U.S. DOT ITS Evaluation Workshop September 20, 2010

Summary

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14. ABSTRACT (Maximum 200 words)
This document presents a summary of the Intelligent Transportation Systems (ITS) Evaluation Workshop conducted on September 20, 2010 in Irvine, California. Sixty-four participants shared ideas and exchanged information on the evaluation of ITS research and deployments in the context of emerging technologies, and the need to support sustainability and livability. Participants also discussed ways of assessing ITS research initiatives as well as evaluating sustainability and livability goals. Among the ideas expressed in the workshop are the following:

- The emergence of technologies that enable continuous data collection requires changes in the way entities share and analyze data.
- Evaluation should be used as an iterative feedback mechanism aimed at improving projects on an ongoing basis.
- ITS is a valuable tool for reducing greenhouse gases.
- Maintenance and operations costs are elements that belong in the evaluation analysis.
- The ITS Knowledge Resources databases are valuable and the benefits databases should include high-level summaries of benefits.
- Legacy ITS projects and applications such as ramp metering still require evaluation.

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Executive Summary

The United States Department of Transportation (U.S. DOT) conducted a workshop on September 20, 2010 in Irvine, California for stakeholders to exchange information and explore ideas for advancing the practice of evaluation in Intelligent Transportation Systems (ITS). Addressing ITS evaluation is important at the current time because of the changing context for ITS research and deployment. Rapid developments in technology and the increasing urgency to deploy sustainable transportation solutions require a fresh look at evaluation tools and methods. For evaluation to continue to add increased value to ITS research and deployments, it is necessary that the evaluation process adapts to technological advances as well as develop meaningful measures of environmental outcomes. Thus, the workshop provided an opportunity for the transportation community to explore how evaluation can adapt to and integrate advanced technology to support national and local ITS projects and assess sustainability and livability.

This document describes the process of the workshop, summarizes the observations from the participants, and presents the next steps in the exchange of information between stakeholders.

Process and Observations

The workshop, organized by the Joint Program Office (JPO) in the Research and Innovative Technology Administration (RITA), was entitled "Emerging Needs and Opportunities in Intelligent Transportation Systems (ITS) Evaluation: Supporting New Directions in Research and Deployment." The topics addressed in the workshop included the impact of new technologies on evaluation, opportunities for knowledge and technology transfer to advance ITS solutions, and the tools and methods needed to evaluate connectivity. Connectivity, characterized by vehicle-to-vehicle and vehicle-to-infrastructure communications, is a potentially transformative concept in surface transportation, involving continuous data streams gathered from these deployments. These changes in technology and goals oblige us to re-consider the tools and techniques best suited to evaluate ITS research and deployments.

The heart of the workshop was a series of breakout sessions in which participants provided ideas and input on the evaluation needs of local and national ITS projects, and innovative methods in evaluation and the need for technology transfer. Other topics included the increasing role of data sharing among organizations and ways in which evaluation can support environmental goals.

The high attendance at the workshop and the active participation of the attendees during the breakout sessions suggest that there is a strong interest among stakeholders in ITS evaluation. Participants expressed the idea that advances in technology will create opportunities for ITS to improve and the potential to develop new ways of data collection and analysis. For example, increasing the number of real-time sensors will likely increase the value of surveillance in traffic management, if there is an effective means to integrate and evaluate the additional data into existing systems. Similarly, the deployment of on-board recording devices in research projects such as the Transportation Research Board's (TRB) Strategic Highway Research Program enables researchers to monitor driver behavior and performance over long periods of time and in the context of infrastructure and environmental conditions. The miniaturization of technology has already produced smaller-sized vehicle on-board

units and weather sensors, allowing agencies to install road weather monitors on urban arterials and collect data related to operations and maintenance. Innovative applications in social media have improved customer services by enabling public agencies to exchange information more easily and directly with the traveling public. These examples are just a few that illustrate how advances in technology produce opportunities for stakeholders to develop interesting, innovative and valuable ITS applications.

The participants cautioned that the advances in technology that enable opportunities also introduce challenges and require that the ITS community learn how to best exploit innovations. For example, the possibility of real-time continuous data collection supplied by connectivity introduces the need to employ advanced data analysis such as expert systems, artificial intelligence and data visualization. Participants also raised the need to resolve potential conflicts arising from data sharing between entities, questions of data propriety and ownership, and privacy rights. The participants provided valuable input on the potential impact of advances in technology on ITS evaluation tools and techniques, and ideas for solutions to data sharing and ownership.

In summary, the integral role of evaluation in advancing new ITS research and deployment requires the transportation community re-visit the practice of evaluation and explore ways of increasing its value to the transportation community. This workshop demonstrated that engaging in a dialogue among stakeholders supports efforts to strengthen the effectiveness and value of evaluation in ITS.

Chapter 1: Workshop Overview

The evaluation of Intelligent Transportation Systems (ITS) provides a critical function in ITS research and deployment activities. However, the emergence of new and innovative technologies in research and deployment has implications for the ways in which we conduct evaluations, as well as how we share evaluation tools, techniques, and results. Not only do advances in technology change the features and characteristics of transportation systems, they create the need and opportunity to advance evaluation methods. In addition, emerging research programs and sustainability goals also have implications on the methods and tools needed for the evaluation of ITS projects. For example, vehicle-to-vehicle and vehicle-to-infrastructure projects are likely to produce real-time, continuous data streams, raising the question of whether the current tools in ITS evaluation will allow us to analyze and interpret new data in meaningful, valid and actionable ways. These advances in technology and ITS research oblige us to re-consider the tools, techniques and processes of evaluation.

