# ITS Horizon Scan

## The Societal, Technical, and Environmental Trends That Will Influence ITS Research and Deployment

www.its.dot.gov/index.htm

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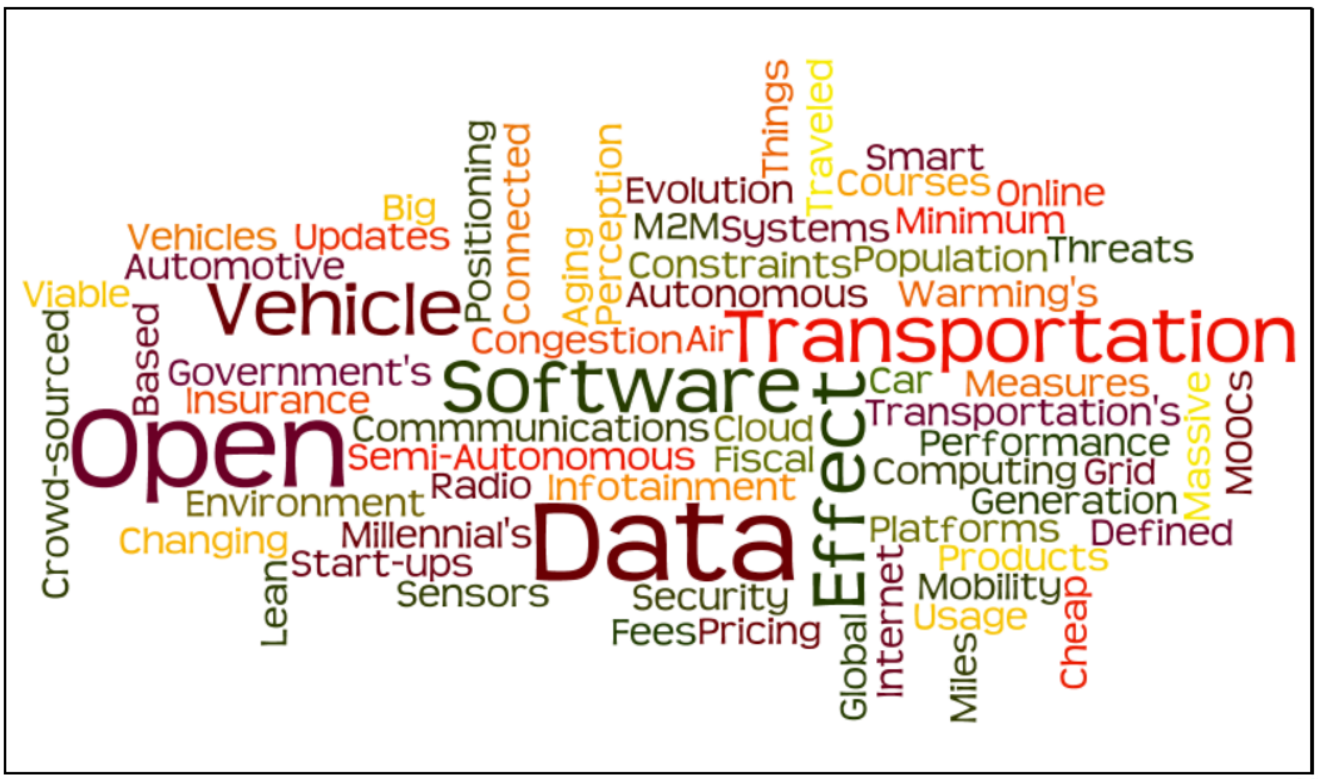


U.S. Department of Transportation
Research and Innovative Technology Administration

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# Notice



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**16. Abstract**

Horizon scans provide a "systematic examination of potential threats, opportunities and likely developments including but not restricted to those at the margins of current thinking and planning" (British Office of Science and Innovation). This horizon scan identified and assessed the technical, institutional, commercial, and environmental trends that may positively or negatively affect ITS deployment over the long term. The purpose of the study was to help the ITS JPO understand the range of opportunities and threats that may warrant further investigation among the research programs. Early identification of these trends and assessment of their impact on the US transportation system enables the ITS program to proactively develop strategies for influencing these developments, mitigating their negative impacts, and maximizing their positive impacts.

Based on an extensive literature scan, 22 trends were identified for further analysis. A small expert panel then was assessed each of these trends in terms of the likelihood of the trend coming to fruition, when the trend was expected to have a significant impact on surface transportation, the types of impact each may have on the ITS program, the potential magnitude of that impact, and the time frame for when USDOT action might be needed.

Based on the expert panel assessment, five trends and trend combinations were selected for further review by the expert panel. These topics were:

- Big and Open Data / Connected Sensors / Machine to Machine Communications
- Performance Measures
- Government Fiscal Constraints
- Semi-Autonomous and Autonomous Vehicles
- Aging Population

Specific actions for consideration by the USDOT were developed for each of these five topic areas.


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# Executive Summary

Horizon scans provide a “systematic examination of potential threats, opportunities and likely developments including but not restricted to those at the margins of current thinking and planning” (British Office of Science and Innovation). Technology and policy developments can have substantial impacts, both positive and negative, on the ITS program. This horizon scan identified and assessed the technical, institutional, commercial, and environmental trends that may positively or negatively affect ITS deployment over the long term. The purpose of the study was to help the ITS JPO understand the range of opportunities and threats that may warrant further investigation among the research programs. Early identification of these trends and assessment of their impact on the US transportation system enables the ITS program to proactively develop strategies for influencing these developments, mitigating their negative impacts, and maximizing their positive impacts.

Based on an extensive literature scan, 22 trends were identified for further analysis. These trends are shown in Table ES-1, grouped by category (no trends were identified that fell into the governance category). A small expert panel then was assessed each of these trends from three perspectives:

- **Impact:** What positive and negative effects will the issue have on the ITS program, and what are the expected magnitudes of these impacts?
- **Probability:** How likely is it the issue will occur?
- **Time:** How far off is the issue on the time horizon and how long does the ITS program have to act?

Figure ES-1 shows the panelists’ assessment of the extent to which the Federal ITS program should be concerned with the trend (on a 1-10 scale along the y-axis) and the year until the trend is expected to have a significant impact on surface transportation (along the x-axis).

The assessments were used as the basis for selecting a smaller number of topics for discussion during a meeting of the expert panel. The five topics selected for discussion were 1) Big/Open Data & Connected Sensors/Machine to Machine (M2M) Communications, 2) Performance Measures, 3) Government Fiscal Constraints, 4) Semi-Autonomous and Autonomous Vehicles, and 5) Aging Populations. The major purpose of the meeting was to develop a set of possible actions for consideration by the ITS Joint Program Office. The suggested actions and items for consideration, by topic, were:

## Big/Open Data (and Connected Sensors/M2M)

- The role of the Federal ITS program lies in the facilitation of standards, with some potential data collection.
- The Federal ITS program could fund research more similarly to a venture capitalist funding a portfolio of projects rather than utilizing a single-winner contract award approach. One mechanism might be through the use of “creative Broad Agency Announcements (BAA’s)”.
- Other industries will take the lead in considering concerns over the way society handles data privacy issues, so it does not need to be an ITS program focus, but the program should track developments in this area.

- The Federal ITS program could function as a national clearinghouse for ongoing development efforts and management on innovation, as a way to coordinate and leverage research and development efforts and reduce duplicative efforts.
- Consideration should be given to establishing a pooled fund program that would fund operational expenses of states sharing the costs of large data repositories and analysis.

## Performance Measures

- The role of the Federal ITS program is a supporting one on Performance Measures, aiding the Offices of Operations, Transportation Performance Management, and Planning in seeing what tools ITS can offer to better support existing measures and what new measures could be developed that provide greater information to the transportation community. Utilization of think tanks and universities could lead to the development of new, complex performance measures through “challenges” and BAAs.
- Education of the transportation community on performance measurement should continue through the ITS Professional Capacity Building (PCB) program’s efforts.
- Creation of a data releasing portal akin to data.gov for transportation data may be useful for crowd sourced development of new performance measures.

## Government Fiscal Constraints

- ITS is a tool to assist Management and Operations, but the differentiation between the two programs should be improved.
- A Federal ITS role could be collecting and providing information and best practices, serving in a technology transfer role on topics such as electronic pricing systems.

## Semi-Autonomous & Autonomous Vehicles

- The U.S. Department of Transportation (USDOT) could assist the industry with the sensor-based technologies prior to the broad deployment of the Connected Vehicle program through functions such as safety oversight and infrastructure improvements (better roadway striping, encouraging the use of particular materials, etc.).
- The Federal ITS program should consider developing a potential roadmap for the deployment of (semi-) autonomous vehicles and the associated use cases. Existing working groups within the ITS JPO, who have experience in thought leadership and visioning, make the ITS JPO ideal for leading the development of this roadmap. The ability of the ITS JPO to reach out to the freight and automotive industries, as well as state and local partners, leaves the ITS JPO well positioned for aiding the development of pilot projects.

## Aging Population

- The Federal ITS role should involve encouraging the collection of data on seniors’ driving habits. The development of testing corridors, so that these assistive technologies are being tested on a larger proportion of the target demographic, could be another role for the JPO.
- The ITS JPO should look into studies on how an aging (but still largely independent) population may affect the transportation network and which technologies have the greatest

potential to allow seniors to maintain their independence. Diverse solutions will be necessary because of differing needs in regional, rural, and urban environments.

**Table ES-1. Trends with the Potential to Impact ITS** *(Created by William Ball)*

| Sensors / Data | Information & Communications Technology | Applications | Governance | Security & Privacy | Demand for ITS | Other Trends |
|---|---|---|---|---|---|---|
| Crowd Sourced Data | Software Defined Radios / OTA Updates | User Based Insurance | | Automotive Security Threats | Mobility for Aging Population | Massive Open Online Courses |
| Open and Big Data | Smart Grid | Autonomous and Semi-Autonomous Vehicles | | | Millennial / Generation Y Perceptions of the Car | Lean Startups and Minimum Viable Product |
| Cheap and Connected Sensors / M2M | Cloud Computing | Open Platforms for Vehicle Infotainment | | | Effects of Transportation on Climate Change | |
| Evolution of Positioning Systems | | Mileage Based Fees | | | Effects of Global Warming on Transportation | |
| | | Congestion Pricing | | | Government Fiscal Constraints | |
| | | Transport Performance Measures | | | Same Day Mail Order Delivery | |

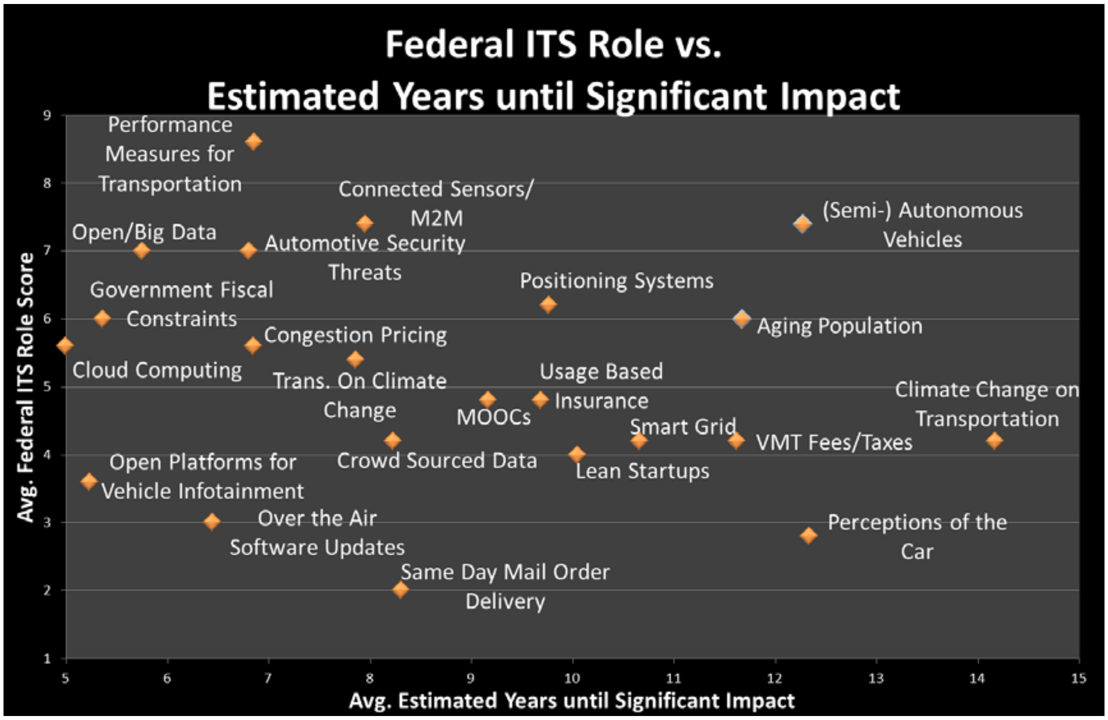



**Figure ES-1. The Assessed Federal Role versus the Years Until the Trend Will Significantly Impact Transportation** *(Created by Noblis, Inc.)*

# 1 Introduction

## 1.1 Overview

Horizon scans provide a "systematic examination of potential threats, opportunities and likely developments including but not restricted to those at the margins of current thinking and planning" (British Office of Science and Innovation). Technology and policy developments can have substantial impacts, both positive and negative, on the ITS program. This horizon scan identified and assessed the technical, institutional, commercial, and environmental trends that may positively or negatively affect ITS deployment over the long term. The findings from this study helps the ITS JPO understand the range of opportunities and threats that may warrant further investigation among the research programs. Early identification of these trends and assessment of their impact on the US transportation system enables the ITS program to proactively develop strategies for influencing these developments, mitigating their negative impacts, and maximizing their positive impacts.

Each identified trend is assessed from three perspectives:

- **Impact:** What positive and negative effects will the issue have on the ITS program, and what are the expected magnitudes of these impacts?
- **Probability:** How likely is it the issue will occur?
- **Time:** How far off is the issue on the time horizon and how long does the ITS program have to act?

Once this assessment was complete, the most important trends were then further analyzed to identify recommendations for USDOT action. Actions can take several forms. The first type are actions that may be taken to increase the likelihood or magnitude of a positive trend or decrease the likelihood of a negative trend. These types of actions are most relevant to transportation-specific trends, as the ITS program can have little influence over broad-based trends such as cloud computing or global warming. The second type of actions are those taken by the ITS program to maximize the benefits from positive trends or minimize the impact of negative trends. For example, the ITS program may decide to conduct research and make recommendations concerning the role of cloud computing in traffic management, or conduct research on how to increase the resilience of transportation networks to weather extremes.

## 1.2 Outline of This Report

Chapter 2 of this report describes the study approach. Chapter 3 summarizes the Horizon Scan Expert Panel's assessment of each of the identified trends. The trends themselves are defined and summarized in Appendix B. Brief biographies of the members of the Expert Panel are provided in Appendix C. The Expert Panel developed recommendations for actions on a subset of the identified trends (those of the most importance and of the most interest to the ITS JPO). These recommendations are provided in Chapter 4. Chapter 5 provides a brief overall assessment of this initial ITS horizon scan.

# 2 Approach

Successful horizon scanning requires information collection from a wide array of sources and a diversity of perspectives. An important constraint was that this study was to be conducted with a relatively low level of effort. To achieve this, we combined information collection and analysis by Noblis staff with a *Horizon Scan Expert Panel* consisting of subject matter experts selected for both their expertise and vision. The Horizon Scan utilized a four-step approach, as shown in Table 2-1.

