector General found earmarks often may cause lower local priority projects to be funded over higher priority projects, and may in fact reduce funding for a State’s core programs (US DOT Inspector General, 2007). Others found that the directed funding often does not increase overall funding to the area or agency that receives it as other funds in the local process are “balanced” to take the additional revenues into account (Sciara, 2009). Because of redirection of local funds to meet matching requirements of the earmark or competitive grant, receiving a grant for one project can also lead to reductions in the ability to carry out other efforts. The Pace et al. paper found either a negative or tenuous relationship between the directed funds (earmarks) and additional deployment of a particular technology. Based on this result, the authors recommend exploring provision of funds through more regular and ongoing sources of funds in order to influence deployment.

Receiving a grant for one project can also lead to reductions in the ability to carry out other efforts as local funds are redirected to meet matching requirements.

The Commercial Vehicle Information Systems and Networks (CVISN) deployment program provides an example of the effect of directed funding. The CVISN deployment program was designed to provide a systematic deployment grant and training process intended to move all states to a basic level of deployment CVISN (Level 1). However, the success of this program was negatively affected by the introduction of the TEA-21 deployment earmarks, which required that funding go to earmark recipients rather than the wider audience as intended. Other budgetary pressures additionally complicated the progress of deployment. Many states that are otherwise qualified for federal CVISN grants could not obtain them because the required nonfederal matching funds were not available. Some states made great strides in deploying their CVISN systems, only to see them decline because budgetary pressures restricted ongoing operations and maintenance resources (Brown et al., 2009).

Given that there is generally agreement regarding the key decision factors, the gaps concern the degree to which each factor impacts ITS deployment, with the Pace study providing the sole econometric analysis of the data thus far. It is also unknown how these factors might work together to influence ITS adoption and deployment.   Another gap is the increasing influence of user/market characteristics as we move forward with connected vehicle technologies (CVT), discussed in section 3.8. These topics will be further discussed in Chapter 5, Gaps and Needs.

3.1 Summary of Decision Factors Influencing ITS Deployment Based on Review of Literature

Factors influencing ITS adoption and subsequent activities of expansion, maintenance, contraction, or decline were initially organized within three categories: technology application, implementer and user factors, and external environment factors. Most if not all of the literature focuses on adoption of ITS as the central consideration, with far lesser focus toward maintenance, expansion, contraction or decline. After a more extensive review of the literature we concluded that user and market characteristics such as user's attitudes toward technologies are often different than the factors that influence implementers of the technologies and that these individual user preferences are expected to play a more important role in the decision to use ITS 3.0 and beyond. In light of this finding, Figure 3-1 presents the enhanced deployment decision process.

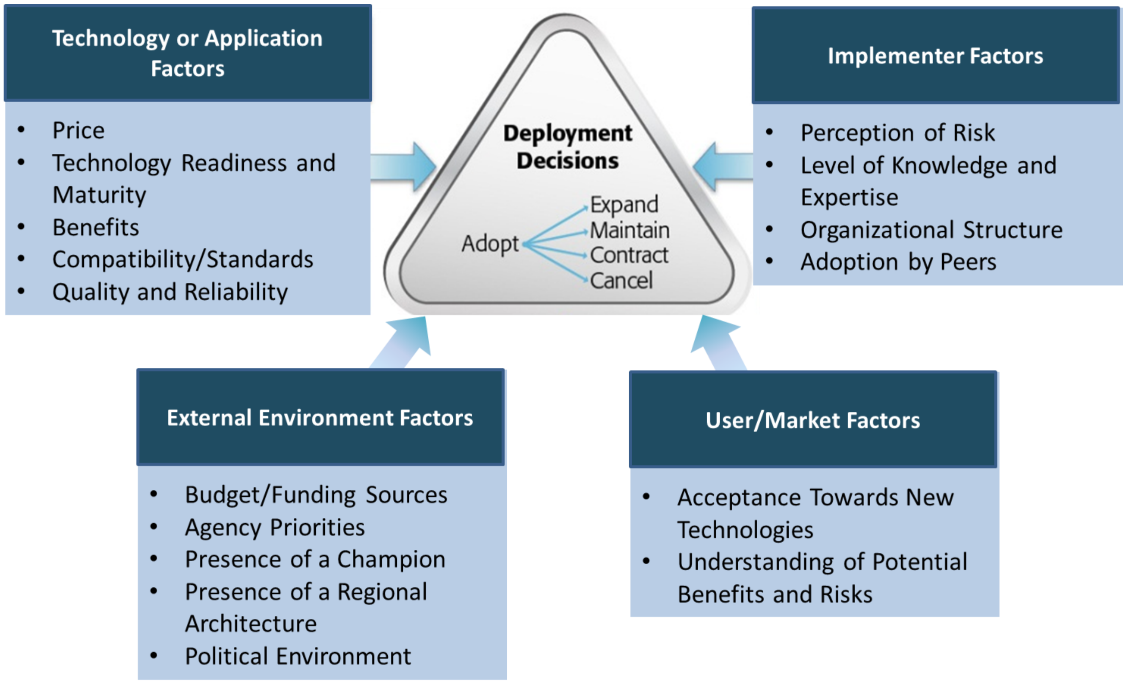


Figure 3-1 ITS Deployment Decision Process

Findings from the literature review are aggregated and listed based on the four categories: application factors, implementer factors, market or user factors, and external environmental factors. The subsequent subsections list the adoption and deployment factors under each of the four categories and discuss examples of previous experiences from the literature.

3.1.1 Technology or Application Factors

Technology factors include characteristics of the technology or innovation being considered for adoption. Individual ITS technologies can be characterized as incremental or disruptive, depending on the changes required to implement. Decision factors such as interoperability and compatibility with existing systems are factors often cited by agency staff in their decision to deploy ITS. Price is also a significant factor, and is heavily dependent on the level of maturity and state of deployment of the technology. In reviewing the various literature, technology or application factors are frequently cited as a key consideration in the adoption and deployment of ITS, and below are selected highlights:

- **Price of technology**
  An Analysis Of The Factors Influencing ITS Technology Adoption And Deployment showed that agencies will likely want to see evidence that new technologies are cost effective before adopting them. (Pace et al., 2011)

  An ITS Deployment Tracking analysis of ITS Technology Adoption And Observed Market Trends, suggests that price constraints compared to the availability of agency funds do play a key role for agencies considering a switch to ETC technologies because the ETC technology options are limited to major companies whose systems generally are not interoperable. (Hagemann et al., 2010)

  Some studies have found that the price of operating and maintaining ITS investments can exceed the initial deployment, which affects agency decisions to expand or sustain such systems (GAO, 2012).

- **Technology Readiness and Maturity**
  A national evaluation of the Metropolitan Model Deployment Initiative (MMDI) showed that the quality (readiness and maturity) of Advanced Traveler Information Systems (ATIS) service was a factor in ATIS use and deployment decisions. In Seattle and Phoenix, personal digital assistants (PDAs) were used for the receipt of real-time traffic information, however the PDA technology was not ready for deployment. It was expensive and unreliable therefore had low market penetration (Perez, 2000).

  An evaluation of several MMDI sites found that an important consideration for technology implementation is the potential for widespread deployment (SAIC,2001).

- **Demonstrable Benefits**
  An Analysis Of The Factors Influencing ITS Technology Adoption And Deployment showed that agencies will likely want to see evidence that new technologies provide clear benefits before adopting them (Pace et al., 2011).

  Results from an *Advanced Traveler Information System (ATIS) Implementation* evaluation in New York state (Falcocchio, 2007) and an MMDI evaluation (SAIC, 2001) in several states found that being able to measureable benefits of the technology was an important decision factors for implementation.

A Commercial Vehicle Information Systems and Networks (CVISN) evaluation found that two important decision factors in participating in CVISN deployment were potential staff time savings and getting trucks into service more quickly (Brown et al., 2009)

- **Compatibility/Use of Standards**
  In an *ITS Deployment Tracking analysis of ITS Technology Adoption And Observed Market Trends*, researchers found that a degree of lock-in to previous technology selection is an important determinant of technology selection. In addition, baseline infrastructure requirements and expectations for continuing supplier support was found to be an important factor in support adoption of TMS technologies (Hagemann et al., 2010).

  A Traffic Management and Traveler Information Event Study for the 2002 Salt Lake City Olympic games found that new traveler information technologies must be implemented compatibly with the traditional distribution channels (Glazer et al., 2003).
  Reports in the ITS Knowledge Resources suggest that open source designs and non-proprietary software are also important factors to take into consideration. Open source and non-proprietary software may provide great advantages of a competitive bidding environment for implementation, operation, and maintenance costs. Having open source material will also help compatibility with other systems (U.S. DOT ITS-JPO, 2012b).
  The InnoSuTra *Innovation Processes in Surface Transport report* found that the involvement of knowledge institutes, including standards bodies, was a very effective public policy tool for initiating innovations (InnoSuTra, 2012).

- **Quality and Reliability**
  Technologies that do not deliver information in a timely manner or deliver inaccurate information lower user acceptance and may taint users' expectations of future deployments (Skarpness et al., 2003).

  Technologies that do not deliver information in a timely manner or deliver inaccurate information lower user acceptance and can negatively affect users' expectations of future deployments (Skarpness et al., 2003).

  Systems that rely on data, including traveler information systems, need to be designed to work when data failures occur (Haas et al., 2009).

  A Commercial Vehicle Information Systems and Networks (CVISN) evaluation found that data quality is a factor in the deployment of a new technology (Brown et al., 2009).

  An ITS Deployment Tracking analysis of ITS Technology Adoption And Observed Market Trends, suggests that system quality is an important consideration particularly when technology options are limited to major companies whose systems generally are not interoperable (Hagemann et al., 2010).

  Several evaluation such as an evaluation of the Minnesota MAYDAY/9-1-1 Field Operation Test (Battelle, 2006) and a commercial vehicle electronic screening systems study (Belella et al., 1998) found that system reliability is an important factor in the decision to implement a particular technology.

3.1.2 Implementer Factors

Implementer factors are those that are intrinsic to the agency or company making the purchasing decision. Factors such as risk tolerance, degree of technical sophistication, and the influence of peers determine an agency's status as innovators, early adopters, early or later majority, or laggards. Implementer decision factors are recognized as key in the decision to adopt ITS technologies, and excerpts from the literature review are listed below.

- **Perception of Risk**
  A commercial vehicle electronic screening systems study found that perception of risk is an important decision factor when implementing new technologies (Belella et al., 1998).

- **Level of Knowledge and Expertise**
  Several major evaluation reports and studies in ITS Knowledge Resources agree that the choice of specific technologies to deploy should consider and reflect the availability and skill of support staff to implement, operate and maintain the system (Booz Allen Hamilton, 2000; Zimmerman et al., 2000; Iteris, 2003; Haas et al., 2009; U.S. DOT ITS-JPO 2012b). In particular skills in ITS and systems engineering are essential to manage ITS projects (Amodei et al, 1998, U.S. DOT ITS-JPO, 2012b, Haas et al., 2009).

  Additionally, The iFlorida Model Deployment project showed that leveraging FHWA experience and expertise and maintaining presence of FHWA personnel is important for a successful deployment (Haas et al., 2009).

- **Organizational Structure**
  Evaluations of ITS implementations have found that strong institutional framework of multi-disciplinary, interagency cooperation and regional support is a factor is ITS deployment. (Bolcza, 1999; Carter et al.,2000; Lappin et al., 1998; Gordon et al., 2011). The authors of the 1998 study *Market ITS Infrastructure in the Public Interest* suggest that regions where transportation and related agencies do not work well together are the least likely to adopt more advanced technology strategies. Agencies that were well organized and showed interagency and inter-jurisdiction cooperation, had the highest level of ITS deployment (Lappin et al., 1998).

- **Adoption by Peers**
  Previously ITS rich environments are more likely to deploy ITS expansion and integration projects (Jensen et al., 2000; Pace et al., 2011). In addition, results of a Bass model study of factors affecting ITS technology implementation, indicate that the adoption of the ITS technologies is mainly driven by imitators, as opposed to innovators. The ITS markets develop slowly and the tendency is for transportation agencies to wait until others have adopted the technology before implementing it themselves (Pace et al., 2011).

  A key determinant to the selection of a technology is usage by neighboring agencies. Three main cross cutting studies on ITS technology adoption show that agencies value integration with neighboring agencies and therefore are more likely to choose technologies already used by another agency (Gordon et al., 2011; Pace et al., 2011; Lappin et al., 1998).

3.1.3 User/Market Factors

User/market factors are those that characterize the end user of the technology and the overall market acceptance of the technology under consideration. The user perspective, blended with an aggregate market perspective, becomes more important when the individual must make a conscious decision to adopt a specific ITS technology, such as a fare payment card or transponder. The literature review identified a number of factors that are aggregated and categorized into two areas:

- **User's acceptance/attitudes towards technology**
  User's willingness to use new technology is an important factor in considering technology deployment. Agencies must consider the user's perspective including users' needs and comfort with new technologies (Perez, 2000; Haas et al., 2009). In a Seattle study of traveler information, results showed that market Uncertainty, or not knowing whether consumers would accept ITS products and services, contributed to some development uncertainty and associated deployment problems (Wetherby, 1998).

- **User's knowledge/understanding of potential benefits and risks**
  Marketing is important to ensure that potential users understand the benefits and risks of deploying new technologies (Carter et al., 2000, Hagemann et al., 2010). Hagemann et al. (2010) suggest that a challenge of deploying Traffic Signal Priority (TSP) and Emergency Vehicle Preemption (EVP) technologies is limited adoption because of the perception that these technologies may increase congestion. (Hagemann et al., 2010) Other studies also show that informing potential users, particularly of privacy/security concerns, results in greater user acceptance (Carter et al., 2000, Brown, 2009).

3.1.4 External Environment Factors

External environment factors are those extrinsic to the implementer considering the adoption of the technology and include elements such as budget and funding sources, government policies and priorities, public needs and the state of transportation infrastructure. As observed in the literature review, the external environment factors can often launch or derail agency adoption decisions. The literature review identified a number of external environment factors that are aggregated and categorized into four areas:

- **Agency Budget/Funding Sources**
  The four main cross cutting studies on ITS technology adoption reviewed in this paper show that agency budgets are a critical factor in deploying new ITS technologies. (Hagemann et al., 2010; Gordon et al., 2011, Pace et al., 2011; Lappin et al., 1998) . In the 2010 National survey, arterial and transit management agencies placed funding and grant availability as most important (Gordon et al., 2011). Higher levels of ITS deployment are shown in regions where there is a sufficient transportation budget, in

particular in locations where transportation receives dedicated funds (Lappin et al., 1998).

A Summary of the 2010 National Survey Results showed that earmarks and grant availability were factors in ITS deployment decisions, (Gordon et al., 2011) although this observation was contradicted by the Pace study that found that earmarks had no impact on ITS deployment. Federal involvement in the Atlanta NAVIGATOR project was a key factor determining ITS deployment (Amodei et al, 1998).

In addition to federal funds, federal experience can also influence ITS deployment. The iFlorida Model Deployment project showed that leveraging FHWA experience and expertise and maintaining presence of FHWA personnel was important for a successful deployment (Haas et al., 2009).

- **Agency Priorities**
  A need for readiness of major events, such as the Olympics games can facilitate deployment and expansion of ITS (Iteris, 2003). Similarly, major construction projects can also be opportunities for inclusions of ITS components (Lappin et al., 1998).

  Regions with greater need to managing high congestion levels demonstrate a need for high tech solutions and thus have higher levels of ITS deployment (Lappin et al., 1998).

- **Presence of a Champion**
  Support of state and local elected and appointed officials and regional experience with other inter-jurisdictional projects correlated strongly with higher levels of ITS deployment. The presence of a mayor or other strong local political leadership who understands how the technology can address an urban transportation agenda has a positive influence on the amount of ITS deployment. (Lappin et al., 1998).

- **Presence of Regional Architecture**
  The presence of a regional Architecture has a positive effect on technology adoption and deployment. Specifically, a regional architecture is important for adoption of technologies that are in an early stage of market diffusion (Pace et al., 2011).

- **Political Environment**
  Studies in the knowledge resources show that political environment can be a factor in technology deployment. Politics may open up new opportunities with funding but can also shut projects down if they take on a political issue. Particularly, political support is important in the deployment of controversial technologies such as congestion and road pricing projects (U.S. DOT ITS-JPO, 2012b).

3.2 An Analysis Of The Factors Influencing ITS Technology Adoption And Deployment

In this paper, Pace et al. presents an analysis of the diffusion of ITS technologies and examines factors that may influence ITS adoption and deployment. The methodology for this study uses two statistical approaches to analyze information from the ITS Deployment Tracking database: a Bass model is used to examine the historical diffusion pattern of ITS adoption, and then a two-step econometric model studies what factors influence the levels of ITS adoption and deployment. The Bass models are used to capture high-level adoption trends from the overall market perspective, while the econometric models look at a more granular, agency-level perspective through a series of econometric or behavioral models. Six ITS technology markets were studied over the period of 1999 and 2007:

- Electronic Toll Collection (ETC)
- Highway Data Collection (HDC)
- Traffic Management Systems (TMS)
- Vehicle Data Collection (VDC)
- Transit Signal Priority (TSP)
- Emergency Vehicle Preemption (EVP)

The results of the Bass model indicate the adoption of the ITS technologies analyzed in this study is mainly driven by imitators, as opposed to innovators. The ITS markets develop slowly and the tendency is for transportation agencies to wait until others have adopted the technology before implementing it themselves. However, the study notes that the falling price of technology over time is not considered in the model and therefore it is important to note that adoption of technologies may also be influenced by falling prices.

The Bass model results show that the aggregate ITS markets examined are mature, dominated by imitators, and therefore are ready for the deployment of substitute or next generation technologies. However, agencies will likely want to see evidence that new technologies are cost effective and provide clear benefits before adopting them. Pace et al. notes that a way to introduce innovation can be through funding targeted at new technologies so that agencies can observe the effects of these technologies in practice before adopting.

> Transportation agencies view ITS deployment decision-making as two distinct steps: first whether to adopt the technology, and subsequently how much to deploy

When determining ITS deployment, decision-making by a transportation agency is viewed as containing two distinct steps. The first step is to decide ***whether to adopt*** the technology. One this decision has been made, the second step is to decide ***how much to deploy***. Therefore, to analyze the influence of external factors on ITS adoption and deployment, this study uses a two-step process. To examine how economic and other factors influence both ITS technology adoption and deployment independently, separate econometric models with distinct estimation procedures are used to capture each of the two decisions.

The econometric models included explanatory variables that represent what is important to a transportation agency's decision making process. The variables used in the models are listed in Table 3-1 and were classified into three broad groups: economic and demographic factors, control factors that provide insight into the magnitude of the problem being faced by an agency, and policy related factors:

Table 3-1 Variables used in Pace paper

Type	Variables
Economic and Demographic Factors	• Agency budget • ITS equipment price • Population
Control Variables	• Mobility: Congestion • Safety: Fatal Vehicle Crashes
Policy Influences	• Presence of Regional Architecture • Availability of Earmark Funding

In addition to these variables, the study also used a peer variable to examine the influence of ITS adoption by an agency's peers (nearby agencies or those facing similar problems) on its decision to adopt the technology.

The effect of these external factors were not found to be consistent across all technologies studied. However, based on the results of the econometric models, some general implications of the effect of key external factors on either adoption and/or deployment of ITS technologies were found, including:

Adoption of ITS Technologies:

- The presence of a regional architecture has a positive effect on technology adoption. The effect is more pronounced for technologies that are less mature.
- The size of the agency's budget has a positive effect on technology adoption.
- The use of complementary technologies has a positive effect on technology adoption
- Earmarks were found to have no effect on technology adoption.
- The effect of price of the technology was not examined.

Deployment of ITS Technologies:

- The presence of a regional Architecture has a positive effect on technology deployment.
- The size of the agency's budget has a positive on technology deployment.
- The use of complementary technologies showed mixed effects on technology deployment.
- Earmarks were found to have small, negative or no effect on technology deployment.
- The price of the equipment had a negative effect on technology deployment

The results of these models suggest that policy makers and legislators have an opportunity to influence the pattern of adoption and deployment of ITS technologies through increasing the size of agency's budget, reducing focus on earmarks, emphasizing collaboration on regional architectures, sharing knowledge among peers and sponsoring research designed to produce evidence that support technology adoption.

The authors suggest that future federal efforts focus programmatic efforts for adoption toward technologies that have not yet been widely adopted since the models show that budgets and regional architectures have the most impact on additional adoption for technologies that are in an early stage of market diffusion. (As adoption reaches higher levels, the benefits from budgets and regional architecture dwindle). Programs that increase adoption will also benefit from the imitative nature of the public sector ITS market, spurring further technology diffusion as adoption levels increase.