Workshop Purpose

The purpose of the workshop was to initiate a dialogue among ITS stakeholders on a new direction and next generation of ITS evaluation. The U.S. Department of Transportation (DOT) ITS Strategic Plan for 2010 – 2014 set the stage for the workshop, as well as the increasingly urgency for public and private organizations including federal, state and local DOTs to develop sustainable transportation solutions. This changing arena suggests that now is a good time for stakeholders to explore how best to move ITS evaluation forward. The purpose, objectives, and expected outcomes of the workshop, outlined in the public announcement, were as follows:

Purpose

- To explore the next generation of evaluation in ITS
- To discuss the impact of emerging trends in ITS technologies and shifting transportation priorities on ITS evaluation
- To explore ideas for measuring and evaluating livability and environment-related goals
- To exchange knowledge and ideas between the JPO and the transportation community on how ITS evaluation can best support state and local ITS projects and the ITS Strategic Research Plan

Objectives

- To identify evaluation needs at the local, state and federal levels
- To obtain thoughts on developing and applying innovations in evaluation
- To list ideas and document feedback from participants on the ITS evaluation program

Expected Outcomes

- To gain stakeholder feedback and Stakeholder thoughts on priorities in evaluation
- To get feedback on the ITS Evaluation Program

Participants

One of the goals of the workshop was to get feedback from a well-balanced cross-section of stakeholders from state and local agencies. Thus, the workshop team undertook activities to ensure that a diverse group would attend. Final registration for the workshop surpassed the anticipated capacity, with a total registration of sixty-four (64) participants (not including the three U.S. DOT ITS JPO staff and four Noblis staff that supported the workshop). See Appendix B for the list of participants. As shown below, the audience was a diverse group and included:

- 24 private sector consultants or ITS system providers/integrators
- 13 state department of transportation representatives
- 11 researchers from research or academic institutions
- 8 local agency staff (Metropolitan Planning Organization, transit, city or other organization)
- 5 representatives from other Federal agencies or departments including the Federal Railroad Administration
- 3 representatives from other institutions (Transport Canada, ITE, and TRB)

Breakout Sessions

There were two main breakout sessions, one in the morning and one in the afternoon. Each session had a theme and focus questions for the participants to discuss. The tables below list the themes and focus questions for the morning and afternoon sessions. To facilitate personal interactions and face-to-face discussion in the breakout sessions, the participants broke into smaller groups.

In the opening session of the workshop, the JPO Evaluation Team provided background information on the 2010-1014 ITS Strategic Plan and the ITS Evaluation Program. James Pol, ITS JPO Team Leader of Program Management and Evaluation, delivered a presentation on "The Role of Evaluation in the ITS Strategic Plan 2010-2014." Marcia Pincus, ITS JPO Program Manager, provided the charge to participants and set up the context and purpose of the breakout sessions. Ms. Pincus emphasized that, although the workshop would address the ITS research program and its emerging evaluation needs, the broader objective was to gain the perspectives of stakeholders on local and state needs for evaluation as well as ideas for evaluation.

The theme for the morning session was "Key Innovations and Opportunities in ITS Research and Deployment Evaluations." There were four focus questions for this session, so participants broke into four groups of approximately 15 people. There was one facilitator for each question. The facilitator interacted with the group and recorded comments on flip charts. Each group addressed a question for about 25-30 minutes, and then moved on to discuss the next question. This allowed each participant the opportunity to address each question.

The theme for the afternoon session was "New Goals and Priorities in ITS Research and Deployment Evaluations" and consisted of two focus questions. James Pol facilitated the discussion for the first question and Marcia Pincus facilitated the discussion for the second question. The participants split into two groups and each group addressed both questions.

Table 1-1. Session on "Key Innovations and Opportunities in ITS Research and Deployment Evaluations."

Morning Session Focus Questions	Contributions
1. How do we make effective and innovative use of new technologies, new techniques, and new results? 2. How can we best and most creatively evaluate new JPO initiatives? 3. What innovations are you aware of that can be applied, or that have potential, for evaluation? 4. How do we effectively identify technology transfer opportunities?	Most important innovative approaches and opportunities Thoughts for obtaining and sharing these innovative evaluation techniques and results Thoughts and considerations for the ITS Evaluation Program Thoughts for Knowledge Sharing and Training Identification of exemplary practices

Table 1-2. Session on "New Goals and Priorities in ITS Research and Deployment Evaluations."

Afternoon Session Focus Questions	Contributions
1. How do we obtain and best share meaningful evaluation techniques and results? 2. How do we measure and evaluate livability and environment-related goals?	Most important new goals and priorities Specific needs and approaches for addressing these new goals and priorities Thoughts for evaluating livability and environment-related goals Thoughts and considerations for the ITS Evaluation Program Thoughts for Knowledge Sharing and Training

Chapter 2: Synthesis of Discussions in the Breakout Sessions

This chapter summarizes the discussions that took place in the breakout sessions on each focus question. The discussion summary immediately follows each of the six questions addressed by the participants. The headings for the discussions for each question represent similar or overlapping themes and related points expressed by the participants.

