Safety Pilot Model Deployment

Lessons Learned and Recommendations for Future Connected Vehicle Activities

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16. Abstract

The Connected Vehicle Safety Pilot was a research program that demonstrated the readiness of DSRC-based connected vehicle safety applications for nationwide deployment. The vision of the Connected Vehicle Safety Pilot Program was to test connected vehicle safety applications, based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications systems using dedicated short-range communications (DSRC) technology, in real-world driving scenarios in order to determine their effectiveness at reducing crashes and to ensure that the devices were safe and did not unnecessarily distract motorists or cause unintended consequences.

The Connected Vehicle Safety Pilot was part of a major scientific research program run jointly by the U.S. Department of Transportation (USDOT) and its research and development partners in private industry. This research initiative was a multi-modal effort led by the Intelligent Transportation Systems Joint Program Office (ITS JPO) and the National Highway Traffic Safety Administration (NHTSA), with research support from several agencies, including Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), and Federal Transit Administration (FTA). This one-year, real-world deployment was launched in August 2012 in Ann Arbor, Michigan. The deployment utilized connected vehicle technology in over 2,800 vehicles and at 29 infrastructure sites at a total cost of over $50 million dollars in order to test the effectiveness of the connected vehicle crash avoidance systems. Overall, the Safety Pilot Program was a major success and has led the USDOT to initiate rulemaking that would propose to create a new Federal Motor Vehicle Safety Standard (FMVSS) to require V2V communication capability for all light vehicles and to create minimum performance requirements for V2V devices and messages.

Given the magnitude of this program and the positive outcomes generated, the Volpe National Transportation Systems Center conducted a study sponsored by the ITS JPO to gather observations and insights from the Safety Pilot Model Deployment. This report represents an analysis of activities across all stages of the Safety Pilot Model Deployment including scoping, acquisitions, planning, execution, and evaluation. The analysis aimed to identify specific accomplishments, effective activities and strategies, activities or areas needing additional effort, unintended outcomes, and any limitations and obstacles encountered throughout the Model Deployment. It also assessed the roles of organizations and the interactions among these organizations in the project. Findings were used to develop recommendations for use in future deployments of connected vehicle technology. Information for this analysis was gathered from a combination of over 70 participant interviews and a review of program documentation. It is anticipated that findings from this study will be valuable to future USDOT research programs and early adopters of connected vehicle technology.

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Acknowledgements

Conducting a retrospective analysis focused on gathering the lessons learned from a major program is always a challenging task as it requires a large amount of openness and feedback from the key team members. The development of this report is no exception. The Volpe Center, in combination with Booz Allen Hamilton, conducted over 70 interviews to gather raw observations that could be processed and synthesized into polished recommendations which will be useful to the next team charged with deploying and testing connected vehicle technology.

As such, we would like to thank all of those members of the Safety Pilot Program team that participated in the interviews and provided honest, unfiltered feedback regarding the Connected Vehicle Safety Pilot Program.

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Executive Summary

The Connected Vehicle Safety Pilot was a research program that demonstrated the readiness of DSRC-based connected vehicle safety applications for nationwide deployment. The vision of the Connected Vehicle Safety Pilot Program was to test connected vehicle safety applications, based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications systems using dedicated short-range communications (DSRC) technology, in real-world driving scenarios in order to determine their effectiveness at reducing crashes and to ensure that the devices were safe and did not unnecessarily distract motorists or cause unintended consequences.[1]

Research from the National Highway Traffic Safety Administration (NHTSA) showed that connected vehicle technology has the potential to address a very significant number of light vehicle crashes and heavy truck crashes by unimpaired drivers. Since safety is the USDOT's top priority, the potential safety benefits of this technology could not be ignored. At the time, more research was necessary to determine the actual effectiveness of the applications and to understand the best ways to communicate safety messages to motorists without causing unnecessary distraction.

The Connected Vehicle Safety Pilot was part of a major scientific research program run jointly by the U.S. Department of Transportation (USDOT) and its research and development partners in private industry. This research initiative was a multi-modal effort led by the Intelligent Transportation Systems Joint Program Office (ITS JPO) and the National Highway Traffic Safety Administration (NHTSA), with research support from several agencies, including Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), and Federal Transit Administration (FTA).

The overall goals of the Safety Pilot Program included:

- Support the 2013 NHTSA agency decision[2] by obtaining empirical data on user acceptance and system effectiveness;
- Demonstrate real-world connected vehicle applications in a data-rich environment;
- Establish a real-world operating environment for additional safety, mobility, and environmental applications development; and
- Archive data for additional research purposes.

This one-year, real-world deployment was launched in August 2012 in Ann Arbor, Michigan. The deployment utilized connected vehicle technology in over 2,800 vehicles and at 29 infrastructure sites at a total cost of over $50 million dollars in order to test the effectiveness of the connected vehicle

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[1] http://www.its.dot.gov/safety_pilot/
[2] On August 18, 2014, the National Highway Traffic Safety Administration (NHTSA) issued an advance notice of proposed rulemaking on vehicle-to-vehicle communications technology. Press release found here: http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications

crash avoidance systems. Overall, the Safety Pilot Program was a major success and has led the USDOT to initiate rulemaking that would propose to create a new Federal Motor Vehicle Safety Standard (FMVSS) to require vehicle-to-vehicle (V2V) communication capability for all light vehicles (passenger cars and light truck vehicles) and to create minimum performance requirements for V2V devices and messages.

Given the magnitude of this program and the positive outcomes generated, the Volpe National Transportation Systems Center conducted a study sponsored by the ITS JPO to gather observations and insights from the Safety Pilot Model Deployment. This report represents an analysis of activities across all stages of the Safety Pilot Model Deployment including scoping, acquisitions, planning, execution, and evaluation. The analysis aimed to identify specific accomplishments, effective activities and strategies, activities or areas needing additional effort, unintended outcomes, and any limitations and obstacles encountered throughout the Model Deployment. It also assessed the roles of organizations and the interactions among these organizations in the project. Findings were used to develop recommendations for use in future deployments of connected vehicle technology. Information for this analysis was gathered from a combination of over 70 participant interviews and a review of program documentation.

The report is organized into six major chapters. The first two chapters focus on Program Management and Outreach. Both of these areas spanned the entire Safety Pilot Model Deployment. The remaining four chapters cover topics that relate to the execution and evaluation stages of the Model Deployment, and include Experiment Setup, DSRC Device Development, Device Deployment and Monitoring, and Data Management. All chapters are divided into several sections which each describe a topic relevant to the Safety Pilot Model Deployment. Each section begins with background information on the given topic. This is followed by observations expressed by the interviewees as well as information gathered from the program documentation review. Finally, the section concludes with recommendations for future connected vehicle activities.

This report contains hundreds of recommendations, which are compiled in Appendix A for quick reference. In looking at the Safety Pilot Model Deployment overall, five key findings resulted from this study:

- Selecting a single, “ideal” Model Deployment site was highlighted as a significant challenge. A site optimized for a light vehicle demonstration may not be the best location for a heavy vehicle demonstration; or a site with many positive characteristics may be lacking a key aspect (e.g., a test track or closed facility for testing or demonstration).
- The hard deadlines associated with the NHTSA decision-making imposed management processes and maintained a focus on activities that were considered critical to the primary mission of the project. Participants broadly acknowledged success in this area.
- Although the focus was on the 2013 NHTSA agency decision on light vehicles, other opportunities were accommodated and pursued within the Model Deployment, including V2I application development and contextual data analysis. In general, those affected by these additions indicated a preference for earlier engagement in subsequent pilot projects; indicating a need for efforts to predict potential expansions of scope early in the process in the future.
- While the effectiveness of many of the project management processes was strongly endorsed (e.g., the nature and frequency of meetings), other, more technically-focused processes and tools (e.g., development of a SEMP; configuration management; requirements

generation; data types and formats specification) should be given greater emphasis in a future pilot project.

- It is important to ensure that future pilot projects can accommodate the planning and conduct of effective, rigorous testing activities needed for various devices, equipment, and systems. Provision should be made for sufficient time and resources for iterative testing that can commonly occur in programs of this nature.

It is anticipated that findings from this study will be valuable to future USDOT research programs, including the Connected Vehicle Pilots Deployment Project, and also to early adopters of connected vehicle technology.

This report is not intended to be a full account of all activities conducted during the Safety Pilot Model Deployment. It highlights notable activities and findings as gleaned from the interviews and gathered observations. The Test Conductor developed a report that discusses many of the activities carried out during the Safety Pilot Program as part of the Test Conductor's work. The Test Conductor report titled *Safety Pilot Model Deployment: Test Conductor Team Report*[3] is complementary to this report and can be used for additional information and details on topics presented herein.

[3] Bezzina, D., & Sayer, J. (2015, June). Safety pilot model deployment: Test conductor team report. (Report No. DOT HS 812 171). Washington, DC: National Highway Traffic Safety Administration.

Introduction

Purpose of Report

Connected Vehicle Safety Pilot was a research program that demonstrated the readiness of DSRC-based connected vehicle safety applications for nationwide deployment. The vision of the Connected Vehicle Safety Pilot Program was to test connected vehicle safety applications in real-world driving scenarios in order to determine their effectiveness at reducing crashes and to ensure that the devices were safe and did not unnecessarily distract motorists or cause unintended consequences[4]. The Safety Pilot Program was the largest and most expensive field test of advanced crash avoidance safety systems ever conducted by the U.S. Department of Transportation (USDOT). The research initiative was a major multi-modal effort led by the Intelligent Transportation Systems Joint Program Office (ITS JPO) and the National Highway Traffic Safety Administration (NHTSA), with research support from several agencies, including Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), and Federal Transit Administration (FTA). This one-year, real-world deployment was launched in August 2012 in Ann Arbor, Michigan. The deployment utilized connected vehicle technology in over 2,800 vehicles and at 29 infrastructure sites at a total cost of over $50 million dollars in order to test the effectiveness of the connected vehicle crash avoidance systems. This test involved all types of vehicles including passenger cars; light, medium, and heavy-duty trucks; and transit buses. Overall, the Safety Pilot Program was a major success and has led the USDOT to initiate rulemaking that would propose to create a new Federal Motor Vehicle Safety Standard (FMVSS) to require vehicle-to-vehicle (V2V) communication capability for all light vehicles (passenger cars and light truck vehicles) and to create minimum performance requirements for V2V devices and messages.

Given the magnitude of this program and the positive outcomes generated, the Volpe National Transportation Systems Center conducted a study sponsored by the ITS JPO to gather observations and insights from the Safety Pilot Model Deployment. This study analyzed activities across all stages of the Safety Pilot Model Deployment including scoping, acquisitions, planning, execution, and evaluation. The analysis aimed to identify specific accomplishments, effective activities and strategies, activities or areas needing additional effort, unintended outcomes, and any limitations and obstacles encountered throughout the Model Deployment. It also assessed the roles of organizations and the interactions among these organizations in the project. These findings were then used to develop recommendations for use in future deployments of connected vehicle technology. The USDOT anticipates that findings from this study will be valuable to future USDOT research programs, including the Connected Vehicle Pilots Deployment Project, and also to early adopters of connected vehicle technology.