**Table 2-1: Steps in the Horizon Scan**

| Steps | Activities |
|---|---|
| 1. Scan Literature | Cast a broad net for leads, utilizing technical, policy, transportation, telematics, and futurist sources. |
| 2. Identify Trends | Identify, define, and summarize trends based with potential impact on the Federal ITS program. |
| 3. Assess Impacts | Expert panel assesses likelihood, time frame, impact on transportation, relevancy to Federal ITS program, and time frame for action for each identified trend. |
| 4. Determine Potential Actions | Expert panel meets to discuss the trends with the highest relevancy to the Federal ITS program and recommends potential actions for consideration by ITS Joint Program Office. |

The first step was to set up an ongoing, low-intensity literature scan. Leads were identified by scanning Really Simple Syndication (RSS) feeds from over 30 publications and websites, ranging from the Federal Highway Administration (FHWA) Research News to Wired:Automotive to the McKinsey Quarterly. The few sentence summaries could be quickly scanned several times per week. Articles of potential interest were then read, and if they seemed to fit a pattern of an emerging trend, they were categorized and stored. Based on this literature scan, approximately eighteen trends were flagged for further analysis (plus a few additional potential trends to watch and some specifically looked for trends for which there were no data to support flagging it as a trend (e.g., scalability of mobile ad hoc networks). The initial list was modified slightly based on discussion with ITS JPO staff and the expert panel, and the final 22 topics were agreed upon. For each topic, a 1-2 page summary was prepared describing the trend, identifying its potential relevance to ITS, identifying closely related trends, and providing references to the articles that had been identified concerning the trend. These summaries are provided in Appendix B.

The summaries were then sent to a small expert panel, who were asked specific questions on each trend, using the Survey Monkey tool. The Expert Panel members and their area(s) of expertise are shown in Table 2-2. Additional background information on the panelists is provided in Appendix C.

**Table 2-2. Members of the Horizon Scan Expert Panel**

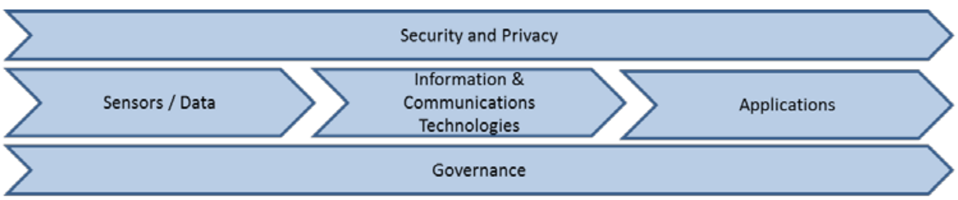
| Panelist | Area(s) of Expertise |
|---|---|
| William Ball, Merriweather Advisors | Automotive industry and telematics |
| Mark Dunzo, VP, Kimley-Horn & Associates | Transportation infrastructure deployment |
| Dr. H. Gilbert Miller, VP and CTO, Noblis | Networking, communications, and computing technologies |
| Stan Pietrowicz, Senior Principal Consultant, Applied Communication Sciences | Telecommunications, information security, and Smart Grid |
| Phil Tarnoff, Consultant | Transportation Management & Operations, ITS |

Based on the results of the assessment, a small subset of trends was identified to be further discussed at a meeting of the panel. As part of the meeting, the panel developed a recommended set of potential actions for consideration by the ITS JPO. These recommendations are presented in Chapter 4.

# 3 Trend Assessment

## 3.1 Overview

The initial ITS Horizon Scan identified 22 technical, societal, and environmental trends that had the potential to impact the ITS program. These trends are listed in Figure 3-1. The top of the figure shows that ITS can be divided into Sensors and Data, Information and Communications Technologies, and Applications. Security and Privacy are concerns for all three areas. Similarly, governance issues affect all three. Each of the 22 trends is then listed in the table below, grouped into seven categories (there were no trends identified that fit into the Governance category. A summary of each of these trends and why they were chosen is provided in Appendix B.




| Sensors / Data | Information & Communications Technologies | Applications | Governance | Security & Privacy | Demand for ITS | Other Trends |
|---|---|---|---|---|---|---|
| Crowd Sourced Data | Software Defined Radios / OTA Updates | Usage Based Insurance | | Automotive Security Threats | Mobility for Aging Population | Massive Open Online Courses |
| Open and Big Data | Smart Grid | Autonomous and Semi-Autonomous Vehicles | | | Millennials / Generation Y Perceptions of the car | Lean Startups and Minimum Viable Product |
| Cheap & Connected Sensors / M2M | Cloud Computing | Open Platforms for Vehicle Infotainment | | | Effects of Transportation on Climate Change | |
| Evolution of Positioning Systems | | Mileage Based Fees | | | Effects of Global Warming on Transportation | |
| | | Congestion Pricing | | | Government Fiscal Constraints | |
| | | Transport Performance Measures | | | Same Day Mail Order Delivery | |

**Figure 3-1. Trends Identified by the Horizon Scan** *(Created by William Ball)*

After the trends were identified and defined, each member of the Expert Panel was asked to assess, on a 1 to 10 scale, how much impact each trend would have on surface transportation in general and how much impact each would have on Intelligent Transportation Systems in particular. In addition, they were asked to estimate when the significant impact would occur. Finally, they were asked if the USDOT's ITS program should devote significant resources in actions related to the trend, and when such action should begin. For purposes of the trend assessment, "significant resources" was defined as $5 million or more. Figure 3-2 plots the assessed impact of each trend on surface transportation versus the extent of relevance the trend has to the Federal ITS Program. For example, Performance Measures for Transportation was seen as having a large effect on transportation and an area where there is a large role for the Federal ITS program. Same Day Mail Order Delivery was seen as having a moderate impact on transportation, but with little or no role for the Federal ITS program.

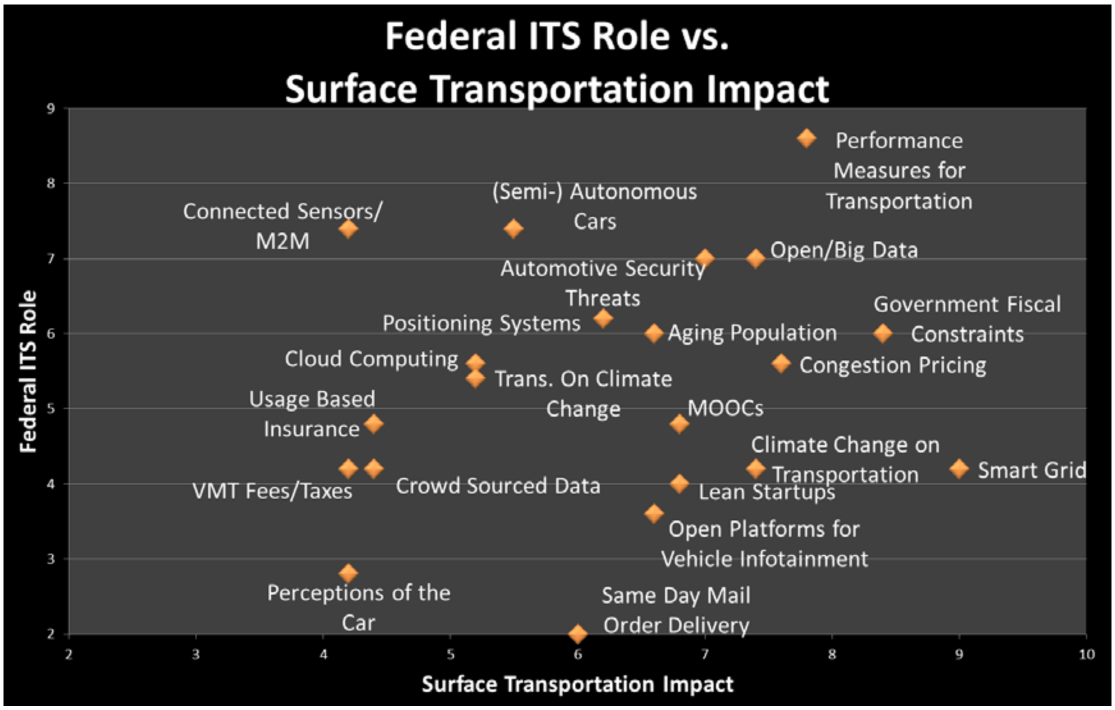



**Figure 3-2. The Assessed Transportation Impact of Each Trend, and the Assessed Magnitude of the Role of the Federal ITS Program** *(Created by Noblis, Inc.)*

Figure 3-3 plots the magnitude of the Federal ITS Role against the years until the trend is expected to have a significant impact on transportation. So, for example, the Federal ITS Program has a significant role to play with regard to open and big data in transportation and it's expected to have a large impact within the next six years. The Federal ITS program is also expected to have a significant role in autonomous and semi-autonomous vehicles; however such vehicles are not expected to significantly affect transportation systems over the next 10 years. The trends expected to have both a significant impact within the next 7 years and significant roles for the ITS JPO are:

- Performance Measures for Transportation
- Open / Big Data
- Government Fiscal Constraints
- Cloud Computing
- Automotive Security Threats, and
- Congestion Pricing

Other trends, such as Massive Online Open Courses (MOOCs) and the concept of lean start-ups in government, while not significantly affecting transportation, still may offer lessons learned to shape the approach and execution, but not the content, of the ITS research program.

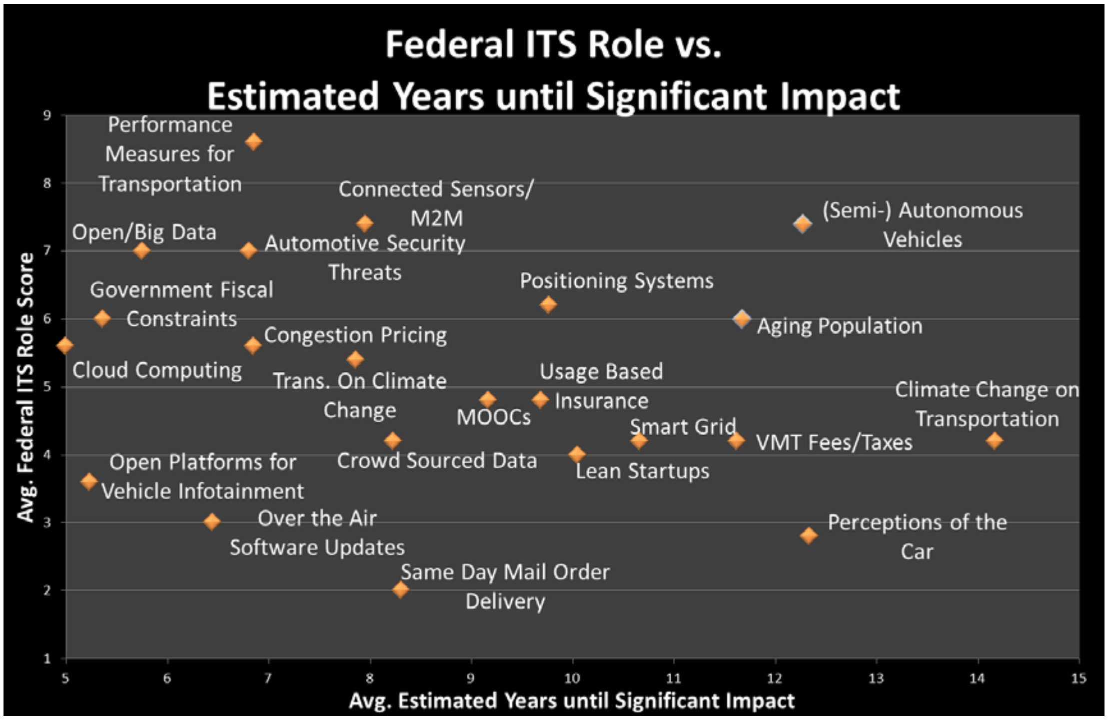



**Figure 3-3. The Assessed Federal Role versus the Estimated Years Until the Trend Will Significantly Impact Transportation** *(Created by Noblis, Inc.)*

The sections below summarize the expert panel's assessment of each topic. The assessment ratings reflect the expert opinions of the panelists, but are not definitive. A different or larger set of panelists may have ranked the trends differently. As described in Chapter 2, the expert panel examined a small subset of these trends in more detail and provided a number of specific suggested actions for consideration by the ITS Joint Program Office. These suggested actions are provided in Chapter 4.

## 3.2 Mobility for an Aging Population

Panelists felt the Mobility for the Aging Population trend will have a greater than average impact (i.e., scoring a 7 out of 10) on the transportation system and will need greater than average involvement (i.e., scoring 6 out of 10) from the Federal government to address concerns. Panelists agree that this is a very relevant trend where the Federal ITS program may have a role to play at the policy level. Panelists also agreed that planning for this topic should begin now. Data on the habits of drivers who are 65 years old and older is needed to help plan future projects. Planners could be working with various senior programs to identify studies needed for this population segment. The needs of the aging population should be addressed as new technologies are developed for and deployed in vehicles. This may include alterations for applications already being developed to account for driver characteristics for the aging population (e.g. decreased night vision, slower reaction times). These technologies will likely be initiated and implemented by the auto manufacturers, but may also require support at the Federal level. The timeline for getting technologies deployed in vehicles for the Baby Boomer wave requires broad deployment by 2020 and early deployment in 2016-2017, so it may already be too late to develop built-in vehicle technologies for the early part of the wave, but they could be developed in time for the middle and end of the wave.

## 3.3 Changing Perceptions of the Car

Survey panelists found it difficult to understand the ITS program's impact (i.e., scoring only a 3 out of 10) on the Changing Perceptions of the Car trend other than making transit service more usable. Panelists felt that there would be roughly a 50-50 likelihood that this trend would catch on. Panelists scored this trend below average (i.e., 4 out of 10 points) for any substantial impact on surface transportation. Car sharing was found to be more likely among college educated, urban dwellers experiencing delayed family formation due to an extremely stagnant economy. Panelists felt that these folks have entered the economy at the worst time and if economic conditions improve they will want cars especially as they marry, move into the suburbs and need increased mobility to transport children to schools and other individual or family activities.

## 3.4 Crowd Sourced Data

Survey panelists felt that the Crowd Sourced Data trend was very likely to catch on with an average impact (i.e., scoring 5 out of 10) on transportation. Panelists felt that the private sector is in the midst of leveraging this trend. It would seem prudent for the Federal ITS program to let industry and local transportation management agencies (state DOTs, transit agencies, and cities) experiment with this resource. The Federal ITS program impact scored low (i.e., 4 out of 10) however panelists felt the ITS program should keep its ears open in the near-term and begin to see if there is a place to develop tool boxes, policy guidance, liability guidance, validation tools, clearing houses, and/or other means of providing best practices and lessons learned to the broader transportation community. In the near-term, the Federal role may be to facilitate software to integrate into 511 and other traffic management systems, because crowd sourced data's greatest potential for transportation could be in the surveillance of pavement, weather, and traffic conditions on the highway system.

## 3.5 Open Data and Big Data

Survey panelists felt that the Open Data and Big Data trends are very likely to occur and need to be addressed now. Panelist placed a relatively high score (i.e., 7 out of 10) on the impact to transportation and an equally high score (i.e., 7 out of 10) for the impact on the Federal ITS program. Panelists felt there are several potential positive benefits that could result from making data available. It could stimulate new ideas, approaches and solutions. It could encourage entrepreneurship and provide economic stimulus, growth, and innovation. In other words, businesses and processes that we currently have not dreamed of will spring up because of the availability of open and big data. In some ways this is analogous to the development of applications for smart phones. Thus the Federal ITS program should not attempt to lead the use of big data, but should develop a program that ensures that the data is readily available and encourages the development of new applications. The ITS program has a role in creating the environment to enable "big data" to be accessible and to make sure data acquired directly or indirectly with Federal funds are open. The Federal role could include leadership in standards for data formatting and sensing to ensure data from different entities can be merged and that the data being sensed is truly comparable (i.e. measuring the same parameter).

## 3.6 Cloud Computing

Survey panelists felt the Cloud Computing trend was very likely to occur and should be addressed within the next 4-7 years. Panelists gave an average score (i.e., 5 out of 10) for the expected impact on transportation and a slightly greater than average score (i.e., 6 out of 10) for the impact on the Federal ITS program. Cloud models for acquiring data have become prominent in the ITS world and many of the software applications are moving to a services framework for ease of maintenance and deployment. Cloud computing is of interest both because its structure offers a useful architecture for projects producing massive data such as the connected vehicle project and because of its potential to advance the information services offered to users and operators of the transportation system. Cloud computing is an implementation option, mostly driven by economics and availability. Panelists felt it is unlikely to be fast enough or reliably available enough for safety applications. This suggests that it may be limited to non-time sensitive mobility functions like navigation where accessing the cloud may provide up-to-date mapping or routing based on real time traffic/construction/emergency/road condition information. One suggestion was for the ITS program to track the progress of the ERTICO cloud technologies project, and assess the potential of their approach to the US transportation system. This program could be ideal to pursue collaboratively with private industry, which is both a user/contributor and developer of cloud-based systems.