How do we make effective and innovative use of new technologies, new techniques, and new results?

In response to the question posed to them, the participants in turn raised questions about the meaning of "new" and noted that what is new to some may be familiar to others. The adaption of new technology varies across not only the traveling public but also within the ITS transportation community. Early adopters of technology will be further along the technology lifecycle (also known as the "S curve") than most. Even proven technologies can take long periods to reach wide scale deployment. With that in mind, participants offered the following key observations on the question of innovative technologies in evaluation.

Data from mobile devices

The fact that mobile devices have saturated the market provides opportunities for public agencies to use new sources of information. The Wyoming ECAR program is an example of an innovative approach to gathering data from mobile devices. In Wyoming ECAR, the winter road conditions are citizen reported. The program encourages individual citizens to report their information. This program illustrates the potential for engaging the public in providing information to public agencies.

Data from private vendors

In the traditional way of gathering transportation data, public agencies collect data on a regular schedule at specific times and locations (point data). Data are limited but well understood. However, agencies are now starting to use continuously collected data (i.e., 365 days, 24/7) obtained and sold by private vendors. The new approach to data gathering has led to cost savings (up to a seven times reduction), but also raises new questions and requirements. Agencies must assess the reliability and accuracy of the data, understand the data format and interface with the vendor, and resolve legal and policy related issues involving data ownership and proprietary techniques and formats. In addition, there can be limits to the use of data obtained from the private sector. For example, the state of Michigan is collecting data from OnStar, Ford, and Chrysler, but the agreements restricts how the state can use and share the data, and requires that the state delete the data at the end of the project.

Participants also questioned how to compare measures of effectiveness across locations under continuous measurement.

Open data and open standards

The availability of privately owned, continuously collected data has the potential to improve evaluations but is likely to increase the complexity of conducting evaluations. This issue calls for the development of data standards for data definitions, means of collection, and format. The participants highlighted the need for open data and open standards. (The domain of transit provides an example of a model in which agencies and vendors provide data in open data formats. Subsequently, agencies and entrepreneurs are developing transit applications in new and unexpected ways.)

Impact on federal regulations

Innovative technologies may force changes and updates in federal regulations. For example, requirements for the federal evaluation processes used by the U.S. Environmental Protection Agency (EPA) and the Federal Transit Agency (FTA) do not appear to be up-to-date with changes introduced by innovative technologies. Further, litigation may limit the use of some of the new technologies.

Real-time monitors

The participants identified "24/7" real-time monitoring as a major factor in evaluation. The key to their usefulness is to deploy a robust network of real-time monitors. Although the monitors provide greater coverage compared to previous methods, it is not clear how much detail they can provide or how useful the measures they collect will be. For example, one private vendor does not provide speed data that is above the speed limit. In addition, much work is required to translate continuous data streams into performance measures and actionable information for operations and evaluation. Further, agencies will have to integrate the new sources of data into legacy systems. (Other innovative techniques such as mob and crowd sourcing provide innovative approaches for data collection but also require validation before they can provide useful information.)

Video and data streaming provide new capabilities and allow for different types of evaluation. For example, one participant has used video for post-incident analysis of field operational responses to incidents and for providing feedback to field staff. However, legal concerns prevent the agency from saving video recordings on a regular basis, requiring personnel to monitor video for incidents and put forward a request to save the recording when an incident occurs.

Participants noted that another transformational change is the ability to provide feedback in real-time (from real-time monitors) to users of the transportation system, and influence traveler behavior. This interaction adds a complicating dynamic to the transportation system, affecting how best to conduct before/after evaluations.

Learn from others

Participants noted that it is worthwhile for the ITS evaluation community to review how other organizations conduct evaluations, including the following.

- What can we learn from Google? Google collects huge quantities of data from the Internet and has a working culture based around collecting and transforming data into knowledge.

(Participants recommended contacting Google and/or Microsoft directly to inquire about their evaluation techniques and approaches.)
- DARPA has a process for evaluating and tracking new technologies.
- ECAR in Wyoming uses the web and public input to provide status information on their road network and incident conditions.
- ONE-ITS is a non-profit corporation in Canada that is developing web services to provide data interfaces and standardization.

How can we best and most creatively evaluate new JPO initiatives?

The facilitator framed this question in terms of meeting the major transportation goals of safety, mobility and environment as presented in the ITS Strategic Research Plan. This question led to related ones, including:
- How does the evaluation program take advantage of the availability of real-time data on a continuous, 24-hour, 7-day a week basis ("24/7")?
- What, if any, are the acceptable tradeoffs between safety, mobility and environmental goals, and how do we decide what the tradeoffs should be?

The participants contributed the following ideas and general feedback.

Include negative as well as positive results

The participants noted that the evaluation of JPO initiatives must include both the negative and positive impacts and results. It is just as important for evaluation results to reveal what has not worked as well as what has worked in order to pursue promising research and deployments.

Operations and maintenance are important criteria in evaluations

The participants expressed the idea that operations and maintenance is an important area that should be included in evaluation efforts on a continuous basis. Evaluating the operations and maintenance of ITS projects over time distinguishes between the technologies and techniques that continue to provide benefits from those that have reached the end of their useful life.

Tools with potential for evaluation

Participants identified creative tools with which to evaluate JPO research, such as models that use "second life simulation" and "virtual world mockups" of vehicular and infrastructure connectivity under development at the University of Maryland.