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[4] http://www.its.dot.gov/safety_pilot/

This report is not intended to be a full account of all activities conducted during the Safety Pilot Model Deployment. It highlights notable activities and findings as gleaned from the interviews and gathered observations. The Test Conductor developed a report that discusses all of the activities carried out during the Safety Pilot Program as part of the Test Conductor's work. The Test Conductor report titled *Safety Pilot Model Deployment: Test Conductor Team Report* is complementary to this report and can be used for additional information and details on topics presented herein.

Methodology

The methodology used to develop lessons and recommendations from the Safety Pilot Model Deployment included a combination of in-person interviews and a review of program documentation. Both activities were conducted post-facto. The review focused on collecting historical information to develop background on topics highlighted during the interviews. It was also used to limit biases when interpreting information gathered during the interviews.

Over 70 interviews were conducted to gather first-hand accounts of on-the-ground activities and any lessons learned from participating in the project. Interviews were conducted with the USDOT and key members of the various contractors supporting the Safety Pilot Model Deployment. The interviews were focused on obtaining information in four general areas:

- What went well?
- What didn't go well or had unintended consequences?
- If you had it all to do over again, what would you do differently?
- What recommendations would you make to others doing similar projects?

Prior to initiating the interviews, a high-level review of the program documentation from SPMD was conducted to identify potential topics and to develop interview questions. These questions were then matched to individual interviewees based on their involvement in the project. Common questions included:

- What surprises did the team have to deal with?
- What project circumstances were not anticipated?
- Did you develop any useful workarounds or solutions to problems that cropped up during the project?
- For any problems that went unresolved, what preventative measures can you invent now that can help things go more smoothly next time?
- Are there any new "best practices" you can derive from this project? This includes anything that went so well that you would want to repeat the positive experience next time.

The interview results were parsed into separate observations. Observations are the basic component of the lessons learned process. The observation conveys basic details of the observed issue, with detail sufficient for further analysis. At a minimum, each observation addressed "what happened?" and aimed to address a single topic. Each observation was uniquely identified and tagged according to key topic areas identified by the researchers. Hundreds of observations were extracted from the interview results. Observations were compiled in a database and filtered into like categories. Observations were able to be sorted by topic or individual interviewee for review and further analysis.

After the observations were filtered, they were used to create summary lessons and recommendations. For each group, the researchers attempted to differentiate between what was planned in the Safety Pilot Model Deployment versus what actually occurred, according to the documentation and the interview observations. There were both positive and negative differences. The next step of the analysis was identifying why there was a difference and speculating on a root cause. Finally, the recommendations for each topic were developed by asking "what should be done in future activities to repeat this success or avoid the pitfall?"

Report Structure

This report is organized into six major chapters. The first two chapters focus on Program Management and Outreach. Both of these areas spanned the entire Safety Pilot Model Deployment. The remaining four chapters cover topics that relate to the execution and evaluation stages of the Model Deployment.

A brief summary of each chapter is as follows:

- **Chapter 1 Program Management** addresses the overall program management activities of the Safety Pilot Model Deployment, primarily from the perspective of the USDOT. It contains two subchapters that discuss program planning and communication processes and tools utilized by the USDOT to manage and coordinate all SPMD activities.
- **Chapter 2 Outreach and Showcase** describes the approach to outreach and engagement of internal and external stakeholders throughout the Safety Pilot Model Deployment
- **Chapter 3 Experiment Setup** discusses setting up the experiment, including selection of the test area and coordinating, preparing, and managing the vehicle fleets and drivers as part of the Safety Pilot Model Deployment.
- **Chapter 4 DSRC Device Development** outlines the process utilized and the USDOT's role in the development and deployment of thousands of DSRC communications devices, including VADs, ASDs, and RSUs.
- **Chapter 5 Device Deployment and Monitoring** focuses on the processes utilized for the installation and deployment of in-vehicle devices and infrastructure devices as well as for monitoring and maintaining the devices after deployment. It contains three subchapters: device testing, device installations, and monitoring devices.
- **Chapter 6 Data Management** describes the processes that were utilized to define, collect and analyze data collected during the Safety Pilot Model Deployment in support a primary objective of the Safety Pilot Program, which was to collect data to support the 2013 NHTSA agency decision on light vehicles.

All chapters are divided into several sections which each describe a topic relevant to the Safety Pilot Model Deployment. Each section begins with background information on the given topic. This is followed by observations expressed by the interviewees as well as information gathered from the program documentation review. Finally, each section concludes with recommendations for future connected vehicle activities.

Background

Research from the National Highway Traffic Safety Administration (NHTSA) showed that connected vehicle technology has the potential to address a very significant number of light vehicle crashes and heavy truck crashes by unimpaired drivers. Since safety is the USDOT's top priority, the potential safety benefits of this technology could not be ignored. At the time, more research was necessary to determine the actual effectiveness of the applications and to understand the best ways to communicate safety messages to motorists without causing unnecessary distraction.

The Connected Vehicle Safety Pilot Program was part of a major scientific research program run jointly by the U.S. Department of Transportation (USDOT) and its research and development partners in private industry. This Program supported the development of safety applications based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications systems, using dedicated short-range communications (DSRC) technology. The Safety Pilot Program was designed to determine the effectiveness of these safety applications at reducing crashes and to show how real-world drivers would respond to these safety applications in their vehicles.

The overall goals of the Safety Pilot Program included:

- Support the 2013 NHTSA agency decision[5] by obtaining empirical data on user acceptance and system effectiveness;
- Demonstrate real-world connected vehicle applications in a data-rich environment;
- Establish a real-world operating environment for additional safety, mobility, and environmental applications development; and
- Archive data for additional research purposes.

The Safety Pilot Program was initiated by the USDOT in 2010 and continued through 2014.[6] The Safety Pilot Program evaluated everyday drivers' reactions both in a controlled environment through **Safety Pilot Driver Clinics** and on actual roadways with other vehicles through the real-world **Safety Pilot Model Deployment**. Driver reactions were evaluated as they used the latest wireless vehicle safety applications and received in-vehicle warning messages if they approached potentially dangerous traffic situations.

Safety Pilot Driver Clinics

Small-scale driver clinics were conducted at six different sites in the United States to assess user acceptance of the connected vehicle technology. At each driver clinic, approximately 100 drivers tested in-vehicle wireless technology in a controlled environment, such as a race track. The goal was

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[5] On August 18, 2014, the National Highway Traffic Safety Administration (NHTSA) issued an advance notice of proposed rulemaking on vehicle-to-vehicle communications technology. Press release found here: http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications

[6] For a high-level timeline of the Safety Pilot activities: http://www.its.dot.gov/roadmaps/safetypilot2_roadmap.htm

to determine how motorists would respond to and benefit from in-vehicle alerts and warnings. The data generated from the driver clinics was critical to supporting the 2013 NHTSA agency decision regarding connected vehicle technology.

Safety Pilot Model Deployment

Approximately 2,800 vehicles were equipped with wireless connected vehicle devices to test safety applications using DSRC between vehicles, while operating on public streets in an area highly concentrated with equipped vehicles. The model deployment was designed to determine the effectiveness of the technology at reducing crashes. The model deployment included a mix of cars, trucks, and transit vehicles; and was the first test of this magnitude of connected vehicle technology in a real-world, multimodal operating environment. The University of Michigan Transportation Research Institute (UMTRI) led a diverse team of industry, public agencies, and academia in supporting this effort.[7]

This report focuses on the activities of the Safety Pilot Model Deployment (SPMD). The sections below provide the following background information:

- **Stages of the Model Deployment:** A high-level description and timeline for the four major stages of the SPMD;
- **Scope of the Model Deployment:** A brief overview of the scope of the SPMD, including the categories of vehicles equipped with DSRC devices, the different types of devices deployed in the vehicles, and a listing of the safety V2V and V2I applications tested by vehicle category and device type; and
- **Roles and Responsibilities:** A list of the roles and responsibilities by each of the organizations involved in the SPMD.

Stages of the Model Deployment

The Safety Pilot Model Deployment consisted of the following four major stages:

1. **Device Development**
   The first stage included the development of devices that would be used throughout the SPMD. Device development was handled under multiple separate procurements conducted by the USDOT. These procurements resulted in the creation of research Qualified Product Lists (rQPLs) for three categories of devices: Vehicle Awareness Devices (VAD); Aftermarket Safety Devices (ASD); and Roadside Units (RSU).

2. **Pre-Model Deployment Planning and Testing**
   The purpose of the second stage of the SPMD was to test, identify and resolve all critical issues before proceeding to the Model Deployment Execution stage. The Pre-Model Deployment Planning and Testing stage included the following three activities:
   - Planning for the Model Deployment Execution;
   - Preparing and installing the required infrastructure and in-vehicle devices; and
   - Conducting interoperability and dry run tests.

[7] http://www.its.dot.gov/factsheets/safety_pilot_factsheet.htm

3. **Model Deployment Execution**
The third stage of the SPMD focused on the deployment and maintenance of all equipped vehicles into the connected vehicle environment. The maintenance of the devices included repairing or replacing non-functional units, updating device software and downloading data.

4. **Post-Model Deployment Evaluation**
This final stage of the SPMD involved analysis of the data collected during the Model Deployment Execution stage by the Independent Evaluator and the USDOT to determine the effectiveness of the connected vehicle systems.

Table 1 below outlines the timeframe for each of the stages of the Safety Pilot Model Deployment.

Table 1. Safety Pilot Model Deployment Stages

Stage	Start	End
Device Development	Jul 2010	Oct 2012
Pre-Model Deployment Planning and Testing	Aug 2011	Aug 2012
Model Deployment Execution	Aug 2012	Aug 2013
Post-Model Deployment Evaluation	Aug 2013	Aug 2014

Source: USDOT

Scope of the Model Deployment

The Safety Pilot Model Deployment established a real world model deployment test site for enabling wireless communications among vehicles and with infrastructure for use in generating data to enable driver safety warning systems through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications. The safety systems for connected vehicle technology is based on dedicated short range communications (DSRC) which are two-way, short-range (approximately 200 to 300 meters) wireless communication capabilities that permit secure, very fast data transmission critical in communications-based, active safety applications. To enable the applications, the in-vehicle devices transmit and receive the Basic Safety Message (BSM), as defined in Society of Automotive Engineers (SAE) standard J2735 and J2945, via DSRC to surrounding vehicles. The BSM contains safety data regarding vehicle state, such as position, speed, and heading. This message is broadcast from the vehicle's DSRC device at a rate of 10 times per second. Applications use this data to issue warnings and alerts to drivers regarding nearby vehicles. The majority of the applications tested during the Safety Pilot Model Deployment were V2V applications, of which the BSM was the key data element exchanged. See Table 3 on page 11 for a complete list of applications implemented during SPMD.