They also suggest establishing programs, or developing technologies, that lower costs as the most likely method for positively affecting deployment by local traffic agencies. The study showed that technologies purchased by local traffic agencies had deployment positively affected by lower price. Deployment of technologies used on arterials or for managing traffic is also sensitive to changes in price. If the next generation ITS technologies, and in particular those related to the Connected Vehicle Initiative, are most likely to be deployed by local agencies, or used on arterials or for traffic management, then efforts that may moderate price increases would positively affect their deployment.

The paper closes by discussing policy opportunities of how the ITS program can modify its research to better influence the rate of adoption and diffusion of ITS technologies:

- Make recommendations for surface transportation funding reauthorization on topics such as access to federal funds for state and local agencies' overall budgets, and whether to include earmarks.
- Regulate, in conjunction with partner programs: continued support, promotion and refinement of standards and planning requirements, such as regional architectures; and data collection or other functions that would directly or indirectly require technology purchases
- Support development of standards
- Conduct research, testing and evaluation
- Conduct outreach and capacity building

3.3 ITS Technology Adoption and Observed Market Trends From ITS Deployment Tracking

In the *"ITS Technology Adoption And Observed Market Trends From ITS Deployment Tracking"* report by Hagemann et al., the authors conducted interviews with public purchasers (for example, state transportation departments) and suppliers of ITS, and attended trade conferences to highlight market dynamics. They identify key events influencing deployment trends, and suggest factors that may play an important role in shaping the market's future. Market analyses cover electronic toll collection (ETC), highway data collection (HDC), and arterial technologies to include vehicle data collection (VDC), transit signal priority (TSP), emergency vehicle preemption (EVP), and traffic management software (TMS).

The Hagemann et al. study found that the key factors influencing ETC adoption decisions include improved safety and environment as well as reduced congestion and operating costs. Price constraints compared to the availability of agency funds do play a key role for agencies considering a switch to ETC. The ETC technology options are limited to major companies whose systems generally are not interoperable. Consequently, the key determinants to selection of a technology include system quality, usage by neighboring agencies, and degree of lock-in to previous technology selection. As initial adopters near the end of lifespan of their toll readers and other equipment, and new technologies offer extra benefits, the ETC market may look toward other technologies such as connected vehicle, smaller tags, cell phone payment technologies and cameras. The rate of private sector ETC technology innovation may remain dampened until the outcome of the Federal decision on 5.9 GHz spectrum allocation for traffic and transportation use. Thus, government action in setting standards and promoting interoperability can play a role in accelerating deployment of the next generation of ETC technology.

Traditional sensor-based and newer probe-based HDC technologies that collect data have shown recent growth in deployment to support downstream ITS technologies such as Variable Message Signs (VMS) and 511 services. The sensor-based market is established, diverse, and competitive. Conversely the probe-based market continues to mature with tendencies toward a single supplier market with the accompanying cost implications. Google's entry into the HDC market is also noted as a consideration for private sector investment in HDC. A key gap in the HDC market is the availability of comprehensive guidelines for procuring data from a third party and establishing data ownership rights. Agencies tend to have to develop the process from scratch and the requirements for a data service are different enough from those of hardware that they likely require different sets of criteria and rules.

Instructions on expedient procurement, infrastructure requirements, and continued supplier support expectations would support adoption of traffic management software

VDC, TMS, TSP and EVP are addressed in the Hagemann arterial analysis section. The authors note that as with HDC the initial supplier of VDC often remains as the continuing market power given the difficulty to integrate into existing systems. They also state that VDC adoption is driven by other needs such as TMS, TSP, or EVP implementations. TMS has proven to be a valuable tool for managing complex traffic networks. The market is characterized by a high degree of customization, and agencies often create an in-house or custom-built solution. Federal and local environmental initiatives limiting emissions will likely stimulate and broaden the demand for TMS. Adaptive TMS are suggested as the future direction for arterial management by both suppliers and purchasers, and guidance for adopters is noted as a gap. Specifically, the authors recommend that instruction on efficient and expedient procurement, baseline infrastructure requirements, and expectations for continuing supplier support would support adoption of TMS technologies.

Hageman et al. suggest that there is still a lack of awareness of TSP and EVP technologies, which has limited adoption. Other challenges to adoption include the perception that these technologies may increase congestion while providing preference to individual vehicles, as well as the requirements for coordination among multiple agencies (i.e. emergency, transit, and arterial agencies). EVP and TSP markets are limited to a relatively few suppliers, and price has decreased with the introduction of GPS technologies.

The Hagemann study also analyzes 2004 and 2007 ITS Deployment Tracking Survey to monetize mobility, safety, and environment benefits associated with the deployment and diffusion of Intelligent Transportation Systems (ITS) technologies across the United States. The benefits analyses were conducted based on the premise of linearly additive benefit; that is, the addition of the 1st unit generates the same benefit as the addition of the 100th unit for an ITS system. This reports concludes that while most ITS technologies had positive total benefits, red light cameras presented a negative benefit due to the fact that rear-end collisions increase when drivers brake to avoid camera fines. The report identifies the limits of the benefits estimation methodology, and suggests a possible direction for future work in examining patterns in benefits levels within each segment of the normal life-span of a technology.

3.4 Deployment of ITS: A Summary of the 2010 National Survey Results

This report by Gordon et al. presents a summary of the 2010 survey conducted through the ITS Deployment Tracking Project. The Project measures the rate of ITS deployment within the nation's largest metropolitan areas through a survey of state and local transportation and emergency management agencies. Seven survey types including freeway management, arterial management, transit management, transportation management center (TMC), electronic toll collection (ETC), public safety – law enforcement, and public safety – fire/rescue were distributed among nearly 1,600 state and local transportation agencies in 2010 with an 85 percent response rate.

This implementation of the ITS Deployment Tracking Project went beyond previous surveys to solicit feedback on opinions about ITS. In reviewing this as well as other literature, the focus is on identifying factors influencing agencies' decision to adopt, maintain, expand, contract, or deselect technologies; consequently, we focus on the section "Agencies Opinion Concerning ITS" within the Gordon et al. report. This report notes that based on survey findings, ITS has moved beyond experimental to mainstream, and investments and interest in ITS continues to be strong. Findings suggest that one-third to three-fourths of agencies plan to expand current deployments, while half are planning to invest in new technologies over the next three years.

The 2010 National Survey requested freeway, arterial, transit, and toll agencies to rate the importance of nine factors in making decisions to purchase ITS technologies. All nine factors had ratings that on average leaned above neutral and often between somewhat to very important. The importance level placed on these factors varies by agency type. Safety was most frequently rated as very important across the agencies. While most freeway and toll management agencies placed safety followed by integration with existing system as most important, arterial and transit management agencies placed funding and grant availability as most important, followed by safety. The proportion of toll agencies (40 - 60 percent) that categorized funding and grant availability as important is far lower than for any other type of agency surveyed.

The remaining factors rated by the freeway, arterial, transit, and toll agencies included:

- Environmental benefits
- Integration with other agencies,

- Mobility benefits,
- Price of equipment,
- Public/constituents involvement, and
- Technology already used by another agency.

The 2010 National Survey also asked freeway, arterial, and transit management agencies to rank the benefits of specific technologies with which they had individual operational experience, using a purely subjective ranking scale from 0 (no benefit) to 5 (significant benefit). An overlapping set of technologies were ranked among the three agencies as identified in the table below. Findings from the individual Gordon et al. report are tabulated below in Table 3-2. Arterial agencies generally ranked technologies lower than freeway or transit agencies. Both freeway and arterial agencies ranked sensor loops and cameras near the top. Transit agencies subjectively ranked 11 technologies. The most significant benefits were perceived for communications, security cameras, computer aided dispatch, and automated vehicle location technologies. Weather information system technology was the only technology with an average score closer to no benefit than significant benefit.

Table 3-2 Summary of 2010 National Survey Qualitative Ratings of Benefits

Qualitative Rating of Benefits of ITS Technologies
by Agencies Having Technology Operational Experience

ITS Technology	Agency Management Type		
	Freeway (9)	Arterial (8)	Transit (11)
sensor loops	4.35	4.49	
cameras	4.85	4.45	
traveler information	4.66	3.86	4.15
archived data	3.93	3.81	
adaptive signal control		3.68	
lane management	4.09	3.49	
vehicle probes	3.64	3.31	
automated enforcement	3.92	3.19	
ramp control	4.42		
toll tags	4.26		
communications			4.82
security cameras			4.67
computer aided dispatch			4.58
automated vehicle location			4.57
data management - GIS			4.21
electronic fare payment			4.19
automated passenger counters			4.06
maintenance tracking			4.06
transit signal priority			3.22
weather information system			2.8

LEGEND:

Close to significant benefit (4.5 - 5.0)

Close to near significant benefit (4.0 - 4.49)

Moderate to near significant benefit (3.0-4.0)

Less than moderate benefit (below 3.0)

Category not queried/relevant

The 2010 National Survey also requested information on plans for future investment in ITS deployment of specific technologies. The response rate for this section was far lower than others; consequently, findings specific to freeway, arterial and transit agencies are discussed in the subsequent paragraphs. Investment intent of course varies by agency type. The overarching similarity among the three agency types is the need for real-time system performance data and distribution of this information to system users.

Fifty seven technology deployment plans among freeway management agencies were captured in the 2010 National Survey. The most frequently identified deployments are for DMS and CCTV (47 percent), followed by radar sensor and travel time systems (28 percent). Seventy three technology deployments plans among arterial management agencies were captured in the 2010 National Survey. The most frequently identified planned ITS technology deployments are for CCTV and communications with devices (18 percent and 14 percent, respectively) followed by DMS and closed loop (11 percent and 10 percent, respectively).

One hundred and ten technology deployment plans among transit management agencies were captured in the 2010 National Survey. By far, the greatest number of planned deployments are for smart card and other fare enhancements (19 percent), followed by real time traveler information and AVL (15 percent each).

A key driver supporting ITS adoption is the development of interagency communications standards that enable real-time operational coordination

Gordon et. al highlights the key trends from analysis of the 2010 National Survey to note that real-time data collection has moved beyond planning support to operations support both through traffic advisories and active data-driven traffic and incident management. Another significant trend is the migration of traffic advisories from generalized broadcasting to personalized messaging via mobile devices and social media. Additionally, a key driver supporting ITS adoption is the development of interagency communications standards that enable real-time operational coordination. The analyses also assert that ETC systems have transformed tolling from a manual to a largely automated process supporting more safe, environmentally sensitive, and accurate transactions while supplying valuable real-time data on traffic conditions. Finally, for transit agencies, vehicle tracking and dispatch technologies have supported demand responsive operations and real-time information for greatly improved customer service.

3.5 Marketing ITS Infrastructure in the Public Interest

Lappin et al., conducted the study, “Market ITS Infrastructure in the Public Interest” in 1998 and among its study goals was to “investigate motivations and obstacles for ITS procurement in typical metropolitan areas” to derive lessons the U.S. DOT can leverage to stimulation deployment of ITS. The study visited 12 of the 75 largest metropolitan regions based on a set of criteria ranging from population factors and infrastructure age to availability of varied transportation facilities (e.g. transit and toll) and air quality non-attainment status.

The study findings highlighted that ITS adoptions decisions typically involves many individuals at various level of authority across jurisdictions involving both transportation authorities and planning agencies. Deployment is expedited when all affected parties in the transportation and planning community have experience working together on projects of mutual interest and when these organizations have endorsement from elected or appointed political constituencies. Lappin et al. identified four stages for ITS adoptions: awareness, evaluation, commitment, and acquisition. This study also stratified the adopters as market leaders, lead adopters, later adopters, and uncommitted.

Five key factors are outlined by Lappin et al. to include transportation needs, institutional considerations, budget and procurement constraints, community issues, and access to ITS information. Each of these factors as discussed in Lappin et al. is summarized below. The key recommendations made to promote ITS deployment include segmenting customers by adoption rate, targeting decision makers, maintaining national awareness, following private organization structures for marketing success, and creating regional ITS service plans.

3.5.1 Transportation Needs

Regions expressing a greater need for managing congestion are also those with higher levels of ITS deployment, plans and momentum. Places with medium or low levels noted greater infrastructure repair and replacement needs. Weather conditions were motivators for some places with low levels of ITS deployment, plans or momentum. The decision of a region to address congestion with ITS, as opposed to investing in infrastructure repair also appears to correlate strongly with population density and economic growth. This last point is discussed in the community factors section.

3.5.2 Institutional Considerations

Support of state and local elected and appointed officials and regional experience with other inter-jurisdictional projects correlated strongly with higher levels of ITS deployment. State officials and DOT leadership influence the rate of deployment both for projects on state facilities (highways) and for local projects where state expertise, leadership, and funding can help. Similarly, the presence of a mayor or other strong local political leadership who understood how ITS applications could be applied to address an urban transportation agenda, was positively correlated to any amount of ITS deployment.

Regions where transportation and related agencies do not work well together are the least likely to adopt more advanced technology strategies. Of the twelve sites, those with the highest level of ITS deployment and momentum were the best organized, and demonstrated a minimum of inter-agency and inter-jurisdictional tension. The presence of a local champion was a useful, but not necessary precondition for higher levels of ITS deployment. The majority of high deployment regions frequently have multiple champions distributed among the transportation and planning agencies.

3.5.3 Budget and Procurement Constraints

In regions with a coordinated ITS plan that responds to well-articulated local needs, funds can usually be assembled from a variety of local, state and federal sources. By contrast, in areas where priorities are vague, uncoordinated or non-existent, funding is often cited as a major impediment. There are higher levels of ITS deployment in regions where there is a sufficient transportation budget, and especially where there is a separate revenue stream dedicated to transportation (such as curb-cut fees in a Portland suburb) which protects transportation projects from competition for general funds.

Major construction creates an opportunity to include ITS in a larger budget project that would otherwise be perceived as too expensive if introduced separately. This strategy is also used effectively in smaller projects, such as the replacement of traffic signal systems, where the incremental cost to allow the system to support more advanced signal timing functions is small relative to the overall cost of the system.

3.5.4 Community Factors

Transportation managers will favor previously successful solution over ITS systems unless such systems can readily demonstrate better performance at lower costs, particularly with high visibility public projects. Public scrutiny can dampen risk-taking. The lowest ITS planning and momentum exists where the proponents of advanced technologies have been unsuccessful in managing information about technology to positively affect decision makers. Where local government and business leaders relate transportation and mobility to economic vitality, especially in cities experiencing economic growth, they are more actively involved in advocating for transportation system improvements, including ITS. In several cities, very high profile accidents were the catalyst for ITS. The incident works as a catalyst by causing transportation and incident management groups to work together toward a shared goal. The events led to a search for improved communications among public safety agencies and the traveling public, focused on incident management systems, variable message signs, or roadside call boxes.

3.5.5 Access to ITS Information

Access to information by all levels of transportation and planning staff affects the rate of ITS adoption in a region. Several different means of obtaining information were explored, including written information, active membership in professional organizations, access to others with ITS experience, information provided by FHWA field offices, and travel for first hand observations.
On average, there is better access to and use of information in areas with greater levels of ITS deployment and momentum. In tandem with access to information, interaction with others who have actually procured and operated ITS is a major factor in its eventual adoption. Innovative ways of obtaining information and contact with knowledgeable peers included inviting vendors for demonstrations on a regular basis (even when there is no intent to buy), accepting high staff turnover so that new up-to-date staff can be hired frequently, relying heavily on consultants, and taking advantage of touring technology demonstrations by the FHWA, Public Technologies, Inc., or other organizations.

State DOTs, local traffic engineering offices and MPOs seem to rely for information more on regional chapters of national professional organizations, in which they are members. Transit agencies seem to rely more on transit publications than attendance at professional organizations; the American Public Transit Association was cited most frequently as a source of information. Finally, the U.S. DOT regional and division offices were cited as credible sources or purveyors of useful ITS information.

3.6 State Reports and ITS Knowledge Resources

Over 30 specific state level reports were reviewed to identify information specific to technology adoption, growth, maintenance, decline, and discontinuation. This list of reports are listed in Appendix B, and selected findings are summarized within the ***State Reports*** subsection. Additionally, nearly 200 “lessons learned” and “Benefits” entries were scanned based on keyword term searches to identify relevant knowledge.

3.6.1 State Reports

Eleven state reports offered information related to ITS technology adoption. These reports, published from 2002 through 2012, relate to the states of Minnesota, Idaho, Washington, New York, and Virginia. Below are summaries that identify factors influencing the decision to adopt ITS technology.

The Washington State Transportation Innovative Partnership program is responsible for evaluating and creating public/private partnerships to develop transportation projects. The report makes recommendations to the Washington State Legislature on how the program can best proceed and be successful. Thus, public/private partnerships can be an enabling decision factor in the adoption of technology.

The SR 99 Alaskan Way Viaduct Replacement Report details a project to build a tunnel for the SR 99 in Seattle, Washington. The report presents how the project will be funded, partly by tolling drivers in the tunnel, and the potential use of ITS technology to support this activity. The advantages and constraints for tolling revenue are reviewed. From this review, a key external factor to adoption was the potential for revenue generation in light of alternate routes in the area.

The Annual Minnesota Transportation Performance Report (2010) outlines their ITS programs. Minnesota is currently installing Automatic Vehicle Location (AVL) systems in all of their snow plow vehicles to help facilitate snow and ice removal during the winter. Minnesota is also actively pursuing advanced traffic management (ATM) systems as well as operating managed lanes with pricing. The report notes, “Actual project decisions are affected by changing factors such as revenues, costs and community input. Corridor measurements of travel speed, congestion, throughput and crashes help identify needs and design options but do not alone determine which projects are built. Specific designs for highways or transit facilities are shaped by MnDOT planners and engineers and contracted engineering firms.”

A key external factor to adoption was the potential for revenue generation in light of alternate routes in the area.

The Minnesota Freight Report primarily focuses on non-ITS related improvements to help freight movements around the Interregional Corridors. They do suggest the use of ITS in supporting freight efficiency and that traffic modeling tools be employed in developing cost and benefits estimates for ITS technologies.

> “Use intelligent transportation systems (ITS), when cost-effective, to improve the travel time and efficiency of freight movement on IRCs throughout Minnesota. Effective ITS initiatives reduce congestion, accidents and stops through the use of technology as an alternative to costly roadway expansion or reductions in traffic. Strategies include traffic sensors and computerized signals that can be used to give freight haulers preference at intersections, real-time traffic monitoring for fast responses to traffic incidents, signs and other communications modes to alert drivers to adverse conditions, and weigh-in-motion inspection

> technology that can eliminate the need for weigh station stops. ITS approaches to IRC improvements for freight may prove more cost effective than traditional strategies. Mn/DOT should take advantage of recently developed traffic modeling tools that assess the costs and benefits of ITS in order to determine where ITS strategies could improve freight movement on Minnesota's IRCs."

Jared Cerullo (2009) reports on Wichita's ITS program in a new article. The ITS program included installing cameras on interstates but had been put on hold for budget concerns. They hoped the program will resume in 2009 or 2010. Polls showed Wichita ranks as one of the easiest commuting areas in the country; consequently, they are not seen as a priority for ITS funding. The existence and identification of transportation needs and problems is clearly a driving force in the decision to deploy a technology. Budget limitations and availability is an equally important decision factor. Public perception also played a role in this decision to halt deployment.

The New York State Security Applications Reports (2002) focused on ITS security just after 9/11 and suggested that large scale major disruptions in the transportation network push agencies to consider adopting or upgrading ITS technologies. It also stated ITS technologies may be able to help add to the development of homeland security systems. ITS technologies can provide increased security while lowering the manpower needed in the field. The 2002 Context for ITS in New York State report surveyed ITS agencies in New York and found six areas that were barriers to ITS implementation or opportunities to increase deployment. The six areas are:

- funding,
- institutional fragmentation and coordination,
- policy,
- procedural issues,
- public awareness, and
- training and expertise.

Four opportunities for successful ITS implementation were also identified as:

- integrating ITS components to achieve common transportation goals,
- building upon existing institutional foundations,
- models and best practices, and
- the role of the metropolitan planning organization.

3.6.2 ITS Knowledge Resources Exploration

The JPO ITS Knowledge Resource maintains a database of reports, articles, and summaries of ITS information and technologies within the United States and abroad, organized among the following categories: benefits, costs, lessons learned, deployment statistics, and applications. A number of keyword searches were conducted over the benefits and lessons learned summaries to mine factors related to the decision to deploy ITS. Selected decision factors obtained from these Benefits and Lessons Learned queries are included in the Summary of Literature Review above.

3.7 Decision Factors for Trucking Industry Technology Adoption

Over the past decade, a number of Intelligent Transportation System (ITS) technologies have been adopted to varying degree by the trucking industry. These include wireless applications, backroom data management systems, vehicle and cargo tracking devices and other vehicle-to-vehicle and vehicle-to-infrastructure communication systems for safety, security and operational applications.

Motor carriers typically consider a wide range of factors prior to investing in a new technology, including the specific needs of the fleet, whether the system will yield a competitive advantage, pricing, return-on-investment (ROI) and pay back periods. Since the majority of the industry operates on very thin profit margins, potential capital investments are thoroughly researched prior to purchase.