Traditional ITS technologies and applications still require evaluation

Many participants expressed the concern that, even as we work toward developing new technologies, we must continue to evaluate the large amount of existing "traditional" ITS technologies maintained and deployed across the country. The evaluation program should continue to support traditional deployments, even as it works to evaluate new research areas and technologies.

Engage the public

Several participants indicated the importance of engaging the public and evaluating how travelers behave over time. They stressed the importance of measuring customer satisfaction and documenting how driver behavior and customer satisfaction are important factors in determining overall system benefits.

What innovations are you aware of that can be applied, or have potential to be applied, for evaluation?

The participants discussed innovations for exchanging information with the public, as well as for conducting ITS evaluations. For example, participants identified innovations in traffic management, surveillance, data collection and analysis, and associated issues requiring exploration and clarification for these innovative methods and tools to become useful. The participants discussed the following specific topics in response to this question.

Mobile devices as a tool for traveler input ("an electronic diary")

Mobile devices enable new ways of collecting traveler experiences and input in real-time, as they occur. Mobile devices have potential advantages over traditional means of gathering customer data such as telephone surveys, questionnaires or focus groups by collecting data in real-time (or nearly real-time), and over periods of time. An additional application of mobile devices is for travelers to inform agencies of incidents and road conditions.

Internet and social media as tools for outreach

Agencies are currently using the Internet as a means to obtain feedback from the traveling public. For example, Minnesota DOT developed a website dedicated to collecting input from the public on projects for specific corridors. This on-line community of travelers, selected by a market research group, provides feedback on specific projects over time. This approach is a cost-saving way to receive input from the public compared to traditional surveys (mail-based, telephone) and enables tracking of individuals or groups for the duration of a project. Several state DOTs use Facebook for outreach, but participants were not certain whether Facebook is used to get feedback from the public, as much as to provide information to the public. Indeed, the U.S. DOT Secretary actively uses Facebook, Twitter and a weblog to communicate with the public.

A participant described the application of crowd sourcing, which helped incident investigators identify the location of an explosion on a bridge. Analyzing twitter and cell phone entries made by travelers on or near the bridge helped investigators locate the source of the explosion. Currently, human operators monitor these sources. However, the participant noted that to take full advantage of these new sources of data, as well as continuously streaming data from monitors, requires artificial intelligence and neural networking applications.

Technological advances are making environmental sensors smaller

The miniaturization of weather sensors is an example of a technological advance that supports traffic operations and maintenance by improving road weather management. As road weather stations

become smaller, it is easier to install them in urban areas and on arterials. These weather sensors will provide a rich and continuous source of information on road conditions and performance. Improving road weather forecasting should enhance personal trip decision-making, maintenance planning (for example, New York State has equipped state DOT maintenance trucks with weather sensors), and operations planning.

The challenges of tapping into a continuous stream of traffic-related data

The increasing availability of real-time data that is continuously collected introduces many possibilities but also raises many questions and concerns. For example, specifically how will we use vehicle performance data and connectivity data produced by SHRP2? The sheer volume of data is enormous, challenging us to devise innovative ways to make use of it. Several participants noted that there are lessons learned on organizing and using large volumes of data from other organizations with experience in this regard, such as the Federal Aviation Administration.

Other Innovations

- Mobile sensors can supplement fixed sensors and turn vehicles into probes. These technologies include Global Positioning System (GPS), Automatic Vehicle Location (AVL), environmental condition sensors for air temperature, and humidity levels.
- Roadside sensors at 5.9 GHz provide status and data. However, a framework to establish and guide how evaluators can make use of data from these sources would be desirable. .
- Kiosks: In Tyson's Mall in Virginia, Virginia DOT (VDOT) operates kiosks that present traffic information to shoppers. The data used to compute the traffic information comes from vehicle probe data.

Challenges associated with innovations

- Technological advances may require institutions to collaborate more closely in terms of sharing data and applying solutions. The issue raises the question of how to integrate data and systems from different agencies, including county, state, private and public. Sharing data can benefit many entities. For example, it is of benefit to many to have interoperable cameras.
- Connectivity will produce volumes of data in real-time, introducing the need for new approaches to data processing and analysis. A participant suggested that analyzing the streams of continuous data will require artificial intelligence, automation and expert systems that use algorithms to process, compile and convert data into actionable . An example of this type of application is to use automated systems for adjusting traffic signals in response to incoming real-time data.
- Different transportation stakeholders have differing information and presentation needs. To improve our understanding of these needs, participants stated that a study to explore various visualization tools would be useful. For example, the amount of detail and the kinds of information desired by the public is different from that of transportation engineers, planners and analysts. In addition, as the volume of data increases, it may become useful to re-consider the best ways to present information according to user needs.

How do we effectively identify technology transfer opportunities?

The discussions surrounding this question revealed that the participants held the opinion that the issue of knowledge transfer is just as important as that of technology transfer, since knowledge underlies the ability to apply technology effectively. To obtain knowledge and technology transfer, the participants recommended leveraging the private sector and public/private partnerships. Several participants highlighted the need for the transportation community in general and the public sector in particular to make better use of the knowledge and expertise of the private sector. There are different kinds of end users of technology transfer, suggesting that it is valuable to present information differently, according to the needs of the end users. Decision makers must also be included, and we must be sensitive to their information needs.