There were three categories of vehicles equipped with DSRC devices in the Safety Pilot Model Deployment:

- **Light Vehicles** – Vehicles whose weight is less than 10,000 pounds. This category generally refers to passenger cars.

- **Heavy Vehicles** – Vehicles whose weight is greater than 10,000 pounds. This category generally refers to medium and heavy duty trucks, such as delivery trucks and articulated trucks.
- **Transit Vehicles** – Vehicles used to transport large numbers of travelers at one time on roadways.

The vehicles were equipped with a mix of integrated, retrofit, and aftermarket safety systems. There were four different types of in-vehicle devices deployed during the SPMD:

- **Vehicle Awareness Device (VAD)** – This device only broadcasts a single type of message, a Basic Safety Message (BSM), as defined in SAE standards J2735 and J2945. This device is not connected to in-vehicle data ports, does not have a working driver-vehicle interface (DVI) and does not receive messages. Even though VADs are not capable of issuing a warning to a driver, they provide a large number of vehicles transmitting BSMs that the other device types can interact with.
- **Aftermarket Safety Device (ASD)** – This device can broadcast and receive BSMs and can process the content of received messages to provide warnings and/or alerts to the driver of the vehicle in which it is installed. The device is not connected to in-vehicle data systems; however, it does have a DVI. ASDs demonstrate that aftermarket equipment is capable of being installed in vehicles post-production by a qualified installer and still function at the same performance levels as devices installed during the production process.
- **Retrofit Safety Device (RSD)** – This device can broadcast and receive BSMs and can process the content of received messages to provide warnings and/or alerts to the driver of the vehicle in which it is installed. This device is connected to proprietary data ports and can provide highly accurate information from in-vehicle sensors. It also has a DVI. These devices demonstrate that DSRC devices can be retrofit in vehicles that have a longer life span than light vehicles, such as heavy trucks and transit vehicles.
- **Integrated Safety Device (ISD)** – This device can broadcast and receive BSMs and can process the content of received messages to provide warnings and/or alerts to the driver of the vehicle in which it is installed. This type of device is connected to proprietary data ports and can provide highly accurate information from in-vehicle sensors. It also has a DVI. Integrated devices demonstrate the preferred approach of installing the DSRC devices in vehicles as they are being produced and can utilize equipment already integrated into the vehicle such as navigation displays, antennas, and other electronics.

Table 2 shows the planned number of each device type deployed during the Model Deployment. The actual number of devices deployed at any point in time varied based on the number of devices that were recalled to troubleshoot and remediate operational issues. A more detailed summary of the characteristics of DSRC devices deployed in the Model Deployment can be found in Section 1 of *Safety Pilot Model Deployment: Test Conductor Team Report*.[8]

[8] Bezzina, D., & Sayer, J. (2015, June). Safety pilot model deployment: Test conductor team report. (Report No. DOT HS 812 171). Washington, DC: National Highway Traffic Safety Administration.

Table 2: Device Allocation by Vehicle Category

Vehicle Category[9]	ISD	RSD	ASD	VAD	TOTAL
Light Vehicles	64	0	300	2,318	**2,682**
Heavy Vehicles	3	16	0	50	**69**
Transit Vehicles	0	3	0	82	**85**
TOTAL	67	19	300	2,450	**2,836**

Source: USDOT

Nearly 200 of the 2,836 vehicles were equipped with a data acquisition system (DAS). The 200 vehicles included ASD-equipped light vehicles, RSD-equipped transit vehicles, RSD-equipped heavy vehicles, and the ISD-equipped light vehicles. A DAS is a custom designed computer with a complement of input sensors and data connections, and typically consists of multiple CAN bus inputs, multiple video inputs, audio, gigabit Ethernet ports, USB ports, automotive-grade hard-disk storage, an integrated GPS receiver and cellular modem, and a dedicated microcontroller and backup battery for power management. The DAS recorded data about the driver and connected vehicle system for use in the independent evaluation of the performance of the safety applications.

Table 3 lists the V2V and V2I safety applications tested and evaluated for each device and vehicle categories. Note that VADs are communication-only devices and do not contain safety applications; therefore VADs are not included in the table below.

Table 3: Safety Applications Tested by Vehicle Category and Device Type

Vehicle Category	Device Type	Applications[10] Tested
Light Vehicles	ISD	Forward Collision Warning (FCW) Emergency Electronic Brake Lights (EEBL) Do Not Pass Warning (DNPW) Left Turn Assist (LTA) Intersection Movement Assist (IMA) Blind Spot Warning & Lane Change Warning (BSW & LCW)
Light Vehicles	ASD	Forward Collision Warning (FCW) Emergency Electronic Brake Lights (EEBL) *Curve Speed Warning (CSW)*

[9] Throughout the Model Deployment and within this report, the 64 light vehicles with ISDs and 3 heavy vehicles with ISDs are commonly referred to as Integrated Light Vehicles (ILV) and Integrated Heavy Vehicles (IHV), respectively. These vehicles are also sometimes referred to as “fully integrated” vehicles. The RSDs installed on the three transit vehicles were part of a transit safety retrofit package (TRP) system and commonly called TRP devices or TRP equipped vehicles.

[10] Application descriptions available at: http://www.iteris.com/cvria/html/applications/applications.html

Vehicle Category	Device Type	Applications[10] Tested
Heavy Vehicles	ISD RSD	Forward Collision Warning (FCW) Emergency Electronic Brake Lights (EEBL) *Curve Speed Warning (CSW)* Intersection Movement Assist (IMA) Blind Spot Warning & Lane Change Warning (BSW & LCW) *Bridge Height Information*
Transit Vehicles	RSD	*Pedestrian in Signalized Crosswalk Warning (PCW)*[a] Vehicle Turning Right in Front of Bus Warning (VTRW)[a] Forward Collision Warning (FCW) Emergency Electronic Brake Lights (EEBL) *Curve Speed Warning (CSW)*

Source: USDOT

Notes. Applications in *italics* in Table 3 are V2I applications. All other applications are V2V applications.
[a] Transit-specific application

In addition to the vehicle devices, the Vehicle-to-infrastructure (V2I) applications are also dependent on the cooperation of infrastructure components. The infrastructure DSRC devices, referred to as **Roadside Units (RSU)**[11], were installed in the deployment site. The RSU was required to broadcast to the vehicle a variety of messages to support the V2I applications. These devices transmitted the following to vehicles equipped with DSRC devices:

- **Signal Phase and Timing (SPaT)** – This message contains information and current status on the phase and timing of the traffic signals for each approach in the intersection.
- **Map Data (MAP)** – This message includes roadway geometry and intersection geometry information. The Intersection geometry information includes an intersection ID, road/lane geometry for all approach roads (e.g. geometric intersection design or GID), location of stop lines, and lane numbering scheme associated with movements.
- **Traveler Information (TIM)** – This message is designed to enable broadcast advisory messages to the vehicle driver based upon location and situation relevant information. Examples include traffic information, traffic incidents, major events, evacuations, etc.

In addition to broadcasting messages, the RSUs also received and stored BSMs from passing vehicles before sending this information through the network backhaul to the back-office servers. The RSUs also played a key role in the security system, by providing a secure connection for in-vehicle devices to connect to the Security Credential Management System (SCMS).

[11] At the time of the Safety Pilot Model Deployment, the term roadside equipment (RSE) was defined as the roadside device that facilitates communication between transportation infrastructure and vehicles and other mobile devices by exchanging data over DSRC; however, following the conclusion of SPMD, a revised RSU specification was issued (v4.0) and the term was changed from RSE to RSU. Now RSE is used to describe all infrastructure equipment at the roadside (signal controllers, backhaul connections, etc.), and RSU refers to original definition of RSE (i.e. the DSRC radio).

Roles and Responsibilities

The Safety Pilot Model Deployment was executed by a collection of organizations that each had a different role and set of responsibilities which are described in the table below. The Test Conductor team, which was led by the University of Michigan Transportation Research Institute (UMTRI), was composed of eight partners including HNTB, Parsons Brinkerhoff, Mixon-Hill, Leidos (formerly SAIC), Bosch (formerly Escrypt), Michigan Department of Transportation (MDOT), the City of Ann Arbor, and Texas A&M Transportation Institute (TTI). More information about roles and responsibilities of the test conductor team can be found in Section 1 of *Safety Pilot Model Deployment: Test Conductor Team Report.*

The Crash Avoidance Metrics Partnership (CAMP) is a partnership comprised of eight automotive companies (Ford, General Motors, Honda, Hyundai/Kia, Mercedes Benz, Nissan, Toyota, and Volkswagen) established by the USDOT's Intelligent Vehicle Initiative to work on research common to both industry and the government in order to accelerate the implementation of crash avoidance countermeasures in passenger cars. CAMP played a major role in the Safety Pilot by developing the sixty-four (64) integrated light vehicles that were used to gather the majority of the light vehicle data that was used to analyze the performance of the connected vehicle safety systems.

The remainder of the organizations that supported the Safety Pilot Model Deployment are briefly described in the table below.

Table 4: Roles and Organizations in SPMD

Role Name	Organization	Role Description
Test Conductor	University of Michigan Transportation Research Institute (UMTRI)	Establish and manage the SPMD
Integrated Light Vehicle (ILV) Developer	Crash Avoidance Metrics Partnership (CAMP)	Develop, test, and maintain the integrated light vehicles deployed in SPMD
Integrated Heavy Vehicle (IHV) Developer	Battelle	Develop, test, and maintain the integrated heavy vehicles deployed in the SPMD
Retrofit Heavy Vehicle Developers	Battelle, Southwest Research Institute (SwRI)	Develop, test, and maintain the retrofit safety devices deployed in the heavy vehicles in SPMD
Transit Safety Retrofit Package (TRP) Developer	Battelle	Develop, test, and maintain the retrofit safety devices installed in the transit vehicles in SPMD
SCMS Manager	Leidos (formerly SAIC)	Develop and manage the prototype Security Credential Management System (SCMS)

Role Name	Organization	Role Description
VAD Developers	Savari, Cohda	Develop, test and maintain the VADs deployed in SPMD
ASD Developers	Denso, Cohda, Delphi, Visteon	Develop, test and maintain the ASDs deployed in the SPM
RSU Developers	Arada, Savari	Develop, test and maintain the RSUs deployed in the SPMD
Independent Evaluator (IE)	John A. Volpe National Transportation Systems Center (Volpe)	Assess the system performance, application effectiveness, and driver acceptance of the connected vehicle systems in the SPMD.
Real-Time Data Capture and Management Team	FHWA Turner-Fairbank Highway Research Center (TFHRC)	Develop an archive of SPMD data and meta-data and make it openly available to researchers and the public.