## 3.7 Cheap & Connected Sensors / Machine to Machine (M2M) Communications

Panelists agree that the Cheap and Connected Sensors/Machine to Machine (M2M) Communications trend is already in full-swing and will continue for the foreseeable future. They scored the impact on transportation high (i.e., 8 out of 10) and they also scored the impact on the Federal ITS program high (i.e., 7 out of 10). They felt that the role for the ITS program is at a policy and standards level. While the sensors themselves will be developed by private industry, the data collected from the sensors (both in vehicles and on infrastructure) should be comparable across OEMs and applications must be developed that maintain legacy systems as part of Connected Vehicle technologies.

## 3.8 Usage Based Insurance

Panelists agreed that the Usage Based Insurance trend is already taking hold. They felt the impact on transportation was just above average scoring a 6 out of 10, and the impact on the Federal ITS program was just average scoring a 5 out of 10. They felt this is a private sector initiative with a government role limited to regulation that should be addressed within the next 4-7 years. The biggest issues may be policy considerations about privacy and political concerns regarding whether implementation of this technology is "fair" to consumers. Insurance companies have strong incentive to work with consumers to deploy these systems in order to reduce overall payouts, and there is additional incentive for them to share their data with transportation system owners and operators to help them make transportation systems safer. However, while this trend is likely to continue, its impact is difficult to predict. For example, how much will usage-based insurance influence the behavior of the two high-risk groups (young and elderly)?

## 3.9 Autonomous and Semi-autonomous Vehicles

Panelists agreed that the Autonomous and Semi-autonomous Vehicles trend is very likely to continue. They scored the impact to transportation high (i.e., 9 out of 10) and also scored the impact to the Federal ITS program high (i.e., 7 out of 10). There was some consensus on that this trend should be addressed within the 4-7 year range. Panelists were mixed on the Federal ITS role, although one panelist felt a lack of private sector integration of autonomous vehicles with Connected Vehicles could prove to be a future concern. There was some consensus that the private sector remains very engaged in this research and the ITS program should remain involved with these technological developments, monitoring performance, aiding standards development and facilitating advances on a case-by-case basis.

## 3.10 Automotive Security Threats

Panelists felt the Automotive Security Threats trend was very likely to continue and the time to address these issues is now. They scored the impact to transportation relatively high (i.e., 7 out of 10), and the impact to the Federal ITS program equally high (i.e., 7 out of 10). Panelists felt that this is part of an overall Federal national security problem that will certainly impact transportation systems. As the Federal ITS program explores connected vehicles, the V2I element poses a significant cyber threat and, similar to the auto industry, the traditional ITS operators are substantially behind in securing these networks. While the presence of solid security may not directly benefit surface transportation, for example to improve safety, the lack of it will negatively impact the success of many ITS innovations. Connected vehicle deployments will fail if security issues cannot be successfully resolved. Moreover, security will be an ongoing concern. The Federal ITS program should work with other government agencies and the OEMs whose emphasis on computer security is rapidly increasing. The ITS program should probably focus on standards and cross-fertilization related to the transportation industry. The ITS Program should also pay attention to security of infrastructure based systems such as TMCs and dispatching systems.

## 3.11 Over-the-Air Software Updates

Panelists agreed that the Over the Air Software Updates trend is very likely to continue, but may not encounter issues that would need to be addressed by the Federal ITS program for 10 years or more. Panelists felt that the impact to transportation would be just over average (i.e., 6 out of 10), and the impact to the ITS program would be low (i.e., 3 out of 10). Panelists stated that over-the-air software updates is a capability that all electronic product makers are incorporating because of the business benefit. They felt this is an enabling technology that will be a bi-product of the other developments occurring in the transportation field. The use of this technology will be determined by the private sector purveyors of software and equipment to the industry. Panelists generally agreed that except to the extent that it affects security and safety, there is very little that the Federal ITS Program can or should do to influence this technology. It is not something that the Federal ITS Program needs to drive because it is already happening for many more compelling reasons.

## 3.12 Open Platforms for Vehicle Infotainment

Survey panelists agreed that the Open Platforms for Vehicle Infotainment trend is very likely to continue. They scored the impact to transportation relatively high (i.e., 7 out of 10), and scored the impact to the Federal ITS Program at just under average (i.e., 4 out of 10). The panelists were somewhat split on when this trend needed to be addressed at the Federal level with half indicating that these issues should be addressed now and half indicating that they should be addressed in 4 or more years. They generally felt that this is primarily a private sector matter between the suppliers and the consumers and suppliers need to address opening interfaces to let others bring innovation into vehicles. The government role is regulation and safety assurance of applications and interfaces delivered across the government provided transportation information infrastructure. The role of the program should be focused on the safety and human factors issues related to the growing amount of information being provided to the driver. They felt it was difficult to see much of an ITS role in this area, since it will be driven mostly by application developers, and standard setting organizations such as the Automotive Grade Linux (AGL) Working Group. The Federal role in this area is most likely to be the impact of these applications on safety, and this is probably NHTSA's responsibility.

## 3.13 The Impact of Transportation on Climate Change

Panelists agreed that the Impact of Transportation on Climate Change is very likely to initiate transportation research and these issues should be addressed now. Panelists scored the impact on transportation relatively high (i.e., 7 out of 10), and scored the impact on the Federal ITS program at just above average (i.e., 6 out of 10). Panelists expressed that this is a daunting problem that the ITS Program could address in many ways including adjusting the measures of effectiveness that are the basis for adaptive strategies, to favor environmental issues. To use signal timing as an example, most traffic engineers tend to emphasize minimization of delays and travel time. On the other hand, stops have a greater impact on fuel consumption and emissions and yield differing control strategies. Panelists also suggested that the ITS Program could invest in tools that estimate ITS technology impacts on the reduction of greenhouse gas emissions. This could lay a foundation for planners and decision makers to objectively utilize ITS as a strategy to help mitigate/reduce the impacts of transportation on climate change.

## 3.14 The Impact of Global Warming on Transportation

Panelists were split on whether the impact of global warming on transportation is likely to initiate increased transportation research, but felt that these issues do need to be studied and addressed in the near term. Panelists scored the impact to transportation at just over average (i.e., 6 out of 10), and scored the impact on the Federal ITS Program at just under average (i.e., 4 out of 10). Panelists felt the science is still unclear as to the rate of impact in terms of rising oceans, etc. Today, climate change (defined broadly) is episodic and hence the ITS contribution in addressing climate change impacts is driven by ITS technology that supports response to episodic events. Connected Vehicle Technology (CVT) as (1) a data collector and (2) a traffic management assist in evacuation would seem to be the principal ITS contributions. Additionally, designing resilience and improved network monitoring capability into transportation systems should be considered in upcoming capital investments. This trend could be seen as primarily impacting the conditions, initial design, and maintenance of the road infrastructure including use of specific construction materials, rate of repair, and maintenance.

## 3.15 Smart Grid

Panelists agreed that the Smart Grid trend is very likely to continue. The panelists felt there will be a slightly higher than average impact on transportation (i.e., 6 out of 10) and the impact on ITS scored slightly less than average (i.e., 4 out of 10). The panelists were somewhat split on when this trend needed to be addressed at the Federal level with half indicating that these issues should be addressed now and half indicating that they should be addressed in 4 or more years. This trend is a case for the Federal government to demonstrate technology and to justify the use cases to the state and local governments. Panelists felt that the opportunities to decrease energy consumption of roadway lighting are enormous and should be aggressively explored. The roadway lighting energy savings (similar to the change out to light-emitting diode (LED) signals) can be directly monetized in terms of energy costs to the agency as well as decreased carbon footprint. Additionally, panelists felt that the penetration of electric vehicles into the fleet should be at a pace to not overwhelm the grid, and the grid is important to supporting electric vehicles and range extended electric vehicle charging, but otherwise its role relative to ITS is unclear.

## 3.16 Government Fiscal Constraints

Panelists agreed that the Government Fiscal Constraints trend is very likely to continue and unanimously agreed that this issue needs to be addressed now. Panelists scored the impact to transportation high (i.e., 8 out of 10) and scored the impact to the Federal ITS program just above average (i.e., 6 out of 10). Panelists felt that better government fiscal management is necessary and inevitable. Transportation systems are critical to economic growth and sustainability. Reducing maintenance costs by better selection of expansion (because every expansion grows maintenance, which may have a larger long term cost than initial capital), advanced materials, and mass transit may have more direct impact. The funding arrangement for the Highway Trust needs to be revisited and tax increases may be necessary to implement improved public transportation, which is lacking. ITS projects can provide savings, but may not be significant enough to address the problem of fiscal constraints limiting transportation funding. This is a multifaceted issue for ITS. On one hand, it seems almost certain to affect demand for new ITS systems and potentially for investment in ITS R&D. New system investment will likely be subjected to rigorous return on investment (ROI) criteria. However, panelists did not feel that ITS solutions would offer more than a stop-gap fix. On the other hand, if ITS data were also used to help create awareness of problems and roadway surface sensing, there arises an issue of whether the OEMs will pay to connect all this ITS relevant sensing to the ITS radio and, again, who pays to process the data. The issue may solve itself if the public becomes disenchanted with road and congestion conditions to the extent that gas taxes can be raised and highway funding restored.

## 3.17 Vehicle Miles Traveled

Panelists were generally split on the likelihood of the Vehicle Miles Traveled trend and felt that if this trend is going to be addressed at the Federal level it could be addressed in the next 4 or more years. Panelists scored the impact to transportation at just under average (i.e., 4 out of 10) and scored the impact on the Federal ITS Program at just under average (i.e., 4 out of 10). Panelists felt that technically, VMT can be made to work as an alternative to the gas tax. The larger question is whether it will be adopted as the replacement to the gas tax. If so, then it is hard to see the Federal ITS Program not having a role in making VMT work and helping to evolve VMT systems with IT technology. If not adopted, then what is the Federal ITS Program role? Perhaps, the Federal role could be to help facilitate VMT technology for vehicle insurance programs? Panelists also suggested that commercial trucking could be an early adopter of VMT systems.

## 3.18 Congestion Pricing

Panelists all agreed that the Congestion Pricing trend is very likely to continue and concerns associated with this trend need to be addressed now. Panelists scored the impact to transportation relatively high (i.e., 7 out of 10) and scored the impact on the Federal ITS Program at just above average (i.e., 6 out of 10). Panelists agreed that as funding of infrastructure continues to be a challenge, alternate models to fund roads including user fees as well as cost as a means to manage demand will be key strategies in funding and management going forward. They agreed that fee payment can easily be accommodated by CVT and that the ITS Program role could include standards development, and should include research related to the impact of various pricing strategies on both long distance and local travel behavior in urban areas and on freeways. There are many unanswered questions that could be addressed through both field data collection and simulation.

## 3.19 Performance Measures for Transportation

Panelists agreed that the performance Measures for Transportation trend is very likely to continue and should be addressed now. They scored the impact to transportation high (i.e., 8 out of 10) and they scored the impact to ITS very high (i.e., 9 out of 10). Panelists agreed that ITS Program has a major role to play in the collection of data for performance measurement. With the MAP-21 performance measurement requirements coming in the near future, one panelist recommended that the Federal ITS Program provide assistance or guidance for the development of low-cost techniques and tools for performance measurement. Another panelist mentioned the importance of determining what is measured that will provide useful information about our transportation systems. Performance measurement related to mobility and safety is an important area that could affect the manner in which transportation agencies manage their systems. The current concern is that mobility-related measures are expensive to collect, and analysis tools are not readily available. The ITS Program could make a significant contribution to this area if it began work on low-cost techniques and tools for performance measurement in the very near future. Since rules are currently being developed for performance measurement, it would be useful if this work began in the near future.

## 3.20 Lean Startups & Minimum Viable Products

Panelists agreed that the Lean Startups and Minimum Viable Products trend has already taken hold and is very likely to continue. They scored the impact on transportation low (i.e., 4 out of 10) and the impact on the Federal ITS program equally low (i.e., 4 out of 10). They agreed that the lean startup approach has already arrived and it is the antithesis of the government-funded research approach which is a linear approach that is slowed by procurement policies, and is difficult to execute iteratively. Within the bounds of existing procurement regulations, the ITS Program could encourage this process by encouraging application development by supporting open data, offering government resources to support application development, and/or financial incentives. This trend was not considered a high priority because much of this work will be driven by the IT industry, as well as the likelihood that the OEMs will open their on-board systems for non-safety application development. It would seem this trend covers mostly applications. It is difficult to conceive how this trend would alter vehicle development. It may allow some installation of some type of minimally viable safety system or ITS related capability with the expectation that the platform would be robust enough to be upgradeable perhaps over-the-air in the future. Safety-critical and life-critical products probably should not follow this model.

## 3.21 Massive Online Open Courseware (MOOCs)

Panelists were split on the likelihood of the Massive Online Open Courseware trend. They scored the impact on transportation low (i.e., 4 out of 10) and scored the impact on the Federal ITS program as average (i.e., 5 out of 10). Panelists were also split on the time for the ITS program to address this trend with some suggesting that work on this issue should begin now and some suggesting that work on this issue could wait for another 10 or more years. One panelist stated that, "most, if not all, of the features of the MOOCs described for this trend are already contained in on-line courses offered by organizations such as CITE, and noted that CITE's enrollment has significantly increased since the organization began offering these courses at no cost to the student. The difficulty with applying the MOOC business model to the ITS community is the fact that this is a very small community, when compared with others such as the IT or project management communities. Recently, Steve Lockwood of Parsons Brinckerhoff estimated that there are a total of 3,000 professionals in this practice area. As a result, on-line instruction will always require some degree of Federal support if it is to succeed. Both CITE and the JPO are actively pursuing this subject, and other than the continued updating of courseware and experimenting with new delivery techniques, it is unlikely that a new program is required."

## 3.22 Same Day Mail Order Delivery

Panelists were split on the likelihood of the Same Day Mail Order Delivery trend. They scored the impact on transportation low (i.e., 4 out of 10) and scored the impact on the Federal ITS program even lower (i.e., 2 out of 10). The general consensus was that there would be no need for the ITS program to address this trend within the next 4 or more years. Panelists generally felt that it is too early to judge the impact of same day delivery. It is still not clear if it will succeed in the marketplace. At this point, it is too speculative to address. FEDEX and others are already moving in this direction and it is part of the larger just in time delivery trend and it will be part of a larger re-organization of how we shop and build things. However, it is not clear that there is a strong ITS program interest except that entities seeking to engage in same-day delivery will be large and that should be studied if the trend does catch on.

## 3.23 Evolution of Positioning Systems

Panelists agreed that the Evolution of Positioning Systems trend is likely to continue. They scored the impact to transportation relatively high (i.e., 7 out of 10) and the impact on the Federal ITS program at just over average (i.e., 6 out of 10). Panelists were somewhat split on the time for the ITS program to address this issue with just under half believing that the issue should be addressed now and just over half feeling that it could be addressed in 4 or more years. Panelists agreed that the Federal ITS program will not be the leading driver for positioning system capability. However, the ITS domain will become a user as positioning systems evolve and will be in the position of trying to leverage the technology advancement. The positioning system technology is a cornerstone for many ITS applications including CV. The ITS program needs to be the advocate for the transportation community. If hardware can be developed to integrate the information from the different positioning systems the accuracy will be extraordinary. The positioning device industry will develop the hardware but the ITS program should be following the development closely to identify areas where federal funding to support innovation would be desirable.

# 4 Recommendations for Action

The Horizons Panel's individual assessments of the trends discussed in the previous section were used to select a smaller number of topics for discussion during a meeting of the expert panel. The five topics selected for discussion were 1) Big/Open Data & Connected Sensors/Machine to Machine (M2M) Communications, 2) Performance Measures, 3) Government Fiscal Constraints, 4) Semi-Autonomous and Autonomous Vehicles, and 5) Aging Populations. The sections below summarize the discussions on each topic and present the recommendations for USDOT action that were made by the panel.