Incentivize innovations

The participants emphasized the need to incentivize innovations in evaluation and technology transfer, but cautioned that innovation entails risk, requiring a balance between risk and innovation. There is also a need to determine effective means of sharing state and local experiences with ITS deployments. Crosscutting studies that examine and compare ITS projects across different jurisdictions would help illuminate local experiences. The participants emphasized that there is a need for updated guidelines on how to conduct ITS evaluations. In fact, it would be valuable to have standard guidelines. The fact that there are a variety of different metrics and computational methods renders it difficult to compare results and anticipate likely outcomes of projects.

Exploit existing knowledge and technology sharing methods

The participants identified several ways of sharing knowledge and technologies that take advantage of existing communication methods, including the following:

- State chapters of ITS America provide a ready means and opportunity to exchange knowledge about technologies and methodologies.
- American Association of State Highways and Transportation Officials (AASHTO) and Institute of Transportation Engineers (ITE), as national transportation associations, provide good venues to share information.
- Exploit conferences, workshops, and other peer exchange mechanisms.
- Give credit to professionals for going to conferences and sharing their knowledge and results; this activity must be validated as an important job function.
- Facilitate the use of list servers among communities of practice. List servers exist now but are under-utilized in some cases, simply because people are not aware of them. For example, the International Benefits, Evaluation and Costs Working Group (IBEC) list serve is a mechanism for sharing ITS evaluation information. A portal could link transportation professionals to a variety of list servers.
- Use learning technologies (e.g., Internet-based tools, you-tube videos). However, participants noted that there is no substitute for face-to-face exchange of information and actual observation.
- Use existing channels such as the Federal Highway Administration's local technical assistance programs (LTAPS), even if they have not been traditionally used for ITS.

Suggestions for improving the effectiveness of knowledge and technology sharing

- Develop a one-stop shop for technology transfer and education. Having too many disparate sites involved with technology transfer risks a piecemeal transfer of knowledge.
- Address whether other natural mechanisms for technology transfer are sufficient to do the job (for example, ITE, AASHTO, ITS America, and FHWA's LTAPS).
- Share interim results, as opposed to waiting for the final report before distributing information.
- To be effective, technology transfer material should be relevant, short, concise, and tailored according to the needs of the targeted end users.
- Make use of vignettes and short stories.
- Use plain English, and keep it simple.
- Sponsor the sharing of evaluation information among states (similar to a pooled fund).
- Technology transfer includes maintenance innovations and best practices.
- The timeliness of information is very important. Too much delay in sharing information hinders the ability to learn from existing projects.
- Encourage participatory outreach and ask people to contribute content.

How do we obtain and best share meaningful evaluation techniques and results?

The participants offered suggestions for obtaining and sharing ITS evaluation results, and highlighted challenges in conducting evaluations and barriers to sharing evaluation results. Key observations from the breakout session included the following:

Barriers to producing and sharing meaningful results

- There is a perception that sharing negative results risks scrutiny, criticism, or worse, an audit. Agencies that conduct self-evaluations have a lingering perception that an evaluation that reports negative results will trigger scrutiny. One participant said, "An evaluation is an audit."
- Participants expressed the view that agencies do not readily share results with industry.
- Self-evaluations are likely to have a bias toward reporting positive results, due to organizational self-interest.
- Conducting self-evaluations is costly and time-consuming. As noted by a participant, an evaluation is a "project in itself." Thus, there must be a sufficiently strong incentive and/or enough resources for agencies to conduct objective self-evaluations.

Remedies to the barriers listed above

- Sponsor evaluation activities separately from the research or deployment project.
- Ensure that evaluation results become available to the public.
- Use a third party to conduct evaluations to help avoid a conflict of interest.
- Use evaluation as a tool for deployment in which evaluators and deployment staff meet at the outset and at the mid-term of a project to enable mid-course corrections.
- Evaluations should assess the public impact of a project.

Geographic Relevance and Transferability

The participants described the importance of geographical relevance of ITS benefits. The question is whether benefits realized by a deployment in one location will generalize to other locations. The participants noted the complexities of determining geographical relevancy of results. Even the same location can undergo substantial changes in infrastructure, population growth and traffic patterns that influence the outcome of a project deployed over a long period, affecting the ability to evaluate the project's benefits. Nonetheless, the participants indicated that integrating geographical relevance would enhance the ITS Knowledge Resources and benefits database.

A participant noted that the transferability of a benefit depends also upon the audience for that benefit. For example, the mayor of a city interested in sustainable solutions may be keen on learning about the benefits from deployments in a "green" city (e.g., Chicago). In contrast, a traffic engineer modeling signal timing is likely to consider the geographical context in detail. The participants identified factors important to geographic context of benefits and made the following suggestions:

- Separate benefits, costs, lessons learned and deployments by urban/rural factors.
- Include high-level summaries of a benefit that are less likely to differ by location.
- Use a corridor-based indicator (as opposed to a region or city-based indicator) to provide more detail than the urban/rural distinction.
- Note the importance of the different audience of the benefit. Engineers may be more interested in seeing benefits from similar corridors but elected officials may prefer to see how projects worked in general, regardless of the location of the deployment.

Benefits

- When presenting benefits, it is important to address the operational scenario as well as the technology, because maintenance and operations of a deployment will influence benefits. Benefits change over time, as well, so it is of value to conduct iterative evaluations.
- Consider the application of a capability maturity matrix for ITS, similar to the application for planning in operations.
- Selling carbon credits requires measuring benefits over time; it would be valuable to compare previous evaluations to subsequent ones for verification of outcomes (benefits).