Source: USDOT

Chapter 1 Program Management

This chapter addresses the overall program management of the Safety Pilot Model Deployment (SPMD) primarily from the perspective of the USDOT. It is divided into two subchapters:

- **Program Planning** – This subchapter focuses on both the structure and the content of the Test Conductor statement of work and addresses the prioritizing critical activities and deliverables, managing procured equipment, implementing program management tools and utilizing performance metrics.
- **Program Communications** – This subchapter focuses on the communication processes and tools utilized by the USDOT to manage and coordinate the entire SPMD.

Program Planning

Developing a statement of work (SOW) for the Test Conductor required a significant amount of time and effort and was itself a significant milestone in the program planning phase. There was concern over the Test Conductor scope becoming too large and therefore the technical tasks were divided across several different organizations through various procurements.[12] One of the challenges with developing the statement of work was defining the scope of the Test Conductor as it related to the various other procurement SOWs within the Safety Pilot Program. An extensive analysis was conducted by the USDOT to determine the structure and technical content of the Test Conductor SOW, and even with this analysis there were still numerous modifications to the scope of this contract throughout the Model Deployment. See Section 2 of the *Safety Pilot Model Deployment: Test Conductor Team Report* for a full list of contract modifications that impacted the scope of the project.

This subchapter explores the following topics:

- **Section 1.1 Defining Scope and Prioritizing Critical Activities** discusses the importance of prioritizing the critical activities that are necessary to support the primary objectives of the research program.
- **Section 1.2 Identifying Schedule of Deliverables** discusses the importance of scheduling deliverables to align with the project critical path and with key project activities. It highlights the dangers of front-loading deliverables early in the project, resulting in constrained resources and compromised quality of key deliverables.
- **Section 1.3 Developing Practical Project Management Tools** highlights the critical nature of requiring a consistent level of detail in project schedules and work plans for all contractors and tasks in order to efficiently monitor the project.

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[12] A complete list of the acquisitions resulting in contracts and cooperative agreements can be found in the Background Section in Table 4 on page 11

- **Section 1.4 Developing GFE Management Plans** outlines potential issues associated with procuring and transferring major Government Furnished Equipment (GFE), specifically focused on vehicle purchases.
- **Section 1.5 Utilizing Quantitative Performance Measures** explains the importance of developing, utilizing, and tracking performance measures, and developing and implementing response plans if performance falls below target levels, to ensure that overall objectives of the project are met. This section includes several examples of performance measures developed and monitored for the SPMD.
- **Section 1.6 Preparing for Project Closeout** describes the provisions for inventorying and decommissioning equipment (including plans for removal and decommissioning in-place) used in the SPMD.

1.1 Defining Scope and Prioritizing Critical Activities

One of the challenges with developing the Safety Pilot Model Deployment statement of work (SOW) was defining and organizing the scope of the Test Conductor in a way that the pilot could be managed to achieve its primary objectives, while also conducting many other supplemental activities. The SOW initially required the Test Conductor to conduct many activities in parallel and often utilize the same resources for these activities. One example was the requirement to deploy multiple vehicle types and device types into the Model Deployment simultaneously. This included aftermarket safety devices (light vehicles), vehicle awareness devices (for all vehicle types), retrofit safety devices (for transit and heavy vehicles), and integrated light vehicles. The device installation, driver recruitment and deployment activities for each of the vehicle and device types were very resource intensive. After evaluating the resource demands for each activity, the Test Conductor determined it was not feasible to conduct all of these activities in parallel.

The USDOT subsequently identified all critical activities in the Safety Pilot Model Deployment that were needed to ensure that the primary objective of the SPMD could be met; that is to collect data to support the NHTSA 2013 agency decision on V2V technology for light vehicles. It was determined that only the deployment of the integrated light vehicles and the vehicle awareness devices was necessary to support the NHTSA decision. Therefore, the USDOT decided that the remaining vehicles and devices (aftermarket safety devices, integrated heavy vehicles, and retrofit transit/heavy vehicles) could be deployed after the Model Deployment launch, instead of in parallel as originally planned.

A positive aspect of how the SOW was structured was the use of modular type approach. Essentially the project was broken down into smaller, flexible and more numerous components, making it easier to move components of the project around in the schedule. Categories of vehicles and device types were treated somewhat like a 'mini-projects' with stages and milestones, as compared to looking at the SPMD as a whole, with key stages such as design, development, testing, and deployment where each aspect of this process could not be commenced until the previous stage was completed. A modular approach also made it easier to implement changes and improvements from lessons learned as the project progressed.

This approach allowed project resources to be focused on the critical activities first, and then address the less critical activities at points in the project when resources were more readily available. The Test Conductor was able to successfully deploy all 64 integrated light vehicles along with over 300 VADs at the SPMD launch on August 21, 2012, ensuring that the integrated light vehicles would be able to collect that necessary data to support the NHTSA decision. The remaining vehicles were deployed after the Model Deployment launch. Even with a staggered launch, all vehicles and devices were deployed into the field by the end of the calendar year, which provided sufficient time for them to support the objectives of their inclusion in the Safety Pilot Model Deployment, e.g., demonstration of aftermarket devices, evaluation of effectiveness, etc.

In general, the fixed deadlines associated with the NHTSA decision-making process imposed management processes and maintained a focus on activities that were considered critical to the primary mission of the project. However, other opportunities were able to be accommodated and pursued within the SPMD, such as V2I application development and contextual data analysis. The modular approach worked reasonably well for dealing with changes in requirements in any of the smaller components or when a new idea came to light midway through the project. However, participants noted that some of the components were added too late in the schedule. In general, those affected by these additions indicated a preference for earlier engagement in subsequent pilot projects; indicating a need for efforts to predict potential expansions of scope early in the process.

In future projects, if new elements are considered, as was the case during SPMD, carefully assess and weigh the impacts to primary objectives, while maintaining objectives and integrity of the research of the new element as well. A stakeholder analysis should be conducted early in the planning process for any additional added elements. The analysis will need to identify all persons, groups, and institutions that may have an interest in the project. This allows for management of stakeholder interests and expectations so that the project runs as smoothly as possible. Include any anticipated internal stakeholders during the initial planning stages, even those who may be initially deemed low probability of participating. Engaging stakeholders early in the process will ensure that those involved understand the purpose of each element, it will give stakeholders a sense of involvement in the project, and it will allow the team to provide potentially valuable information and insight into technical approach, scheduling, potential risks. The analysis should be conducted in the early stages of a project so that any risks and required communication can be included in the overall project plan. This can significantly increase the chances of project success.

Recommendations

- Utilize a modular project structure to reduce non-critical component impacts to launch. Prioritize the program's objectives and link them to specific tasks and activities within the project. During the planning phase, identify the level of effort required and resource requirements for each task to ensure adequate resources are available to accomplish the established objectives.
- For each modular project element, conduct a needs analysis and involve any stakeholder during the initial planning stages, even those who may be initially deemed low probability of participating.
- If new project elements are considered, carefully assess and weigh the impacts to primary objectives, while maintaining objectives and integrity of the research of the new element.
- Ensure that all contractors are aware of the prioritized objectives and the relationships of the critical supporting tasks and activity dependencies during the planning phase.

1.2 Identifying Schedule of Deliverables

The Test Conductor Statement of Work (SOW) required completion of a large number of deliverables within the first year after award, from August 2011 through the launch of the Model Deployment in August 2012. The majority of the resource intensive deliverables were required within the first 60 days of award. Examples include:

- Program Management Plan
- Model Deployment Site Plan
- Security Management Operating Concept
- Safety Analysis and Threat Assessment Plan
- Experimental Plan
- Aftermarket Safety Device (ASD) and Vehicle Awareness Device (VAD) Installation Plans
- Outreach Plan

Most of the deliverables identified in the SOW were not linked to specific activities or milestones, or associated with task linkages or critical paths. Instead, deliverables were tied to the contract award date; for example, the SOW used language such as, “due twenty (20) days after award”. While it makes sense that some deliverables are directly linked to the award date, such as the Program Management Plan, and are front loaded at the beginning of the project, other deliverables should have been prioritized and scheduled according to project activities. Because of the compressed schedule for SPMD, the documentation requirements included in the SOW were not feasible.

Front-loading most of the deliverables into the first two months of the SPMD resulted in: 1) documentation for activities lagging behind schedule; and 2) compromised quality of deliverables. Many of these deliverables did not need to be completed that early in the project. A clear example was the ASD and VAD Installation Plans. The installations plans were due in October 2011; however, device installs were not scheduled to start until June 2012. The plans were required before the Test Conductor even received the research Qualified Product Lists (rQPL) from the USDOT. Therefore, the Test Conductor did not have a list of approved suppliers or access to prototype ASDs and VADs to use in developing the installation process. As a result, the initial drafts of the installation plans were incomplete and required several revisions during the first year of the contract. The delivery of these documents should have more closely aligned with the rQPL delivery and the actual device installations since there was slack time in the project until these plans were necessary. This was also the case with several other deliverables, including the Security Management Operating Concept, which needed to be revised numerous times due to refinements in the Security Credential Management System.

Preparing multiple revisions of deliverables throughout the SPMD constrained resources. This ‘update cycle’ required additional resources from the Test Conductor to develop the various drafts of materials as well as additional resources from the USDOT to review and accept the deliverables. In some cases, the updates lagged significantly behind the completion of the activity; therefore, the most current documentation was not a reflection of what was actually deployed in the Model Deployment. This created an issue when new stakeholders became involved in the project as a complete set of up-to-date documentation was not available for their review and indoctrination. Delivering completed documentation behind schedule also made the documentation less valuable, for example, the Interoperability Test Reports were delivered over one month after the testing was completed.

Recommendations

- Identify all project deliverables at the start of the project and prioritize which are critical for the success of the project. Directly link deliverables to specific activities or milestones to ensure that multiple revisions of deliverables are not required. Ensure that due dates for contracted deliverables are not heavily front-loaded unless necessary to execute the work.
- Develop an initial 'at a glance' project checklist to quickly assess deliverable dates and progress for high-level project check-ins.
- Analyze the non-critical deliverables to determine the appropriate delivery schedule based on related activities and potential resource constraints.

1.3 Implementing Practical Project Management Tools

All contractors in the Safety Pilot Model Deployment were required to provide project schedules and work plans as a part of their contract or agreement. However, the level of detail and format was not always specified in the procurement documents. This resulted in consistencies in project schedule definitions. For example, some contractors provided project schedules in Microsoft Project to three (3) work-breakdown structure levels and others provided a table in Microsoft Excel that listed high-level tasks and delivery dates.

This inconsistency made integrating the various project schedules into a single schedule for all of SPMD very difficult. With varying levels of detail, the dependencies between each of the projects could not be easily identified and linked. The Project Management Office at the ITS JPO was tasked with developing an integrated schedule for the SPMD; however, the resulting schedule had a large number of gaps as it lacked sufficient detail for some of the projects. Furthermore, a software product called SharePoint Project Management Central was selected as the primary tool for storing, viewing and managing the integrated schedule. Not all participants felt that this tool was well suited for this task. Users reported that the interface for reviewing project status and entering data was very inefficient and time-consuming as the system lacked basic functionality such as sorting and filtering. As a result, the majority of the USDOT staff did not utilize this tool to review and update the SPMD schedule.