3.7.1 Decision Factors

Several studies have recently been completed on the decision factors related to trucking industry Intelligent Transportation System (ITS) technology adoption. The American Transportation Research Institute (ATRI) investigated the deployment status of in-vehicle technologies in 2003 and 2006 (ATRI, 2006b). Through an online survey administered to over 225 carriers, ATRI found that while many fleets were equipped with cellular or satellite-based communication technology, real-time position tracking and navigation systems, onboard safety systems (OSS) were primarily deployed by medium to large fleets. The low level of market penetration was attributed in the report to OSS being an emerging technology. A limited number of vendors produced these systems and little research had been completed at that time to adequately assess functionality/applicability and potential ROI.

Onboard Safety Systems (OSS) were primarily deployed by medium to large fleets (ATRI survey).

These surveys also asked respondents to rank a list of 10 anticipated benefits to purchasing decisions for in-vehicle technologies, in order of their importance. Ranked from most to least important, the benefits sought by motor carriers from in-vehicle technology investments were:

1. Improved safety
2. Improve on-time performance
3. Reduced vehicle maintenance costs
4. Optimized fleet utilization
5. Reduced fuel consumption
6. Improved driver comfort
7. (tie) Management of driver efficiency
7. (tie) Quick identification of stolen vehicles
8. Reduced vehicle emissions
9. Automated vehicle location tracking

Furthermore, while carriers are willing to adopt new in-vehicle technologies, the majority expect relatively short payback periods (see Figure 3-2). More than two-thirds (72 percent) of the survey respondents required a payback period of less than 2 years while only 28 percent found a payback period of over 2 years acceptable.

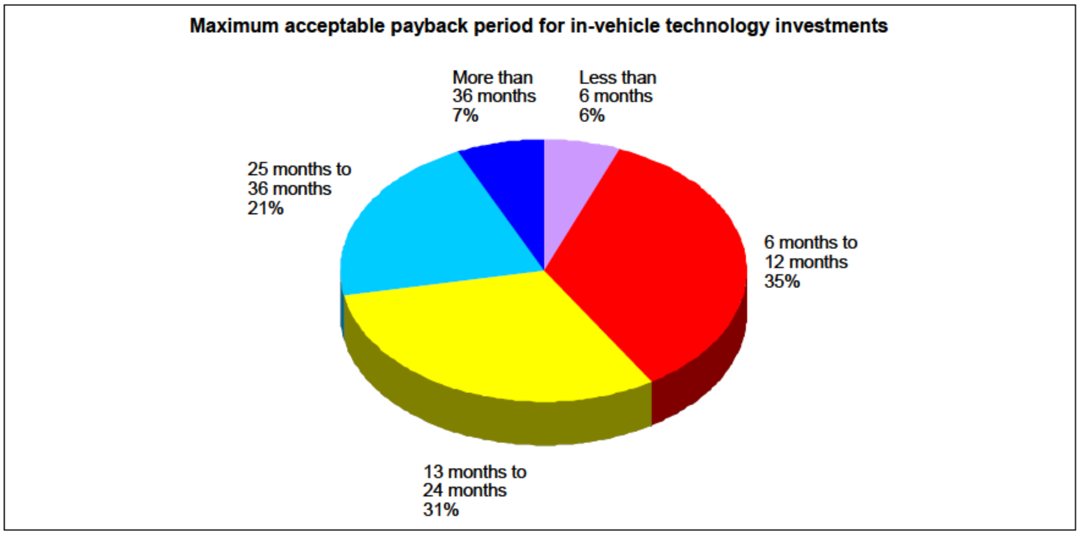


Figure 3-2 Maximum acceptable payback period for in-vehicle technology investments (ATRI, 2009)

FMCSA sponsored research in 2005 that assessed the decision-making factors that trucking industry stakeholders employ when choosing to purchase, use or make onboard safety technologies (Battelle and ATRI, 2005). Motor carriers, drivers, original equipment manufacturers (OEMs), vendors, commercial vehicle insurers and trucking associations were surveyed through structured interviews and broad strategies for accelerating the deployment of safety technologies were identified. The most common decision-making factors included:

- Return on investment (ROI)
- Demonstrated effectiveness to improve safety
- Reliability and maintainability
- Liability
- Market demand
- Initial cost
- Investment required for research and development of new technology
- Market Image
- Driver acceptance
- In-cab technology interface integration

3.7.2 Incentives

In 2007, the Federal Motor Carrier Safety Administration (FMCSA) sponsored research that examined a range of incentives that could expedite the manufacture, purchase and deployment of OSS (ATRI, 2007). Five industry stakeholder groups including motor carries provided feedback on the potential incentives, which included:

- Federal Tax Expenditures
- Public Information
- Federal Loans
- Insurance
- Corrective Tax
- Project Grants
- Tort Liability

The researchers found that a tax credit (or deduction) for carriers and OEMs, the dissemination of data and research findings, the availability of expert testimony, loans provided directly to a motor carrier, and carrier and OEM grants had the greatest potential to successfully accelerate the manufacture, purchase and deployment of OSS.

3.7.3 Analyses of ITS Applications in the Trucking Industry

The American Transportation Research Institute (ATRI) and the Federal Motor Carrier Safety Administration (FMCSA) performed cost-benefit analyses on three types of onboard safety systems (OSS) in 2009: forward collision warning, lane departure warning and roll stability control (ATRI, 2009). For these analyses, the potential benefits (reduced crash costs) were measured against the purchase, installation and operational costs of the technology and the expected ROI and payback periods were also calculated. The report noted that it was important to consider the technology deployment decision factors of small carriers separately from larger fleets due to discrete differences in their financial and operating environments. Additionally, indirect crash costs, such as impacts on safety ratings, public image and employee morale can add to the benefits of purchasing OSS for all carriers.

A recently released report by FMCSA also examined the safety impacts of speed limiting devices (Hanowski, et al., 2012). The analysis focused on the reduction of truck-involved crashes that could have been avoided with this type of technology installed and utilized crash data provided directly from motor carriers. The researchers found that trucks equipped with the speed limiter technology experienced a nearly 50 percent lower crash rate of speed limiter-relevant incidents. Furthermore, the study found that the cost of the technology is generally considered reasonable by most fleets and has actually been a standard feature on new trucks for several years.

Electronic onboard recorders (EOBR) have also gained popularity among motor carriers in recent years, most notably among larger fleets. ATRI studied EOBR adoption issues in preparation for the 2006 Notice of Proposed Rulemaking (NPRM) (ATRI, 2006a). The researchers examined the costs and functionalities of the devices, carriers' willingness and ability to purchase EOBRs and the role of several non-technical factors. More than half of all of the motor carrier respondents indicated that their primary reason for using EOBRs was for HOS compliance. The top reasons that carriers' gave for not using EOBRs or supporting an EOBR mandate were concerns over the cost of the equipment and driver opposition due to privacy issues.

3.7.4 Ranking of Issues Challenging the Industry

Finally, ATRI surveys motor carriers annually in an effort to identify and rank the most important issues that are challenging the industry (ATRI, 2011b). In 2011, the top industry issues were:

1. Economy
2. Hours-of-Service
3. Driver shortage
4. Compliance, Safety, Accountability
5. Fuel Issues
6. Congestion
7. Transportation Funding
8. Tort Reform
9. Onboard Truck Technologies
10. Truck Size and Weight

After first surfacing in 2007 as a top ten issue, Onboard Truck Technologies has fluctuated among the final three positions in the annual survey. The impetus for opportunities arise from onboard safety technology benefits, while concerns generally stem from efforts by the U.S. and Canada to mandate the use of both EOBRs for HOS compliance and speed limiters/governors for speed management. As previously noted, while there has been significant investment in the testing and evaluation of onboard safety systems (lane departure warning, collision warning, roll stability control), the lack of direct incentives often makes these systems too costly for many carriers. Lastly, there are research efforts underway to use technology as a way to enhance or even replace roadside safety enforcement practices. Continued attention on technology as a means for monitoring compliance and increasing safety will likely mean that Onboard Truck Technology will continue to rank in the industry's top ten issues going forward.

3.8 Decision Factors For Connected Vehicle Technology Adoption

Connected vehicle applications refer to the suite of applications made possible through Dedicated Short Range Communications (DSRC) and supplemental wide-area communications between vehicles and the infrastructure and between vehicles. The ITS Strategic Plan is built around a research agenda for supporting the development of connected vehicle applications and the necessary underlying infrastructure along the theme of connectivity (U.S. DOT ITS JPO, 2012a).

Connected vehicle ***safety applications*** are designed to increase situational awareness and reduce or eliminate crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission that supports: driver advisories, driver warnings, and vehicle and/or infrastructure controls. These technologies may potentially address up to 82 percent of crash scenarios with unimpaired drivers, preventing tens of thousands of automobile crashes every year.

Connected vehicle ***mobility applications*** provide a connected, data-rich travel environment. The network captures real-time data from equipment located on-board vehicles (automobiles, trucks, and buses) and within the infrastructure. The data are transmitted wirelessly and are used by transportation managers in a wide range of dynamic, multi-modal applications to manage the transportation system for optimum performance.

Connected vehicle ***environmental applications*** both generate and capture environmentally relevant real-time transportation data and use this data to create actionable information to support and facilitate "green" transportation choices. They also assist system users and operators with "green" transportation alternatives or options, thus reducing the environmental impacts of each trip. For instance, informed travelers may decide to avoid congested routes, take alternate routes, public transit, or reschedule their trip — all of which can make their trip more fuel-efficient and eco-friendly. Data generated from connected vehicle systems can also provide operators with detailed, real-time information on vehicle location, speed, and other operating conditions. This information can be used to improve system operation. On-board equipment may also advise vehicle owners on how to optimize the vehicle's operation and maintenance for maximum fuel efficiency.

Using a five-year strategic research plan, the Department is committing to the use of the DSRC technologies for active safety for both vehicle-to-vehicle and vehicle-to-infrastructure applications. The Department is also reaffirming its intention to explore all wireless technologies for their applicability to safety, mobility, and environmental applications. In 2008, the ITS Program framed the definition of connectivity to include both DSRC and non-DSRC technologies as a means of providing an open connected vehicle platform.

The vehicle buyer does not control the rate at which CVT penetrates the fleet or government invests in roadside infrastructure.

Realizing the vision of a connected vehicle environment requires active participation and investment decisions by the automotive original equipment manufacturers (OEMs) as well as the aftermarket electronics equipment business sector. In order to address the likelihood that automotive OEMs will adopt connected vehicle technology (CVT) equipment into their automotive fleets and offer them to consumers, we need to understand the motivating factors for technology adoption by the automotive OEMs. The following insights are drawn from a project technical memorandum authored by William L. Ball, an expert in automobile telematics and the former Vice President of Public Policy for OnStar at General Motors. (Ball, 2012).

3.8.1 OEM Considerations for CVT Adoption

Connected vehicle technology (CVT) presents a unique “value proposition” dilemma that is important to keep in mind when thinking about how automotive OEMs and others will evaluate and are evaluating CVT.

The CVT value proposition is dependent on two independent variables: fleet penetration for Vehicle-to-Vehicle (V2V) applications and infrastructure penetration for Vehicle-to-Infrastructure (V2I) applications. This makes CVT unique as there has been no other technology integrated into vehicles that could not deliver significant immediate value to the vehicle buyer if desired by the buyer.

Bluetooth integration and satellite radio are both examples of vehicles being equipped with technology that might not deliver an immediate benefit. However, in each case, the vehicle buyer could activate the value proposition (albeit with an additional expenditure of money) - in the case of Bluetooth by purchasing a Bluetooth equipped phone and cellular subscription and in the case of satellite radio by subscribing to the service after the included demonstration period expired. (It is worth noting that in the case of satellite radio, the consumer’s cost for the radio was partially subsidized by the manufacturer as a result of OEM/satellite radio provider bounties and stock ownership arrangements.)

In the case of CVT, the vehicle buyer does not control the rate at which CVT penetrates the fleet or at which government highway agencies invest in roadside infrastructure. This dynamic affects both OEMs because they anticipate that consumers will not value CVT technology and government agencies because they will be concerned that voters and elected officials will challenge investments in CVT/V2I until there is substantial fleet penetration - especially if budget constrained environments continue. (Note this constrained environment is likely as gas tax receipts will continue to fall with improved fuel economy absent tax increases which have proven difficult. An improving economy to some extent will mask this long term trend if VMT increases, as would be expected, as the economy recovers.)

The following factors would affect CVT adoption decisions:

Technology or Application Factors

- Lead time before initial installations begin
- Phase-in time table - typically 3-4 model years
- Cost/functionality – OEMs will recognize the first generation CVT hardware and software will be the most expensive and most functionally limited. (Experience curve/Moore's Law)
- Technology maturity e.g. Are all necessary standards adopted/implemented, resolution of harmonization issues especially with Canada
- Technology reliability/operating life/warranty requirements - uniquely important in CVT owing to the desirability for maximum fleet penetration, n.b. emission systems have mandated warranties

Implementer Factors

- Engineering resource constraints
- Manufacturer liability for technological obsolescence – telematics providers are in class action litigation with selected consumers over the obsolescence resulting from the FCC decision to allow cellular providers to discontinue analog service.

User/Market Factors

- Anticipated consumer reaction to any privacy issues (potentially very important with respect to roadside infrastructure applications)
- Anticipated consumer reaction to distraction / ease of use issues
- Ability to price to recover cost - this is particularly important with CVT given the value proposition does not appear to offer any marketable benefit in the short or possibly intermediate term that visibly supports increasing the vehicle price. Moreover OEMs will be concerned that in this time frame vehicle prices may be rising steeply to accommodate advanced powertrain technology to meet fuel economy mandates. There has already been concern expressed that the escalation of vehicle prices may dampen demand adversely affecting sales and the economy.
- Dealer education
- Consumer education including, especially for CVT, education of used car purchasers

External Environment Factors

- GPS backward compatibility commitment resolved with the U.S. Air Force as new generations of GPS are launched (OnStar, 2008)

Usually, competitive advantage and technological leadership would be a critical factors but given the nature of CVT it would seem unlikely that these factors will be of any importance in this ITS decision.

Another consideration for some ITS technology is insurance company willingness to offer discounts. In this case, because the penetration will be over a long period of time, it seems unlikely that in the early years the insurance industry will be able to develop actuarial data that would support discounted premiums. This might be a consideration to accelerate aftermarket penetration in later years if the experience data bears out the expected benefits from the safety use cases.

3.9 ITS Professional Capacity Building Program: Setting Strategic Direction 2010-2104

The insights gained from the literature generally align with the findings of the ITS Professional Capacity Program (PCB) Strategic Plan which was developed in 2010 (Greer, et al., 2011). In developing the plan, The PCB Program conducted three user workshops gaining stakeholder feedback from 148 multimodal public and private sector users in two interactive web meetings. In these sessions, the stakeholders stressed the importance and challenges of developing a skilled workforce, the need to develop and grow champions of ITS to influence decision making, the need to coordinate educational efforts among different organizations, and the possibility of leveraging technology transfer tools to accelerate the adoption of new connected vehicle technologies.

The decision factors surfaced in the literature confirm the first two needs, as the **Level of Knowledge and Expertise** and **Presence of a Champion** were cited as a key factors in the decision to deploy a technology. Further, in the strategic planning workshops, stakeholders indicated that they primarily would like real-world experience “from the source,” emphasizing the opportunity to hear from peers as a desirable way to learn about ITS deployment. This feedback supports the literature review finding that peer networks are extremely influential in the decision to deploy ITS technologies.

The Professional Capacity Building strategic plan also include goals aimed at coordinating the educational efforts of a variety of organizations, including The U.S. DOT Research and Innovation Technology Administration (RITA), Federal Highway Administration (FHWA), and their federal training partners, and a goal to accelerate the adoption of ITS technology through the use of test beds and knowledge and technology transfer activities. There is a gap in the literature about the effectiveness of these activities in accelerating the adoption and deployment of ITS, although they are believed to be beneficial.

In its recent report “Improved DOT Collaboration and Communication Could Enhance the Use of Technology to Manage Congestion, The U.S. Government Accountability Office (GAO), devoted a section to ITS Knowledge Challenges, noting that “ITS is a rapidly developing field that requires a specialized workforce familiar with emerging technologies, including a need for knowledge in a variety of areas, such as project management and systems engineering” (GAO, 2012). The GAO report generally confirms the Professional Capacity Building program strategic vision to enhance the professional development of current and emerging ITS professionals, and places a high emphasis on peer learning as a means to achieve the vision.

The GAO recommends that the USDOT take the following actions to effectively target efforts, leverage resources, better promote and support the use of ITS technologies by state and local governments, and improve access to and awareness of ITS resources:

- Clearly define and document the respective roles and responsibilities of RITA and FHWA in promoting and supporting the use of ITS,
- Revise ITS information on RITA and FHWA websites to improve its usefulness for state and local audiences based on their needs, and
- Include in RITA's strategy for promoting the adoption of ITS technologies plans for collaborating with external partners to (1) further enhance communication about the availability of ITS resources and (2) facilitate learning exchanges.

3.10 Innovation Processes in Surface Transportation Final Reports

The Innovation Processes in Surface Transport effort is a joint European initiative through partnership among six European research organizations to understand how the innovation process evolves within European transportation markets, and how adoption of beneficial concepts or technologies can be improved (InnoSuTra, 2012). This three-year study employed a multi-layered approach which first identified innovations across a broad spectrum of categories, second identified the barriers placed in the path of the innovation and the support processes used to overcome these barriers, third differentiated innovation into three main phases and later continuous processes, fourth analyzed in detail the various factors which affect the progress of an innovation, and fifth, applied a systems innovation (SI) analytical framework to identify external factors and actors influencing each innovation. This multi-layer approach employed multiple workshops with experts providing insight into innovations. For public and private sector entities within road, maritime, rail, inland waterways, and intermodal transportation, this study identifies:

- key players enabling innovation,
- the process by which innovation is adopted and deployed,
- strategies to stimulate innovation,
- determinants for successful innovations, and
- governmental actions that can and should best spur innovation.

This study distinguishes innovation along technological, organizational, cultural, and policy-related characteristics and notes that many technological innovations often require accompanying organizational and cultural innovations. The study focuses predominantly on incremental innovation, although radical innovation observations are also noted. Barriers to innovation are distinguished between adoption barriers and implementation barriers. Figure 3-3 identifies the innovation adoption path proposed by the InnoSuTra initiative. The innovation path differs for public versus private cases in some respects, but for both innovation will be slow to start if the relevant initiator, that with the most to benefit, does not lead the innovation effort. Further, both public and private initiators must create an environment and network for stakeholder, and be able to influence stakeholder direction.

In total, 59 private commercial innovation cases were initially evaluated from the 1970s to the present and categorized along the spectrum of success, termed the innovation

> *The policy interventions marked as having greatest influence in innovation included infrastructure development, regulation, legislation, finance, and environmental policies*

S-curve. Stakeholder workshops were held to select best practices and failure cases for further analysis, identify the relative importance of factors, and define success and failure thresholds. The consensus of participants was that the most important elements of any innovation to succeed in adoption and deployment are business and social acceptability.

In conducting in-depth analyses of 23 sector-specific innovation cases, the researchers ranked the relative importance of policy intervention strategies, actors and their roles, and factors and barriers to adoption. The factors and barriers are listed in Table 3-3.