Importance of and Timing of Evaluation

- The value and relevance of an evaluation increase with the risk of a project. Thus, it may be more effective to spend evaluation resources on projects having increased risk.
- At what point should we stop doing evaluations of ITS technologies that have proven benefits? For example, transportation agencies know much about Dynamic Message Signs (DMS), but some agencies still require evaluations of DMS projects to justify their deployment.
- One challenge for management is that it is necessary to justify current research that may not produce applications or technologies for years to come.

ITS Knowledge Resources

To introduce the topic of the U.S. DOT ITS Knowledge Resources, the facilitator had asked the participants in each breakout group whether they are aware of the ITS Knowledge Resources website

and if they used it. More than half of the participants in Group 1 and up to eight participants from Group 2 indicated that they were aware of the resource and had used it. Participants made the following comments on the value of the Knowledge Resources and ways of improving the benefits, costs and lessons learned databases:

- It would be helpful if there were a means for users to add information to the databases.
- The Knowledge Resources are an excellent application; continue to build upon it and do not neglect it.
- Users are interested in seeing similar benefits integrated into benefits "packages."
- The databases do not provide an integrated, comprehensive overview. It would be useful to categorize benefits by user type (e.g., elected official or transportation planner) and by geographic characteristics.

Performance-based management

Participants noted that performance-based management will be a "game-changer" and that the next authorization for the U.S. DOT is likely to emphasize performance measurement. Performance-based management will require agencies to prove that they spent funds effectively and to show that performance continually improves. This requirement implies that evaluations will continue to serve an important function in the ITS program. Participants raised the following questions and concerns about performance-based management:

- Continual evaluations should improve performance, but there can be resistance. For example, an agency that uses performance measures may show benefits early in a deployment but those benefits can change over time, showing decreased benefits.
- Performance-based management in TIGER grants is broad (such as improving regional transportation). This goal may be different from ITS project goals and disconnect evaluation at the federal level from the local evaluation.
- How shall we determine agency-wide performance measures?

How do we measure and evaluate livability and environmentally related goals?

The facilitator introduced this topic by highlighting the importance of evaluating ITS in terms that make sense for livability and environmentally related goals. There remain questions about the appropriate methods and tools with which to assess how ITS impacts environmental outcomes. Framing ITS in the context of environmental benefits is not a new concept. What is new is the increasing importance of sustainability as a factor in transportation planning and deployment decisions. The heightened role of livability, sustainability and environmentally related goals (all of which are intertwined), requires that we take a fresh look at the measures used to assess how they are impacted by ITS. Participants in general agreed that methods and tools for measuring environmental impacts already exist. However, how to capture livability and sustainability remains less understood, and involves concepts that can be subjective. Further, their importance may change from place-to-place and over time.

One significant suggestion from the participants was to develop a policy analysis tool that connects sustainability to day-to-day operations. The tool would examine the tradeoffs between the three dimensions of mobility, societal impacts, and the environment as a function of changes in daily conditions. The relative priorities and importance of the three dimensions may change depending on

the situation. For example, a code-red air quality day could trigger changes in operations to reduce emissions. Participants contributed feedback in several main categories, presented below:

Environmental, energy, and air quality impacts

- The initial focus of AERIS is on the emissions and air quality benefits produced by ITS.
- It is important to use causal modeling to understand the impact of ITS on system operations, vehicle performance, and travel behavior. ITS can create changes in emissions (due to high accelerations and decelerations, trip starts and ends, trip routing, travel speeds, etc.).
- Full production, cradle-to-grave analyses that include emissions and energy in the calculations for the production, transport and storing of different types of energy is desirable.
- Traditionally, the Metropolitan Planning Organization (MPO) addressed emissions and air quality issues through the Congestion Mitigation and Air Quality (CMAQ) process. Thus, it is important to integrate and connect travel times to MPO planning tools and modeling, as well as the day-to-day MPO planning processes.

ITS and carbon offsets

- Participants described a project in Portland, Oregon, in which the Climate Trust (a non-profit organization) contracted with the City of Portland to buy carbon offsets from an advanced traffic signal deployment project. The project improved the timing of traffic signals in 17 major arterials in the Portland area, which increased the efficiency of traffic flow, reduced idling and acceleration time, thereby reducing emissions. The Climate Trust helped provide the resources needed for city agencies to model, develop and deploy the traffic signal system.[1] This example underscores the need for the ITS community to develop the evaluation techniques that can demonstrate the environmental benefits of ITS.
- In San Diego, the Regional Transportation Plan (RTP) included ITS as one of the ways to meet greenhouse gas emissions requirements mandated by the California Air Resources Board (CARB). The RTP views ITS as a key tool for reducing greenhouse gas emissions from cars and light trucks by 7 percent per capita by 2020 and 13 percent by 2035 (as required by CARB).