Since the integrated schedule was not utilized, monitoring the project schedule was much more difficult. The USDOT staff developed ad-hoc reports and documents to ensure that the Safety Pilot Model Deployment launched on schedule. One such report was the Model Deployment Checklist, which was a Microsoft Word document that identified 1) the critical tasks that must be completed prior to launch and, and 2) the required completion timing for each critical task. This document was heavily utilized in coordination meetings as well as in briefings to senior management to convey the progress the team was making toward the launch of the Safety Pilot Model Deployment.

A risk management plan was also implemented as part of the SPMD. The plan was developed to foresee risks, estimate impacts, and define responses to any issues that could have impacted the SPMD launch or other critical activities. The USDOT and Test Conductor cooperatively developed risk mitigation response plans to eliminate or reduce the risks that could have impacted schedule, resourcing, budget or not meeting the key project objectives. Since risk management is an ongoing process during the project lifespan, the plans were reviewed regularly by the Test Conductor and USDOT.

While the effectiveness of many of the project management processes and tools was strongly endorsed by most participants, other more technically focused tools, for example, the development of a Systems Engineering Management Plan (SEMP), configuration management, requirements generation, and data types and formats specification, should be given greater emphasis in a future pilot project.

Many of the high risk components, including both devices and systems, grew in complexity and impacted the overall project schedule. Some of the issues that led to schedule delays could have been better monitored with a systems engineering plan that included critical gate reviews and schedule tracking. Future projects should consider implementing a SEMP that addresses the following elements:

- Organization of the device and system development teams
- Technical environments for the project and how they will be managed, including discussion of the pre-production and production environments
- Description of the evaluation and decision-making process when resolving technical questions
- System Engineering Methodology
    - Configuration Management – descriptions of how project configuration items will be managed
    - Requirements Verification and Validation – descriptions of how requirements are validated and updated requirements are reviewed and approved
    - Architecture and Design Process – description of how issues will be discussed and resolved for both logical and physical design
    - Build Management process used to create and manage builds
    - Testing process to be used that encompasses the requirements
- Description of how external interfaces will be developed and managed
- Description of how data conversion development will be performed and managed

Several of these issues are addressed individually in future chapters.

Recommendations

- Provide clear direction in the contracts and cooperative agreements in regards to the project management expectations. Require consistent level of detail of the project management deliverables from each contractor participating in the program. All project management plans should contain at least 3 levels of a work breakdown structure.
- Develop a master project management plan (PMP) immediately after the program planning stage to facilitate detailed planning at a sufficient work breakdown structure (WBS) level of detail. Maintain plan, track linages, critical paths, and contingencies throughout. This is particularly crucial if there is inflexibility with key milestone dates or project end dates.
- Define the requirements for internal program management tools early in the overall program development. Be prepared to modify the requirements, if necessary, to meet changing management and reporting needs. Develop a plan in advance for modifying and implementing changes to the program management tools.
- Develop, maintain, and monitor a “Readiness Checklist” to ensure that all critical tasks are completed prior to pilot launch. Include all critical tasks and required completion timing for each task as part of the checklist.

- Repeat the good practice of tracking and monitoring risks. Develop and maintain a risk management plan during the planning phase. Identify critical risks that could have severe impacts on the project. Develop a serious of risk response plans with triggers and responses for each identified risk.
- Develop a System Engineering Plan (SEMP) early in the project and follow it throughout the program. Include critical gate reviews for all devices and systems.

1.4 Developing GFE Management Plans

The USDOT provided the Test Conductor with sixty-four (64) integrated light vehicles (ILV) as government furnished equipment (GFE) for deployment into the Model Deployment test environment. The 64 ILVs were equally distributed between the eight (8) OEMs that were represented by the Integrated Light Vehicle Developer (CAMP) in the Safety Pilot Model Deployment. Several challenges were encountered with procuring the light vehicles and with transferring these vehicles to the Test Conductor for use in the Model Deployment.

Two key issues complicated and delayed the light vehicle procurement process. First, each OEM was responsible for selecting the types of vehicles to be used in Safety Pilot for their integrated vehicles. When making these selections, three (3) of the eight (8) OEMs selected vehicles manufactured outside of the United States. Direct purchase of these vehicles was restricted by the USDOT Buy America provisions[13] and required a waiver from the Secretary of Transportation granting authority to the acquisitions team to procure these vehicles. The process of acquiring this waiver took approximately 6 months to complete before the procurement of these vehicles could be initiated. This time was not incorporated into the original schedule. The second complicating factor in procurement was that many of the 64 vehicles required a specific option package not typically purchased by dealers. For example, one OEM required their vehicles to be equipped with a navigation system but not the adaptive cruise control package, which are often coupled together. Similarly another OEM required the premium package but not with the sunroof that typically accompanies it. Generally the procurement of standard goods involves first issuing a Request for Proposal (RFP). Then the USDOT selects the lowest bid that matches the requirements specified. For SPMD, the initial set of RFP responses did not meet the specified requirements since most of the vehicle options specified were not typically carried or even special ordered by most car dealers. This resulted in the USDOT having to issue additional procurements to identify car dealers with vehicles in stock or that could be special ordered with the appropriate option packages. Because some vehicles had to be special ordered by the dealers, they were delivered at various times from July 2011 to February 2012. The delay in vehicle delivery significantly impacted the timeline for development, testing, and integration of the integrated light vehicles, which was originally scheduled to be completed by June 2012.

Once the vehicles were ready for delivery, there were several challenges encountered with transferring the vehicles between the USDOT, the Integrated Light Vehicle Developer, and the Test Conductor. First, the 64 integrated light vehicles were delivered by various car dealers to the OEM research facilities, located in Michigan, California or Ohio. A USDOT representative had to be present at the time of delivery to sign-off on receipt of the vehicles, take possession from the dealer, and then transfer possession to the OEM. The OEMs then integrated the V2V systems into the vehicles. Once

[13] http://www.dot.gov/highlights/buyamerica

the V2V systems integration was completed, the vehicles had to be shipped to Ann Arbor, MI where a USDOT representative was required to be physically present to transfer the light vehicles from the Integrated Light Vehicle Developer to the Test Conductor. Having a USDOT representative on-site in Michigan and having the responsibility of transferring the 64 vehicles was a time consuming and costly process.

Finally before the vehicles could be deployed in the test environment, the USDOT had to register each vehicle in the State of Michigan to acquire the license plates and vehicle registrations. This was another time consuming process, taking approximately 3 months, where the vehicle titles had to be physically mailed from the USDOT contracting officers to the USDOT representative charged with registering the vehicles in the State of Michigan and then returned to the contracting officers.

The USDOT was ultimately successful in procuring, registering, and transferring the integrated light vehicles to the Test Conductor for use in the Safety Pilot Model Deployment; however, this required a significant time and budget commitment from Federal resources, and parts of this process may have been more efficiently conducted by the Test Conductor.

Recommendations

- If providing vehicles or other major equipment as GFE under a contract, develop a plan describing how the GFE will be acquired, transferred, managed, and deployed over the course of the project.
- When procuring high-value equipment through the federal acquisition process, be aware that non-standard options and foreign made equipment can significantly impact the procurement and delivery schedule. If the schedule is constrained, investigate alternative means of specifying or acquiring the necessary equipment.

1.5 Utilizing Quantitative Performance Measures

One of the key objectives of the Safety Pilot Model Deployment was to collect a sufficient amount of data to support the NHTSA 2013 decision on V2V technology for light vehicles. However, the Test Conductor SOW did not specify performance measures to monitor achievement of this goal. It also did not describe a process to develop and implement corrective responses plans if performance was lacking.

After the award of the contract, the USDOT decided that performance measures would be developed, utilized, and tracked for the Model Deployment to ensure that the overall objectives of the project could be met. When performance measures were below set targets, the USDOT and Test Conductor developed and implemented response plans to improve the performance of the Model Deployment.

Below are several examples of performance measures developed and monitored by the USDOT during the Safety Pilot Model Deployment:

- *Device Lane Accuracy*: This metric measured the percentage of time that the installed device (VAD, ASD) was able to correctly identify the lane in which the vehicle was traveling. This metric was utilized to assess the performance of various GPS antenna installation configurations. Configurations with less than acceptable performance were not approved for use in the Model Deployment. More on this can be found in Section 6 of *Safety Pilot Model Deployment: Test Conductor Team Report.*

- *Drivers Recruited*: This metric measured the number of naïve drivers that volunteered to have at least one type of V2V device installed in their vehicle. Prior to the launch of the Model Deployment, the driver recruitment performance measure was well below the established target of 3,000 drivers. As a result, the Test Conductor implemented a number of changes to the recruitment process in order to bring the performance measure back into an acceptable range. Details on the modified recruitment process can be found in *Section 3.5 Recruiting and Selecting Light Vehicle Drivers*.
- *VADs / ASDs Installed*: This metric measured the number of VADs and ASDs installed in the vehicles of volunteer drivers. After the launch of Model Deployment, the number of VADs installed was slightly below the targets outlined in the Test Conductor's Program Management Plan due to the complexity of the device installation (as discussed in *Section 5.4 Installing In-Vehicle Devices*). The USDOT authorized the Test Conductor to contract with a third-party installer to augment existing installation staff and also to pay overtime to existing installation staff in order to accelerate the deployment of VADs into the Model Deployment Test Environment.
- *V2V Interactions*: This metric measured the number of instances when two vehicles equipped with V2V technology were within close proximity of each other. When the V2V interactions were lower than projected, the USDOT authorized the Test Conductor to utilize staff to drive VAD equipped vehicles throughout the Model Deployment area to increase potential exposure of integrated vehicles to other V2V equipped vehicles. This is described in greater detail in *Section 3.3 Estimating Number of V2V Interactions*.

The USDOT tracked each of these performance measures – either on a weekly or monthly basis depending on the measure - to ensure they were at the target levels. The performance measures and corrective response actions developed by the USDOT and the Test Conductor were a useful tool for gauging the progress of the Test Conductor in collecting the data necessary to support the NHTSA decision. Without the use of these measures, it would have been far more difficult to ensure that enough data was collected during the Model Deployment.

Recommendations

- Develop quantitative measures of performance and incorporate them into the Statement of Work and other procurement materials to ensure the contractor understands how their performance will be measured. If the performance measures are not known at the time of writing the SOW, indicate that they will be developed after award of the procurement and utilized throughout the contract. An alternative approach could be to allow the contractor to propose performance measures as part of their proposal.
- Limit the measures developed and tracked to those that are directly linked to the program objectives, otherwise resources will be spent on measuring information that may not be critical to the program's success.
- Indicate in the Statement of Work that potential corrective responses will be jointly developed for use in the event that the measures of performance are below the established targets.