## 4.1 Big/Open Data (and Connected Sensors/M2M)

The faced paced evolution of the field of Big Data in the private sector is largely incompatible with the current research and deployment model used in the government sector. The panelists agreed that the time between research and deployment should be shortened to be more in line with current private sector practices.

The recent proliferation and reliance on privately collected data by state and local departments of transportation raised the important question of "who owns the data?" The use of privately collected data is not necessarily a bad thing, due to these companies' ability to collect and store the data more reliably and cheaply than the public sector, however, this is likely to change "business as usual" for DOTs at all levels. The example of the TIGER line files was used as an example for when the federal government purchases data, it becomes public data. The I-95 Corridor project was also used as an example to show that when the government helps to fund the deployment of sensors, that they retain the right to use the data collected by those sensors.

Differences between vehicles and sensor technologies of various companies necessitates some need for government oversight in the regards to the measurements and data captured, in order to guarantee that appropriate statistics and metrics are being developed despite the multitude of vehicle makes and models. The development of the applications that utilize these data would fall to industry because they have the expertise and motivation to develop innovative applications.

**Recommendations:**

- The role of the Federal ITS program lies in the facilitation of standards, with some potential data collection.
- The Federal ITS program could fund research more similarly to a venture capitalist funding a portfolio of projects rather than utilizing a single-winner contract award approach. One mechanism might be through the use of "creative Broad Agency Announcements (BAA's)".
- Concerns over the way society handles data privacy issues will been led by other industries, so it does not need to be a program focus, but it is an effort to stay aware of.
- The Federal ITS program could function as a national clearinghouse for ongoing development efforts and management on innovation, as a way to coordinate and leverage research and development efforts and reduce duplicative efforts.

## 4.2 Performance Measures

ITS technologies provide many opportunities for the collection of data for performance measurement. Not only do they allow data for existing performance measures to be collected more cheaply and easily, but they also have the potential to encourage the development of more complex and meaningful measures involving data that were not previously collectable. New performance measures could provide very helpful information and statistics for FHWA, NHTSA, EPA, and other federal, state and local agencies, including planners.

The continued rise of data science expands the opportunities for the use of the large amount of data currently collected by ITS technology, a quantity that will continue to grow as ITS is adopted more widely at the state and local level. Reliability of the technology and accuracy of the collected data remains a concern, but as the field ages and grows, the technology improves.

**Recommendations:**

- The role of the Federal ITS program is a supporting one on Performance Measures, aiding the Offices of Operations, Transportation Performance Management, and Planning in seeing what tools ITS can offer to better support existing measures and what new measures could be developed that provide greater information to the transportation community. Utilization of think tanks and universities could lead to the development of new, complex performance measures through “challenges” and BAAs.
- Education of the transportation community on performance measurement should continue through the ITS Professional Capacity Building (PCB) program’s efforts.
- Creation of a data releasing portal akin to data.gov for transportation data may be useful for crowd sourced development of new performance measures.

## 4.3 Government Fiscal Constraints

The panelists were united in their conclusion that ITS is not the solution to the problem of insufficient funding for the nation’s transportation infrastructure. Increased political accountability for spending may deemphasize ribbon cutting opportunities when there more affordable ITS solutions available to solve the problem. While ITS provides solutions that serve as cost-effective alternatives to large infrastructure projects, there are limits to the additional capacity gains made through ITS deployments and those infrastructure expansions will likely be necessary in the long term. ITS solutions can also help determine where roadway investment is actually necessary based on the collection of various performance measures.

However, the use of ITS is not limited to capacity expansion, but also includes asset management. As the trend of asset monetization continues, the transportation system will begin to be treated more like other public utilities.

**Recommendations:**

- ITS is a tool to assist Management and Operations, but differentiating the two programs should be improved.
- A Federal ITS role could be collecting and providing information and best practices in a technology transfer function on topics such as electronic pricing systems.

## 4.4 Semi-Autonomous & Autonomous Vehicles

While the USDOT is currently involved in the Safety Pilot for their digital short-range communications (DSRC)-based Connected Vehicle (CV) program, auto manufacturers and other companies such as Google are moving the field of autonomous vehicles closer to reality through the use of sensor-based systems. Many semi-autonomous technologies such as adaptive cruise control and lane keeping assistance are already being deployed in private automobiles. This subject raised a large number of questions including what should the Federal ITS role in the semi-autonomous/autonomous vehicle field be prior to the broad deployment of CV technologies and what potential “consequences” might arise from the growing level of autonomy in the personal vehicle.

Panelists commented that the continued advance of these sensor-based technologies (rather than DSRC-based) is not a bad thing. ITS is not dependent on the “mesh network” of vehicles, but rather the intelligence of the vehicles. Smarter vehicles of any type will improve the system by being safer and collecting data about the functionality of the system. The redundant systems that will be required in the autonomous vehicles will keep vehicle-errors low, while reducing driver-error, thus improving the overall safety of the transportation system.

Potential consequences include increased distracted driving in the short term and limited shift toward transit/carpool in the long term. Additionally, high price points would likely leave out many who would benefit the greatest from an autonomous vehicle – the elderly and low income individuals. However, the sharing of these semi-autonomous/autonomous vehicles could help reduce the impact of these negative effects.

**Recommendations:**

- The USDOT could assist the industry with the sensor-based technologies prior to the broad deployment of the Connected Vehicle program through functions such as safety oversight and infrastructure improvements (better roadway striping, encouraging the use of particular materials, etc.).
- The Federal ITS program should consider developing a potential roadmap for the deployment of (semi-) autonomous vehicles and the associated use cases. Existing working groups within the ITS JPO, who have experience in thought leadership and visioning, make the ITS JPO ideal for leading the development of this roadmap. The ability of the ITS JPO to reach out to the freight and automotive industries, as well as state and local partners, leaves the ITS JPO well positioned for aiding the development of pilot projects.

## 4.5 Aging Population

Due to the constraints of deployment timelines for vehicles (early deployment by 2017 for broad deployment by 2020), it is likely that many of the Baby Boomers at the early part of the wave may not be recipients of built-in technologies that will assist aging drivers, but it is very possible that mid- and late- Boomers will. There will also likely be a myriad of off-the-shelf technologies available to all drivers in the coming years that will assist aging drivers.

A major obstacle to planning for the increase in aging drivers is a lack of data on the driving habits of seniors. Additionally, there have been significant societal changes in regards to where seniors live over the past few decades, with more seniors choosing to live more independently and fewer seniors living in multi-generational housing. This shift may change the way that the concept of “livability” will evolve in the coming years.

**Recommendations:**

- The Federal ITS role should involve encouraging the collection of data on seniors’ driving habits. The development of testing corridors, so that these assistive technologies are being tested on a larger proportion of the target demographic, could be another role for the JPO.
- The ITS JPO should look into studies on how an aging (but still largely independent) population may affect the transportation network and which technologies have the greatest potential to allow seniors to maintain their independence. Diverse solutions will be necessary because of differing needs in regional, rural, and urban environments.

# 5 Conclusions

This initial broad horizon scan was successful and met its goals. The study cast a broad net and identified a broad set of trends of interest, providing useful input to ITS strategic planning efforts. The study broadened the perspectives of both the sponsor and the participants by identifying and assessing external trends that have not yet had an impact on transportation and by examining social and policy trends as well as technical ones.

Horizon scans such as this one reduce risks and increases opportunities for the federal ITS program. By examining the broader information and communications technology (ICT) landscape, the study helps avoid investments in duplicative or soon to be obsolete research topics. In addition, it increases the opportunity to leverage developments in other ICT domains, potentially reducing the cost of ITS and speeding its implementation.

Specific elements of the approach were successful, and are recommended for use in future scans. In particular:

- The use of RSS feeds proved to be an effective tool for efficiently scanning a diverse set of sources and identifying relevant literature for more detailed review.
- The modified Delphi approach using a small expert panel with a structured set of evaluation questions presented individually to each panelist, followed by sharing of the assessment results and group discussion, was effective at assessing the trends and recommending potential actions for USDOT consideration.

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# APPENDIX A. List of Acronyms

| Acronym | Meaning |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ACC | Adaptive Cruise Control |
| AGL | Automotive Grade Linux |
| API | Application Programming Interface |
| ATMS | Active Traffic Management System |
| BOC(1.1) | Binary Offset Carrier 1.1 |
| BSM | Basic Safety Message |
| CAHPC | Center for Applied High Performance Computing |
| CATT | Center for Advanced Transportation Technology |
| CBO | Congressional Budget Office |
| CIO | Chief Information Officer |
| CITE | Consortium for ITS Training and Education |
| CORS | Continuously Operating Reference Stations |
| CTO | Chief Technology Officer |
| CVT | Connected Vehicle Technology |
| DAB | Digital Audio Broadcasting |
| DARPA | Defense Advanced Research Projects Agency |
| DOT | Department of Transportation |
| DSRC | Digital Short-Range Communications |
| ELMS | Electrical Lighting Management System |
| EPA | Environmental Protection Agency |
| ERTICO | Intelligent Transport Systems and Services for Europe |
| EVAA | Electric Vehicle Association of the Americas |
| FAA | Federal Aviation Administration |
| FEDEX | Federal Express, Inc. |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| FTP | File Transfer Protocol |
| GDGPS | Global Differential Global Positioning System |
| GJU | Galileo Joint Undertaking |
| GLONASS | Russian military global navigation satellite system |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GSA | General Services Administration |
| GTFS | General Transit Feed Specification |
| HOT | High Occupancy Toll |
| HTF | Highway Trust Fund |
| ICT | Information and Communications Technology |
| IGS | International GNSS Service |

| Acronym | Meaning |
|---|---|
| ITRE | Institute for Transportation Research and Education |
| ITS | Intelligent Transportation Systems |
| JPL | Jet Propulsion Laboratory |
| JPO | Joint Program Office |
| LED | Light-emitting diode |
| LPS | Local Positioning System |
| MAP-21 | Moving Ahead for Progress in the 21st Century |
| MIT | Massachusetts Institute of Technology |
| MITM | Man in the Middle |
| MOOC | Massive Open Online Course |
| MTA | Mass Transit Account |
| MVP | Minimum Viable Product |
| NASA | National Aeronautics and Space Administration |
| NDGPS | Nationwide Differential GPS |
| NHS | National Highway System |
| NHTSA | National Highway Traffic Safety Administration |
| NICC | Noblis Innovation and Collaboration Center |
| NRSCC | National Remote Sensing Centre of China |
| NTOC | National Transportation Operations Coalition |
| OBD-II | Onboard Diagnostic System |
| OPUS | Online Positioning User Service |
| PAYD | Pay as You Drive |
| PCB | Professional Capacity Building |
| PHYD | Pay How You Drive |
| RFID | Radio-frequency Identification |
| RITA | Research and Innovative Technology Administration |
| ROI | Return on Investment |
| RSS | Really Simple Syndication |
| SAE | Society of Automotive Engineers |
| SCADA | Supervisory Control and Data Acquisition |
| TASS | TDRSS Augmentation Service Satellites |
| TDRSS | Tracking and Data Relay Satellite System |
| TMC | Transportation Management Center |
| TSAG | Transportation Safety Advancement Group |
| UBI | Usage Based Insurance |
| USB | Universal Serial Bus |
| USDOT | United States Department of Transportation |
| VDOT | Virginia Department of Transportation |
| VII | Vehicle Infrastructure Integration |
| VMT | Vehicle Miles Traveled |
| WAAS | Wide Area Augmentation System |

# APPENDIX B. Trend Summaries

## Mobility for an Aging Population

### Definition

Mobility for an aging population can be defined by the demands that the aging population place on the transportation system. Two of the top concerns for mobility of the aging US population include how to handle the safety of those with diminished capacity and how to address the needs of the large demographic of baby boomers (Americans born between 1946 and 1964).

### Reasons for Identifying this Trend

Today one baby boomer is turning 63 every 7 seconds. The boomer population is estimated to be about 88,000,000 million adults. Transportation planners and providers need to consider how the boomers' aging, transportation demands, expectations, and transition from the workforce will impact the future of the transportation system.

Understandably, boomers' are not expected to age like their parents nor have the same expectations in retirement. Boomers are expected to work longer and live longer while managing multiple chronic illnesses due to obesity related diseases. The boomers are more educated and active than previous generations and it is expected that a higher level of activity and learning will continue well into retirement. Both male and female boomers are expected to drive/travel more in retirement than their parents did. Boomers have experienced seamless affordable mobility, new technology, high style and the expectation of improvements. They are likely to demand more than public transportation alternatives. However, just like previous generations, however, boomer aging and illnesses will be accompanied by reduced reaction time, reduced cognitive capability, fragile bodies, etc. Safety systems and transportation alternatives for our aging population could help the aging population maintain mobility.

Meeting the automotive needs of the aging population will take considerable advance planning. This is due to the fact that the vehicle fleet does not turn over quickly. The average age of vehicles on the roadway was approximately 11 years in 2011). The average age of vehicles on the roadway has been trending upward for some time, and based on current economic conditions, that trend is likely to continue in the foreseeable future. Because people tend to keep a vehicle for on average 11 years, any new in-vehicle system intended to aid seniors will not be half the vehicles until well over a decade after its introduction (since it is unlikely to be initially deployed in all makes and models). In order to reach a greater percentage of baby boomers while they are still alive and driving, attention will need to be paid to aftermarket and brought-in technologies and services.

### Related Trends

This trend is related to the autonomous and semi-autonomous vehicles trend, in that utility of truly autonomous vehicles would mean that travelers are free to for example watch movies, Skype with friends, study, pursue other interests, learn new skills, play video games, check on loved ones, access social media, etc. This trend would also be useful to those with diminished capacity such as living with the threat of stroke, poor vision, or early onset of dementia.

Car sharing is expected to rise as boomers find innovative ways to preserve retirement resources. Car sharing can be a way to turn a liability into an asset. Just as some are finding that house sharing can significantly reduce the cost of vacations, car sharing can significantly reduce the cost of owning a vehicle.

# Changing Perception of the Car by Millennials and Generation Y

## Definition

The generation born between the early 1980's and the early 2000's are often referred to as either Generation Y (the generation after Generation X) or as Millennials (those growing up around the change in the millennium). A number of studies have shown that Millennials see cars as less of a status symbol, place less importance on car ownership than previous generations, and also place a higher value on technology and infotainment features.

The cyber world has opened up a new style of living. Millennials grew up relying on the internet to provide them with conveniences, low cost products and digital resources. Through the internet they can quickly find the best way to accomplish almost anything. They have the ability to view a large selection of products in a wide range of prices. Likewise, they know how to sell things they longer need. They have been introduced to the concept of buying virtual products. During their school years they are no longer saddled with overloaded backpacks as they walk around campus because intellectual resources are now digitized. Many of the everyday conveniences for them have taken on a less physical form. They are more familiar with the concept of buying digital products as opposed to physical stuff. To make life even easier, they can access these digital resources from almost anywhere, providing the ultimate in convenience and productivity.

The internet has also enabled greater information about public transportation options for younger travelers, especially in urban and suburban areas. Knowing that they can easily find affordable and convenient transportation has perhaps made them less concerned about owning a personal vehicle or willing to wait longer until they can afford personal transportation that suits their style. They are coming of age at a time when there are car sharing options available and a depressed economy, making alternatives to car ownership more attractive to some.

## Reasons for Identifying this Trend

This trend was cited due to the potential impact that Millennials' transportation purchasing and driving influences may have on the transportation network and on ITS applications. These groups are increasingly associating themselves with more environmentally responsible travel, less material possessions, and smarter purchasing choices which could open the doors for more public transportation and private transportation services like car sharing. These influences could change the dynamic for future transportation infrastructure and vehicle needs and investments.

*Getaround* is one service that enables people to rent cars from people nearby, through this service users are allowed to grant and gain access to idle cars through mobile phones, allowing users to share assets regardless of geographic location. Social media is also helping to make these connections as users feel less risk associated with lending their vehicle to friends of friends.