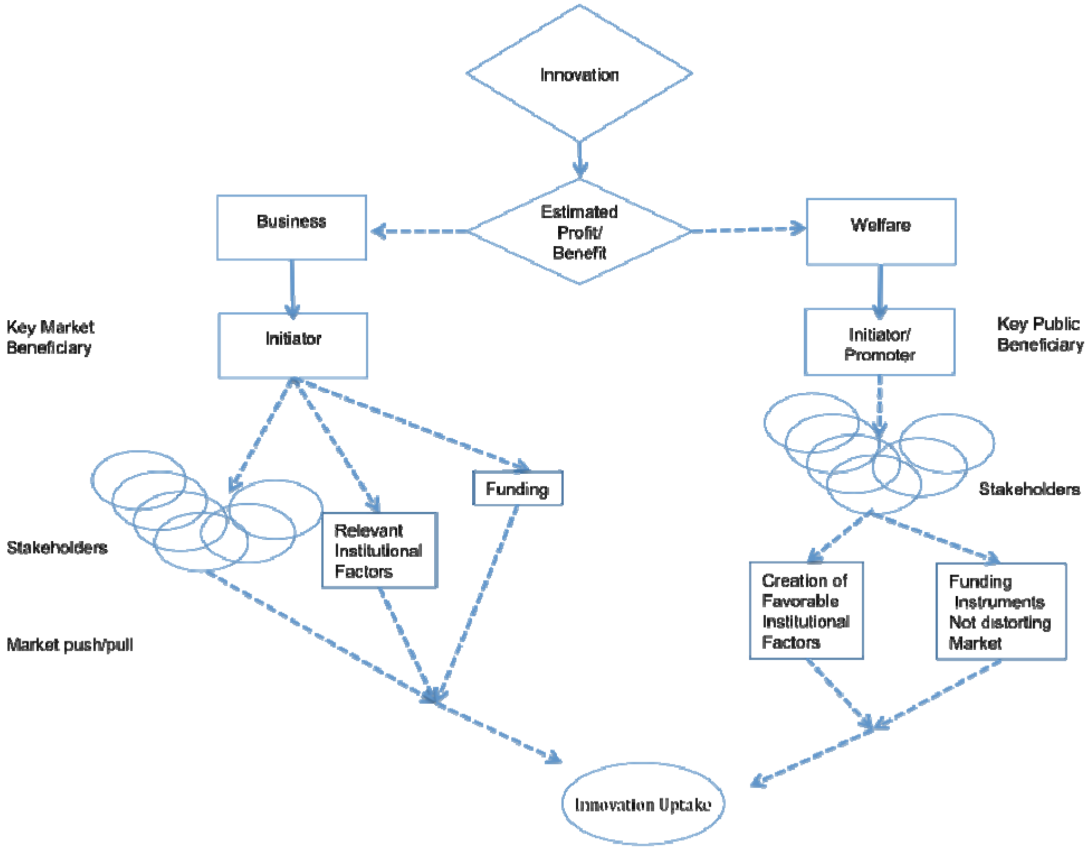


Figure 3-3 Innovation Pathway Diagram (Source: InnoSuTra, D6, page 31)

Nine of 23 cases were identified as successes while 8 were categorized as ‘not-yet successful,’ and the remaining 6 were intermediate cases. Among the 23 innovation cases and the dozen types of actors in the general innovation process, implementers, developers, and lobbyists actors were ranked on average as having greatest influence in innovation with average scores above 3.5 based on a 5-point rating scale. Monitoring agents, R&D agents, regulators, and inventors were ranked with scores below 1.5. Among the dozen types of policy interventions in the general innovation process, five received an average score between 2.0 and 3.0, while other policy interventions on average were below the 2.0 value. The policy interventions marked as having greatest influence in innovation included infrastructure development, regulation, legislation, finance, and environmental policies.

Specific to the 9 successful innovations, the key factors having influence over innovation success included knowledge and expertise availability, stakeholder involvement in the project, and net benefits for actors. Other factors strongly influencing innovation include legislative guidelines, available administrative partners, support in local and regional assemblies, and the role of interest groups. The least influential factors noted are clarity about division of responsibilities and link to universities/research/innovation. The barriers having greatest influence among the 9 successful innovations are high cost followed by lack of qualified personnel, lack of standardization and certification, and lack of competition in the market.

Table 3-3 Summary of 2010 National Survey Qualitative Ratings of Benefits

CONTRIBUTING FACTORS LIST	BARRIER LIST
Technological	**Technical**
knowledge and expertise available	Lack of interoperability
availability of technologies	Difficult adaptation to a new technology
compliance with standards	Lack of lack of standardisation and certification
Administrative and legal	**Legal and regulatory**
legislative guidelines	Administrative barriers
administrative partners available	Weakness of property rights
(lack of) clarity about division of responsibilities	Legislation, regulations, taxation
Political and process-related	**Available Information (Knowledge)**
support in local, regional assemblies	Lack of information on information
the role of interests groups	Lack of information on markets
cross boundaries effects	Lack of qualified personnel
Socio-cultural and psychological	**Cultural and Societal**
incentives, motivation, spirit of entrepreneurship	Scarce attitude of personnel towards change
involvement in the project on the part of the stakeholders	Inability to devote staff to innovation activity
link universities/research/innovation	Scarce acceptability
Economic and financial	**Economic and financial**
net benefits for actors	High costs (too high costs)
revenues for actors	Lack of funds within the enterprise and subsidies from outside
availability of subsidies	Lack of competition in the market
	Decision making
	Lack of cooperation among partners (public, private,…)
	Fragmentation of decision levels
	Lack of Vision and Policy Growth

Specific to the 8 ‘not-yet successful’ cases, half of these are policy innovation cases, while a quarter are technological cases and the remaining quarter are organizational cases. This makeup is the opposite of successful cases where more than half were technological. The developers, lobby groups and industrialists actors have highest weightings, while the same were weighted far lower amongst the successful cases. Policy interventions generally exhibit lower influence for the “not-yet successful” category compared to the “successful” category. Among the policy interventions, stimulation of R&D, regulation and planning, legislation, and environmental issues place highest with regard to influence. the key factors having influence over innovation success for this set of case studies (with ranking higher than 3.5) includes availability of technologies, compliance with standards, the role of interests groups, cross boundaries effects, and stakeholder involvement in the project. The main barriers to the “not-yet successful” cases include lack of qualified personnel; lack of legislation, regulation, and taxation; high costs, lack of competition in the market, and lack of vision and policy growth.

The barriers appeared, in general, to be weaker for the innovations considered successful compared to the “not-yet-successful’ innovations. The estimated net benefits were also ranked and it was observed that for some successful cases the net benefits appeared to be relatively low.

3.10.1 Findings from Innovation Framework and Overall InnoSuTra Recommendations

The set of cases were analyzed through clustering based on type of innovation introduced and the wideness of impact. This analysis along with the overall study yielded the following key recommendations by innovation category.

- Technological innovations require support from standardization bodies for market success and require public and/or private support during initial stages in funding. Equally important in some cases is the involvement of knowledge institutes.
- Policy innovation across the market may fail if actors’ interests are not integrated in support of the innovation. The emphasis for public policy innovations is to conduct a socio-economic benefit cost analysis to establish a net benefit, and potentially to compensate ‘losing’ stakeholders.
- Organizational innovation is best supported by actions that ensure all networked actors (including weak actors) are involved in all phases of the innovation process.
- Three main areas of potential policy intervention will support cultural/marketing innovation: ensuring all key actors are involved, ensuring adequate infrastructure, and ensuring the presence of sufficient economic demand. The innovation also needs to be strongly marketed by the initiator.

A common factor in successful innovation is a committed initiator that can bring together relevant stakeholders. Private funds serve as a powerful tool in private sector adoption of innovation; however, private sector funding through subsidies may lead to market distortions. Public policy actions/interventions are most effective in terms of support for initiating innovations either through the provision of innovation grants or loans, but equally important in some cases is the involvement of knowledge institutes, including standards bodies. In all innovation cases, action to utilize and strengthen actor networks is a cornerstone.

4 Review of Application Areas Focusing on Implementing Agencies

Whereas Chapter 3 reviewed the factors influencing ITS adoption and growth, this chapter focuses on the state of ITS deployment among six application areas as surveyed in the ITS Deployment Tracking Surveys from years 2007 and 2010, and discussed in the ITS Benefits, Cost, Deployment, and Lessons Learned (BCDLL) report. The six application areas are:

- Transit management
- Public Safety Fire Rescue
- Public Safety Law Enforcement
- Freeway Management
- Electronic Toll Collection (ETC)
- Traffic Management Centers (TMC)

The intent of this chapter is to highlight specific agencies that have made decisions for adopting, growing, maintaining, or deselecting specific ITS technologies, and to identify among these set of agencies, the metropolitan regions for further investigation through direct interview or survey. Pace et al. notes that while overall deployment has been trending upward, the pattern of deployment varies both by geography and by technology type. More tried and tested technology categories exhibit higher adoption rates throughout both urban and suburban areas across the nation. However, newer technologies such as emergency vehicle preemption (EVP) exhibit far lower adoption rates with adoption varying between urban and suburban areas. The *Review of the ITS Knowledge Resources* Benefits, Cost, and Lessons Learned database also cited a number of cases noting that adoption increases as the number of peers using the technology grows and budget levels increase.

The ITS Deployment Tracking Surveys for years 2007 and 2010 are compared within each of the six aforementioned sections with the goal of identifying unique agencies that exhibit different states of growth both from an agency and ITS perspective. A seventh survey for arterial management agencies is also conducted; however, differences between surveys implemented in 2007 and 2010 preclude comparative analyses of meaningful ITS variables.

> *For most ITS technologies captured in the Deployment Tracking Survey, the market has bridged the chasm from early to majority adopters, and beyond to laggard adopters.*

A distinct survey was prepared and distributed for each of the six application areas, and furthermore, surveys from 2007 to 2010 differed significantly among most variables. Consequently, two (2) to six (6) key ITS variables common between the two survey years are compared for each application area. The survey on traffic management centers proved less informative than the TMC information collected within the Freeway Management section; consequently, this survey is analyzed in identifying adoption in the TMC market.

4.1 Summary of Application Area Analysis

Figure 4-1 summarizes the sample size for each agency and the subset of agencies with specific ITS technologies. Clearly, toll collection agencies are near 100 percent implementation for ITS technologies such as electronic toll collection. The lowest level for technology penetration is for emergency vehicle preemption (EVP) among law enforcement agencies, and freeway-ramp based technologies among freeway management agencies. The former may be on the rise as an emerging technology for this application group; while the latter, which is an established technology, may not have proven an attractive benefits-cost case for many agencies where freeway congestion is not as dramatic as in the most congested metropolitan regions.

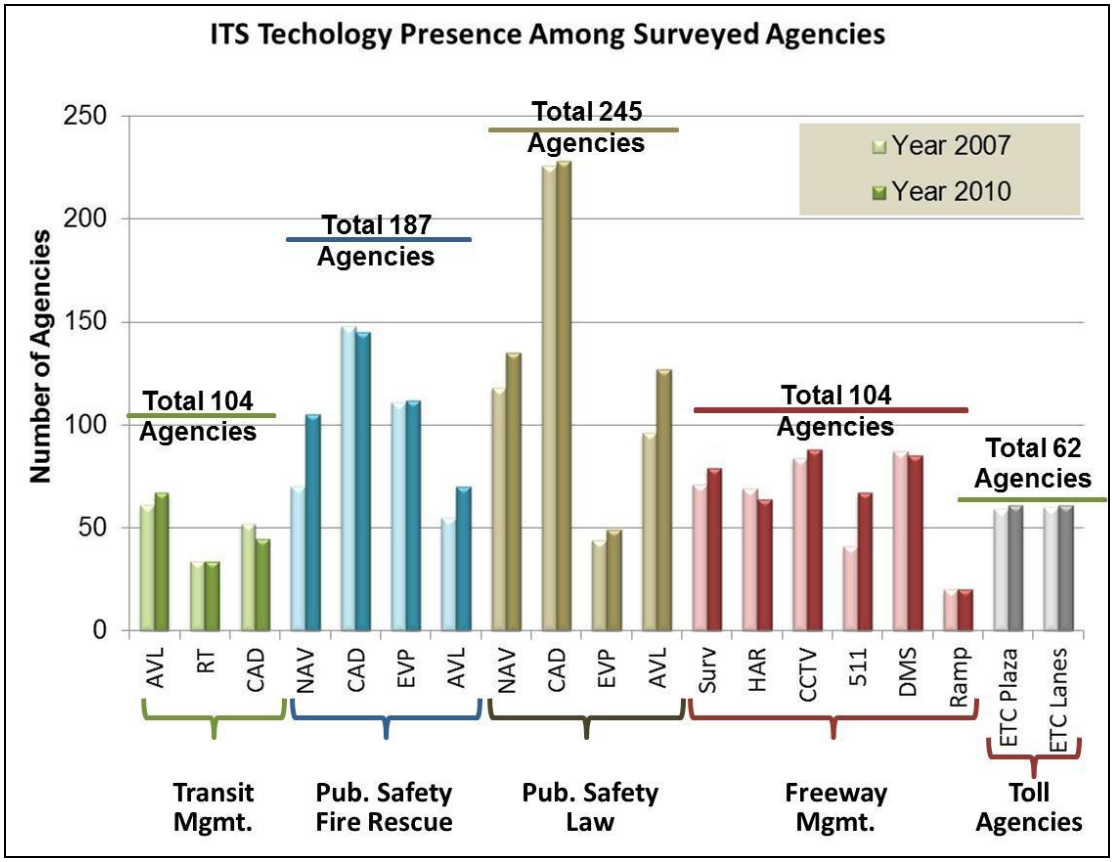


Figure 4-1 ITS Technology Presence Among Surveyed Agencies for Various Application Areas

Interpreting the current adoption of the technologies presented in Figure 4-1 through the lens of “Crossing the Chasm” (Section 2.3.1), most technologies reviewed have crossed the chasm from early adopters to early majority and beyond. For example, ETC is near 100 percent adoption reaching beyond the late majority to the laggards. This snapshot can be interpreted to recognize that revenue positive technologies such as ETC are far quicker to bridge from early adopters to early majority compared to technologies that are dependent on public and local expenditures (RT for Transit Management).

Emergency vehicle preemption within the public safety law enforcement market is the only technology among those reviewed that may still be ‘bridging the chasm’ from early adopters to early majority. In contrast, ramp metering, a technology which has been around for nearly three decades, is one for which the viable market is likely only a fraction of freeway management agencies, and adoption rates remain stagnant from 2007 to 2010.

Figure 4-1 does not convey ITS market share (deployment levels) for each application area but rather whether specific technologies were present within an agency. Figure 4-2 provides the percentage of fleet among all agencies that are equipped with a specific technology. For, example if one agency with 10 vehicles agency has AVL on 9 vehicles (90 percent), while another agency with 90 vehicles with AVL available on 41 vehicles (46 percent), the AVL market share would be 50 percent (50 out of 100 total vehicles).

Figure 4-2 illustrates that in the Transit Management and Public Safety Fire Rescue application areas, computer-aided-dispatch (CAD) is on the decline, while in-vehicle navigation (NAV) and automated vehicle location (AVL) market share is growing. CAD, along with the other three technologies (NAV, EVP, and AVL), continues to grow within the Public Safety Law Enforcement application area.

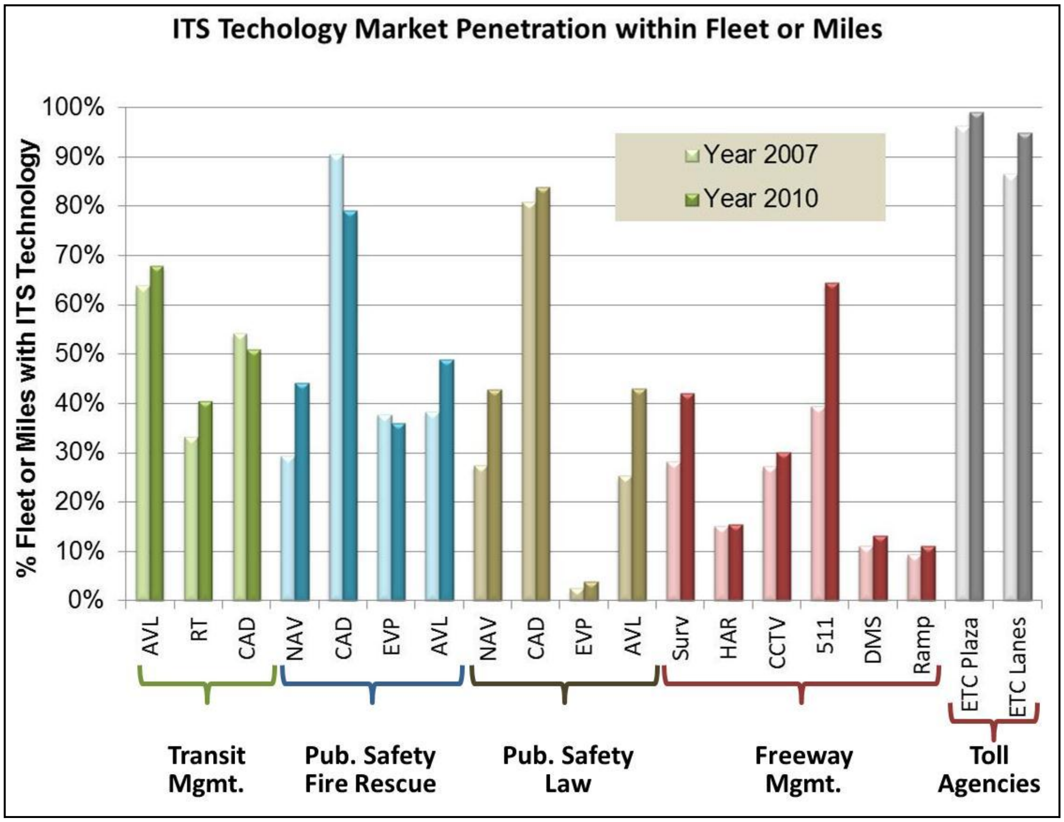


Figure 4-2 ITS Technology Market Penetration By Application Area for Vehicle Fleet or Coverage Miles

The subsequent sections for each technology highlight specific agencies that exhibit growth, maintenance, or decline in their ITS market share with the backdrop of agency fleet or miles coverage growth, steady state, or decline. Overall trends vary by technology sector and more so by the size and geographic location of agencies.

Of note, this analysis is a preliminary selection based on survey comparisons from years 2007 and 2010. At this juncture, no additional communications have been established with agencies having completed the survey. Consequently, the underlying story associated with changes in ITS have not been established. This will be a component of the subsequent task to this effort. In analyzing the data, all suspect pair outcomes were excluded. These included, for example, unrealistic values for data such as millions of miles of freeway managed by a single agency, or a growth in a specific ITS technology that exceeds the agency's fleet size.

Table 4-1 below summarizes the metropolitan regions wherein differing levels of ITS growth, stability, and decline occur by application area. The specific agencies within the region are summarized in the specific application area within the following subsections. The next step will be to communicate with agencies within these regions to establish the accuracy of the information provided and to establish the baseline factors influencing the evolution of ITS adoption and deployment.

Table 4-1 Metropolitan Regions with ITS Variation from 2007 to 2010

	Region	Application Areas
Growth	Phoenix	Law (2), Transit
	St. Paul	Law, Fire
	Tampa	Freeway, Transit
Maintain	New Orleans	Law, Fire
	Milwaukee	Law, Transit
	Detroit	Law (2), Fire
	Boston	Fire, Transit
Decline	Buffalo	Law, Transit
	Detroit	Law, ETC
	Salt Lake City	Fire, Freeway
	Philadelphia	Fire (2)
	Cleveland	Freeway, Transit

4.2 Transit Management

The transit industry in the United States consists of over 173,000 vehicles (65,000 buses, 69,000 paratransit, and 39,000 rail and other types), providing 4.6 billion revenue vehicle miles of service, resulting in 55 billion passenger miles of travel, and $12.2 billion in passenger fares collected. Despite service cutbacks due to the economic downturn, in the past 10 years the transit industry has grown by over 20 percent—faster than either highway or air travel (National Transportation Database 2009, and Dickens 2011). These statistics are noted in the ITS Benefits, Cost, Deployment, and Lessons Learned (BCDLL) report prepared by Bunch et al. (2011).

During this time ITS has matured and is becoming part of standard practice in transit operations across the country in order to meet the increased passenger demand in a cost effective way and provide safer and more reliable service. Agencies are moving beyond the implementation of first generation stand-alone systems. Trends include deploying transit ITS systems that integrate automated vehicle location (AVL) and computer-aided dispatch (CAD), automatic passenger counters (APC), electronic payment and smart card systems, and real time information. Transit agencies are actively participating in Integrated Corridor Management (ICM) systems. Transit agencies are also at the forefront in providing open source real time data for third party application developers, and there is a growing trend to provide transit data to Internet map and routing providers (e.g. Google maps, Bing Maps, Map Quest) for multimodal trip planning applications.

The 2007 ITS Deployment Tracking Survey acquired responses from 235 transit agencies while the 2010 Survey acquired responses from 143 agencies. All 143 agencies from 2010 also were present in 2007 Survey; however 26 of these agencies reported a zero fleet size for both 2007 and 2010, resulting in a sample size of 117. Of the 117 participants, a few of the larger transit agencies had not provided entries for key variables such as fleet size. For example, the New Jersey Transit Corporation provided a fleet size of 2,356 in 2010 and no entry in 2007. This agency along with another twelve others are excluded from analyses given that their fleet and ITS growth are a function of non-reporting in 2007. Consequently the number of agencies analyzed shrinks to 104.

Among the 104 agencies with relatively complete data, 50 percent indicated a reduction in fleet size. The maximum percentage reduction is over 90 percent (22 to 2 buses) for Lorian County Transit, and a maximum magnitude reduction of 394 buses (18 percent reduction) for Chicago Transit Authority. Another 30 percent of agencies indicated a growth in fleet size. The maximum percentage growth is exhibited by the South Florida Regional Transportation Authority which had no buses in 2007 and 18 buses in 2010. The maximum magnitude growth in fleet size is by the New York City Transit Authority which increased its fleet by 1295 buses (28 percent growth).