1.6 Preparing for Project Closeout

The Test Conductor SOW originally included a task for the decommissioning of the Safety Pilot Model Deployment, extending over a 6 month period after the conclusion of the data collection phase. The purpose of the decommissioning phase was to allow time for the Test Conductor: (1) to administer post-experiment surveys and conduct one or more focus groups with the test subjects driving the ASD vehicles; and (2) to inventory and remove all equipment used in SPMD, including in-vehicle devices and infrastructure equipment installed in the Ann Arbor area.

This task was included in the SOW based on the assumption that all equipment would be government property at the conclusion of the contract since it was purchased with Federal funds. However, further research into the Federal Acquisitions Regulations[14] resulted in a clarification based on acquisition cost of the equipment. For equipment with a unit acquisition cost of less than $5,000, the equipment becomes property of the contractor at the conclusion of the contract. Therefore, the acquisition costs of all equipment purchased by the Test Conductor had to be re-reviewed to determine the disposition of the equipment at the end of the contract. Most of the equipment used in SPMD, specifically the vehicle devices such as ASDs and VADs, became the property of the Test Conductor at the conclusion of the contract.

For the field infrastructure equipment, the SOW allowed the USDOT to give the option to the local public sector partners to keep the field infrastructure in place after the completion of the model deployment. The Test Conductor would only be responsible for decommissioning any equipment that the local transportation agency did not intend to keep. With this provision, the local agency would be responsible for all ongoing operational and maintenance costs for the field hardware and software[15] left in place. This included data connections to the RSU, power, and routine maintenance.

Although provisions for decommissioning the equipment were in place, the USDOT decided to transition the SPMD into the Ann Arbor Test Environment, a connected vehicle test bed, rather than decommissioning all of the equipment following the conclusion of the SPMD data collection period. This was a direct result of the success of the environment in generating the necessary V2V interactions and safety data needed for analysis. Since all in-vehicle and infrastructure equipment remained in place following the conclusion of the Model Deployment, the decommissioning period in the Test Conductor contract was removed through a subsequent modification.

Leaving the equipment in place had a positive impact on the project from both the USDOT and Test Conductor perspective. Not having to account for and decommission approximately 2,800 devices at the end of the Safety Pilot was a significant cost reduction for the USDOT. The Test Conductor was also able to utilize the devices in future connected vehicle research without having to repurchase and reinstall all of the equipment.

Recommendations

- Develop decommissioning plans that include the disposition of all government purchased equipment well in advance of when the contractors will need to initiate those plans. Be aware

[14] http://www.acquisition.gov/far/html/52_245.html
[15] All software running on the equipment prior to its decommissioning was considered part of the equipment.

of any acquisition cost thresholds on equipment that could determine ownership following the end of the project.

- Develop transition and sustainability plans for converting a test environment into a live deployment. Identify roles, responsibilities, and funding sources for continuing to operate and maintain the environment. Ensure that updates can be made to any contracts to keep the environment intact if so warranted.

Program Communications

After the scopes of the Safety Pilot Test Conductor and the other organizations were solidified and the procurements executed, the USDOT was faced with the challenge of managing and coordinating many highly interrelated contracts and agreements. There were numerous dependencies between organizations, as well as tasks that required the successful collaboration of multiple organizations in order to successfully complete the task. Also, these various contracts and agreements generated a tremendous amount of documentation for the USDOT to manage. Therefore, the USDOT had to develop tools and processes to facilitate the sharing of critical information across multiple contractors and senior management in an efficient manner. This subchapter explores these topics in the following sections:

- **Section 1.7 Developing a Communications Plan** discusses the critical nature of establishing communication guidelines to coordinate interrelated activities between teams. This is particularly important for projects that involve a multi-modal effort with a large number of contracts and cooperative agreements, each responsible for various components of the project.
- **Section 1.8 Identifying Cooperative Tasks** focuses on the level of coordination and communication required at the technical, day-to-day level.
- S**ection 1.9 Sharing Program Documentation** highlights the magnitude of documentation produced, reviewed, and approved by a project of this size, as well as the importance of sharing results and documentation with other teams in an expedient manner. It identifies the resource intensive nature of multiple reviews and challenges with managing this level of documentation.

1.7 Developing a Communications Plan

The Safety Pilot Model Deployment was a major multi-modal research initiative, led by the Intelligent Transportation Systems Joint Program Office (ITS JPO) and the National Highway Traffic Safety Administration (NHTSA), and supported by several agencies including Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), and Federal Transit Administration (FTA). The program was composed of a large number of interrelated contracts and cooperative agreements that were each responsible for various components of the Safety Pilot Model Deployment. Each contract or cooperative agreement was awarded from a different modal administration. A Federal contracting officer's representative (COR) was assigned to each acquisition to provide technical direction to the project. For example, acquisitions were awarded in support of the SPMD and oversight was provided as shown in Table 5 below.

Table 5: SPMD Acquisitions and Managing Agencies

Acquisition	Contractor	Managing Agencies
SCMS Manager	Leidos	ITS JPO
Test Conductor	UMTRI	ITS JPO, NHTSA
Integrated Light Vehicle Developer	CAMP	NHTSA
Integrated Heavy Vehicle Developer	Battelle	ITS JPO, FMCSA
Retrofit Heavy Vehicle Developers	Battelle, SwRI	ITS JPO, NHTSA, FMCSA
Transit Safety Retrofit Package Developer	Battelle	FTA
Independent Evaluator	Volpe Center	NHTSA

Source: USDOT

Each contractor was required to conduct all of their activities through their assigned Federal COR. This included receiving technical direction, submitting deliverables and receiving project updates. The challenge with this approach was that many of the contracts and agreements were interrelated – activities and deliverables of many of the contracts and agreements were often dependencies for another contract or agreement. For example, the delivery of the integrated light vehicles was a major deliverable for CAMP and was a major dependency for the Test Conductor. As a result, the coordination of these related contracts and agreements took a significant effort between the Federal CORs to ensure that each contractor was supplied with the appropriate deliverables at the necessary time in order to execute their work plan.

To facilitate effective and efficient two-way communications with the various teams, a communications plan was developed to describe how communications would occur, including communication method and frequency. The coordination between contracts was primarily handled through a set of themed conference calls, for example, there were standing calls that addressed data, security, program management, and outreach. These meetings were a useful tool for sharing information across contracts and agreements. One element that was not incorporated into the communication plan was a process for dealing with business-sensitive information. There were instances of meetings that included topics bordering on business sensitive information, in which the contractors would then decline to discuss in the open form. This resulted in having to schedule a separate meeting that may not have originally been included in the project schedule.

The communication across the program was exemplary for a program of this size; however, at times the communication protocols did limit the speed at which certain decisions could be made and actions could be initiated. There were some examples where the flow of information from one Federal COR to another and down to the contractor was not as efficient or effective as it could have been. In addition, it was a challenging process for contractors to communicate directly with each other, as the Federal CORs were required to be involved and establish the communication.

While the effectiveness of many of the project management processes was strongly endorsed by participants, specifically the nature and frequency of meetings, there were several issues identified that prevented meetings from being as effective as they could have been. For example, some participants remarked that many of the coordination calls did not have formal meeting minutes and few recorded actions. Also, some expressed that meetings had “too much transparency”, most notably when device problems were discussed with many different vendors present on the call. For future pilots, it is suggested that the good practice of meeting face-to-face on a monthly basis be repeated, and team/specialty teleconferences be held on a weekly basis. Also, a method for developing and sharing meeting minutes and action items should be developed and the list of 'required vs optional' attendees should be discussed prior to the meeting being scheduled. This will ensure that all pilot participants are given the opportunity to use their time most effectively.

In addition to developing and executing a communications plan and communicating project status between teams, another important element of program communications is capturing lessons learned and best practices from the project. It is important to determine which elements of the less optimal project experiences should be avoided in the future, and what contributors to project success should be repeated for future projects. For example, as discussed in *Section 3.6 Selecting Heavy Vehicle Fleets*, the ownership and licensing of vehicles of the heavy vehicles to a commercial carrier for profit-making operations was difficult and overlooked early in the SPMD. To ensure that critical steps and processes such as these are not lost in future projects, these should be carefully documented.

For SPMD, the lessons learned were captured at the end of the project. For large projects, it may be useful to execute this exercise at the completion of each major phase. This will ensure that participants interviewed still have a fresh memory of what worked well and where improvement is needed, and the results should be more accurate and useful.

Recommendations

- With closely related contracts, utilize a single contracting officer's representative (COR) or ensure close communications between CORs in order to coordinate the interrelated activities across the contracts. Note that as more distinct contracts are added to a program, more overhead is required to manage and coordinate.
- Develop a communication management plan that identifies guidelines and establishes a structure for managing overall project communications, including meeting schedules, email communications protocols, and main points of contact.
- Identify a process for addressing inquiries into business sensitive information as a part of the guidelines of the communication plan. For example, contractors should notify their USDOT COR if business sensitive information is being requested and the request can be evaluated.
- Adopt a formal mechanism to ensure that key practices and specific lessons learned are captured and implemented in future projects or future phases of the existing project.

1.8 Identifying Cooperative Tasks

As discussed in *Section 1.7 Developing a Communications Plan*, coordination at the contractual level for all of the related contracts and agreements that formed the Safety Pilot Model Deployment was extensive. This level of coordination and communication was also required at the technical, day-to-day level. The contracts and agreements identified each contractor's responsibilities at a fairly general level, and so there were numerous details that needed to be agreed upon by all stakeholders as the project progressed.

A number of tasks in the Safety Pilot required multiple contractors to work cooperatively to achieve the desired outcome. For example, the driver training for the integrated light vehicles was cooperatively conducted by the Integrated Light Vehicle Developer and the Test Conductor. The Test Conductor was required to provide the training facilities and schedule the participants for the training class, while the Integrated Light Vehicle Developer was required to conduct the training class and demonstration drive. This required a significant amount of coordination. For example, with the driver training event, the Test Conductor had to identify the specific training facilities that would be available for use by the Integrated Light Vehicle Developer. Also the Test Conductor had to create and implement safety protocols to ensure training facilities were closed to the public. Another key example of contractor collaboration was the monthly harvesting of data from the integrated light vehicle data acquisition systems. The Test Conductor was responsible for providing adequate facilities for the Integrated Light Vehicle Developer to use in the harvest event and for scheduling the participants to bring the ILVs to the specified facility. Discussions between these two entities were necessary in order to identify the requirements for adequate facilities (i.e. number of garage bays, internet access, etc.) as well as the timing for the data harvesting process.