Additionally, the transportation influences from Millennials may also increase the need for public transportation investments. These groups are identifying more with the convenience that living in urban areas provides and will need the types of transportation services that support that lifestyle.

## Related Trends

This trend is related to the autonomous and semi-autonomous vehicles trend, in that utility of truly autonomous vehicles would mean that travelers are free to for example watch movies, Skype with friends, play video games, check on loved ones, access social media, etc.

Car sharing is expected to rise as Millennials feel less need to or are less able to afford to own a private vehicle. Car sharing can be a way to turn a liability into an asset. Just as some are finding that house sharing can significantly reduce the cost of vacations, car sharing can significantly reduce the cost of owning a vehicle.

# Crowd-Sourced Data

## Definition

Crowdsourcing is a process that involves outsourcing tasks to a distributed group of people. This process can occur both online and offline. The difference between crowdsourcing and ordinary outsourcing is that a task or problem is outsourced to an undefined public rather than a specific body, such as paid employees. For example, within an hour after being contacted by government officials after Hurricane Sandy, Waze had a simple system up and running that allowed users who visited a gas station to get a system message that prompted them to report the conditions there. The users were able to leave a chit-chat message explaining if there was gas available, how the lines were and how long the wait was. The Waze application also displayed pins on its maps for local gas stations that were open. Government officials were able to use this information to help direct gasoline trucks to those who needed it most. Waze is a free mobile navigation application for the iPhone and Android platforms that allows drivers to build and use live maps, real-time traffic updates and turn-by-turn directions.

## Reasons for Identifying this Trend

In the example above, the Federal Emergency Management Agency (FEMA) and Waze were able to quickly communicate with those affected by hurricane Sandy to identify their needs and provide a more focused response. This type of spontaneous public data gathering could clearly help with many aspects of transportation operations and in particular emergency operations. This same type of crowd-sourced data collection could help not only during hurricanes and flooding events, but also during major traffic incidents, snow storms, tornados, and even to make planned events run more smoothly.

Crowd-sourcing applications could also be used to report transit location and seat availability during normal operations, or during traffic or weather incidents. Transit vehicle location and passenger count systems can be expensive. Crowd-sourcing applications could be one method of providing affordable transit vehicle on-time arrival and seat availability information to transit users.

## Related Trends

Car sharing is expected to rise in the future as owners begin to treat their car as less of a liability and more of an asset. Crowd-sourced data may also be a way to communicate transportation needs and provide a method to reach out to those with available transportation solutions including car sharing services, private transportation providers, and transit organizations.

Transportation related environment and climate change applications may be able to incorporate crowd-sourced data to optimize operational solutions.

# Open Data and Big Data

## Definition

This is a combination of two trends: Open Data and Big Data. Open Data is data available at little or no cost (typically no more than the cost for sharing it), that can be used, reused, and redistributed in any way. The only restrictions, which may or may not be present, may be a requirement to provide attribution to the original creator and/or to share any enhanced data in a similar manner (called "share-alike"). To be truly useful, Open Data must be provided in a standardized, published, and free machine-readable format that can be easily machine read and processed, not as text in a document or web page.

A subset of the Open Data movement is Open Government Data. This is defined as institutional data available for public use in machine-readable formats on a large scale. Common examples include the General Transit Feed Specification (GTFS) data provided by many of the major metropolitan public transit systems, as well as information provided by HealthData.gov. Both of these examples are publically available in order to allow the public and developers to innovate and create applications and visualizations that provide elected officials and the public with better information than they previously had, in order to enable them to make better decisions.

Big Data is the growing volume of massive data sets becoming available from massive sensor networks, from social networks and other Internet uses, from shopping, mobile phone use, and other sources. As two examples, Wal-Mart's customer transactions database is estimated to contain 167 times the amount of information in the entire Library of Congress, while Facebook contains 40 billion photos [17]. These massive data sets present both challenges and opportunities, opening up entirely new approaches for analysis.

## Reasons for Identifying this Trend

The data currently collected by cameras and sensors in ITS systems is abundant. The volume of data that will be generated through the Connected Vehicle program is almost unimaginable. As of July 2012, nearly 45 billion public transit passenger-miles (85% of the 2010 nationwide total passenger miles) were covered by agencies with open route and schedule data [15]. That number encompasses nearly a fourth of all transit providers, especially those in major metropolitan areas, who utilize the standard GTFS format to provide this open data. The standardized information contained in a connected vehicle basic safety message (BSM), if publically available at little or no cost, could provide a similar platform for the creation of third party applications without the government paying for their development.

Todd Park, former CTO of Health and Human Services, leveraged the liberation of government health data, along with “datapaloozas”, to encourage entrepreneurs and innovators to create applications with concrete business plans that provide services to the public based on that free data in 90 days. Events such as meet-ups and datapaloozas allow government agencies to let developers and the public know what sort of data is available, leading to innovative ways to visualize and share the data in a usable format for public benefit.

## Related Trends

Lean startups are connected to open data through the development of applications away from the government institution. The lean startup approach allows for quick turn around and innovation in developing applications that utilize government data. Instead of using a top-down model that can take 18 months to see results that may only be mediocre, a lean-startup model could result in spending a week and produces a failed project, but that loss is not disastrous because of the limited amount of time spent on the project.

Cheap and connected sensors are related to open and big data because as the number of sensors continues to grow and the systems become more interconnected, the available data will grow in quantity and complexity. The development of ways to analyze the complex data could potentially be done through open and big data sharing practices.

Cloud computing resources are also related, as they lower the cost of processing and storage resources needed to keep and analyze big data.

# Cloud Computing

## Definition

The National Institute of Standards and Technology defines cloud computing as “a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [25]. The “cloud” may be private, shared, or public, and hosted internally or externally. There are three service models: providing software applications (the Software as a Service model), providing an environment with tools and service to allow customers to build and operate their own software (the Platform as a Service model), or can provide network access to fundamental computing resources such as storage and processing power (the Infrastructure as a Service model).

Cloud computing often reduces costs and increases flexibility. Outsourced clouds significantly reduce up-front costs, as the customer does not need to invest in computing resources. For internal clouds, shared resources also reduce the up-front costs, although to a lesser extent. The reduced up-front costs reduce the barrier to deployment of new or experimental services. Elasticity (the ability to rapidly expand and contract the amount of computing resources) can further reduce cost by avoiding the need to provision year-round for peak demands.

Software as a Service models eliminate the need for companies to handle the internal costs associated with updating software to the latest versions. Instead, the provider handles all upgrades and includes this in the cost of their services.

## Reasons for Identifying this Trend

This trend is already moving forward rapidly in the general IT field and was identified for its applicability to the Connected Vehicle program, as well as more general ITS applicability. The use of ITS technologies generates large amounts of data, which are generally archived for later analysis in addition to being used for real time analysis. These data could be migrated to cloud storage in order to increase the interactivity of data from various sources, like Transportation Management Centers (TMCs), across geopolitical boundaries. En masse cloud migration may also lead to the development of more standardized data structures to allow for the interoperability of the various systems. In addition, traffic data providers are increasingly offering analytic capabilities using their own "cloud" computing resources and DOTs are examining the extent to which cloud services can reduce the cost and improve the operations of Traffic Management Centers.

This trend may also impact ITS application areas, such as Incident Response, with cloud computing providing more mobile solutions for service patrols that are connected with State Police communications and operations. The reduced reliance on a physical location could allow for more flexible operations in the case of a natural disaster or another event that could cause the temporary closure of a TMC.

The availability of data at off-site locations also could improve the coordination between planning and operations for transportation systems because planners would have greater access to performance measures of the existing system from both a historical and real time perspective. Some cloud analytics could reduce the costs for obtaining this type of data.

## Related Trends

Cheap and connected sensors are related to cloud computing because their increased deployment in ITS infrastructure will generate larger amounts of data that individual TMCs and Departments of Transportation (DOTs) will not have the technical expertise to store, secure and maintain on their own datacenters. The same is true for the related "Big Data" trend.

# Cheap & Connected Sensors / M2M Communications

## Definition

Cheap and connected sensors refer to the trend of decreasing prices for basic sensors and their incorporation into the ever growing number of Wi-Fi or telecom accessible devices that individuals own. These sensors may also be considered cheap in that by combining several "off the shelf" components, a sophisticated sensor can be created for a fraction of custom built or proprietary designs.

Machine to Machine (M2M) communication is direct communication between two machines, without middleman intervention, that is typically triggered by a sensor actuation. Sensor actuation could occur from a major event such as a vehicle crash to a benign event as a refrigerator sending a message to the car to say that there is no milk at home.

## Reasons for Identifying this Trend

The connected vehicle program is itself an example of this trend, with an increasing number of sensors deployed on vehicles and V2X communications occurring without human intervention.

However, the trend is not limited to vehicles. Increasingly inexpensive sensors are appearing in all fields, and may be applicable to roadside sensors and new in-vehicle sensors not found on current vehicles. These sensors are often linked to wireless networks, either using co-located Wi-Fi networks or a variety of short-range, low-cost wireless mesh network devices, such as those using the ZigBee specification.

## Related trends

Cloud computing and remote storage are impacted by this trend because the mobile nature of these devices necessitates off-device processing and storage of data collected from these sensors.

Big data is impacted by these topics because the sheer volume of data generated by an increasing number of sensors will surpass the capabilities we have to analyze data. A need for better algorithms and processing power is going to grow as the quantity of data available for collection grows. It has been estimated that the world now collects more data than it has the ability to store.

Crowd-sourced data is related to the increasing number of cheap and connected sensors because having that large number of sensors broadcasting information could allow for more in-depth analysis on the way the world works, such as the amount of fuel that was *actually* wasted in a traffic jam because every car can broadcast its fuel level every so often.

# Usage Based Insurance

## Definition

A new innovative insurance product that continues to gain traction is Usage Based Insurance (UBI), also known as pay as you drive (PAYD) and pay how you drive (PHYD) insurance. Mileage-based auto insurance is a type of automobile insurance whereby the costs of motor insurance are dependent upon the type of vehicle used, measured against time, distance, behavior and location. Currently, eight of the top ten and the majority of the top twenty auto insurance companies in the US either publicly offer UBI or are close to doing so. Many of the smaller insurance companies are sitting on the sidelines to see what trends may be most advantageous for them.

In the US, some insurance companies have taken UBI offerings nationwide (e.g., Progressive and State Farm) and it appears that others will have the motivation to follow suit. These companies are also working to gather as much and as detailed data as possible from device providers, so that they have all the requisite data to build strong solutions. To their advantage the cost of these types of devices has decreased, as has the cost of transmitting data.

By some estimates it takes at least two years to get the algorithms, system, and electronics in place to deliver a viable UBI product. Increasing in-vehicle technology advances will likely shorten these timelines even further. With UBI systems in place companies will have the motivators to actually stimulate drivers toward safer behavior. In addition to collecting driving usage data some of these systems include driver alert devices. These instant feedback devices are behavior-shaping and facilitate immediate benefits and savings, as the cost of accidents goes down, lost time goes down, and worker compensation claims go down.

For all the promise that UBI solutions do hold, and despite all the traction they seem to be gaining, the fact remains that most insurance companies are still in a period of trial and error with their individual products. Insurers are trying things out which is healthy for the sector, but a lot of this currently seems to be experimentation and has not been based on long-term strategic plans. It is critical that these companies develop strategies for these products if they expect to ultimately transition to these types of business models.

## Reasons for Identifying this Trend

With robust systems like these in place, companies will have the infrastructure to support broader services. One possibility being investigated is assistance with the collection of road user fees and in particular the replacement of the gas tax. Some entities have looked at the feasibility of partnering with insurance companies to collect road user fees. In addition, there may be other types of transportation services that could be facilitated by these types of private UBI service providers.

Usage-based insurance technologies have additional benefits related to the operations and management of transportation systems. Some insurance companies include analytics and gamification strategies that assess nearly every aspect of an individual's driving characteristics, including hard-braking, quick accelerations and potential delay characteristics and reward better driving habits. The insurance industry could for example make value propositions to consumers by reducing annual fees based on safe driving data. Implementation of connected vehicle technology and the related safety applications could help drivers to minimize insurance fees by avoiding crashes and help insurance companies to have access to the data needed to adjust driver fees.

## Related Trends

Car sharing is expected to rise in the future as owners begin to treat their car as less of a liability and more of an asset. The increased number of drivers for one vehicle may impact how UBI is applied as each driver will have a unique safety record. The insurance companies will then have to determine what impact this will have on insuring a vehicle that is a participant in car sharing.

Over the air software updates will undoubtedly be a concern for UBI providers as they will need to continually monitor and update their products on the vehicle. These updates will likely have to be performed in a wireless manner and without interruption to the driver or vehicle owner.

# Autonomous and Semi-autonomous Vehicles

## Definition

The autonomous vehicle spectrum includes four major categories: "feet off"; "hands off"; "eyes off"; "people out." Feet off is generally considered to be the use of Adaptive Cruise Control (ACC) in order to automatically adjust a vehicle's speed in order to maintain a headway between vehicles. The driver must still steer and operate all other aspects of the vehicle. This technology is currently available commercially in packages from several auto manufacturers.

Hands off is ACC with additional lane centering technology that allows the driver to remove their hands from the wheel while the car is operating in this mode. This type of technology is currently being tested by General Motors, with potential deployment in model year 2014.

Eyes off is a fully autonomous vehicle that drives with a "driver"/passenger present in order to intervene if necessary. This technology is currently being tested by Google. The Japanese government is investigating the potential for having this technology on their roadways by the early 2020s.

People out is a fully autonomous vehicle that is capable of driving itself without a driver and could function as a “robotaxi” that could pick up passengers. This technology has been tested through the Defense Advanced Research Projects Agency (DARPA) challenges. Ultimately, the convergence of connected vehicle technologies and sensor technologies will make this possible.

Other semi-autonomous vehicle technologies include “intervention only” strategies, such as the one being tested by a team from MIT’s Department of Mechanical Engineering, where the computer only overrides driver actions in case of unsafe conditions (going too fast around a curve) or in the event of a potential crash (automatic breaking). Europe will soon be requiring the inclusion of automatic breaking technology on all new vehicles beginning in 2014.

For purposes of the Horizon Scan, the evaluation should include all of the categories except “feet off” as this is already commercially deployed by multiple companies.

## Reasons for selecting this trend

Major reasons for selecting this trend are the current deployment of semi-autonomous technologies, such as ACC and automatic breaking, in the field and the multiple companies that are pursuing both autonomous and semi-autonomous technologies throughout the world. These technologies mimic, but do not match, some of the applications envisioned as part of the broader Connected Vehicle Program’s set of safety, mobility and environment applications. The convergence of the Connected Vehicle Program and the sensor filled car creates great potential for the emergence of a commercially available autonomous vehicle in the 2020s.

Additionally, government study and support of this trend is occurring in Europe and Japan, as well as the U.S.  Several states have passed legislation allowing “eyes off” vehicles to operate on their roads for research purposes, and NHTSA is funding research into safety implications.

A key to the widespread development and adoption of autonomous vehicles will be standardization of legislation across all states, in order to reduce the regulatory hurdles auto manufacturers would be required to navigate in order to make the use of these vehicles wide spread.

## Related Trends

One major related trend that arises in a world with many “eyes off” and “people out” autonomous vehicles is the field of insurance telematics, which would be effected by liability laws and adoption rates of these technologies. Theoretically, in a fully autonomous and connected system, redundancies should reduce the system to be virtually “crashless,” and possibly leading to car insurance as a policy to protect against theft and damage incurred while parked.

An important related trend is the over the air software updating that could allow for critical updates to software systems to update as soon as possible, whether they are security, safety, mobility, or even entertainment related.

The people out autonomous vehicles are closely related to the trend of carsharing, as a fully autonomous, driverless vehicle could drop a woman off at work at 8am, and then drive itself to the residence of an elderly person who is driven to the doctor. The use of fully autonomous vehicles would allow for cars to be used by other users during the time when they currently sit idle, potentially reducing the total number of cars owned.  This would also provide personal mobility to those without drivers licenses, including elderly individuals and youths, as well as those who have chosen not to have a license, but may occasionally wish to travel in a car.