The key ITS metrics to identify transit agency growth, decline and steady state trends from 2007 to 2010 include automatic vehicle location (AVL), real-time (RT) technology, and computer aided dispatch (CAD) fleet equipage. RT data as requested in the surveys refers to the real-time monitoring of vehicle components, without specification of component type. Approximately 31 percent of agencies (32 of 104) have zero (0) fleet equipage as measured by CAD, RT, or AVL. Of these 32 agencies, 26 showed a steady state, moderate downturn, or drastic decline in fleet size from 2007 to 2010. Figure 4-3 summarizes the subset of agencies indicating ITS technology presence for years 2007 and 2010. Agencies using CAD declined from 2007 to 2010 while agencies using AVL increased.

The fleet equipage level of AVL, RT, and CAD among the 104 agencies is 61 percent, 51 percent, and 41 percent, respectively based on 2010 surveys. Overall across the 104 agencies, AVL and RT equipage increased by 7 percent and 23 percent, respectively; while CAD equipage declined by 5 percent. One reason for CAD decline is a shift from CAD to AVL technology by a number of agencies within those surveyed. For example, Central Oklahoma Transit had a fleet size of 63 with 11 AVL and 11 CAD equipped vehicles in 2007. By 2010 their fleet size increased to 65, with 22 AVL equipped vehicles and no CAD equipped vehicles.

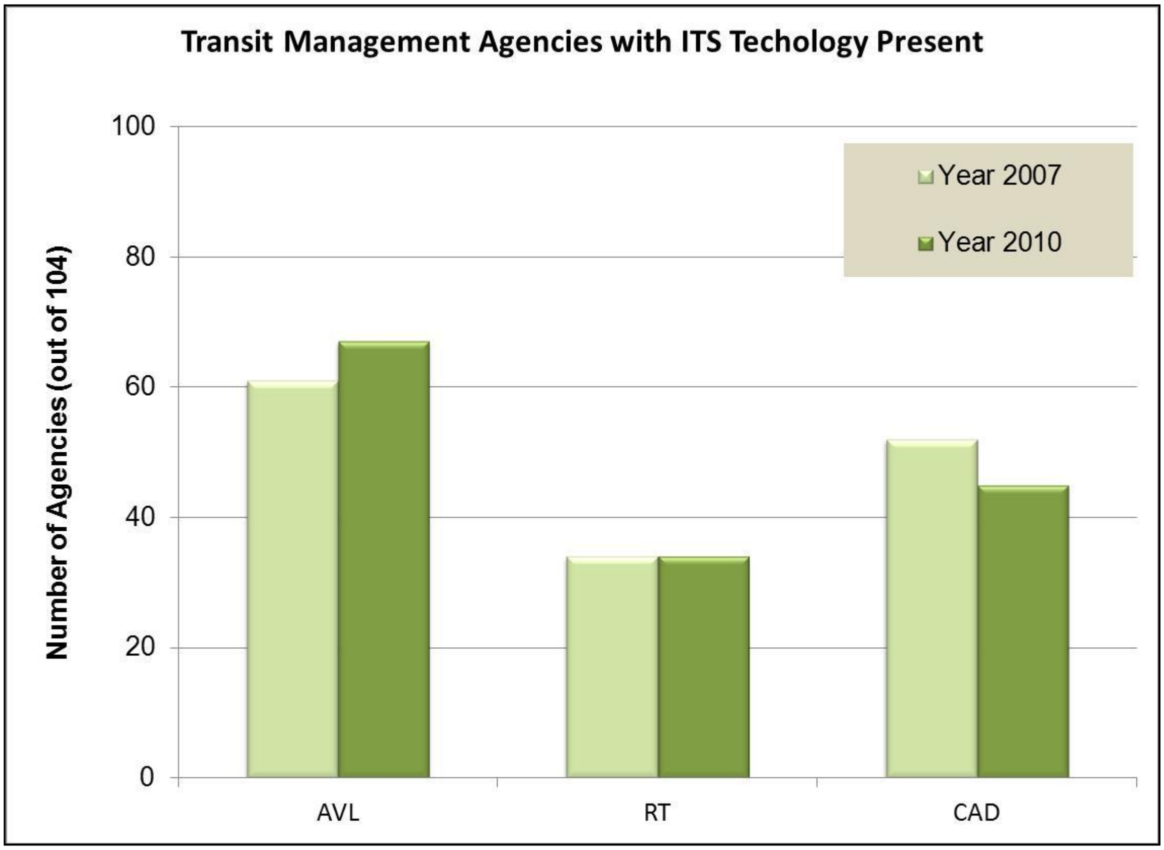


Figure 4-3 Transit Management Agencies with Specific ITS Technology

The 23 percent increase in RT can be attributed overwhelmingly to three large agencies that made a significant investment for deployment of ITS:

- Southeastern Pennsylvania Transportation Authority (SEPTA), which had no RT in 2007, equipped their entire fleet of 1359 buses with RT by 2010,
- New York City Transit Authority (MTA) which had no RT in 2007, equipped 983 of their 5895 buses with RT by 2010, and
- Washington Metropolitan Area Transit Authority, which had 39 percent of their fleet of 1504 vehicles equipped with RT in 2007, completed full fleet equipage through installation for another 923 vehicles.

Agencies experiencing fleet growth often also grew their transit ITS equipage, but not always. Likewise, agencies experiencing fleet contraction, sometimes contracted their transit ITS fleet, but more often were able to maintain or even grow their ITS-equipped fleet. Table 4-2 presents a selection of 18 agencies that illustrate growth, maintenance, and decline of ITS technologies under the backdrop of fleet growth, maintenance, and decline within the Transit Management application area.

Table 4-2 Examples of Growth and Decline in ITS among Transit Management Agencies

Examples of Growth and Decline in ITS for Transit Management Agencies						
TRENDING		**Agency -- Metro Area**	**2007 - 2010 Count and % Change**			
Fleet	**ITS**		**Fleet**	**AVL**	**RT**	**CAD**
Growth	Growth	Reg. Public Transp. Auth. -- Phoenix	157 - 199 27%	140 - 190 36%	0 - 19 NEW	140 - 173 24%
		G G & C Bus Company Inc. -- Pittsburgh, Beaver Valley	4 - 5 25%	0 - 0 -	0 - 2 NEW	0 - 0 -
	Maintain	Sun Tran -- Tucson	199 - 235 18%	199 - 235 18%	199 - 235 18%	199 - 235 18%
		Reg. Transp. Commission/Citizens Area Transit -- Las Vegas	345 - 421 22%	345 - 421 22%	345 - 421 22%	345 - 421 22%
	Decline	Howard Transit Service -- Baltimore	20 - 31 55%	20 - 29 45%	0 - 0 -	20 - 0 -100%
		Veolia Transp./ Jefferson Parish Transit -- New Orleans	33 - 37 12%	33 - 37 12%	33 - 0 -100%	33 - 0 -100%
Maintain	Growth	Hillsborough Area Reg. Transit Auth. -- Tampa, St. Petersburg, Clearwater	195 - 194 -1%	3 - 194 6367%	1 - 190 18900%	3 - 194 6367%
		Academy Lines Inc.(NJ) -- NY, Northern NJ, Southwestern CT	601 - 591 -2%	0 - 478 NEW	0 - 193 NEW	0 - 193 NEW
	Maintain	Massachusetts Bay Transp. Auth. -- Boston, Lawrence, Salem	1000-1000 0%	401 - 401 0%	0 - 0 -	401 - 401 0%
		Belle Urban System-Racine -- Milwaukee, Racine	35 - 35 0%	35 - 35 0%	35 - 35 0%	35 - 35 0%
	Decline	Niagara Frontier Transp. Auth. -- Buffalo, Niagara Falls	332 - 319 -4%	332 - 319 -4%	332 - 0 -100%	332 - 0 -100%
		VIA Metropolitan Transit -- San Antonio	454 - 451 -1%	454 - 451 -1%	454 - 0 -100%	454 - 0 -100%
Decline	Growth	Pierce Transit -- Seattle, Tacoma	261 - 194 -26%	0 - 194 NEW	0 - 194 NEW	0 - 194 NEW
		Hampton Roads Transit -- Hampton Roads	335 - 266 -21%	40 - 266 565%	0 - 266 NEW	40 - 266 565%
	Maintain	Greater Attleboro-Taunton Reg. Transit Auth. -- Providence, Pawtucket, Fall River	47 - 25 -47%	27 - 25 -7%	0 - 0 -	27 - 25 -7%
		Southwest Ohio Reg. Transit Auth. (SORTA) -- Cincinnati, Hamilton	390 - 337 -14%	390 - 337 -14%	0 - 0 -	390 - 337 -14%
	Decline	Greater Cleveland Reg. Transit -- Cleveland, Akron, Lorain	654 - 500 -24%	654 - 457 -30%	654 - 457 -30%	654 - 457 -30%
		Santa Clara Valley Transp. Auth. -- San Francisco, Oakland, San Jose	535 - 412 -23%	535 - 412 -23%	0 - 0 -	535 - 0 -100%

The Hillsborough Area Regional Transit Authority in the Tampa, St. Petersburg, Clearwater metropolitan area appears to have been experimenting with transit ITS in 2007, indicating three (3) or fewer equipped vehicles. By 2010, their fleet size remained the same, while nearly their entire fleet is equipped with AVL, CAD, and RT technologies. This is a clear example of ITS growth within a steady state fleet environment. Other examples can be seen in Table 4-2.

The Pace et al (2010) study provides additional insight for transit adoption of ITS technology, specifically related to transit signal priority (TSP). The analysis suggests that there is slow adoption of transit signal priority (TSP) technology in most of the country with the exception of several heavily concentrated pockets with TSP such as San Francisco, Chicago's northern suburbs, and Seattle. The deployment of TSP at the transit agency level increased from 41 percent in 1999 to 47 percent in 2002, however it has fallen back since 2006 and in 2007 was back to the 1999 level (41 percent). It is notable that the sample size used in this analysis was very small compared to other markets and therefore one agency can have a significant effect in result outcomes. The percent of signals with TSP by agencies that manage arterials has not increased beyond 2 percent, even though the percentage of agencies with TSP increased from 14 percent to 19 percent. Deployment as measured by the percent of buses with TSP has however risen sharply through 2007, moving up from 2 percent to 26 percent.

For TSP technology, budget was identified in the Pace et al. study a significant negative factor but the significance of this position may stem from sample outliers rather than a causational trend. The authors do note that the presence of five large transit agencies in the data with significant budgets, but with relatively small deployment of TSP may have caused this outcome.

4.3 Public Safety – Fire and Rescue

Public safety agencies continue the expansion of the use of on-board vehicle navigation, involving nearly half the vehicles based on the 2010 Deployment Tracking survey. CAD coverage is stable at 80 percent of the fleet. Traffic signal preemption has been adopted by 19 percent of law enforcement agencies and 66 percent of the fire/rescue agencies. (Bunch et al., 2011) Emergency Vehicle Preemption (EVP) and Transit Signal Priority (TSP) are two technologies that change traffic signals in order to speed passage of emergency vehicles or transit vehicles. EVP technology is not heavily deployed across the U.S., however EVP is an older technology with much higher and more widespread adoption than TSP. Although EVP and TSP operate similarly, they do so in distinct markets. These technologies need to be adopted and deployed by agencies that manage the vehicles that require preemption/priority and also by the agencies that control the traffic signal infrastructure that the technologies will affect.

The 2007 ITS Deployment Tracking Survey acquired responses from 386 Fire and Rescue agencies while the 2010 Survey acquired responses from 226 agencies. All 226 agencies from 2010 also were present in 2007 Survey; however 39 of these agencies reported a zero fleet size for 2007, resulting in a sample size of 187.

Among the 187 agencies with complete data, 34 percent indicated a reduction in fleet size. The maximum percentage reduction is nearly 80 percent (17 to 4 vehicles) for Oak Park City Fire Department in Chicago, and a maximum magnitude reduction of 59 vehicles (69 percent reduction) for

Rochester City Fire Department. Another 35 percent of agencies indicated a growth in fleet size. The maximum percentage growth is exhibited by the Roberts Park Fire Protection District in Chicago, which had 3 vehicles in 2007 and 15 vehicles in 2010. The maximum magnitude growth in fleet size is by Baltimore City Fire Department, which increased its fleet by 100 vehicles (48 percent growth).

The key ITS metrics to identify Fire and Rescue agency growth, decline and steady state trends from 2007 to 2010 include in vehicle navigation (NAV), computer aided dispatch (CAD), Emergency Vehicle Preemption (EVP), and automatic vehicle location (AVL) fleet equipage. In 2010, 37 percent, 56 percent, 60 percent, and 78 percent of agencies have some level of AVL, NAV, EVP, and CAD, respectively. Figure 4-4 summarizes the subset of Fire Rescue agencies indicating ITS technology presence for years 2007 and 2010. Agencies using CAD marginally declined from 2007 to 2010 while agencies using AVL and NAV increased significantly.

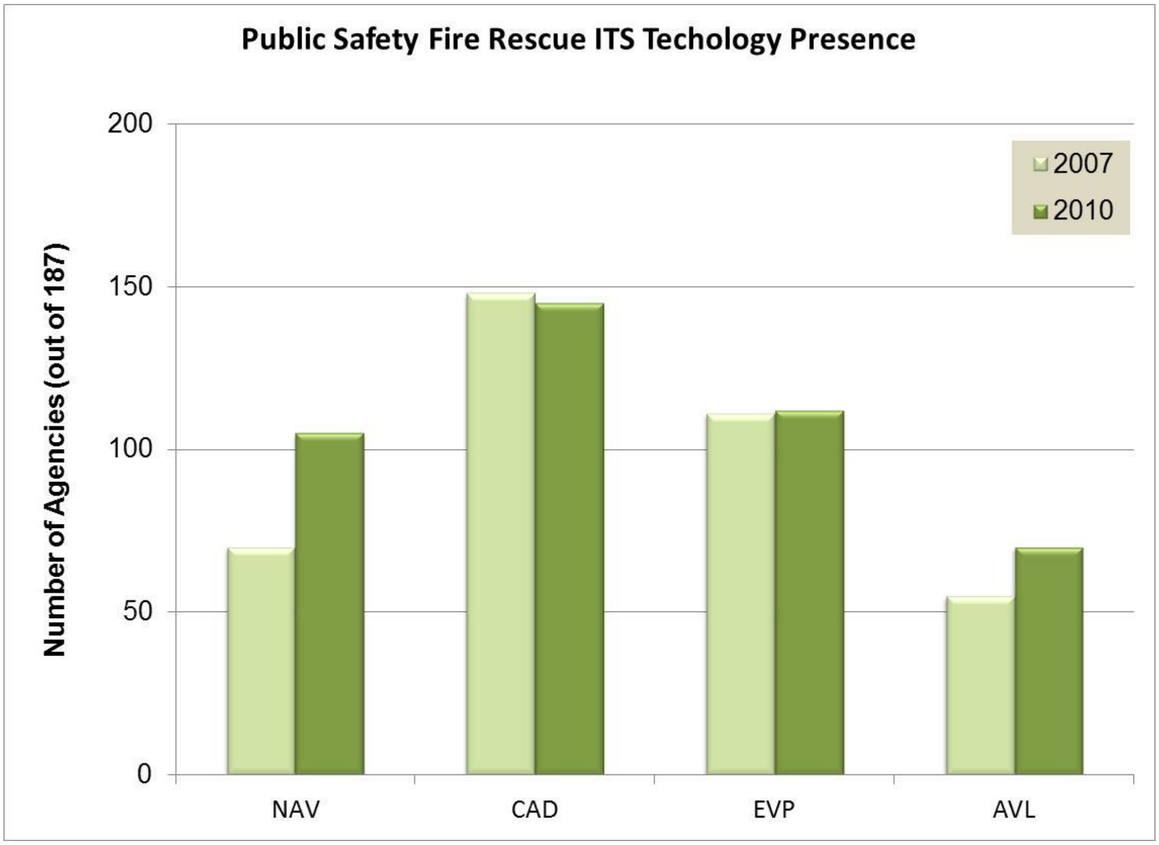


Figure 4-4 Transit Management Agencies with Specific ITS Technology

Overall across the 187 agencies, vehicle fleets have increased by only 1 percent, from 8,296 vehicles to 8,409 vehicles. NAV and AVL equipage increased by 53 percent and 11 percent, respectively; while CAD equipage declined by 11 percent and EVP declined by 3 percent. One reason for CAD decline is a shift from CAD to AVL technology by a number of agencies within those surveyed. For example, West Valley City Fire & EMS Department in Utah had a fleet size of 40 with 0 AVL and 40 CAD equipped vehicles in 2007. By 2010 their fleet size increased to 42, with 10 AVL equipped vehicles and 20 CAD equipped vehicles.

The 53 percent increase in NAV can be attributed overwhelmingly to four agencies:

- Baltimore City Fire Department - no NAV in 2007, and equipped 200 vehicles by 2010,
- DC Fire Department (EMS) - no NAV in 2007, and equipped 136 by 2010,
- Virginia Beach City Fire Department, added an additional 115 NAV vehicles in 2010, and
- Seattle City Fire Department, added an additional 100 NAV equipped vehicles in 2010.

Agencies experiencing fleet growth often also grew their emergency vehicle ITS equipage, but not always. Likewise, agencies experiencing emergency vehicle fleet contraction sometimes also contracted their ITS fleet. Table 4-3 presents a selection of 18 agencies that illustrate growth, maintenance, and decline of ITS technologies under the backdrop of fleet growth, maintenance, and decline within the Public Safety Fire application area.

A good example of an agency that grew significantly from 2007 to 2010, both in terms of fleet size and ITS deployment, is the Kansas City Missouri Fire Department. This department fully equipped all new vehicles with CAD and also began the adoption of NAV and AVL technologies on nearly half their fleet. The agency also expanded their EVP share. Counter to the ‘grow’ example is Philadelphia EMS which grew its fleet by 9 percent but contracted ITS market share across the categories analyzed. This organization in 2007 equipped a single vehicle with EVP and chose to abandon this ITS technology. Further, the fleet proportion with NAV, CAD, and AVL all decline by over 20 percent. More examples can be seen in Table 4-3.

Table 4-3 Examples of Growth and Decline in ITS among Public Safety Fire and Rescue Agencies

Examples of Growth and Decline in ITS for Public Safety Fire and Rescue Agencies							
TRENDING		**Agency -- Metro Area**	**2007 - 2010 Count and % Change**				
Fleet	**ITS**		**Fleet**	**NAV**	**CAD**	**EVP**	**AVL**
Growth	Growth	Fremont City Fire Dept. -- San Francisco, Oakland, San Jose	14 - 49 250%	14 - 33 136%	14 - 25 79%	14 - 49 250%	14 - 25 79%
		Kansas City Missouri Fire Department -- Kansas City	69 - 120 74%	0 - 56 New	69 - 120 74%	3 - 10 233%	0 - 51 New
	Maintain	St. Bernard Parish Fire Department -- New Orleans	18 - 28 56%	0 - 0 -	0 - 0 -	0 - 0 -	0 - 0 -
		Jacksonville Fire & Rescue Department -- Jacksonville	250 - 330 32%	100 - 100 0%	250 - 277 11%	0 - 0 -	0 - 0 -
	Decline	Dearborn City Fire Department -- Detroit, Ann Arbor	13 - 15 15%	0 - 0 -	13 - 0 -100%	13 - 0 -100%	0 - 0 -
		Philadelphia EMS -- Philadelphia, Wilmington, Trenton	75 - 82 9%	75 - 51 -32%	75 - 54 -28%	1 - 0 -100%	45 - 54 20%
Maintain	Growth	Framingham Town Fire Dept. -- Boston, Lawrence, Salem	10 - 10 0%	1 - 10 900%	10 - 10 0%	6 - 7 17%	0 - 0 -
		Charlotte City Fire Department -- Charlotte, Gastonia, Rock Hill	145 - 149 3%	10 - 90 800%	145 - 149 3%	68 - 75 10%	98 - 102 4%
	Maintain	Chandler City Fire Department -- Phoenix	16-16 0%	16 - 16 0%	16 - 16 0%	16 - 16 0%	16 - 16 0%
		Hollywood Rescue Department -- Miami, Fort Lauderdale	20 - 20 0%	20 - 20 0%	20 - 20 0%	20 - 20 0%	20 - 20 0%
	Decline	Sandy Fire Department -- Salt Lake City, Ogden	16 - 16 0%	12 - 10 -17%	16 - 10 -38%	9 - 8 -11%	7 - 6 -14%
		Philadelphia Fire Department -- Philadelphia, Wilmington, Trenton	323 - 326 1%	75 - 52 -31%	300 - 140 -53%	4 - 0 -100%	0 - 0 -
Decline	Growth	Coon Rapids City Fire Department -- Minneapolis, St. Paul	19 - 12 -37%	1 - 7 600%	0 - 7 New	19 - 11 -42%	0 - 0 -
		No other agencies fit this category					
	Maintain	Cambridge City Fire & EMS Dept -- Boston, Lawrence, Salem	52 - 45 -13%	12 - 12 0%	52 - 45 -13%	0 - 0 -	8 - 8 0%
		Warren City Fire Department -- Detroit, Ann Arbor	20 - 16 -20%	0 - 0 -	0 - 0 -	0 - 0 -	0 - 0 -
	Decline	Johnson County Med-Act -- Kansas City	35 - 30 -14%	35 - 30 -14%	35 - 30 -14%	30 - 18 -40%	35 - 30 -14%
		Rochester City Fire Department -- Rochester	85 - 26 -69%	0 - 0 -	85 - 1 -99%	32 - 22 -31%	0 - 0 -

4.4 Public Safety – Law Enforcement

Public safety agencies continue the expansion of the use of on-board vehicle navigation, involving nearly half the vehicles based on the 2010 Deployment Tracking survey. CAD coverage is stable at 80 percent of the fleet. Traffic signal preemption has been adopted by 19 percent of law enforcement agencies and 66 percent of the fire/rescue agencies. Several technologies are also available to speed the investigation of incident scenes and record necessary information for later analysis. Fifty-four (54) percent of law enforcement agencies in the country's largest metropolitan areas use automated measuring equipment to investigate major traffic incidents.