While these responsibilities were clearly defined at the contractual level, at the technical working level, there were a number of details and unresolved issues that needed to be identified and resolved prior to the event. It was also necessary for the USDOT to work collaboratively with the contractors to ensure the responsibilities and expectations were well-defined and that there were no gaps. To that end, the USDOT convened a series of monthly working meetings on-site in Ann Arbor. The goal of these meetings was to develop a coordinated, detailed plan for accomplishing the key activities necessary to achieve a successful launch of Model Deployment. Each meeting focused on specific topics such as antenna positioning, data harvesting, light vehicle deployment, and device installation. These meetings involved all of the key personnel for a specific topic area which allowed for decisions to be made in real-time without a significant time lag.

Recommendations

- Clearly define in writing the USDOT requirements and contractor responsibilities for all collaborative activities that involve multiple parties.
- Identify all key events, such as milestones and deliverables, which may require an increased level of communications between various contractors leading up to that event.
- Plan and conduct in-person working meetings leading up to all key events as a way to coordinate activities and quickly resolve any issues. Ensure that all the key project stakeholders are involved in the meetings to ensure real-time decision-making.

1.9 Sharing Program Documentation

The contractor teams involved in the Safety Pilot Model Deployment were required to develop and deliver various technical artifacts to the USDOT under each of their projects. Examples of these artifacts and documentation included:

- Planning Documents, e.g., a Project Management Plan, Configuration Management Plan
- System Concepts of Operations
- System Requirements
- Test Procedures and Test Reports
- Evaluation Results

- Final Reports

These technical artifacts had to be reviewed and approved, at a minimum, by the USDOT COR responsible for the contract or agreement. In most cases, these documents were also reviewed by many of the USDOT staff managing a contract or agreement in support of the Safety Pilot Program. It was important for the USDOT staff to be aware of the results from other related projects to ensure there would be no inadvertent impacts on other components of the Model Deployment. For example, results from the Integrated Light Vehicle Developer GPS antenna performance tests were important for the Test Conductor to use in their VAD and ASD installation plan development. As another example, the Security Credential Management System documentation was important to all device suppliers as well as the Test Conductor since each organization had to implementation software based on the requirements outlined in that documentation. As such, it was important that these results and documents were shared with the appropriate entities in an expedient manner.

There were two major challenges to this process for the USDOT staff supporting the Safety Pilot Program. First, the sheer volume of material that needed to be reviewed and approved for release was substantial. It was very resource intensive for the staff to review the materials generated across all the contracts and agreements and share them with their contractors as appropriate. Second, the process and structure for archiving and managing these documents in an overall program repository was not very user-friendly. Therefore, Federal staff had to spend additional time and effort managing the documentation generated in Safety Pilot, which at the end of the project exceeded over 1GB of reports, presentations, and other materials.

Recommendations

- Develop an accessible, easy-to-use and complete document repository that USDOT staff can use to support the management of the program. Processes for effectively managing document version control should be implemented. Include resources to ensure the repository is maintained throughout the project and can be used for future use or analysis.
- Utilize technical project briefings and coordination meetings to share information across contracts and agreements with the technical staff involved in the project in a consolidated format.
- Develop a matrix to assign reviews of specific topics to specific program managers so that the results and information can be filtered and distributed to the appropriate staff. This will help to prevent everyone having to review every document produced by a project.

Chapter 2 Outreach and Showcase

This chapter describes the approach to outreach and engagement of internal and external stakeholders throughout the Safety Pilot Model Deployment (SPMD). A key goal of the outreach effort was to create public awareness and acceptance of the Safety Pilot Program, including awareness of the NHTSA 2013 decision on V2V technology for light vehicles. This included a focused initiative to educate industry on the Safety Pilot Program, particularly as it related to the ability to experience and use the model deployment site in Ann Arbor.

The Safety Pilot outreach and showcase activities were conducted as a team effort between the USDOT and the Test Conductor team. The Test Conductor's role within the SPMD Outreach and Showcase task was focused on the local and state media as well as community outreach. Within USDOT, media oversight was divided between RITA[16] for trade press and NHTSA which covered all other aspects of the media outreach, including consumer press. The USDOT also focused on policymaker outreach. The plan was to have a coordinated outreach effort that extended throughout the entire project, starting with the 2011 ITS World Congress in Orlando, followed by the Safety Pilot launch event in August 2012, then following with other activities such as the technology showcase in Ann Arbor, participation in various national and international conferences, and various promotional activities that branded the Safety Pilot Model Deployment.

Outreach and showcase efforts are described in the sections as noted below.

- **Section 2.1 Developing One Message** outlines the approach for providing a consistent message regarding the promotion of Safety Pilot. It discusses the importance of establishing roles, responsibilities, and processes for handling media requests, as well as establishing guidelines for potentially sensitive information.
- **Section 2.2 Conducting Outreach and Engaging Stakeholders** describes the importance of developing an outreach plan and highlights components of a successful effort. Several cautions such as resource constraints and sustaining a media presence through the project are discussed.
- **Section 2.3 Showcasing the Environment** summarizes the various showcase activities carried out by the Test Conductor, including development of showcase facilities at the University of Michigan and conducting demonstrations of connected vehicle applications in real-world conditions.

[16] The United States Department of Transportation's Research and Innovative Technology Administration (RITA) was transitioned into the USDOT's Office of the Assistant Secretary for Research and Technology (OST-R) by President Obama through the Omnibus Bill in January 2014

2.1 Developing One Message

The Safety Pilot Model Deployment was a high profile project that involved a large number of contractors responsible for various components of the program. As such, there were many requests for information from a variety of sources, particularly from the media and external stakeholders. While it was anticipated that there would be requests for information regarding the project, the processes for handling media requests and inquiries were not clearly defined at the outset of the project. There was also no designated point of contact, at the USDOT or the Test Conductor, responsible for collecting and responding to these ad hoc requests. It quickly became clear the importance of establishing the roles and responsibilities for media communications between the USDOT and the Test Conductor.

To consistently provide a unified message and concise information about Safety Pilot, an agreement was established between the USDOT and the Test Conductor. The agreement provided the following:

- Designated points of contact at the USDOT and the Test Conductor to serve as media liaisons;
- Identification of team members authorized to speak to the media;
- A process for tracking media requests and documenting media communications across organizations;
- Assignment of organizational responsibilities for various segments of the media (i.e. national, state, local, trade, etc.);
- Identification of sensitive policy and program topics that should be deferred to USDOT leadership (i.e. policy, national deployment, privacy, etc.);
- A consistent message regarding the promotion of the Safety Pilot; and
- An emergency response plan in the event of a major incident (e.g. crash, theft, security breach, etc.).

It should be noted that there was no language in the agreement prohibiting the Model Deployment participants from interacting with the media. Several participants who were assigned integrated light vehicles did give interviews to the local news media about their experiences driving the connected vehicle; however, this did not prove to be an issue during the Model Deployment or negatively impact the program.

In keeping with the “one message” concept, the USDOT also developed fact sheets in plain language and worked with the Test Conductor to develop publically visible branding elements, for example, the Safety Pilot graphics and content for the website. Communications are typically most effective when accompanied by a “branding” effort to create a unique, recognizable and positive identity for the program. At its most basic level, this may consist of creating a distinctive program name, logo, and tagline. Embedded in the brand identity and carried through the program’s messaging should be the objectives of the program and the benefits it can deliver. The Test Conductor successfully incorporated all of these elements into their materials.

The Test Conductor and USDOT also held monthly outreach coordination meetings where all outreach activities were coordinated across the organizations. This may have been one of the most challenging aspects of maintaining a consistent message, as it was sometimes difficult to reach consensus on approach, objectives, and perspectives with so many modal agencies involved. Ultimately the outreach effort ended up requiring more resources than originally anticipated. It may have been useful to have a full-time public relations firm dedicated to promoting Safety Pilot, allowing the Test Conductor to focus on the more technical aspects of the project. For a deployment effort of this size, it is not unreasonable to expect needing at a minimum, a graphics person and creative manager to support the project.

Recommendations

- Contractually stipulate level of effort and focus of outreach. Determine what role and responsibilities the USDOT and contractors will have when working with the media and incorporate appropriate language into the contracting agreements. Ensure that the balance between outreach to industry, local media, and national media is understood, and that each participant's responsibilities and limitations are well understood by all participants.
- Develop a key message that is agreed upon by all parties at onset of project and establish clear guidelines on what information can be shared with various stakeholders and the public. Identify sensitive policy and program topics in advance.
- Develop a full complement of materials in advance of the pilot launch, such as talking points, project presentations, FAQs, press kits, and fact sheets. This will help to establish and maintain one consistent message.
- Define a process for handling, tracking, and documenting media requests. Ensure that it is agreed upon by all team members. Designate points of contact to serve as media liaisons.
- Consider hiring a public relations agency to work directly with the USDOT under its own contractual vehicle to dedicate efforts towards proactive involvement, such as monitoring media coverage, developing responses to media inquiries, anticipating media needs, and developing creative content with sensitive information.
- Provide guidance to study participants regarding their interactions with the media, particularly if communications regarding the program are sensitive.

2.2 Conducting Outreach and Engaging Stakeholders

The Test Conductor was tasked with developing and implementing an Outreach Plan, intended to disseminate results of the program and acquire stakeholder feedback. The plan outlined an approach for engaging stakeholders and reaching the general public through the development of various promotional materials and participation in numerous conferences and events. To start, four key audiences were identified:

- **Local Community:** Residents, businesses, schools and universities within the Ann Arbor Area.
- **Industry:** Transportation professionals, the auto industry, commercial vehicle operators, public transportation operators, transportation safety advocates, Intelligent Transportation System (ITS) professionals, and the organizations that represent these industry segments.
- **Media:** Local and national media including print, electronic, social and television media.
- **Policymakers:** Elected officials at the federal, state and local levels.

The plan identified target groups, the key messages to be conveyed to each group, and the types of media used to communicate these messages to each of the four key audiences. For the majority of audiences, the messages consisted primarily of program vision and facts, potential benefits, program updates, and FAQs. The Test Conductor utilized several types of media to convey these messages, including a website, technical presentations, technical meetings and conferences, exhibitions, brochures, fact sheets, and newspaper and magazine articles. One major component of outreach that was only used in very limited instances throughout the program was social media. This was due to concerns about participant bias and control of information. The USDOT and the Test Conductor did not want to impact or bias the subjects and experiment since it was tied to a potential regulatory action.

Much of the outreach effort for Safety Pilot was targeted toward the transportation industry and related industry groups. The outreach plan contained opportunities for outreach activities at various industry conferences and events around the world, including the 2011 ITS World Congress, the 2012 SAE World Congress, and the 2013 and 2014 Connected Vehicle Global Symposium. These events typically included demonstration rides, interactive displays to view animated scenarios of V2V applications, product showcases from equipment providers, and printed literature. It is estimated that thousands of people visited the exhibit areas at these events. Attendees often included members of the U.S. Congress, congressional staff, and other key figures from government and industry.