Lastly, autonomous and semiautonomous vehicles will also be impacted by the trend of big data because the need for collecting and processing the data from the sensors and connected vehicle technology could result in a market for driver data and statistics.

# Automotive Security Threats

## Definition

The focus of the automotive security threats discussed in this paper include those that relate to vehicle electronic systems that enable on and off board computing and wireless connectivity. Recent research suggests that there will be explosive development and growth in connected vehicle technology. Implementing these technologies opens the door to potential security vulnerabilities through cyber-attacks initiated by malicious hackers.

Potential vehicle security breaches can occur via onboard diagnostic systems (OBD-II ports), wireless connections, 3rd party infotainment applications, and even tainted CDs played on radio systems. Vehicles use the same wireless technologies that power cell phones and Bluetooth headsets, which makes them particularly vulnerable to remote attacks that are widely known to criminal hackers. Attacks may occur through vehicle immobilization systems and computer viruses and Trojan horses that could turn off the vehicle's lights, lock the doors, shut down the engine, slam on the breaks, and/or allow others to listen to the conversations of the vehicle's occupants.

## Reasons for Identifying this Trend

Currently automakers are implementing new features and technology into vehicles while the potential risks are not fully understood. This introduces opportunities for attack on vehicle systems. Automakers are also making it easier to plug portable computers and phones into vehicles and connect them to the Internet, but in doing so they may also be inadvertently exposing critical systems that run their vehicles to potential attackers because those networks are all linked within the car.

Some of the world's cyber security experts and antivirus software vendors are warning that the proliferation of the connected vehicle will be a prime target for malicious hackers. University researchers have already shown that it is relatively easy to access a vehicle's electronics systems. Some security analysts fear that criminals, terrorists and spies could gradually turn their attention to a vehicle's embedded computers, many of which can be attacked using some of the same techniques as regular computers.

By some estimates the average auto maker is about 20 years behind software companies in understanding how to prevent cyber-attacks. Because of this, security experts are beginning to understand that it is important to reach out to the auto industry and government to address why it is important to develop the sort of engineers the industry is going to need in two, three, five, or 10 years to mitigate potential impacts due to automotive security threats.

Top teams from various organizations including Intel, Society of Automotive Engineers (SAE) International, and many automotive manufacturers are searching for ways to combat electronic bugs that could make automobiles vulnerable to lethal computer viruses. Many automakers are taking the threat very seriously and are investing in security solutions that are built into the product from the outset. SAE International has charged a committee of more than 40 industry experts with advising manufacturers on preventing, detecting and mitigating cyber-attacks.

Some security experts say that automakers have so far failed to adequately protect these systems, leaving them vulnerable to hacks by attackers looking to steal cars, eavesdrop on conversations, or even harm passengers by causing vehicles to crash. Some methods of attacking the vehicle include putting viruses onto compact discs. When unknowing victims try to listen to the CD, it infects the car radio, and then makes its way across the network to more critical systems. Additionally, a combination attack dubbed "Self Destruct," developed as a demonstration, starts when a 60-second timer pops up on a vehicle's digital dashboard and starts counting down. When it reaches zero the virus can simultaneously shut off the vehicle's lights, lock its doors, kill the engine and release or slam on the brakes. In addition to designing viruses to harm passengers in infected vehicles, hackers are able to remotely eavesdrop on conversations inside vehicles, a technique that could be of use to corporate and government spies. Also, when first rolled out about 10 years ago, remote immobilization systems were implemented as an answer to delinquent car payments. The system lets car dealers install a small black box under vehicle dashboards that responds to commands issued through a central website, and relayed over a wireless pager network. The dealer can disable a vehicle’s ignition system, or trigger the horn to begin honking, as a reminder that a payment is due. These are just a few of the know vulnerabilities, but there are likely many more on the horizon.

## Related Trends

Open platforms for vehicle infotainment may lead to increased potential for automotive security breaches.

Related to automotive security threats are the many security threats that plague public transit systems. Some of these known threats include:

1. Accessing payment information through touch surface machines designed to search for the fastest route or for tourist information. Hackers have been able to use these machines to access a command prompt and then connect to File Transfer Protocol (FTP). After taking control of the machine, they can access a router many of which are only secured by using the default password. With information stored in these systems hackers are able to replicate the cheapest monthly rate subway tickets with a magnetic strip and barcode.
2. Because some transportation staff wear a radio-frequency identification (RFID) badge necklace to access trains and subways. Hackers have been able to use social engineering to get close to staff under the guise of needing help, as well as a RFID tag reader disguised in a cigarette box. Hackers can then capture, hack, clone and then own an RFID keychain making all rides free.
3. Additional targets include the transportation network security camera system. After various steps on the wireless access points, things that included antennas, scanning, air-cracking, Wireshark, and man in the middle (MITM) attacks, hackers can get invalid certificates, and then finally a system login. This means supervisory control and data acquisition (SCADA) of critical infrastructure that can be instantly controlled and operated over the Internet.
4. Last but certainly not least, in Spain hackers found public transportation touchscreen machines meant to print or to pay for train tickets that have allowed access to credit card numbers stored without encryption. The big picture was that they were able to get all the credit card numbers of all the customers in the entire country who had ever paid for transportation . . . all stored in plain text files.

# Over the Air Software Updates and Software Defined Radio

## Definition

Just as a smartphone downloads software updates over 3G or 4G wireless or Wi-Fi, the onboard computers responsible for navigation and infotainment in motor vehicles could be provided the capability to receive software updates over the same networks. GM has already used its OnStar technology in order to deploy software upgrades.

Provided security and integrity issues can be adequately addressed, the same capabilities could be expanded to other in-vehicle applications, including safety applications.

Software radio is a radio system that uses installed software to operate on different radio systems around the world with the same hardware, such as XM in the United States and DAB (Digital Audio Broadcasting) in Germany. By replacing traditional hardware components with software, a radio can operate in different frequency bands, using different modulation techniques, and different protocols. The concept has been around for a considerable period of time and has been applied to military radio systems; however the cost had, until recently, limited its more widespread use.

## Reasons for Identifying this Trend

The use of this technology for the constant upgrading of vehicle software has already been deployed by Tesla, while Mercedes-Benz and Chrysler have said that this feature will be utilized by some models in the 2013 model year. With respect to Connected Vehicle applications, the ability to provide over the air updates to vehicles could help ensure that applications all have the most up-to-date security as well as ensuring that if there is a fault in an application, that it is quickly and automatically updated to a safer version of the application.

With over the air updates enabled, it saves automakers' and vehicle owners' time and money that would be spent going to the dealership to get an update or using a USB drive to "plug-in" the update. These require the owners to make time to update their cars which could leave them vulnerable if there is a security or safety problem with an application that their car runs.

The concept of software radio is relevant to the field because if the same hardware for connected vehicle technology could be used globally, even if standards are slightly different, the rate of deployment would likely be higher due to economies of scale captured by auto manufacturers.

## Related Trends

Open platforms for vehicle infotainment are related to over the air software updates because it would allow for constant changes and updates to the infotainment system.

Automotive security threats would also be impacted by over the air software updates because security patches could be distributed more quickly through this format than with current practices. It could, however, also leave the system itself open to security threats due to the lack of "hard" updating through USB drives and dealer distributed updates.

# Open Platforms for Vehicle Infotainment

## Definition

Open platform describes a software system which is based on open standards, such as published and fully documented external programming interfaces that allow using the software to function in other ways than the original programmer intended, without requiring modification of the source code. Using these interfaces, typically known as an application programming interface (API), a 3rd party could integrate with the platform to add functionality.

One of the most common interfaces provided in a vehicle is the interface between a vehicle's onboard diagnostics link (e.g. OBD II) and an off board computing device such as a PC or a Scan Tester. They provide the necessary communications interface between the off board device and the vehicle to enable monitoring of data available from various subsystems that communicate via the diagnostic link.

There are additional wireless and wireline interfaces available through USB and other ports that are now available in the vehicle. These interfaces support connections to various personal computing, communication, navigation, and infotainment applications.

## Reasons for Identifying this Trend

In the past, most automakers had focused primarily on proprietary systems, but now they are seeing the value in providing open platforms. Automakers are finding that consumers are more likely to find value in having the ability to update and upgrade infotainment products throughout the vehicle lifecycle instead of being stuck with outdated products that were either standard features or options when they purchased the vehicle. Automakers have gotten the message that their infotainment stacks need to evolve, and that savvy car buyers want a vehicle that isn't going to saddle them with the equivalent of an embedded brick of a car phone for years. Automakers like Ford, GM, and BMW are opening their APIs to outside developers. For example, Ford Motor Co. is providing third-party mobile application developers access to the in-car information and entertainment system Ford Sync. Ford Sync is designed to provide convergence between automotive and consumer devices such as smartphones.

Linux has been working on a new Automotive Grade Linux (AGL), free and open source software that many hope may gain enough leverage to successfully topple traditional automotive infotainment silos. The Linux Foundation has formed AGL to facilitate widespread industry collaboration that advances automotive device development, providing a community reference platform that companies can use for creating products. The group wants to enable systems that are more flexible and scalable.

The AGL is working with the Tizen project – an open source, standards-based software platform within Linux – to create a reference platform for the design of automotive applications ranging from instrument clusters to infotainment systems. In addition to keeping new cars current, the foundation says that Tizen supports "the long lifecycle of cars," meaning that infotainment system software won't be frozen in time and can be easily updated.

Other organizations are also pushing auto infotainment cooperation, including Genivi, another open source software alliance, and the Car Connectivity Consortium with MirrorLink, a standard for smartphone integration. These organizations include members from OEMs, first tier suppliers, Software, Middleware, Hardware, Service Suppliers, and Silicon Valley.

Additionally, OnStar plans to offer selected developers the opportunity to contribute applications to their telematics system by granting access to their closed proprietary API. Their research indicates the number of smart phone mobile applications is expected to double in the next 12 months, and that by opening their platform to developers, they will be able to offer a broader package of the emergency, security, and navigation features their user's value most.

Open infotainment platforms will affect the development process, time to market, and the economics of in-vehicle ITS applications.

## Related Trends

Open platforms for vehicle infotainment may lead to increased potential for automotive security breaches, so this trend is related to the automotive security threats trend.

This trend is also related the changing perception of the car by Millennials and Generation Y. For vehicle passengers, having the ability to engage in personal interests like watching movies, playing video games, or participating in online courses may present vehicle travel in a more positive and productive light.

# Effects of Transportation on the Environment and Effects of Global Warming on Transportation

## Definition

**"**Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors that include oceanic processes (such as oceanic circulation), variations in solar radiation received by Earth, plate tectonics and volcanic eruptions, and human-induced alterations of the natural world; these latter effects are likely causing global warming, and "climate change" is often used to describe human-specific impacts." [60]

In this assessment, we are looking specifically at potential impacts, mitigation strategies to reduce the negative impacts, and transportation-related efforts to reduce the amount of warming, as well as at other environmentally-driven actions that may be taken in the transportation field.

## Reasons for Identifying this Trend

Science has made enormous inroads in understanding climate change and its causes, and is beginning to develop a strong understanding of current and potential impacts that will affect people today and in the coming decades. Of most concern is the increase in CO2 levels due to emissions from fossil fuel combustion. A good portion of these emissions come from vehicles powered by fossil fuels that use the surface transportation system.

The changing climate impacts society and ecosystems in a variety of ways including air quality and changes in weather patterns. Climate related impacts on our transportation system are occurring across regions of the country and include:

1. Deformities in rail-track due to flooding and freeze-thaw
2. Increased costs due to regional changes in snow and ice removal
3. Contaminated soils and water from snow and ice removal salt and chemical use (reduction overall, but increases in some regions)
4. Pavement failures in some locations due to freeze-thaw conditions
5. Increases in weather-related traffic disruptions
6. Increased flooding of evacuation routes
7. Disruption of construction activities due to extreme weather events or change in weather patterns
8. Changes in rain, snowfall, and seasonal flooding that affect safety and maintenance operations
9. Increased susceptibility to wildfires, causing road closures due to fire threat or reduced visibility
10. Increased susceptibility to mudslides due to increases in severe precipitation events
11. Challenges for emergency evacuation planning, facility maintenance, and safety management due to severe weather events
12. Increased flooding and wind related debris on roads and rail lines, interrupting travel and shipping
13. Increased frequency and potentially more extensive emergency evacuations due to severe weather events

Clearly, there is a need to reduce the impacts to our environment from transportation related emissions and to mitigate the resulting impacts of climate change. Two of the most obvious approaches to finding solutions are to work with the automotive industry to find ways to reduce the carbon footprint due to vehicle emissions and to work with weather experts and weather disaster response teams to better understand weather events and how to mitigate impacts due to climate change.

For many years, weather experts have been working with transportation experts to see if they can harness the potential of surface transportation systems to provide more weather related data. Weather systems rely heavily on satellite images to determine global weather patterns, and these two dimensional satellite images are supplemented with terrestrial data from various weather reporting stations on the Earth's surface to help develop three dimensional weather models. The identification and understanding of terrestrial weather conditions could be greatly improved with additional data reporting sources. Weather experts view transportation resources, both infrastructure and vehicles, as excellent sources for monitoring weather conditions and collecting weather related data. These potential data sources could vastly improve the reporting of weather conditions and help transportation system officials to better operate and maintain the transportation system and the impacts due to climate change.

Intelligent Transportation Systems (ITS) and in particular connected vehicle technologies offer the promise of increased sources for weather related data which can be used to improve weather reporting and improve transportation operations and maintenance associated with the impacts due to weather. The more data sources that are available the more accurate and useful weather related information will be.

Of course, reducing the carbon footprint for transportation will also be important for future developments in transportation and helping to reduce the negative impacts on the Earth's climate. Recent strategies identified for emissions reduction and environmental improvements in transportation incorporate cycling, car sharing, carbon pricing, public transport, regulatory action, connected vehicle apps – more efficient driving, optimized freight movement, and others.

The connected vehicle program shows promise for providing abundant sources of transportation emissions and weather related data that are critical for developing applications to optimize transportation systems in the future and mitigate weather related impacts. Some of these applications will likely include emissions management related applications including:

- Traffic Flow by Cooperative Traffic Light Management
- Green Light optimal speed advisory
- Intelligent Traffic Flow Control
- Cooperative Vehicle-Highway Automation System (Platooning)
- Free-Flow Tolling
- In-vehicle Emissions Management
- Modal Shift Information
- Car Sharing Information

and weather management related applications including:

- Low Visibility Warning
- Low Friction Warning
- Cooperative Glare Reduction
- Extreme Temperature Warning
- Visibility Enhancer
- Vehicle-Based Road Condition Warning
- Infrastructure-Based Road Condition Warning
- Pothole Detection

Again, one of the most important things that will be needed to support these applications will be the increase of good data sources. These data can facilitate the development of future emissions and climate change related applications that are more accurate and reliable.

## Related Trends

Crowd-sourced data may be a way to communicate transportation needs and provide a method to reach out to those with available transportation solutions including car sharing services, private transportation providers, and transit organizations. Crowd-sourced data is also being used as a tool to mitigate the impacts of climate change. After hurricane Sandy hit the east coast FEMA was able to access crowd-sourced data through Waze, a free social global positioning system (GPS) application that learns from users' driving times to provide routing and real-time traffic updates, to help send fuel trucks to where they were most needed. This opens up multiple possibilities for disaster relief.

This trend is also related to the Open and Big Data trend. IBM and Siemens are collecting and using large amounts of open and big data to assist with the development of various types of applications (e.g., transportation, weather, environmental conditions, and smart grid) for their Smart Cities projects. The Smart Cities movement is looking into types of strategies to develop unique solutions based on the characteristics of individual cities. Smart Cities' efforts include intelligent transportation solutions, green buildings, wastewater management, and smart grid infrastructure as just a few of the technology improvements helping to steer urbanization toward sustainability. This work is being done with environmental care as one of the top priorities. As an example of intelligent transportation solutions, these Smart Cities programs include new traffic solutions that incorporate advancements in optimization of fleets, travel, assets, maintenance, and payment services. Many of their efforts are in line with transportation environmental and climate change goals.