Livability

- Addressing livability requires that we first establish the values, goals, objectives, and measures of livability. Defining livability is complicated, partly because it is subjective, and may vary with individual preferences.
- Participants indicated that guidance on how to assess livability is desirable in the context of ITS project evaluations.
- Livability consists of many components: pedestrian safety, bicycle safety, and average commute time, among others. Travel time in general is also a measure of livability, but improving travel introduces the risk that it rewards or encourages people to take more trips.
- Pedestrian safety and bicycle safety are measures of livability. Increasingly, cities are initiating share ride programs for bicycles. Minneapolis, Washington, D.C. and Chicago,

[1] See ITS America Smart Solution Spotlight: Portland, Oregon's Traffic Signal Optimization & Retirement of Carbon Credits

among others, have bicycle-sharing programs that included upgrading roads with bike lanes.
- Mode choice assesses the extent to which travelers have a choice to use modes that may be more sustainable than driving; however, it is necessary to balance mode choice with travel times.
- A participant observed that there was a huge modeling effort undertaken in London to evaluate the environmental effects of a low emission zone in that city. In contrast, there is no real world, large-scale example of a low emission zone in the United States. The results of modeling efforts from other foreign cities including from Sweden or Singapore may not applicable to the United States, due to major differences in gas prices, policies, transit availability, etc.

Sustainability

- The JPO is in the process of developing a definition of sustainability in the context of connectivity and ITS. The goal is to move from a wide or general approach to a more narrow and focused definition of sustainability.

Vehicle and infrastructure connectivity, air quality and carbon emissions

- ITS research involving connectivity will include evaluation of air quality and carbon emissions. Air quality is a localized result, having local impacts, whereas carbon emissions have a global impact, not a local one.
- There is potential for vehicle-to-infrastructure applications to reduce the number of high accelerations and decelerations, improving acceleration profiles and lowering emissions.

Commercial vehicle operations (CVO) and other modes

- CVO have a significant impact on air quality and carbon emissions.
- By next year, New York State's Commercial Vehicle Infrastructure Integration (CVII) program will have at least five wireless roadside inspection screening sites.
- CVO and its applications provide a controlled population and a good testing ground for understanding how advanced technologies and connectivity affect the environment.
- The Integrated Corridor Management program provides an opportunity for operators in each mode to coordinate systems and practices. The extent to which the operators receive credit for working towards a coordinated system with all of the modes is crucial to their efforts.

Evaluating current ITS impacts still important

- A participant emphasized that it is still important that we understand the impacts of current (and legacy) ITS solutions, even in the face of new projects and concepts such as vehicle-to-vehicle connectivity. There is still a need to assess present-day ITS deployments, such as ramp meters, incident management, etc. For example, Hampton Roads has struggled for 10 years to capture and prove the environmental impacts of incident management. At this point, there is truly no proven method in place to justify such projects in statewide transportation improvement programs (STIPs) or local plans.

Chapter 3: Summary and Next Steps

The workshop provided an opportunity for 64 stakeholders from the private and public sectors to engage in wide-ranging discussions on fundamental questions and problems involving the evaluation of ITS. Participants explored ideas for overcoming barriers and providing incentives for conducting evaluations, improving the value of evaluations to deployments, and sharing results, technology and knowledge. Participants identified ways of acquiring and sharing data, and conducting outreach with the public. Participants also provided insight into ways of improving the ITS Knowledge Resources website and benefits database maintained by the U.S. DOT RITA. At the closing session, the facilitators presented summaries of the observations made during the breakout sessions to the plenary, and the JPO Program Managers Marcia Pincus and James Pol provided closing remarks.

Observations

The participants contributed a wide range of ideas throughout the workshop. Among the themes expressed by the participants are the following:

Benefits

- The location and context of the source for the benefit is an important factor in evaluating ITS. Characterizing the geographical relevance of a benefit is necessary before extrapolating results. Factors related to whether a benefit is transferable across locations include the geographic and environmental context and institutional issues involving policy and inter-agency coordination.

Timeframe of evaluation and iterative testing

- There is value in iterative evaluation and incremental, staged deployments, with smaller evaluation reports produced at interim periods aimed at producing deployment adjustments. In addition, reporting benefits and sharing results on an interim basis should be encouraged to provide timely information.
- Using multiple test sites, not just one big one, for research projects enables testing to occur under different conditions with multiple risk factors.

Maintenance and operations

- Include maintenance and operations costs in the evaluation analysis, and include maintenance and operations costs over time in the ITS Knowledge Resources benefits, costs and lessons learned databases. Costs should include not only capital costs at initial installation but also for maintenance and operations.

Learn from others

- Learn from organizations such as the FAA that work with and use large real-time databases. See what they do, how they manage the data, how they structure the databases.
- Learn from other domains, particularly the banking industry, on how they conduct self-evaluations.

Self-evaluations

- Encourage self-evaluations by incorporating them into the project management process.
- Capture positive and negative impacts of deployments. Including negative results not only improves the quality of the report but also the credibility of the information.

Data Sharing

- Sharing data is a key factor in successful deployments and it strengthens the cooperation between entities.

Sustainability

- Framing ITS in the context of the environment is not a new concept, but what is new is the increasing extent to which sustainability is an important factor in transportation planning and deployment decisions. Sustainability requires that we take a fresh look at the measures for assessing the impact of ITS on the environment. A tool that examines the tradeoffs between mobility and environment goals as a function of daily conditions has potential. For example, on "high ozone days," the goal of reducing emissions may override mobility goals.

Next Steps

Envisioned as an initial exchange with stakeholders, the JPO program managers designed this workshop to exchange knowledge on how ITS evaluation can best support the U.S. DOT ITS Strategic Research Plan, and state and local ITS projects. The workshop provided the opportunity for participants to share innovative evaluation practices, identify evaluation needs and provide input on the U.S. DOT ITS evaluation program.