Between the 2007 and 2010 ITS Deployment Tracking Survey, 280 agencies have provided input both years; however, 245 agencies have sufficiently complete data for identification of trending and agencies with growth, steady state, or decline in ITS. Among the 245 law enforcement agencies, the number of vehicles declined marginally by 4 percent from a 2007 level of 59,000 to a 2010 level of 56,800. Nearly as many agencies increased their fleet count (94 agencies) as reduced their fleet count (107 agencies), while 44 agencies remained constant. The 2010 average fleet size is at 224 vehicles with a range of 10 (Farmington City Police Department, Detroit, Ann Arbor metropolitan area) to 3900 (Broward County Sheriff, Miami, Fort Lauderdale metropolitan area).

The set of variables for comparison of ITS trending for Law Enforcement include:

- number of emergency response vehicles with on board navigation capability (NAV),
- number of emergency response vehicles under a computer-aided dispatch system(CAD),
- number of emergency response vehicles with traffic signal system communications, for example, emergency vehicle preemption (EVP), and
- number of emergency response vehicles with automatic vehicle location (AVL).

Figure 4-5 presents the number of agencies that employ these four ITS technologies to support law enforcement based on the 2007 and 2010 survey years. Most agencies (228 out of 245) have CAD. Fewer than 50 of the 250 agencies surveyed use traffic signal system communications (EVP).

Looking beyond agency presence of ITS to individual vehicle equipage, vehicle fleet NAV equipage increases from 27 percent in 2007 to 43 percent in 2010. Vehicle fleet CAD equipage increases from 81 percent in 2007 to 84 percent in 2010; EVP equipage increases from 3 percent to 4 percent, and AVL equipage increases from 25 percent to 43 percent of the law enforcement vehicle fleet.

Law enforcement agencies experiencing fleet growth also generally grew their ITS equipage, but not always. Likewise, law enforcement agencies experiencing fleet contraction, sometimes contracted their transit ITS fleet, but more often were able to maintain or even grow their ITS-equipped fleet. Table 4-4 presents a selection of agencies that illustrate growth, maintenance, and decline of ITS technologies under the backdrop of fleet growth, maintenance, and decline within the Law Enforcement application area. The selection of agencies in Table 4-4 reflects variation for larger and smaller enforcement agencies.

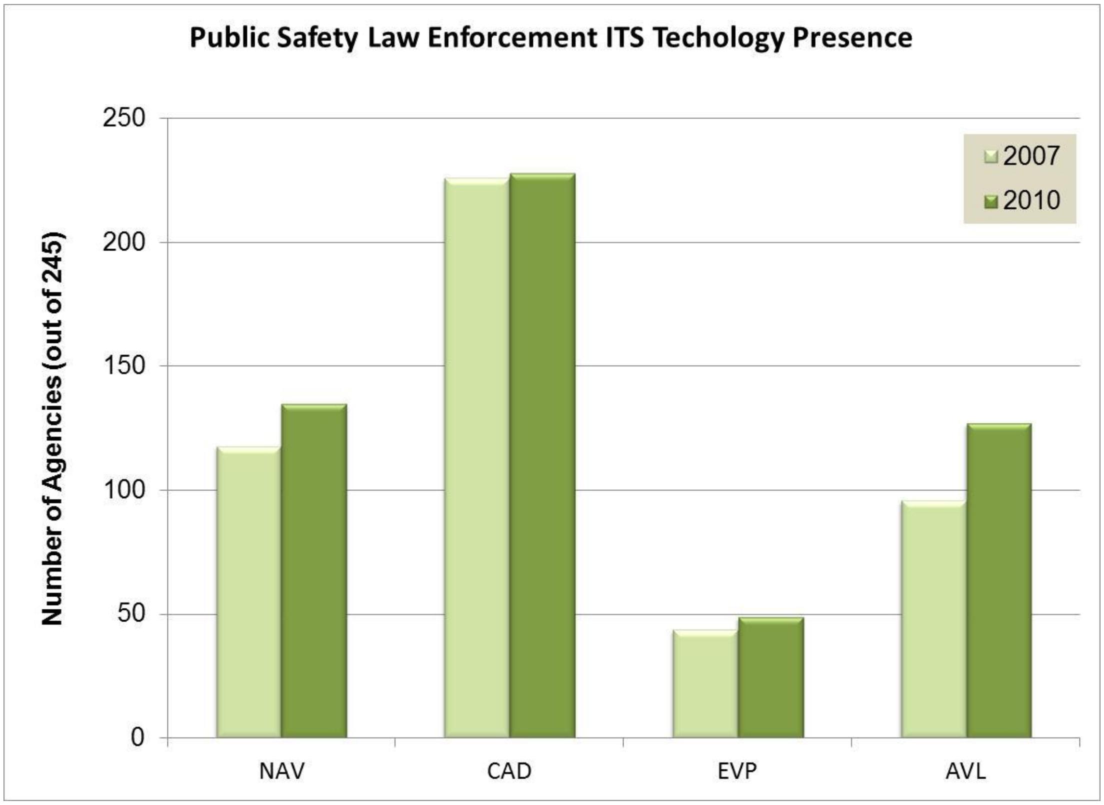
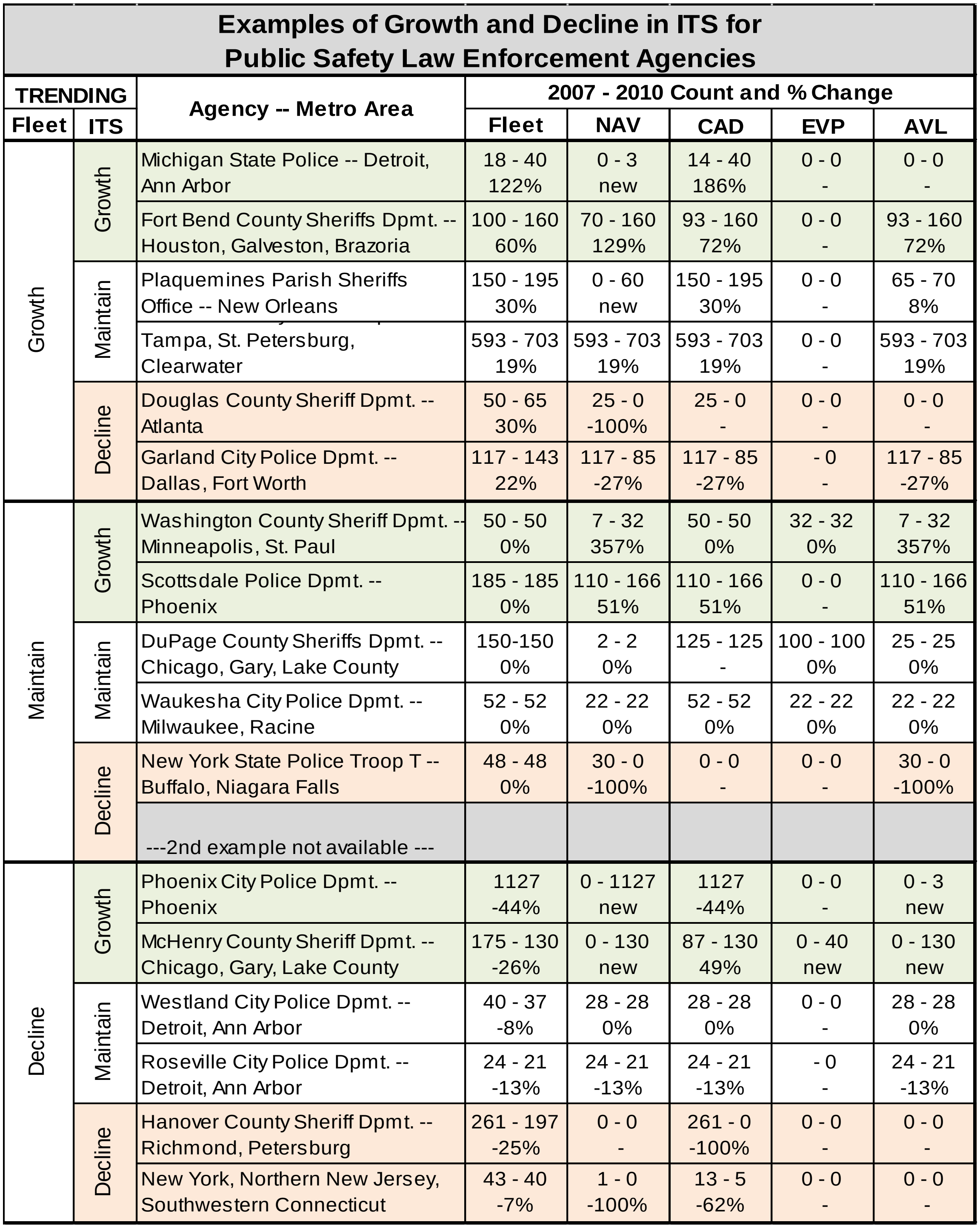


Figure 4-5 Public Safety Law Enforcement Agencies with Specific ITS Technology

One unique case presented in Table 4-4 is for the McHenry county Sheriff Department within the Chicago, Gary, Lake County metropolitan region. This agency experienced a 26 percent decline in fleet size (from 175 to 130), but made ITS a priority and equipped their entire fleet with NAV and AVL by year 2010 as well as complete CAD equipage for their fleet. They also deployed EVP on 31 percent of their vehicle fleet. The Fort Bend County Sheriff Department in the Houston, Galveston, Brazoria metropolitan region is a prime example of both fleet and ITS growth. The agency increased their fleet size from 100 to 160 from year 2007 to 2010. In 2007, their fleet was partially equipped with NAV, CAD, and AVL. As they grew their fleet, they also ensured that 100 percent of the vehicle fleet (old and new) had these technologies.

The Pace et al. report notes a number of factors that support Law Enforcement adoption and growth of ITS. The presence of vehicle navigation and a regional architecture had a positive bearing on adoption. In addition, the percent of signals in the metropolitan area that have emergency vehicle preemption (EVP) capabilities also affects the likelihood of adoption as does the level of Emergency Vehicle Preemption (Law Enforcement) technology. Pace also presents counter-intuitive results for this technology based on a regression analysis. The presence of navigation technology and earmarks result in a negative influence on the level of deployment. This outcome suggests that, in contrast to fire rescue vehicles, navigation may be a substitute for EVP (police vehicles don’t respond from a fixed location, so a navigation tool may be more effective). In the case of earmarks, the negative effect may indicate that additional ITS funding results in a law enforcement agency using funds in other areas.

Table 4-4 Examples of Growth and Decline in ITS among Public Safety Law Enforcement Agencies



Examples of Growth and Decline in ITS for Public Safety Law Enforcement Agencies

TRENDING		Agency -- Metro Area	2007 - 2010 Count and % Change				
Fleet	ITS		Fleet	NAV	CAD	EVP	AVL
Growth	Growth	Michigan State Police -- Detroit, Ann Arbor	18 - 40 122%	0 - 3 new	14 - 40 186%	0 - 0 -	0 - 0 -
		Fort Bend County Sheriffs Dpmt. -- Houston, Galveston, Brazoria	100 - 160 60%	70 - 160 129%	93 - 160 72%	0 - 0 -	93 - 160 72%
	Maintain	Plaquemines Parish Sheriffs Office -- New Orleans	150 - 195 30%	0 - 60 new	150 - 195 30%	0 - 0 -	65 - 70 8%
		Tampa, St. Petersburg, Clearwater	593 - 703 19%	593 - 703 19%	593 - 703 19%	0 - 0 -	593 - 703 19%
	Decline	Douglas County Sheriff Dpmt. -- Atlanta	50 - 65 30%	25 - 0 -100%	25 - 0 -	0 - 0 -	0 - 0 -
		Garland City Police Dpmt. -- Dallas, Fort Worth	117 - 143 22%	117 - 85 -27%	117 - 85 -27%	- 0 -	117 - 85 -27%
Maintain	Growth	Washington County Sheriff Dpmt. -- Minneapolis, St. Paul	50 - 50 0%	7 - 32 357%	50 - 50 0%	32 - 32 0%	7 - 32 357%
		Scottsdale Police Dpmt. -- Phoenix	185 - 185 0%	110 - 166 51%	110 - 166 51%	0 - 0 -	110 - 166 51%
	Maintain	DuPage County Sheriffs Dpmt. -- Chicago, Gary, Lake County	150-150 0%	2 - 2 0%	125 - 125 -	100 - 100 0%	25 - 25 0%
		Waukesha City Police Dpmt. -- Milwaukee, Racine	52 - 52 0%	22 - 22 0%	52 - 52 0%	22 - 22 0%	22 - 22 0%
	Decline	New York State Police Troop T -- Buffalo, Niagara Falls	48 - 48 0%	30 - 0 -100%	0 - 0 -	0 - 0 -	30 - 0 -100%
		---2nd example not available ---					
Decline	Growth	Phoenix City Police Dpmt. -- Phoenix	1127 -44%	0 - 1127 new	1127 -44%	0 - 0 -	0 - 3 new
		McHenry County Sheriff Dpmt. -- Chicago, Gary, Lake County	175 - 130 -26%	0 - 130 new	87 - 130 49%	0 - 40 new	0 - 130 new
	Maintain	Westland City Police Dpmt. -- Detroit, Ann Arbor	40 - 37 -8%	28 - 28 0%	28 - 28 0%	0 - 0 -	28 - 28 0%
		Roseville City Police Dpmt. -- Detroit, Ann Arbor	24 - 21 -13%	24 - 21 -13%	24 - 21 -13%	- 0 -	24 - 21 -13%
	Decline	Hanover County Sheriff Dpmt. -- Richmond, Petersburg	261 - 197 -25%	0 - 0 -	261 - 0 -100%	0 - 0 -	0 - 0 -
		New York, Northern New Jersey, Southwestern Connecticut	43 - 40 -7%	1 - 0 -100%	13 - 5 -62%	0 - 0 -	0 - 0 -

4.5 Freeway Management

There are numerous ITS strategies to improve the operation of the freeway system. Traffic surveillance systems use vehicle detectors and cameras to support freeway management applications. Traffic control measures on freeway entrance ramps, such as ramp meters, can use sensor data to optimize freeway travel speeds and ramp meter wait times. Lane management applications can promote the most effective use of available capacity on freeways and encourage the use of high-occupancy commute modes. Special event transportation management systems can help control the impact of congestion at stadiums or convention centers. In areas with frequent events, large changeable destination signs or other lane control equipment can be installed. In areas with occasional or one-time events, portable equipment can help smooth traffic flow. Advanced communications have improved the dissemination of information to the traveling public. Motorists are now able to receive relevant information on location-specific traffic conditions in a number of ways including dynamic message signs (DMS), highway advisory radio (HAR), even in-vehicle systems. (Other methods of providing traveler information, including those covering multiple modes or travel corridors, are discussed in the traveler information chapter.) Automated systems enforcing speed limits and aggressive driving laws can lead to safety benefits. (Bunch et al. 2011)

The 2007 ITS Deployment Tracking Survey incudes questions related to surveillance, ramp control, lane management, information dissemination, tourism and events, integration, incident management, freeway TMC, and other freeway components. The 2010 Survey also asks similar sets of questions; however most questions related to ITS deployment cannot be compared between the two years given variances in survey wording. For example, the 2007 survey question asks whether the agency offers pre-trip email whereas the 2010 survey asks whether the agency offers desktop email. Consequently, comparable variables include the following four:

- Total miles under surveillance
- Miles with highway advisory radio (HAR) available
- Miles with closed circuit television (CCTV) for incident detection
- Number of dynamic message signs (DMS)
- Number of ramp meters (RM)
- Presence of 511 service

The 2007 ITS Deployment Tracking Survey acquired responses from 127 freeway agencies while the 2010 Survey acquired responses from 122 agencies. Overall, 106 agencies from 2010 also were present in 2007 Survey; however 3 of these agencies have erroneous data for a single variable. For example, one agency indicated management of millions of freeway miles. These agencies are not highlighted. Of the 106 participants, two (2) agencies had not provided entries for key variables. These agency are excluded from analyses given that their growth and decline of ITS on their freeways is a function of non-reporting in 2007. Consequently the number of agencies analyzed shrinks to 104. Figure 4-6 presents the number of agencies that employ these six ITS technologies to support law enforcement based on the 2007 and 2010 survey years. The most significant growth among agency adoption is in the offering of a 511 service.

Among the 104 agencies with relatively complete data, 32 percent indicated an overall reduction in ITS deployment on their freeways. The maximum average percentage reduction is nearly 80 percent Orlando-Kissimmee, FL -- Florida Department of Transportation. Another 65 percent of agencies indicated a growth in ITS deployments on their freeways. The maximum percentage growth is exhibited by the Nashville-Davidson--Murfreesboro, TN -- Tennessee Department of Transportation which had an increase of 286 percent for the total number of freeway miles with surveillance (e.g. loops and detectors), 105 percent increase in miles covered by HAR, 105 percent increase in CCTV coverage, and 67 percent increase in DMS signs. The remaining 3 percent showed relative maintenance in their overall ITS deployment. No agencies remained completely consistent from 2007 to 2010, most agencies decreased one technology but increased in another area. For example, Caltrans District 6 reported a 25 percent and 175 percent increase for miles under surveillance and CCTV coverage, respectively. But they also reported a 20 percent and 12 percent decline in HAR coverage and DMS signs, respectively.

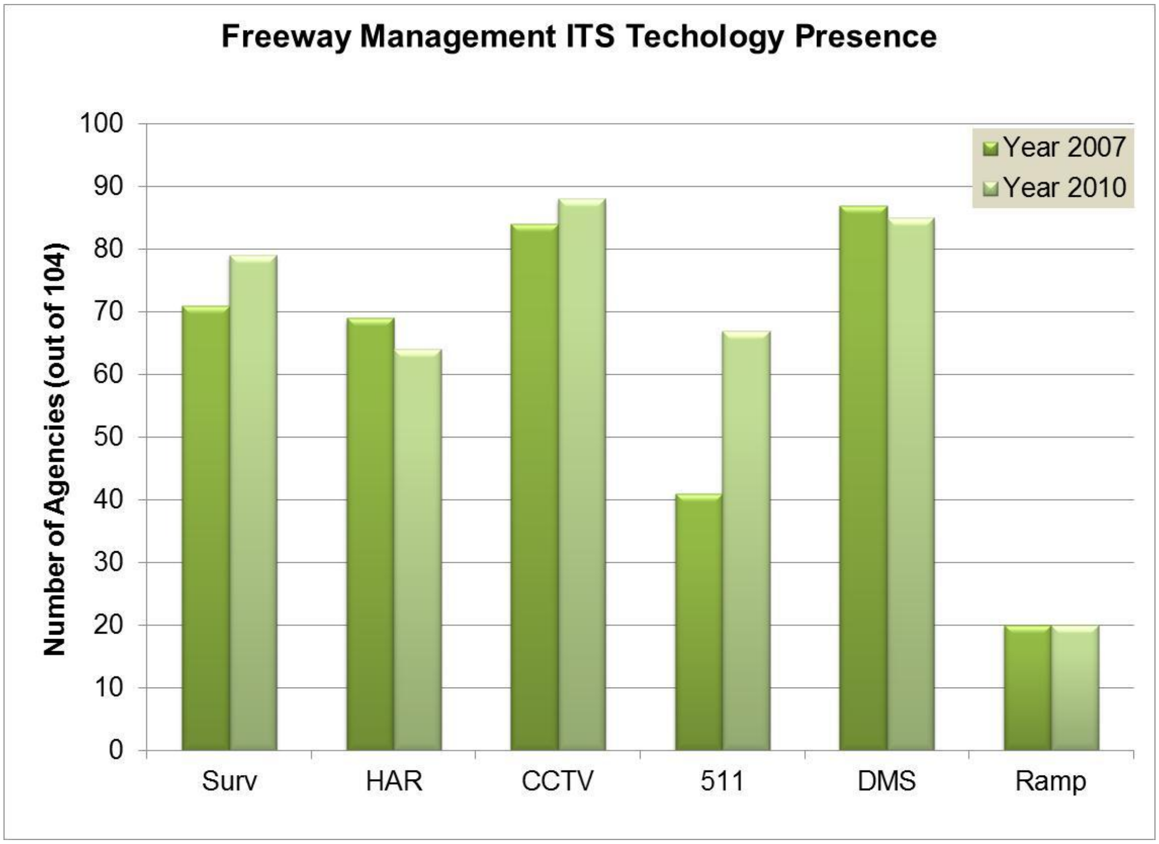


Figure 4-6 Freeway Management Agencies with Specific ITS Technology

Overall across the 104 agencies, all reported an increase in ITS deployment in the categories analyzed. A 49 percent increase in the number of miles under surveillance was reported. An increase of 2 percent was seen for HAR coverage, 11 percent increase for CCTV coverage, 19 percent increase for DMS signs, 18 percent increase for ramp meters and a 63 percent increase in 511 systems.