# Smart Grid

## Definition

“A smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.” [67]

Smart grid technology is needed to maximize the value of many renewable energy sources, as the current grid is not well-equipped to handle the changing supply coming from sources such as wind farms. Smart grid intersects with transportation in the area of electric vehicles. As the percentage of electric vehicles grows, there will be changes in the demand patterns for electricity, a need for efficient charging stations, and the potential for electric vehicles to serve as electrical storage devices that can feed electricity back into the grid when the vehicles are not in use. This has tremendous potential, as peak electric demand often occurs at times when a high percentage of vehicles are not in use (e.g., mid-afternoon). This is referred to as Vehicle-to-grid (V2G). In a V2G system, plug-in electric vehicles and plug-in hybrids can communicate with the power grid and either sell stored electricity back to the grid or modulate their charging rate to smooth demand.

## Reasons for Identifying this Trend

The city of Minneapolis recently installed an Intelligent Transportation Systems (ITS) Electrical Lighting Management System (ELMS) Smart Grid covering twenty-six city blocks throughout the downtown business and entertainment districts.

Among its many features, this Smart Grid system includes individual streetlight control and monitoring, and scheduling of each light. This integration of control allows engineers to illuminate roadways when traffic counts rise to levels at which the American Association of State Highway and Transportation Officials (AASHTO) requires lighting, and allows quick extinguishment or dimming when vehicle counts fall below those levels. Revenue grade metering at each roadside electrical service cabinet is offered along with circuit based ground fault detection. Reporting functions automatically alert the appropriate personnel of system anomalies, including pole knockdowns, light outages and dangerous electrical leakage conditions.

One area where the carbon footprint of roadway infrastructure can be reduced is the roadway lighting system resident on public roads. The estimated 4,424,361 streetlights in our nation’s ten largest metropolitan statistical areas use an estimated 2,988,500,000 kilowatt-hours (kWh) per year of electricity annually producing the equivalent of 2.3 million metric tons of $CO_2$. A 50 percent reduction in kWh used would result in savings of 1,494,250,000 kWh and 1,161,716 metric tons of $CO_2$. The nation's streets and highways are a major source of greenhouse gases from vehicles and from the lighting and related electrical infrastructure. The lamps that light the way for those vehicles consume 52.8 terawatt-hours per year. By switching to more efficient controllable lighting for these roads, the ten largest metropolitan areas could reduce annual carbon dioxide emissions by 1.2 million metric tons — the equivalent of taking 212,000 vehicles off the road — and save $90 million a year. [68]

The connected vehicle program could also be useful for electric vehicles and their access to the Smart Grid. Vehicles could use connected vehicle technology to broadcast their recharging schedule to help optimize charging resources and also to help locate charging facilities.

## Related Trends

Car sharing is expected to rise in the future as owners begin to treat their car as less of a liability and more of an asset. As more car sharing occurs with electric vehicles there will need to be greater awareness and access to recharging stations via the Smart Grid.

Crowd-sourced data could be a method used to help find available charging stations. Drivers could broadcast their recharging schedule to help optimize charging resources.

# Governments' Fiscal Constraints

## Definition

The trend of fiscal constraints at all levels of government can be most simply expressed as balanced budgets. Nearly every state and local government in the US is required to have a balanced budget. While the federal government is not required to have a balanced budget, the Highway Trust Fund (HTF), which funds highway and transit (through the Mass Transit Account (MTA)) projects at the federal level, is projected by the Congressional Budget Office to be insolvent by FY 2015 if it does not receive infusions of general revenue funds [70]. Any reduction of federal outlays for transportation projects would either require state and local governments to make up the difference in federal funds through other means, weighing transportation projects against other community needs, such as schools, or to reduce the scale and price tag of planned projects to reflect reductions in funding. Capital investment in the nation's roadways constituted 50 percent ($91 billion) of the $182 billion total of roadway expenditures. Of the capital spending in 2008, 51 percent was used on system rehabilitation, 37 percent was used for systems expansion, and 9 percent was used for safety, operational or environmental system enhancements. The portion spent on routine maintenance and traffic was nearly $45 billion (25 percent of total spending). The remainder of the $181 billion was used to cover administrative costs, highway patrols and safety programs, as well as paying interest and bond retirement [71].

According to the 2010 Federal Highway Administration (FHWA) Conditions and Performance Report, "sustaining combined highway capital spending by all levels of government at its 2008 level of $91.1 billion in constant dollar terms over 20 years is projected to result in a decline in certain measures of condition and performance." The report states that to maintain the current conditions and performance, $101 billion would have to be spent annually over the same period. Intermediate levels of improvements would require an annual investment level of $133.5 billion, while implementation of "all potentially cost-beneficial improvements" would cost $170.1 billion per year for the 20 year horizon [71]. Costs stated in constant 2008 dollars.

## Reasons for Identifying this Trend

This trend has been identified as having an impact on ITS policy for two reasons. First, ITS technologies have proven to be cost-effective measures for improving roadway and transit service capacity, serving as low-cost alternatives to capital intensive expansion projects. In a more fiscally constrained environment, ITS technologies could become the focus of DOT solutions to congestion problems because of their lower capital costs.

However, fiscal constraints may also cause DOTs to increasingly focus only on maintenance projects, leading to a lull in the deployment of ITS technologies as state and local DOTs struggle to maintain the infrastructure they already have.

## Related Trends

The Road User Fee and Motor Fuel Tax trend is closely related to the trend of Fiscal Constraints because they are revenue sources for transportation departments. The stability of funding levels for transportation projects is dependent on the proportion of transportation funding that comes from dedicated funding streams because other general funds can be reallocated from year to year.

# Vehicle Miles Traveled Fees and Congestion Pricing

## Definition

Road user fees are the taxes and fees that are applied directly to the road users, typically in proportion to their use of the roadways. This is generally applied through roadway pricing or motor fuel taxes, both of which are proxies for miles travelled. For a variety of reasons, transportation policy-makers and analysts are increasingly interested in directly charging based on miles traveled.

One of the most important reasons for considering this alternative is the projected continual decline in fuel tax revenues. A sizable, but shrinking portion of transportation funding in the U.S. comes from federal and state motor fuel taxes. Motor fuel taxes are the per gallon tax that are incorporated into the price of motor fuel. As fuel efficiency increases and hybrid and alternative fuel vehicles grow in popularity, the revenue produced by fuel taxes decreases, while the need for transportation funds stays level or increases. In addition, these taxes are applied at fixed rates per gallon of fuel. They are not indexed either to the cost of fuel or inflation. It has proven very difficult to increase these taxes.

Vehicle Miles Traveled (VMT) fees may be applied at a flat rate per vehicle type or may vary based on a number of variables. Congestion pricing is a strategy used to limit demand in highly congested area either by charging vehicles upon crossing a boundary threshold or by changing the VMT fee for miles traveled in certain areas. The fees may vary based on time of day. For this analysis, VMT fees include both flat pricing approaches and congestion pricing approaches.

## Reasons for Identifying this Trend

Although the motor fuel tax is the main funding source for the HTF, it has not collected enough revenue in recent years to match the level of federal surface transportation spending. Congressional Budget Office (CBO) projections show that the Mass Transit Account (a part of the HTF) and the HTF itself will be insolvent by FY2015 without additional intra-governmental transfers of funds or increases in revenue [70].The decline in motor fuel tax receipts has been identified as a trend because the increased reliance on general revenue for the funding of transportation projects could lead to the postponement or downsizing of projects when they are not considered at top priority under increasingly limited budgets for all levels of government. Because this is an indicator for fewer roadway expansion projects, it could actually encourage investment in ITS technologies due to their lower capital costs and productivity and mobility benefits. However, reliance on ITS technologies to solve congestion or safety problems on smaller budgets could also result in DOTs choosing to only deploying mature, proven technologies, rather than testing new technologies whose benefits have yet to be operationally demonstrated, potentially putting a damper on ITS innovation.

Road pricing strategies have been identified as part of this trend because as fuel tax receipts continue to decline, state and local governments are looking toward ways to generate additional transportation revenues which includes toll roads, congestion pricing, and High Occupancy Toll (HOT) lanes. ITS technologies can provide the capabilities for VMT- based charging strategies, such as those being implemented in Oregon.

## Related Trends

The trend of limited government resources (at all levels) is directly related to this trend through the impact that reduced general funds will likely result in reduced funding for transportation projects. Because of the limited funds, governments will be looking for new revenue sources or increasing existing revenue sources, as well as alternative ways to finance transportation projects (e.g. public-private partnerships).

The Connected Sensor trend is related to this trend because networked vehicles could provide a platform for VMT-based road user fee charging. Charging road user fees based on actual miles traveled versus a proxy of miles travelled (as is currently done with the fuel tax), would allow all road users to be charged for their proportional use of the road infrastructure regardless of their fuel mileage or fuel type. This technology would also increase the ease of setting up boundaries for congestion/cordon pricing strategies.

# Transportation Performance Measures

## Definition

Transportation performance measures have been increasingly used by transportation agencies to analyze their system performance and compare their performance to organization goals and objectives. Efficient investment in and management of transportation systems is critical, especially in times of limited funding.  Performance measures relate to assessing both the current operational performance as well as the expected increase in performance to be gained from various investments, and may also include measures that relate to transportation project management (e.g., project costs and delays).

Performance measures are already playing and important role for many agencies across the nation and the 2012 MAP-21 (Moving Ahead for Progress in the 21st Century, the current legislation authorizing the surface transportation trust fund) transportation legislation will increase the role of performance measures for all agencies. MAP-21, signed into law July 2012, places an emphasis on performance measurement and sets a framework for national and state transportation performance measures.

## Reasons for Identifying this Trend

Over the past 5-10 years, there has been an increasing focus on increasing the use of transportation performance measures. Many states have already placed an increased emphasis on such measures, the Bipartisan Policy Center's National Transportation Policy Project recommended a central role for a performance-based national transportation plan, and Congress has incorporated performance measures into MAP-21.

The Map-21 legislation requires the Secretary of Transportation, working with States, Metropolitan Planning Organizations (MPOs), and other stakeholder to set performance measures for pavement and bridge conditions, performance of the National Highway Systems (NHS), injuries and fatalities on all public roads, traffic congestion and on-road mobile source emission in metro areas over one million in population, and freight movement on the Interstate System.

The legislation establishes 7 national goal areas:

- Safety
- Infrastructure Condition
- Congestion Reduction
- System Reliability
- Freight Movement and Economic Vitality
- Environmental Sustainability
- Reduced Project Delivery Delays

These national goals relate directly to the Intelligent Transportation System (ITS) Program and objectives for improving safety, enhancing mobility, and reducing transportations environmental impact. ITS technologies will be directly involved in helping agencies collect performance data and meeting their performance targets. For example, connected vehicle technologies could allow agencies to collect emissions data directly from every vehicle allowing for real-time calculations of emissions on a roadway, on a corridor, or in a region. This would allow states and local agencies to analyze environmental performance and develop strategies to reduce emission on the roadway. The connected vehicle program in general has the capability to produce detailed probe data on every vehicle mile traveled for personal, freight and transit vehicles. The connected vehicle data could provide previously unobtainable performance data and measurements.

Currently agencies focus on collecting data that is most easily collected. Advances in technology and a federal mandate will help agencies to be innovative with data collection and begin collecting the most valuable data. With the shrinking Gas Tax revenue transportation funding will be highly competitive and ITS technology has the potential to provide low-cost and high benefits with increased system performance and data collection including travel times, transportation accessibility, vehicle emission, roadway conditions and more.

## Related Trends

Big Data is related to performance measure because of the large amount of data that could be collected from transportation systems and connected vehicle technologies. All of this data would need to be analyzed to determine performance of the system.

Crowd sourcing is another related topic that could provide performance data to State and Local transportation agencies. Many agencies already use crowd-sourced traffic data such as INRIX.

The Internet of Things and Machine-to-Machine (M2M) topics are also related to performance measures. A lot of performance can be collected through ITS systems consisting of roadway sensors and probe data all connected to a transportation network with the data collected by a central application and turned into usable performance data.

# Lean Startups (& Minimum Viable Products)

## Definition

The concept of a “lean startup” and minimum viable products (MVP) came into existence in the late 2000s based on a theory by Eric Reis. Lean startups utilize a “build-measure-learn” philosophy in order to maximize user feedback into developing applications that users actually want and features they desire. The lean startup concept is typically applied to web or software based companies, but is also being adopted by some government agencies.

MVP creation relies on creating a product that will be capable of providing that feedback loop with the user (through usage, comments, etc.) without taking a lengthy period to develop. The MVP theory is only really applicable to web and software based products as they are most easily updated without requiring additional purchases on the part of the consumer. MVP aids the process of lean startups by reducing the likelihood that the company spends weeks/months/years developing a product that no consumer wants to purchase. Instead of spending time producing unviable products, the company can focus on incrementally providing updates (typically daily, sometimes more often depending on the product) to products that consumers are interested in.

## Reasons for Identifying this Trend

This trend has been identified as a demonstration of the quickening pace of software and application development that might be applicable to ITS research, field testing, and deployment.

The lean startup concept is being applied to Federal government programs and has been endorsed by the current and previous US Chief Technology Officers. The current CTO, Todd Park, has applied the principles in his previous position as CTO of the Department of Health and Human Services.

This iterative process could allow for faster deployment of Connected Vehicle (CV) applications that would be improved “on the fly” as feedback is received from the vehicles and users, potentially speeding up the roll out of CV technologies. A lean startup model would also reduce the risk of producing applications that the public does not find useful or necessary before large investments have been made. It may have applicability to mobility and environmental application development and field test programs. It is less applicable to safety applications, where stringent performance and reliability, as well as thorough pre-deployment testing, are paramount.

## Related Trends

Over the air software updates are related to this idea because if in-vehicle applications were developed using MVP and agile development principles, frequent updates to software would need to be transmitted to the users. Without over the air updating, the continuous feedback loop necessary for lean development and minimum viable products would be difficult to do because it would require people “plugging in” their cars at home, using devices such as thumb drives, or taking them to the dealership to download software updates.

Open data is also related to this trend because of lean startups’ typical grounding in open source software platforms. Additionally, the availability of data provided by CV communications could allow the emergence of lean startups to provide additional applications beyond those that the USDOT is prescribing. This could reduce future costs for the government, while providing a new industry niche to develop in the private sector.

# Massive Open Online Courses (MOOCs)

## Definition

Massive Open Online Courses (MOOCs, rhymes with dukes) are classes offered only over the internet, which are tailored specifically for the online student, with high levels of feedback between students and professors, as well as between students through class forums and online "office hours." MOOCs are on the rise with the advent of multiple for profit and not for profit companies and university consortiums emerging to fill a global trend in increased desire to access high quality educational resources. Companies like Udacity and consortiums like Coursera operate on a for-profit basis, while edX is a university consortium that operates on a not-for-profit basis.

MOOCs are not traditional online offerings from colleges. An example of a free traditional type of online offering is MIT's OpenCourseWare, which publicly provides video files of lectures along with copies of problem sets, exams and their solutions. In traditional online open learning, there was no interaction with professors or other students. They were simply recorded versions of a standard lecture and not tailored to cater to the online student's needs.

## Reasons for Identifying this Trend

This trend has been identified as having a potential impact on the future of ITS because it may influence the way the ITS Professional Capacity Building (PCB) program educates individuals, both practitioners and students. With a robust set of course offerings, a certification (or set of certifications) could be offered that would allow students and practitioners to take the classes on their own time and at their own pace.

As opposed to a webinar, an online course ensures the attention of the student due to frequent, in-lesson quizzes and a mastery of material would need to be shown to get certification credit for the course. Peer-to-peer interaction through course forums could establish a greater sense of community between ITS practitioners, leading to greater sharing of best practices and lessons learned in a more informal way than the current ITS Knowledge Resources portal.

The public availability of these courses could attract the attention of professionals and students outside of the transportation industry, thus increasing the exposure of the ITS field and providing new perspectives. A greater understanding of the ITS mission and current state of the field by the general public could spur the innovation of new technologies.