As the landscape of ITS continues to evolve due to developments in research and deployment, it will be increasingly valuable for stakeholders to engage in discussions on advancing practices in ITS evaluation. The success of the workshop demonstrated that promoting a dialogue among ITS stakeholders and the transportation community will support efforts to strengthen the effectiveness and value of evaluation in ITS. The JPO plans to continue the dialogue with the transportation community on ideas for enhancing the evaluation of ITS and supporting safety, mobility and environmental goals.

APPENDIX A. List of Acronyms

AASHTO	American Association of State Highways and Transportation Officials
AERIS	Applications for the Environment: Real-Time Information Synthesis
AVL	Automatic Vehicle Location
CARB	California Air Resources Board
CMAQ	Congestion Mitigation and Air Quality
CVII	Commercial Vehicle Infrastructure Integration
CVO	Commercial Vehicle Operations
DARPA	Defense Advanced Research Projects Agency
DMS	Dynamic Message Signs
DOTs	Departments of Transportation
ECAR	Enhanced Citizen-Assisted Reporting
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
FTA	Federal Transit Agency
FHWA	Federal Highway Administration
GPS	Global Positioning System
GHz	Gigaherz (unit of frequency)
IBEC	International Benefits, Evaluation and Costs (IBEC) Working Group
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LTAPS	Local technical assistance programs
MPO	Metropolitan Planning Organization
RITA	Research and Innovative Technology Administration
RTP	Regional Transportation Plan
SHRP	Strategic Highway Research Program
SHRP 2	Strategic Highway Research Program 2
STIP	Statewide Transportation Improvement Program
TIGER	Transportation Investment Generating Economic Recovery (TIGER) Grants
TRB	Transportation Research Board
U.S. DOT	United States Department of Transportation
VDOT	Virginia Department of Transportation

APPENDIX B. Agenda

8:30 am to 9:10 am	Opening Presentation – Huntington Room
	James Pol, RITA • Introductions • Welcoming Remarks and Agenda Overview • The Role of Evaluation in the ITS Strategic Plan 2010-2014 • Workshop Background and Vision
9:10 am to 9:20 am	Directions and Charge to Participants - Huntington Room
	Marcia Pincus, RITA • Identify evaluation needs at the local, state and federal levels. • Produce ideas and thoughts on developing and applying innovations in evaluation. • List ideas and document feedback from participants on the ITS evaluation program.
9:20 am	*Break - Atrium*
9:30 am to 11:30 am	Session 1 - Key Innovations and Opportunities in ITS Research and Deployment Evaluations –
	Focused Questions: • How do we make effective and innovative use of new technologies, new techniques, and new results? • How can we best and most creatively evaluate new JPO initiatives? • What innovations are you aware of that can be applied, or that have potential, for evaluation • How do we effectively identify technology transfer opportunities? Participant Contributions: • Most important innovative approaches and opportunities • Thoughts for obtaining and sharing these innovative evaluation techniques and results • Thoughts and considerations for the ITS Evaluation Program • Thoughts for Knowledge Sharing and Training • Identification of exemplary practices
11:30 am	*Lunch – Dining Room*
12:30 pm to 2:00 pm	Session 2 –New Goals and Priorities in ITS Research and Deployment Evaluations
	Focused Questions: • How do we obtain and best share meaningful evaluation techniques and results? • How do we measure and evaluate livability and environment-related goals? Participant Contributions: • Most important new goals and priorities • Specific needs and approaches for addressing these new goals and priorities • Thoughts for evaluating livability and environment-related goals • Thoughts and considerations for the ITS Evaluation Program • Thoughts for Knowledge Sharing and Training
2:00 pm	*Break - Atrium*
2:15 pm to 3:15 pm	Presentations and Closing Session – Huntington Room
	Marcia Pincus and James Pol, RITA • Summarize Sessions 1 and 2 • Define next steps • Wrap up with final charge to participants
3:15 pm	Adjourn

APPENDIX C. Participant List

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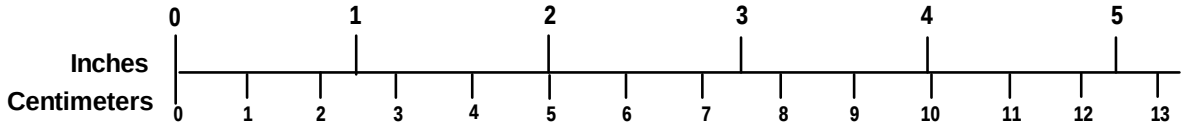
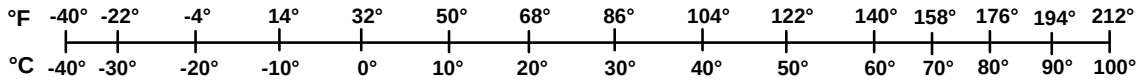
APPENDIX D. Metric/English Conversion Factors

ENGLISH TO METRIC	METRIC TO ENGLISH
LENGTH (APPROXIMATE)	**LENGTH (APPROXIMATE)**
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA (APPROXIMATE)**
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT (APPROXIMATE)**
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)
	= 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME (APPROXIMATE)**
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)	**TEMPERATURE (EXACT)**
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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