Table 4-5 presents a selection of 15 agencies that illustrate growth, maintenance, and decline of ITS technologies under the backdrop of large, medium and small agencies within the Freeway Management application area. Large agencies were defined as reporting more than 300 miles of freeway operated in 2010, medium between 100 and 300 miles operated, and small as less than 100 miles operated.

Table 4-5 Examples of Growth and Decline in ITS among Freeway Management Agencies

Examples of Growth and Decline in ITS for Freeway Management Agencies

TRENDING		Agency -- Metro Area	2007 - 2010 Count and % Change					
Freeway Miles	ITS		Miles Surv.	Miles HAR	Miles CCTV	511 Offered	DMS Count	Ramp Meter
Large	Growth	TN Dept. of Transp. -- Nashville-Davidson-Murfreesboro, TN	44 - 170 286%	83 - 170 105%	83 - 170 105%	YES - YES 0%	33 - 55 67%	0 - 0 -
		Wisconsin Dept. of Transp. District 1 -- Janesville, WI	0 - 200 New	100 - 100 0%	180 - 300 67%	NO - YES New	20 - 25 25%	56 - 65 16%
	Maintain	Minnesota DOT -- Minneapolis-St. Paul-Bloomington, MN-WI	350 - 340 -3%	0 - 0 -	410 - 350 -15%	YES - YES -	105 - 125 19%	422 - 425 1%
		Only one agency fit this category						
	Decline	PA Dept. of Transp. -- Scranton-Wilkes-Barre, PA	0 - 0 -	180 - 108 -40%	70 - 50 -29%	NO - YES New	9 - 9 0%	
		Utah Dept. of Transp., Region 2 -- Salt Lake City, UT	130 - 35 -73%	10 - 10 0%	146 - 50 -66%	YES - YES -	38 - 65 71%	25 - 19 -24%
Medium	Growth	TN Dept. of Transp. -- Memphis, TN-MS-AR	0 - 83 New	0 - 83 New	17 - 83 388%	YES - YES -	3 - 42 1300%	
		Florida Dept. of Transp. -- Tampa-St. Petersburg-Clearwater, FL	87 - 133 53%	0 - 0 -	13 - 133 923%	YES - YES -	21 - 68 224%	
	Maint.	No agencies fit this category						
	Decline	Florida Dept. of Transp. -- Orlando-Kissimmee, FL	247 - 49 -80%	0 - 0 -	247 - 49 -80%	YES - YES -	112 - 25 -78%	
		Ohio Dept. of Transp. District 12 -- Cleveland-Elyria-Mentor, OH	0 - 0 -	46 - 10 -78%	5 - 3 -40%	NO - NO -	1 - 1 0%	
Small	Growth	PA Dept. of Transp. -- Harrisburg-Carlisle, PA	4 - 75 1775%	45 - 70 56%	9 - 35 289%	NO - YES New	15 - 18 20%	
		Ada County Highway District -- Boise City-Nampa, ID	6 - 23 283%	0 - 0 -	19 - 30 58%	YES - YES -	5 - 6 20%	
	Maintain	Oregon Dept. of Transp. -- Portland-Vancouver-Beaverton, OR-WA	82 - 72 -12%	0 - 0 -	75 - 82 9%	YES - YES -	21 - 21 0%	139 - 140 1%
		Sarasota/Manatee Metro Plng. Org. -- Bradenton-Sarasota-Venice, FL	0 - 0 -	0 - 0 -	0 - 0 -	YES - YES New	0 - 0 -	
	Decline	S. Jersey Transp. Authority/Atlantic City Expwy. -- Phila.-Camden-Wilmington	44 - 1 -98%	7 - 0 -100%	3 - 2 -33%	NO - YES New	9 - 2 -78%	
		NJ Tnpk. TOC -- Phila.-Camden-Wilmington, PA-NJ-DE-MD	39 - 39 0%	148 - 39 -74%	68 - 39 -43%	YES - YES -	11 - 2 -82%	

The maintenance of freeway ITS was not common based on the reported numbers. Just about all of the agencies had growth or decline in each category. There were a few agencies that reported consistent number of zero deployment across the both years, but that may be a function of non-reporting. No agencies could be found that fit as a medium agency and reported steady maintenance in ITS deployment. Only one agency could be found that was a large agency and had maintained steady ITS deployment levels. Examples of other categories can be seen in Table 4-5.

4.6 Electronic Toll Collection

Electronic toll collection (ETC) systems support the collection and processing of toll plaza transactions without requiring the driver to stop and pay manually, increasing operational efficiency and convenience for tollway travelers. ETC systems operate as either an integrated multi-state system such as the E-ZPass system, or single-state or single toll authority systems such as the Oklahoma Turnpike system. ETC can reduce fuel consumption and emissions at toll plazas by minimizing delays, queuing, and idling time. Hagemann et al. notes that ETC technologies are one of the few ITS technologies that are revenue generator, hence the consistent growth in deployments of tolling technologies.

The 2007 ITS Deployment Tracking Survey acquired responses from 70 tolling agencies, while the 2010 Survey acquired responses from 65 agencies. There were 62 agencies from 2010 also present in the 2007 Survey. The 62 agencies provided consistent data reporting across both years, and response for each agency was complete. The key ITS metrics to identify tolling agency growth, decline and steady state trends from 2007 to 2010 include tolling plaza and lane count compared with ETC capable tolling plazas and lanes.

Among the 62 agencies, 19 percent indicated a reduction in tolling plazas or tolling lanes. The maximum reduction in tolling plazas was 43 percent (7 to 4 plazas) for the Ohio Turnpike Authority. Another 35 percent of agencies indicated a growth in tolling plazas and tolling lanes. Growth in tolling plaza and lane counts is the highest for the Orlando Orange County Expressway Authority, which increased tolling plaza count from 67 to 76 and ETC lanes from 252 to 288 (13 percent and 14 percent growth respectively). In 2010, 99 percent of the plazas had ETC capabilities and 95 percent of tolling lanes had ETC capabilities. Overall across the 62 agencies, tolling plazas, tolling lanes , ETC plazas, and ETC lanes increased by 6 percent, 1 percent, 9 percent, and 11 percent, respectively.

Table 4-6 presents a selection of 9 agencies that illustrate growth, maintenance, and decline of tolling capabilities under the backdrop of tolling facility growth, maintenance, and decline within the ETC application area. One area did not have an agency to fit the category –no agencies that reported growth in plazas and lanes had a decline in ETC capable plazas and lanes.

The Orlando Orange County Expressway Authority was one of the few agencies that reported growth in all four (4) categories. El Paso City , Texas was the only reporting agency that declined in tolling facilities and ETC capabilities. The city either made the choice to remove three (3) tolling facilities and the ETC capabilities or another agency took over part of the tolling in their jurisdiction. The New Jersey Turnpike Authority was another interesting agency. They were the only agency that showed a dramatic increase in ETC only. They over doubled their deployment of ETC capabilities on their tolling lanes.

Table 4-6 Examples of Growth and Decline in ITS among Tolling Agencies

Examples of Growth and Decline in ITS for Electronic Toll Collection (ETC) Agencies						
TRENDING		**Agency -- Metro Area**	**2007 - 2010 Count and % Change**			
Plazas &Lanes	**ETC**		**Plazas**	**Lanes**	**ETC Plazas**	**ETC Lanes**
Growth	Growth	Orlando Orange County Expressway Auth. -- Orlando-Kissimmee, FL	67 - 76 13%	252 - 288 14%	67 - 76 13%	252 - 288 14%
	Maintain	Harris County Toll Road Auth./Sam Houston Ship Channel Bridge -- Houston-Sugar Land-Baytown, TX	9 - 17 89%	301 - 302 0%	9 - 17 89%	330 - 327 -1%
	Decline	E-470 Public Highway Auth. -- Denver-Aurora, CO	5 - 7 40%	108 - 86 -20%	5 - 7 40%	108 - 86 -20%
Maintain	Growth	New Jersey Tnpk. Auth./PA Tnpk. Extension -- Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2 - 2 0%	16 - 16 0%	2 - 2 0%	5 - 16 220%
	Maintain	VA Department of Transportation Dulles Toll Road -- Washington-Arlington-Alexandria, DC-VA-MD-WV	21-21 0%	59 - 59 0%	20 - 20 0%	58 - 58 0%
	Decline	Detroit Windsor Tunnel LLC -- Detroit-Warren-Livonia, MI	2 - 2 0%	12 - 12 0%	2 - 1 -50%	11 - 6 -45%
Decline	Growth	PA Tnpk. Commission-Entire PA Tnpk. -- Pittsburgh, PA	23 - 22 -4%	146 - 145 -1%	18 - 22 22%	119 - 145 22%
	Maintain	Oklahoma Transportation Auth./H. E. Bailey Tnpk. -- Oklahoma City, OK	8 - 8 0%	42 - 37 -12%	8 - 8 0%	24 - 24 0%
	Decline	El Paso City -- El Paso, TX	3 - 3 0%	18 - 14 -22%	3 - 0 -100%	18 - 0 -100%

4.7 Transportation Management Centers

Transportation management centers (TMCs), often called traffic management centers or traffic operations centers (TOCs), coordinate ITS operations. TMCs can be owned or operated by a single transportation agency or multiple agencies and perform an array of functions including data acquisition, command and control, computing, and communications for many types of ITS applications.

TMCs are integral to a variety of management and operations strategies discussed in the remainder of this report: traffic surveillance, traffic incident management, emergency management, electronic payment and pricing, traveler information, and information management. While some of these strategies can be implemented in a stand-alone manner, others cannot, and each is enhanced through participation in a TMC. Careful planning is needed to gain the best performance through participation in a TMC. For example, TMCs provide an opportunity for centralized collection of data collected by ITS; however, TMC performance requirements are necessary during archived data management systems development for the successful development of such a system (Bunch et al., 2011).

In the 2007 Deployment Tracking Survey 211 agencies responded to the TMC survey, while in 2010, 229 agencies responded. Of those agencies that replied 179 of them replied in both years. These responses are not as relevant for ITS deployment and focus on specific functionalities. The 50 unique TMCs that are identified as a component of the Freeway Management survey from years 2007 and 2010 are a more interesting data and are examined in detail. Of the 50 agencies, two indicated that they had a brand new TMC or had a new TMC coming soon. The new TMC was in Tucson, AZ run by the Arizona DOT. The coming soon TMC will be run by the Arkansas DOT. It is unclear whether the 32 unique responses in 2007 are for TMCs that are no longer operational, or more likely, they are TMCs that did not reply to the survey in 2010 or were absorbed into other TMCs.

5 Conclusions

As the results of the Volpe Transportation System Center Market Research provided in the background material has shown, ITS is at cross-roads with deployment of first generation ITS technologies “at a saturation point” for mature ITS applications, especially in the large metropolitan areas across the United States. Understanding the motivating factors for adopting a technology that supports multimodal operations and for continuing its use and increasing deployment is therefore critical for the continued evolution and deployment of the next generation of ITS and especially for moving to a connected vehicle and multi-modal information and coordinated operations system envisioned for the future.

The purpose of this task was to provide a foundation that captures the state of knowledge for motivating factors influencing ITS adoption, maintenance, and growth. This report highlights the issues and insights that could be drawn from the previous funded research and additional sources, and the questions, gaps, and needs that remain. This foundation, or benchmark of knowledge, will be used to help direct and focus the subsequent tasks of the Longitudinal Study of ITS Implementation.

The decision to continue to operate (expand, remain the same, contract, or cancel) is often much different than the initial one to adopt. An example is the decision of the Kansas State Legislature to scrap additional funding of the Wichita I-T-S system after an initial 6 traffic monitoring cameras had been installed in November 2009 due to the State’s budget crisis (Cerullo, 2009). In 2010 funding was restored through federal stimulus grants.

Another important consideration as we move to the next generation of ITS, and particularly to connected vehicles, deployment of an ITS technology or service will increasingly require concomitant decisions by several different stakeholders including the developers and manufacturers of a technology or service, public sector and private service deployers, and the consumers and users of a service. For example, transit information applications for mobile phones require both the development and implementation of the mobile application, and the use of mobile devices and purchase/installation of the application by the consumer. Another example is the Vehicle to Infrastructure safety application possible through the Connected Vehicle initiative. This application will require decisions by the auto manufactures to develop and install the in-vehicle equipment, the public sector to provide roadside equipment, and the owners/drivers of the vehicles to pay for the vehicles or purchase and install aftermarket equipment. These developments highlight the importance of a systems approach and systems thinking when evaluating new ITS systems and how they may be adopted and deployed. The traditional linear model of innovation to deployment spurred by research and development no longer holds. For today’s second, third, and next generation of ITS, innovation occurs in a far more complex environment with multiple actors, requiring coordination for adoption and a focus on intermediate as well as end users.

This analysis of the theory of innovation presents a number of implications for successful adoption and diffusion of new ITS technologies:

- Innovators/Early Adopters do not necessarily make good references or examples to convince the early majority to adopt a technology, because they are not considered “peers” by the majority of adopters.
- As the technology matures and is mainstreamed, the focus of the design should change from technology centered to consumer/needs centered products. ITS that may appeal to pioneers and large systems may not be attractive to (or needed by) smaller agencies.
- Peer networks and social systems along with their communication channels are very important when promoting imitator-driven innovation.

Research Gaps and Needs

This report has uncovered a number of findings related to identifying the decision factors for adoption and continued implementation of ITS technologies. Analysis of the decision models presented in this report when compared to the findings from the literature and background sources related to ITS implementation reveals the following major research gaps and needs that should be further explored in this study:

- The impact that the performance of the system has on downstream decisions to expand, maintain, or contract ITS implementations, whether measured or qualitatively assessed. For example, if an agency is willing to invest in system performance monitoring and evaluation, is there a greater likelihood that the system will be supported, maintained, and even expanded?
- The transferability of the decision factors from traditional ITS applications and technologies to a connected vehicle environment
- The importance of communication channels and implications for knowledge and technology transfer strategies
- Most of the research regarding decision factors focuses on the initial deployment decision and does not account for the future decisions that must be made regarding expansion, maintenance, or contraction of the system
- The influence that the *change* in the relevant decision factors has on the downstream decisions to expand, maintain, or contract their ITS implementations
- Little is known regarding the most important decision factors (and their relative priority) considered for a system replacement with a newer, next-generation technology
- The relative importance of the many decision factors is not well understood. It is also unknown how these factors might work together to influence ITS adoption and deployment.
- The impact of agency characteristics such as agency size and overall budget on the decision processes is not well-established.
- The extent of differences in the decision factors between the various ITS application areas and their corresponding organizations
- Gathering an understanding of the most important information needs of agencies to facilitate decision-making in the ITS marketplace

Next Steps

The findings of this research will be directly used in the development of survey instruments and questionnaires for task 3 interviews and the gaps and needs will be addressed to add to the body of knowledge. In addition, the deployment survey analysis has identified a potential list of agencies to follow up with as good candidates for the interview task, because they highlight recent decisions to deploy, expand, maintain, or contract their ITS implementations.

References

1. Amodei, Richard, Erin Bard, Bruce Brong, Frank Cahoon, Keith Jasper, Keith. “Atlanta NAVIGATOR Case Study.” Atlanta, Georgia. November 1, 1998a.
2. Amodei, Richard, Erin Bard, Bruce Brong, Frank Cahoon, Keith Jasper, Keith. “Atlanta Centennial Olympic Games and Paralympic Games, event study.” Atlanta, Georgia. November 1, 1998b.
3. ATRI. “Advancing Intermodal Cargo Information System Deployments Across Modes and Regions.” FHWA, USDOT. Washington, D.C. 2003.
4. ATRI. “An Analysis of the Operational Costs of Trucking: 2011 Update.” Arlington, VA. 2011a.
5. ATRI. “Benefit-Cost Analyses of Onboard Safety Systems.” FMCSA, USDOT. Washington, D.C. 2009. http://www.fmcsa.dot.gov/facts-research/research-technology/tech/09-023-TB-Onboard-Safety-Systems-508.pdf
6. ATRI. “Critical Issues in the Trucking Industry – 2011.” Arlington, VA. 2011b. http://atri-online.org/2011_top_industry_issues.pdf
7. ATRI. “Electronic On-Board Recorder Adoption in the Trucking Industry: Issues and Opportunities.” Arlington, VA. 2006a.
8. ATRI. “Incentives for Deployment of Onboard Safety Systems Final Report.” FMCSA, USDOT. Washington, D.C. 2007. http://www.fmcsa.dot.gov/facts-research/research-technology/report/Incentives-for-Deployment-of-OBSS-Final-dec07.pdf
9. ATRI. “In-Vehicle Technology Deployment Survey - Summary.” Arlington, VA. 2006b.
10. ATRI. “Freight Information Highway Assessment.” FHWA, USDOT. Washington, D.C. 2005.
11. Ball, William L. Merriweather Advisors. “Technical Project Memorandum for Longitudinal Study of Implementation.” Grosse Pointe Farms, Michigan. February 2012.
12. Banister, D., “Overcoming barriers to the implementation of sustainable transport”. In: Rietveld, P., Stough, R. (Eds.), Barriers to Sustainable Transport, Institutions, Regulation and Sustainability. London: Spon Press,pp. 54-68. 2004.
13. Bass, Frank M. “A New Product Growth Model for Consumer Durables.” Management Science 15 (5): 215–227. 1969.
14. Bass, Frank M. Website, “The Bass Model Home Page.” 2012. http://www.bassbasement.org/BassModel/, Last accessed March 28, 2012
15. Battelle. “Final Evaluation Report - Evaluation of the MAYDAY/9-1-1 Field Operational Test.” Minnesota. July 2006.