## Related Trends

This trend is not closely related to any of the other identified trends. However there is some similarity to the Open (and Big) Data trend because of similarities in opening the field to "outsiders" which allows for innovation of applications and technologies as new people learn more about ITS and the types of data that are generated through ITS.

Also, the elasticity of cloud computing, allowing resources to be easily scaled to meet fluctuations in demand, makes MOOC's more cost-effective and reduces the barriers to entry.

# Same Day Mail Order Delivery

## Definition

Same day mail order delivery is a process by which if an individual places an online order by a specific time, the item is capable of being shipped or delivered to them later the same day. This is a concept currently being tested by Amazon and Wal-Mart.

The concept of same day pickup is related, but not the same. Currently an item can be ordered online and be picked up at the requested Wal-Mart store in the evening, allowing people to pay at the store when they pick up their items.

## Reasons for identifying this trend

This trend has been identified as potentially impacting the ITS field as a result of likely altered traffic patterns across the larger metropolitan areas. The adoption of same day delivery could alter the physical landscape by the reduction in the number of physical retail stores, reducing consumer traffic. However, there would be a corresponding increase in delivery vehicles in order to implement such a system, as more routes would need to be utilized in order to deliver items on short notice and in higher quantities.

## Related Trends

Autonomous vehicles at reasonable prices are related to this trend because it offers the possibility of even more on-demand type delivery where smaller numbers of items are carried in smaller vehicles that make scheduled deliveries that consumers remove their items from the vehicle at the curbside of their designated location.

# Evolution of Positioning Systems

## Definition

A positioning system is a mechanism for determining the location of an object in space. Technologies for this task exist ranging from worldwide coverage with meter accuracy to workspace coverage with sub-millimeter accuracy.

## Reasons for Identifying this Trend

This paper focuses on government operated Global Navigation Satellite Systems (GNSS) and emerging private Local Positioning Systems (LPS) that will likely be part of the future of ITS technologies. Global navigation satellite systems allow specialized radio receivers to determine their 3-D space position, as well as time, with an accuracy of 2–20 meters or tens of nanoseconds. Currently deployed systems use microwave signals that can only be received reliably outdoors and that cover most of Earth's surface, as well as near-Earth space. Existing and planned GNSS include:

- *Global Positioning System (GPS)* – US military system, fully operational since 1995
- *GLONASS* – Russian military system, fully operational since October 2011

- *Galileo* – Four operational satellites have been launched to date, a total of 30 satellites are expected to be operational by 2019
- *Beidou Navigation System* – Ten satellites became operational in 2011 and 25 more are expected to be added.
- *Indian Regional Navigational Satellite System* – Seven satellites are expected to be launched in the 2013 – 2014 time frame.

In June 2004, in a signed agreement with the United States, the European Union agreed to switch to a modulation known as BOC(1.1) (Binary Offset Carrier 1.1) allowing the coexistence of both GPS and Galileo, and the future combined use of both systems. In October 2004, China officially joined the Galileo project by signing the Agreement on Cooperation in the Galileo Program between the "Galileo Joint Undertaking" (GJU) and the "National Remote Sensing Centre of China" (NRSCC). These types of agreements help to provide International GNSS Service (IGS). The IGS is a network of over 350 GPS monitoring stations from 200 contributing organizations in 80 countries. Its mission is to provide the highest quality data and products as the standard for global navigation satellite systems (GNSS) in support of Earth science research, multidisciplinary applications, and education, as well as to facilitate other applications benefiting society. Approximately 100 IGS stations transmit their tracking data within one hour of collection. As a result of the combined use of multiple GNSS, a number of benefits may be envisioned, such as enhancement in reliability and safety, improved precision as well as possible expansion of the user applications. More specifically, through multi-GNSS constellations, high precision positioning as well as improvement in satellite clock quality will be the possibility.

The Russian GLONASS and US Military GPS satellites have been undergoing modernization. The US GPS modernization program is an ongoing, multibillion-dollar effort to upgrade the GPS space and control segments with new features to improve GPS performance. These upgrades are expected to be completed by 2025 and include new civilian and military signals. These modernization efforts will result in improved accuracy of GPS. However, GPS and/or GNSS will need to be augmented to provide the level of accuracy needed for some ITS and connected vehicle applications.

A GPS augmentation is any system that aids GPS by providing accuracy, integrity, availability, or any other improvement to positioning, navigation, and timing that is not inherently part of GPS itself. A wide range of different augmentation systems have been developed by both the public and private sectors. Some of the public sector augmentation systems include the following:

- *Nationwide Differential GPS System (NDGPS)* - NDGPS is a ground-based augmentation system that provides increased accuracy and integrity of GPS information to users on U.S. land and waterways. NDGPS is built to international standards, and similar systems have been implemented by 50 countries around the world. Modernization efforts include the High Accuracy NDGPS (HA-NDGPS) system, currently under development, to enhance the performance and provide 10-15 centimeter accuracy with integrity throughout the coverage area.
- *Wide Area Augmentation System (WAAS)* – WAAS, a satellite-based augmentation system operated by the Federal Aviation Administration (FAA), supports aircraft navigation across North America. Although designed primarily for aviation users, WAAS is widely available in receivers used by other positioning, navigation, and timing communities. The WAAS specification requires it to provide a position accuracy of 7.6 meters or better (for both lateral and vertical measurements), at least 95% of the time. Actual performance measurements of the system at specific locations have shown it typically provides better than 1.0 meter laterally and 1.5 meters vertically throughout most of the contiguous United States and large parts of

Canada and Alaska. FAA is improving WAAS to take advantage of the future GPS safety-of-life signal to provide even better performance.

- *Continuously Operating Reference Stations (CORS)* – The U.S. CORS network, managed by the National Oceanic and Atmospheric Administration, archives and distributes GPS data for precise positioning tied to the National Spatial Reference System. Over 200 private, public, and academic organizations contribute data from over 1,800 GPS tracking stations to CORS. The web-based Online Positioning User Service (OPUS) offers free post-processing of GPS data sets to the centimeter level using CORS information. CORS is also being modernized to support real-time users.
- *Global Differential GPS (GDGPS)* – GDGPS is a high accuracy GPS augmentation system, developed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) to support the real-time positioning, timing, and determination requirements of NASA science missions. Future NASA plans include using the Tracking and Data Relay Satellite System (TDRSS) to disseminate via satellite a real-time differential correction message. This system is referred to as the TDRSS Augmentation Service Satellites (TASS). The GDGPS System provides decimeter (10 cm) positioning accuracy and sub-nanosecond time transfer accuracy anywhere in the world, on the ground, in the air, and in space, independent of local infrastructure.

Unlike GNSS augmentation systems, the LPSs being developed by the private sector don't provide global coverage. Instead, they use (a set of) beacons which have a limited range, hence requiring the user to be nearby. Beacons include cellular base stations, Wi-Fi access points, and radio broadcast towers. Research on these systems has shown 3 cm accuracy.

Nowadays, LPSs are often used as complementary (and in some cases alternative) positioning technology to GNSS, especially in areas where GNSS do not reach or are weak, for example, inside buildings, or urban centers. Local positioning using cellular broadcast towers can be used on cell phones that do not have a GNSS receiver. Even if the phone has a GNSS receiver, battery life can be extended if cell tower location accuracy is sufficient. [90]

The future of positioning technology is likely to be one that incorporates multiple positioning technologies that are owned by multiple positioning system providers. Cooperation by positioning system providers can lead to systems that provide superior performance in comparison to, for example, using a GPS alone. Positioning system integration can help to overcome GPS related intermittent signal effects (e.g., urban centers, or forested areas), and no signal reception (e.g., inside buildings, underground, or under water). In the case of intermittent signal, GPS would need to be integrated with other positioning technologies to bridge periods of no signal. In the case of no signal, GPS would need to be replaced by another system in order to provide continuous service in a no signal environment.

Already, GPS has proven very useful for car navigation, fleet management, and highway inventory applications. However, an increased level of accuracy, availability, and reliability will be needed for many of the proposed connected and autonomous vehicle applications. Google is one company on the leading edge of autonomous vehicle development and is clearly showing the value of indoor and outdoor location-based services by buying up indoor and outdoor wireless location system patents. This technology can be used not only outdoors to track moving vehicles, but also indoors like in a warehouse, to track pallets and packages and people.

## Related Trends

This trend is related to the autonomous and semi-autonomous vehicles trend, because autonomous vehicles will be dependent on positioning systems, both global and local.

Car sharing is expected to rise as travelers move away from the practice of owning a vehicle. Car sharing applications will also likely be dependent on positioning systems to optimize the use of shared cars.

This trend could be useful when combined with the aging population's trend. Vehicle applications could be developed to track an elderly persons location, their environmental conditions (e.g., crashes or extreme temperatures), and match their conditions with health related data. Alerts could be initiated when a threshold for potentially hazardous conditions are identified.

# APPENDIX C. Members of the Horizon Scan Expert Panel

**William Ball**

Mr. Ball is a national expert on vehicle telematics with 25 years of experience in policy development, marketing, and public outreach with General Motors (GM). As Vice President-Public Policy at GM, he led all aspects of OnStar's public policy initiatives at both the state and federal levels. Prior to his work at OnStar, he served as the Director for Strategic Planning for Advanced Technology Vehicles at General Motors and directed GM's Washington, DC Public Policy Center and Government Relations staff.

He has co-chaired the Electric Vehicle Association of the Americas (EVAA) and delivered Congressional testimony on the trade association's behalf. He served on the Transportation Safety Advancement Group (TSAG) and its predecessor, the Public Safety Advisory Group; the VII Executive Leadership Team, two U.S. Centers for Disease Control convened expert panels; and the Board of Directors of the ComCARE Emergency Response Alliance.

Mr. Ball will provide the perspective of an industry leader who has worked with members of Congress and professional associations to impact policy and rule making.

Mr. Ball received his B.S. in Chemical Engineering and J.D. from the University of Minnesota. He received his M.B.A. from Stanford University. He holds admission to the Washington, DC Bar. He has a patent pending on a Method of Establishing a Communications Connection from a Deactivated Telematics Unit on a Motor Vehicle.

**Mark Dunzo, P.E.**

Mr. Dunzo, Vice President at Kimley-Horn and Associates, has over 17 years of project experience in Intelligent Transportation Systems in the areas of planning, specifications, and estimates (PS&E) development, construction phase services for ITS projects, development of ITS systems engineering, architecture, strategic deployment plans, and development of regional ITS communications plans.

Recent project experience includes acting as Project Lead for an institutional requirements and implementation assessment of SANRAL's nationwide ITS and Freeway management program in South Africa, which included developing a national ITS strategy. He served as Deputy Project Manager for the (Virginia Department of Transportation) VDOT's design-build program to deploy an Active Traffic Management System (ATMS) on a 32 mile segment of the I-66 corridor. As part of this project, Kimley-Horn will be collaborating with VDOT to enhance their ATMS software to support ATMS functionality. Mr. Dunzo served as Project Manager for MDOT's ATMS Software Functional Design and System Implementation Management for their next generation ATMS software.

As Senior Technical Advisor to USDOT, he is working to develop an Operational Concept for EnableATIS, a high priority area within the Dynamic Mobility Applications program that represents a framework for next generation traveler information approaches. Mr. Dunzo co-facilitated a stakeholder workshop in 2011, and is providing strategic insights in the Operational concept and its market readiness. He recently served as Senior Technical Advisor to the SHRP2 project on Integrating Business Processes to Improve Travel Time Reliability. As part of this project, Kimley-Horn oversaw the development of case studies of innovative business process integration within transportation agencies, conducted a workshop with industry experts, and developed a Guidance document for transportation agencies using process integration to improve and manage systems with a focus on travel time reliability.

Mr. Dunzo received his B.S. in Civil Engineering from Massachusetts Institute of Technology, and his M.S. in Civil Engineering and Master of City and Regional Planning from the University of California, Berkeley. He is a Professional Engineer in North Carolina and Michigan. He serves on the North Carolina University Institute for Transportation Research and Education (ITRE) Advisory Panel and the Transportation Research Board Signal System Committee.

**H. Gilbert Miller, Ph.D.**

As Corporate Vice President and Chief Technology Officer of Noblis, Dr. Miller is responsible for advancing Noblis science and technology capabilities, including telecommunications and networks, computing and software, data and knowledge management, information and network security, modeling and simulation. Dr. Miller brings over 30 years of experience in large scale systems engineering and acquisition projects, spanning nearly every federal government agency, as well as state and local governments. He has represented federal clients with members of Congress and their staff, and has served as advisor to several GSA administrators.

Dr. Miller was responsible for creating Noblis' Innovation and Collaboration Center (NICC), an 11,000 square foot advanced computing, innovation, and collaboration center. He currently heads Noblis' public-private partnership that is establishing the Center for Applied High Performance Computing (CAHPC) in Danville, Virginia. This center houses the first Cray XMT supercomputer found outside a federal lab or university.

In 2011, Dr. Miller was awarded the Northern Virginia Technology Council/Washington Technology Government Contractor CTO Innovator Award in recognition of his leadership in advancing Noblis' science and technology capabilities to better support Noblis' clients. It also recognizes his role in creating the public-private partnership that established the supercomputer center.

Dr. Miller received his B.S. in Electrical Engineering from the University of Maryland, a M.S. in Computer Science from Johns Hopkins University, and a Ph.D. in Engineering and Public Policy from Carnegie-Mellon University. He serves on the advisory board of the Volgenau School of Information Technology and Engineering at George Mason University.

**Stanley Pietrowicz**

Mr. Pietrowicz is a Senior Principal Consultant in the Advanced Technology Solutions business unit of Applied Communication Sciences (formerly Telcordia). With over 20 years of experience in Communications, Intelligent Transportation Systems, and Smart Energy sectors, Mr. Pietrowicz is responsible for business development, project management, technical delivery and research on government and commercial programs. He has held management and lead technical positions in vehicle networking, communication systems engineering, cyber and Smart Grid security, software development, service design and deployment, embedded systems development, and interoperability and security testing. He founded and successfully launched a new embedded software business called Telcordia DeviceWare, which required establishing key alliances and partnerships with major semiconductor and computer suppliers. He holds 11 U.S. patents, with 6 applications pending.

Recently, Mr. Pietrowicz led a comprehensive security risk and threat analysis of connected vehicle communications. He managed development of a prototype Telematics Web Portal for a Tier 1 automotive supplier that realizes a vision of personalized in-vehicle entertainment. As the business lead for SmartGrid, he acts as security advisor for several high profile utilities, having pioneered security assessment of Smart Grid systems. He led a Next Generation Network vulnerability study for the President's National Security Telecommunications Advisory Committee and managed National Security/Emergency Preparedness studies for satellite and wireless integration.

Mr. Pietrowicz received his B.S. and M.S. in Electrical Engineering from Stevens Institute of Technology. He has widely published on the topic of secure vehicular communications.

**Phillip J. Tarnoff**

Mr. Tarnoff has been a leader in the areas of traffic operations and Intelligent Transportation Systems (ITS) for the last 30 years, serving in senior management positions within the public, private and university sectors of the transportation community. In the 1980s, he founded Farradyne Systems, Inc. (now PB Farradyne), one of the largest ITS consulting and systems integration firms in the U.S. Beginning in 1997, he founded and directed the Center for Advanced Transportation Technology (CATT) at the University of Maryland. He has been an active participant with the National Transportation Operations Coalition (NTOC), the I-95 Corridor Coalition, and the Consortium for ITS Training and Education (CITE) which provides more than 30 online courses related to ITS and other associated disciplines. He was the Principal Investigator for the development of an adaptive traffic signal program (RT-TRACS) that automatically retimes signals based on variations in traffic demand. He has been active in the development of performance measures for transportation operations. He is a co-inventor on the pending patent for use of Bluetooth wireless technology to measure travel times.

Mr. Tarnoff has served on a number of blue-ribbon commissions and executive boards for both the public and private sectors. He chaired a high-level panel to investigate and make recommendations to the Virginia Department of Transportation in connection with a major roadway closure incident at the Hampton Roads Bridge Tunnel, reporting to the VDOT Commissioner of Transportation.

Mr. Tarnoff received his B.S. in Electrical Engineering from the Carnegie Institute of Technology and M.S. in Electrical Engineering from New York University.

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