16. Battelle. "Evaluation Methods and Lessons Learned from the Minnesota Department of Transportation Intelligent Vehicle Initiative Field Operational Test." Minnesota. September 26, 2003.
17. Battelle and ATRI. "Factors in Decisions to Make, Purchase and Use Onboard Safety Technologies." FMCSA, USDOT. Washington, D.C. (2005)
18. Belella, Paul, Dave Millar, Sameer Sharm. "Intelligent Transportation Systems Field Operational Test Cross-Cutting Study: Commercial Vehicle Operations – Roadside." November 1998.
19. Bolcza, Richard. "Metropolitan MDI Workshop Wisdom: Project Organization and Outreach." NY-NJ-Connecticut, Phoenix, San Antonio and Seattle. March 1999.
20. Booz Allen Hamilton "Integrated Corridor Traffic Management Final Evaluation Report." Minnesota DOT. April 1, 2000.
21. Booz Allen Hamilton. "Intelligent Transportation Systems Field Operational Test Cross-Cutting Study: Commercial Vehicle Administrative Processes." 1998.
22. Brown, V.J., M.S. Anderson, P.J. Balducci, J.E. Orban, M.A. Kiefer, A. Desautels. "Evaluation of the National CVISN Deployment Program: Volume 1 Final Report." March 2, 2009.
23. Bunch, James, Carolina Burnier, Elizabeth Greer, Greg Hatcher, Amy Jacobi, Firoz Kabir, Cheryl Lowrance, Mike Mercer, and Kathryn Wochinger. "Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned Desk Reference: 2011 Update" Noblis Inc. Sponsored by ITS-Joint Program Office, Research and Innovative Technology Administration, U.S. DOT. 2011. http://www.benefitcost.its.dot.gov/its/benecost.nsf/files/BCLLDepl2011Update/$File/Ben_Cost_Less_Depl_2011%20Update.pdf
24. Carter M. C. Cluett , A. DeBlasio , F. Dion , B. Hicks , J. Lappin , D. Novak , H. Rakha , J. Riley, C. St-Onge , M. Van Aerde. "Metropolitan Model Deployment Initiative San Antonio Evaluation Report." Phoenix, Arizona. May 1, 2000.
25. Cerullo, Jared, "Intelligent Transportation System Hits Roadblock." Kakeland, November 23, 2009. http://www.kake.com/news/headlines/70679812.html.
26. Christensen, Clayton. M. "The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail." Boston, Massachusetts, USA: Harvard Business School Press. 1997. http://books.google.com/books/about/?id=SIexi_qgq2gC .
27. Davis, Fred D. "Perceived usefulness, perceived ease of use, and user acceptance of information technology", MIS Quarterly 13(3): 319–340. 1989.
28. DeBlasio, Allan J., David Jackson, Anne C. Tallon, Gerald M. Powers, John P. O'Donnell. "Successful Approaches to Deploying a Metropolitan Intelligent Transportation System." Phoenix; Seattle; San Antonio; NY-NY-Connecticut. March 1999.
29. Dickens, Matthew. John Neff. "2011 Public Transportation Fact Book 62nd Edition." American Public Transportation Association. Washington DC. April 2011.
30. Falcocchio. "Advanced Traveler Information System ATIS Implementation and Integration: Task 11." May 2007

31. FHWA. "The Electronic Freight Management (EFM) Initiative." USDOT. Washington, D.C. 2006. http://ops.fhwa.dot.gov/freight/intermodal/efmi/electronic.pdf
32. FHWA. "511 Traveler Information Telephone Number Program Support Assistance Program; Request for Applications." Federal Register Volume 66, Number 141. Pages 38335-38338. Monday July 23, 2001.
33. FHWA. "511 Travel Information Telephone Services." http://www.ops.fhwa.dot.gov/511 August 2011.
34. Floor Management Network. "Gartner's Hype Cycle." Floor|eTrends. 2012. http://www.floor.nl/ebiz/gartnershypecycle.htm. Last accessed on April 2, 2012.
35. Foxon, Timothy J. "Inducing Innovation for a Low-carbon Future: Drivers, Barriers and Policies." London: The Carbon Trust. 2003.
36. Frost & Sullivan. "All Signs Point Toward Mobility Integration - But Who Will Lead?" Frost & Sullivan Market Insight 2011.
37. GAO. "Intelligent Transportation Systems: Improved DOT Collaboration and Communication Could Enhance the Use of Technology to Manage Congestion," U.S. Government Accountability Office, Report No. GAO-12-308, Washington, DC: March 2012.
38. Gartner Research Inc. "Hype Cycle Research Methodology | Gartner Inc." http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp, Last accessed on April 2, 2012.
39. Glazer, Lawrence J., Roberto Cruz. Iteris. "Intelligent Transportation Systems at the 2002 Salt Lake City Olympic Games: Traffic Management and Traveler Information Case Study." Salt Lake City, Utah. April 1, 2003.
40. Glazer, Lawrence Jesse, Roberto Cruz. Iteris, Inc. "Intelligent Transportation Systems at the 2002 Salt Lake City Olympic Games: Traffic Management and Traveler Information Event Study." Salt Lake City, Utah. April 29, 2003.
41. Gordon, Steve, Jeff Trombly "Deployment of ITS: A Summary Of The 2010 National Survey Results." FHWA, ITS-JPO. 2011.
42. Greer, Elizabeth, Cassandra Allwell, Charlotte Burger, Larry Raskin. "ITS Professional Capacity Building Program: Setting Strategic Direction 2010-2104" U.S. Department of Transportation, ITS Joint Program Office, March 2011
43. Grubb, Michael. "Technology Innovation and Climate Change Policy: An Overview of Issues and Options." Keio Economic Studies 41 (2): 103. 2004.
44. Haas, Robert, Mark Carter, Eric Perry, Jeff Trombly, Elisabeth Bedsole, Rich Margiotta. "iFlorida Model Deployment Final Evaluation Report." Florida. January 2009.
45. Hagemann, Garrett, Jennifer Michaels, Paul Minnice, David Pace, Sari Radin, Arlen Spiro, and Rachel West. "ITS Technology Adoption and Observed Market Trends from ITS Deployment Tracking." U.S. Department of Transportation, Research and Innovative Technology Administration, Volpe Center National Transportation Center. October 2010.
46. Halsnæs, K., P. Shukla, D. Ahuja, G. Akumu, R. Beale, J. Edmonds, C. Gollier, A. Grübler, M. Ha Duong, A. Markandya, M. McFarland, E. Nikitina, T. Sugiyama, A. Villavicencio, J. Zou,. 2007. "Chapter: 2: Framing Issues. In Climate Change 2007: Mitigation." In Contribution of

Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, United Kingdom: Cambridge University Press. 2007.

47. Hanowski, Richard J., Gene Bergoffen, Jeffrey S. Hickman, Feng Guo, Dan Murray, Richard Bishop, Steve Johnson, Matthew Camden. Mainway Services. "Research on the Safety Impacts of Speed Limiter Device Installation on Commercial Motor Vehicles: Phase II Final Report." FMCSA, USDOT. Washington, D.C. 2012. http://www.fmcsa.dot.gov/facts-research/research-technology/report/Speed-Limiters.pdf
48. Hill, Christopher J. Ph.D., J. Kyle Garrett. Mixion Hill, Inc. "AASHTO Connected Vehicle Infrastructure Deployment Analysis" June 2011.
49. Inman, V. W., J. I. Peters. "TravTek Global Evaluation and Executive Summary." Orlando, Florida. March 1, 1996.
50. Inman, V. W., R N. Fleischman, R. R. Sanchez, C. L. Porter, L. A. Thelen, G. Golembiewski "TravTek Evaluation Rental and Local User Study." Orlando, Florida. March 1, 1996
51. Inman, V. W., R. Sanchez, C. Porter, L. Bernstein. "TravTek Evaluation Yoked Driver Study." Orlando, Florida. October 1, 1995.
52. Inman, V. W., R. Sanchez, L. Bernstein, C. Porter. "TravTek Evaluation Orlando Test Network Study. Orlando, Florida. September 1, 1996.
53. Inman, V. W., R. Sanchez, L. Bernstein, C. Porter. "TravTek Evaluation." Orlando, Florida. September 1, 1996.
54. InnoSuTra. "Innovation Processes in Surface Transportation, Final Reports" (PIR, WP2.2, D3, D4 and D5, D6, D7, and D8). Innovation Support Transfer Consortium (European Commission sponsored study), January 2012.
55. Interagency Working Group for Public Transportation. "Annual Report to the Idaho State Legislature 2005." 2005.
56. Jensen M., Christopher Cluett, Karl Wunderlich, Alan Deblasio, R. Sanchez. "Metropolitan Model Deployment Initiative Seattle Evaluation Report Final Draft." Seattle. May 30, 2000.
57. Kane, Matt, Alison Wallingford. "Freight Transportation: Improving Travel Time and Efficiency for Trucks and Intermodal Freight, Smart Investments in Transportation for Minnesota." November 2009.
58. Kohler, Jonathan, Chiara Frencia, Daniela Carvalho, Joao Vieira, Joao Bernardino. "Market-Up, Innovation Theory and Trends in R&D Initiatives in Transport - Deliverable 1.1." Funded by the European Commission under the 7th FP. 2011.
59. Kohler, Jonathan, Chiara Frencia, Daniela Carvalho, Joao Vieira. "Market Uptake of Transport Research: Transport's Innovation System and Trends Towards Climate Friendly Mobility in Europe." Belgrade, Serbia. 2011.
60. Lappin, James, Sari Radin, David Jackson, Anne Tallon, Allan J. DeBlasio, John O'Donnell, Jeffrey W. Trombly, Ph.D., Claire Barrett, David Connell, Lyn Pozzi. "Marketing ITS Infrastructure in the Public Interest." John A. Volpe National Transportation Systems Center. Cambridge, MA May 1998.
61. Miller, Sheryl., Jennifer Rephlo, Christopher Armstrong, Keith Jasper, Gary Golembiewski "National Evaluation Of The Safetrip-21 Initiative: Combined Final Report California

Connected Traveler (CACT).” Test Bed (San Francisco Bay Area); I-95 Corridor Test Bed (I-95 Corridor from North Carolina to New Jersey). March 31, 2011.

62. Minnesota DOT. “2009 ITS Annual Report.” Minnesota Department of Transportation Office of Traffic, Safety and Technology ITS Section, St. Paul, MN .2009a. Benefit ID: 2011-00690
63. Minnesota DOT. “2009 ITS Annual Report.” Minnesota Department of Transportation Office of Traffic, Safety and Technology ITS Section, St. Paul, MN .2009b. Benefit ID: 2011-00688
64. Minnesota DOT. The Office of Capital Programs and Performance Measures. “Annual Minnesota Transportation Performance Report 2010.” 2010.
65. Mlot, Stephanie. “CSX bridge clearance warning is doing its job.” Frederick News Post. April 2, 2011. http://www.fredericknewspost.com/sections/news/display.htm?storyid=119321 Last Accessed September 16, 2011. Benefit ID: 2011-00750
66. Monahan, Patricia, Carol Schweiger, and Tom Buffkin. “Evaluation of the Metropolitan Atlanta Rapid Transit Authority (MARTA) intelligent transportation system.” Atlanta, Georgia. July 1, 2000.
67. Moore, Geoffrey A. “Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers.” Harper Business. 2002.
68. NetMBA.com. “Product Life Cycle”. http://www.netmba.com/marketing/product/lifecycle/ .last accessed on April 2, 2012.
69. Norman, Donald A. “The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution First ed.” The MIT Press. 1998b.
70. Norman, Donald A. “The Life Cycle of a Technology.” 1998a http://www.nngroup.com/reports/life_cycle_of_tech.html
71. O’Leary, Daniel E. “The Impact of Gartner’s Maturity Curve, Adoption Curve, Strategic Technologies on Information Systems Research, with Applications to Artificial Intelligence, ERP,BPM, and RFID.” Journal of Emerging Technologies in Accounting 6. 45–66. 2009.
72. OnStar. “OnStar testimony to U. S. House of Representatives subcommittee.” May 2008.
73. Orr, Greg. “Review of Diffusion of Innovations.” 2003. http://www.stanford.edu/class/symbsys205/Diffusion%20of%20Innovations.htm
74. Pace, David, Rachel West, Garrett Hagemann, Paul Minnice, Arlen Spiro, Sari Radin. “An Analysis of the Factors Influencing ITS Technology Adoption and Deployment” FHWA-JPO-12-002. Cambridge, Massachusetts: U.S Department of Transportation Research and Innovative Technology Administration, Volpe National Transportation Center. 2011.
75. Perez, William A., Mark R. Carter. “Metropolitan Model Deployment Initiative: National Evaluation.” Phoenix, San Antonio and Seattle. 2000.
76. Peyrebrune , Henry, Allison L. C. de Cerreno. “Security Applications of Intelligent Transportation Systems.” NYU Wagner Rudin Center for Transportation Policy and Management. July 2002.
77. Peyrebrune , Henry, Allison L. C. de Cerreno. “The Context for Intelligent Transportation Systems in New York State.” NYU Wagner Rudin Center for Transportation Policy and Management. July 2002.

78. Pitale, Jaswandi T., Craig Shankwitz, Howard Preston, Michael Barry. “Benefit/Cost Analysis of In-Vehicle Technologies and Infrastructure Modifications as a Means to Prevent Crashes Along Curves and Shoulders.” Prepared by the University of Minnesota for the Minnesota DOT. St. Paul, MN. December 2009. Benefit ID: 2011-00728

79. Qi, Yi, Xin Chen, Lane Yang, Bin Wang, Lei Yu. “Vehicle infrastructure integration (VII) based road-condition warning system for highway collision prevention.” Prepared by Texas Southern University for Texas A&M University. College Station, TX. May 27, 2009. Benefit ID: 2011-00729

80. Rodrigue, Jean-Paul, Claude Comtois, and Brian Slack. “The Geography of Transport Systems (Paperback). New York: Routledge.” 2009. http://www.routledge.com/books/details/9780415483247/

81. Rogers, Everett M., Diffusion of Innovations, 5th Edition. Free Press. 1995.

82. SAIC. “Deploying and operating integrated ITS; twenty questions and answers: guidance from the Evaluation of the MMDI sites.” Phoenix; Seattle; San Antonio; NY-NY-Connecticut. December 2001.

83. Sciara, Gian-Claudia, Planners and the Pork Barrel: Metropolitan Engagement in and Resistance to Congressional Transportation Earmarking, Dissertation, University of California, Berkeley: ProQuest/UMI, 2009.

84. Skarpness, Bradley, Ph.D., Fred Kitchener, Ed Boselly, Amy Thomas. “Final Report of the FORETELL Consortium Operational Test: Weather Information for Surface Transportation.” Iowa, Wisconsin, Missouri, Minnesota, Illinois. April 1, 2003.

85. Sorensen, Jon. “2012 Forecast for Emerging and Next-Generation Intelligent Transportation Systems.” Terranautix. December 2011. http://terranautix.com/2011/12/20/2012-forecast-for-next-generation-intelligent-transportation-systems/

86. The Crescent Evaluation Team. WHM Transportation Engineering Consultants, Inc., Castle Rock Consultants, Western Highway Institute / ATA Foundation. “The Crescent Project: An Evaluation of an Element of the HELP Program.” Washington, Oregon, California, Arizona, New Mexico, Texas; British Columbia, Canada. February 1994.

87. U.S. DOT Federal Highway Administration. “2010 ITS Deployment Tracking National Survey: Summary Report - Freeway Management.” February 10, 2011.

88. U.S. DOT Federal Transit Administration. "National Transit Database," http://www.ntdprogram.gov/ntdprogram/data.htm. Last Accessed July 11, 2011.

89. U.S. DOT Inspector General. “Review of Congressional Earmarks with Department of Transportation Programs,” USDOT Inspector General, Report Number AV-2007-066, September 7, 2007. http://www.oig.dot.gov/library-item/4256

90. U.S. DOT ITS-JPO . ITS Knowledge Resources databases, 2012b. www.itsknowledgeresources.its.dot.gov Last Accessed: April 12, 2012.

91. U.S. DOT ITS-JPO. Connected Vehicle Program. 2012a. http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm, Last Accessed: April 12, 2012.

92. U.S. DOT NHTSA. “National Highway traffic Safety Administration (NHTSA) Traffic Safety Facts 2009 Data: Pedestrians, 2011.” http://www-nrd.nhtsa.dot.gov/Pubs/811394.pdf. Last accessed July 27, 2011a.
93. U.S. DOT NHTSA. “National Highway traffic Safety Administration (NHTSA) Traffic Safety Facts 2009 Data; Bicyclists and other cyclists.” 2011. http://www-nrd.nhtsa.dot.gov/Pubs/811386.pdf. Last accessed July 27, 2011b.
94. U.S. DOT Volpe National Transportation Systems Center. “ORANGES Electronic Payment Systems Field Operational Test Evaluation: Final Report.” Orlando, Florida. December 6, 2004.
95. Van der Bergh, J.C.J.M., van Leuwen, E.S., Oosterhuis, F.H., Rietweld, P., and Verhoef, E.T. “Social learning by doing in sustainable transport innovations: Ex-post analysis of common factors behind successes and failures”. Research Policy 36 pp. 247-259. 2007.
96. Virginia DOT. “Virginia Department of Transportation Dashboard Performance Reporting Systems for Projects and Programs.” 2012. http://dashboard.virginiadot.org/default.aspx
97. Washington State DOT. “Report on the Transportation Innovative Partnership Program.” Washington State Transportation Commission. January 2007.
98. Washington State DOT. “SR 99 Alaskan Way Viaduct Replacement Updated Cost and Tolling Summary Report to the Washington State Legislature.” January 2010.
99. Washington State DOT. “The Gray Notebook 43 Lite.” Washington State Department of Transportation. November 2011a.
100. Washington State DOT. “The Gray Notebook 43.” Washington State Department of Transportation. November 2011b.
101. Washington State DOT. “Washington State Commute Trip Reduction (CTR) 2005.” CTR Task Force Report to the Washington State Legislature. 2005.
102. Wetherby, Bruce, Ph. D. “SWIFT: Seattle Wide-area Information for Travelers: Institutional Issues Study.” Seattle, Washington. October 19, 1998.
103. Youngbin Yim, Mark A. Miller. “Evaluation of TravInfoTM Field Operational Test.” San Francisco April 25, 2000.
104. Zimmerman, C., J. Marks, J. Jenq. “Phoenix Metropolitan Model Deployment Initiative Evaluation Report (Draft).” Phoenix, Arizona. April 1, 2000.
105. Zuylen and Weber. “Strategies for European innovation policy in the transport field, Technological Forecasting & Social Change”, p.929–951. 2002.

APPENDIX A. List of Acronyms

APC	Automatic Passenger Counter
ATIS	Advanced Traveler Information Systems
ATA	American Trucking Associations
ATM	Advanced Traffic Management
ATM	Automatic Teller Machine
ATMS	Advanced Traffic Management System
ATRI	American Transportation Research Institute
AVL	Automatic Vehicle Location
BCDLL	Benefits, Costs, Deployment and Lessons Learned
BPM	Business Process Management
CACT	California Connected Traveler
CAD	Computer Aided Dispatch
CCTV	Circuit Television
CVISN	Commercial Vehicle Information System and Network
CVO	Commercial Vehicle Operations
CVT	Connected Vehicle Technology
DMS	Dynamic Message Signs
DOI	Diffusion of Innovations
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DTA	Dynamic Traffic Assignment
DTV	Digital Television
EFM	Electronic Freight Management
EOBR	Electronic Onboard Recorder
ERP	Enterprise Resource Planning
ETC	Electronic Toll Collection
EMS	Emergency Medical Services
EVP	Emergency Vehicle Preemption
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GAO	Government Accountability Office
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Highway Advisory Radio

HDC	Highway Data Collection
HOS	Hours of Service
ICM	Integrated Corridor Management
IRC	Interregional Corridor
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MARTA	Metropolitan Atlanta Rapid Transit Authority
MDI	Model Deployment Initiative
MIS	Management Information System
MIT	Massachusetts Institute of Technology
MMDI	Metropolitan Model Deployment Initiative
MOE	Measures of Effectiveness
MPO	Metropolitan Planning Organization
MTA	Metropolitan Transportation Authority
NAV	In-vehicle Navigation
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of Proposed Rule Making
NYU	New York University
OEM	Original Equipment Manufacturer
OSS	Onboard Safety System
PCB	Professional Capacity Building
PDA	Personal Digital Assistant
R&D	Research and Development
RITA	Research and Innovative Technology Administration
RFID	Radio Frequency Identification
RFTP	Request for Task Proposal
RM	Ramp Meter
ROI	Return on Investment
RT	Real Time
SAIC	Science Applications International Corporation
SEPTA	Southeastern Pennsylvania Transportation Authority
SR	State Road
SWIFT	Seattle Wide-area Information for Travelers
TAM	Technology Acceptance Model
TMC	Transportation Management Center
TMS	Traffic Management System

TRB	Transportation Research Board
TRID	Transportation Research International Documentation
TSP	Traffic Signal Priority; Transit Signal Priority
URL	Uniform Resource Locator
USDOT	U.S. Department of Transportation
UTAUT	Unified Theory of Acceptance and Use of Technology
VDC	Vehicle Data Collection
VMS	Variable Message Sign
VMT	Vehicle Miles Traveled
WMATA	Washington Metropolitan Area Transit Authority

APPENDIX B. Listing of Reviewed State Reports

State Reports Review:

Annual Minnesota Transportation Performance Report 2010, The Office of Capital Programs and Performance Measures.

Annual Report to the Idaho State Legislature 2005, Interagency Working Group for Public Transportation.

Washington State Commute Trip Reduction (CTR) 2005, CTR Task Force Report to the Washington State Legislature.

Freight Transportation: Improving Travel Time and Efficiency for Trucks and Intermodal Freight, Smart Investments in Transportation for Minnesota, November 2009, Matt Kane and Alison Wallingford.

The Gray Notebook 43 Lite, Washington State Department of Transportation November 2011.

The Gray Notebook 43, Washington State Department of Transportation, November 2011.

Intelligent Transportation System Hits Roadblock", Jared Cerullo, News article (Kakeland, November 23, 2009) http://www.kake.com/news/headlines/70679812.html.

The Context for Intelligent Transportation Systems in New York State, NYU Wagner Rudin Center for Transportation Policy and Management, Henry Peyrebrune, Allison L. C. de Cerreno, July 2002.

Security Applications of Intelligent Transportation Systems NYU Wagner Rudin Center for Transportation Policy and Management, Henry Peyrebrune, Allison L. C. de Cerreno, July 2002.

SR 99 Alaskan Way Viaduct Replacement Updated Cost and Tolling Summary Report to the Washington State Legislature, January 2010.

Report on the Transportation Innovative Partnership Program, Washington State Transportation Commission, January 2007.

Virginia Department of Transportation Dashboard Performance Reporting Systems for Projects and Programs. http://dashboard.virginiadot.org/default.aspx 2012.

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free “Help Line” 866-367-7487
www.its.dot.gov

FHWA-JPO-12-043

U.S. Department of Transportation
Research and Innovative Technology Administration