A key outreach activity was the highly successful launch event, signifying the start of the Safety Pilot Model Deployment on August 21, 2012. This high-profile, premiere event was hosted in Ann Arbor, MI and included leaders from various industry segments, there to witness the unveiling of the technology and the program. Guests included the USDOT Secretary of Transportation, the Governor of Michigan, and many other industry representatives. The successful launch drew national recognition for Safety Pilot and included real-time coverage by major media outlets such as the Today Show and CNBC. All major wires and papers were present. The launch was a stellar success for numerous reasons including careful preparation and invitation of key political figures; development of a compelling story; close collaboration between the USDOT, Team Conductor team, and OEMs; and most importantly allowing the media to participate in an interactive demonstration of V2V technologies.

The outreach and showcase efforts were an important part of the project and were considered a great success. As a result, the Safety Pilot project was recognized both nationally and internationally. One limitation of the outreach effort was that only nominal measures of performance were gathered to gauge the impacts of particular outreach strategies, for example, the number of website hits. More detailed information, such as the number of individuals by category, e.g., industry, media, policymaker, that were reached and some measures of change in their understanding, perception or opinion were not collected. This made it difficult to assess the impacts of the various outreach activities being conducted. In future pilots, particularly in cases where resources are constrained, evaluation tools could be implemented to determine what types of media are most effective for reaching the target audience. There was also some concern by USDOT that stakeholder outreach was not diverse enough, particularly in the case of the trucking industry, and that limiting outreach to presentations and conference participation may have been too passive for this particular audience.

There were also challenges with maintaining a sustained media presence. After having such a successful launch event in August 2012, it was difficult to find a new captivating press event, despite what were first bi-weekly and then monthly meetings to coordinate new ideas for outreach. This was somewhat due to USDOT's conservative approach to information sharing and their reluctance to having mainstream media attention unless there was something new to report. As a result, media outreach was somewhat limited after the initial launch/release. The downside was that even though there may not have been new messages to share, there were potentially important audiences that were not aware of the key message if they missed the initial outreach push.

Recommendations

- Ensure that all key stakeholders are actively addressed in outreach activities. Develop a focused outreach plan that identifies all stakeholders, the message appropriate for each stakeholder and the method in which you will reach the stakeholders. Review the plan with the project team and obtain buy-in on the levels of outreach needed for each stakeholder. Periodically review the plan to ensure that the types and levels of outreach selected for each stakeholder are appropriate.
- Include a well-organized, high-profile launch event, and dedicate sufficient resources to this effort. Be prepared to maintain momentum throughout the project by establishing a plan to use a variety of tools to support the interests and needs of various stakeholders and audiences. After the prominent launch event, be sure to follow-up with other high visibility elements, to increase recognition of ongoing activities.
- Implement performance measures to gage the impacts of particular outreach strategies. In cases where resources are constrained, evaluation tools could determine what types of media are most effective for reaching the target audience.

2.3 Showcasing the Environment

In addition to the Outreach Plan, the Test Conductor was also tasked with preparing a Showcase Plan. The showcase effort was used to expose stakeholders and decision makers to the Model Deployment site. The Test Conductor created a facility intended to immerse users in the Safety Pilot experience by demonstrating firsthand the connected vehicle technologies. Showcase activities were also used to encourage suppliers and manufacturers to leverage the environment for their own application development and testing.

The Test Conductor utilized the model deployment site in two key ways for showcase activities. First, a technology showcase was developed at the North Campus Research Complex (NCRC) on the campus of the University of Michigan. The NCRC site was promoted as a destination for industry meetings and conferences. The showcase included sample devices and literature and was used to increase visibility and program awareness throughout the duration of the deployment. The Test Conductor also gave tours of the installation facilities where vehicles were equipped with devices and device maintenance was performed.

The second element of showcasing the environment was the demonstrations. For Safety Pilot, technology demonstrations were the critical outreach component, particularly for explaining how the technology and applications would function in a real-world environment. People tend to be more engaged and have a better understanding of complex technologies when they can “see” and experience something firsthand. This is especially useful for non-technical stakeholders and media outreach. The Test Conductor originally planned to incorporate an integrated light vehicle into their outreach plan, however, this proved difficult since the Test Conductor did not have access to the integrated light vehicles for demonstrations, as they were all in use by the participants. There were also no plans for a closed test track area where the demonstration could be conducted. This made it difficult for stakeholders to truly experience the environment early in the Model Deployment. Later in the project the Test Conductor was able to outfit a 15 passenger van with an ASD and driver-vehicle interface (DVI) for use in on-road demonstrations around the environment. This provided demonstrations of the in-vehicle V2V ASD safety applications, the V2I applications, as well as demonstration of how the RSU was integrated at SPaT-enabled intersections.

Recommendations

- For maximum effectiveness, ensure that any showcase is interactive and includes a prominent field demonstration component. These elements should be in place early in the deployment for stakeholders to be able to experience the environment soon after launch. This could include a closed course demonstration or outfitting a vehicle for on-road demonstrations through the environment.
- Develop incentives and events to draw the industry decision makers and leaders to the deployment site to observe the technology in live operations.
- Establish a team dedicated to coordinating and conducting tours and demonstrations of the test site and facilities. Institute a liaison between the technical team and the outreach team to better support group visits and demonstrations.

Chapter 3 Experiment Setup

This chapter discusses setting up the experiment, including selection of the test area and coordinating, preparing, and managing the vehicle fleets and drivers as part of the Safety Pilot Model Deployment. These elements were key components of the Experimental Plan, which was developed by the Test Conductor in conjunction with the Independent Evaluator. The Experimental Plan also included the Test Conductor's plans for collecting all data and ensuring data quality as required by the Independent Evaluator to perform its independent evaluation in support of the 2013 NHTSA agency decision. Further discussions about data within the SPMD can be found in Chapter 6.

The following sections are included in the chapter:

- **Section 3.1 Developing Initial Size Analysis** outlines the analysis used to initially size the experiment, in terms of duration, number of test subjects, and number of equipped vehicles required. This information established the minimum requirements included in the Request for Proposal (RFP).
- **Section 3.2 Selecting the Geographic Area** describes the approach to defining the geographic area of the Model Deployment, including factors such as traffic patterns and traffic volumes, and crash data used to identify roadways that could potentially produce a sufficient number of interactions and conflict situations between equipped vehicles. It also discusses identifying intersections and roadways to support installation of various infrastructure components for data collection and testing exercises.
- **Section 3.3 Estimating Number of V2V Interactions** explains how a traffic simulation model was used to validate that the selected site would produce the amount of data needed for evaluation. It also highlights the importance of 1) developing performance targets for measuring progress towards project goals and 2) risk response plans in the case that targets are not met throughout the project.
- **Section 3.4 Requirements for Light Vehicle Drivers** provides a summary of minimum requirements that needed to be met in order to qualify to drive an integrated vehicle or to have a device installed in a personal vehicle as part of the SPMD.
- **Section 3.5 Recruiting and Selecting Light Vehicle Drivers** outlines the recruitment approach for obtaining and selecting over 2,500 volunteer drivers for VADs, ASDs, and ILVs. It describes the change in approach between Phase 1 and Phase 2 for selecting the ILV drivers, in an effort to increase interactions with other V2V equipped vehicles.
- **Section 3.6 Selecting Heavy Vehicle Fleets** discusses the importance of coordinating the site selection with development of specifications for heavy vehicles and commercial fleets.
- **Section 3.7 Managing Transit Vehicle Drivers** highlights the challenges encountered with incorporating transit vehicles into the pilot site. This includes operations of a transit agency and taking into account driver schedules, routes, designated bus stops, and driver training.

3.1 Developing Initial Size Analysis

Prior to developing the statement of work for the SPMD Test Conductor, the USDOT needed to determine what size test was necessary to generate sufficient data for the evaluation of the V2V safety applications. The test size depended on numerous parameters, including the number test participants, number of V2V-equipped vehicles, and the test duration. All could have major impacts on the Test Conductor scope of work and budget required. Therefore it was critical to get an accurate size estimate prior to starting the experiment.

To determine the test parameters, the Independent Evaluator (IE) conducted an analysis in 2010, approximately 2 ½ years prior to the launch of the SPMD, to estimate the following variables:

- Duration of the test;
- Number of integrated light vehicles equipped with V2V Safety Applications, defined as a vehicle that issues warnings and alerts to the driver;
- Number of test subjects, defined as the number of drivers of the light vehicles equipped with V2V Safety Applications; and
- Number of vehicles equipped with V2V technology, defined as the number of vehicles capable of broadcasting a BSM.

The analysis utilized prior field test results as well as statistical analysis methods to estimate the test size. For example, estimates of the number of participants necessary in the SPMD were derived from results from the Automotive Collision Avoidance Systems (ACAS) Program[17]. The Integrated Vehicle-Based Safety Systems (IVBSS)[18] program provided data on the number of forward collision warnings per 1,000 miles driven. Using the IVBSS results, the IE was able to estimate the different durations of the test needed for participants to experience 2, 3, or 4 warnings.

The IE recommended that each participant in the SPMD experience 3 warnings over the duration of the test. Subsequently, the parameters of the SPMD were developed using this as a benchmark. The results of the analysis are shown as recommended values in Table 6 below. The recommended values were used as a basis for the minimum requirements included in the SOW. The values in the actual column represent the true values used in the SPMD.

Table 6: Recommended Values from Test Area Size Analysis

Variable	Recommended	Actual
Duration	5 months	6 months
Integrated Light Vehicles (equipped with V2V Safety Applications)	55	64

[18] http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811516.pdf

Test Subjects	108	128
Vehicles Equipped with V2V Technology	2,500 – 3,000	2,836

Source: USDOT

Note that the recommended number of Test Subjects (108) was nearly double the recommended number of Integrated Light Vehicles equipped with V2V safety applications (55). This is because the SPMD was divided into two phases, defined by two sets of naïve drivers selected to drive the integrated light vehicles. The analysis recommended 55 Integrated Light Vehicles – this included 54 vehicles per design, plus one spare vehicle. Having 54 vehicles with 2 test subjects per vehicle totals 108 Test Subjects. However, the actual number of Integrated Light Vehicles used was 64. This exceeded the required 55 vehicles, and therefore, spare vehicles were not required since they were essentially built into the design. Having 64 Integrated Light Vehicles with 2 test subjects per vehicle required 128 test subjects.

The actual values in the SPMD resulted in the successful collection of the necessary data for the independent evaluation. More information on the processes used to define, collect and analyze the data from the Safety Pilot Model Deployment can be found in Chapter 6.

Recommendations

- Conduct an analysis using prior field test data to properly scope the size of a new test to meet the data collection and evaluation objectives. Do this early in the planning process as test size can have major impacts on scope and budget, and can be difficult to modify once the experiment has started.
- After establishing the minimum values required to meet established data collection and evaluation objectives, consider adding more vehicles or devices to act as 'spares' to ensure that the minimum number of devices required will be operational during the entire test.

3.2 Selecting the Geographic Area

The USDOT did not define specific requirements for the Model Deployment Geographic Area (MDGA), for example, there were no prescriptive requirements for area size or population density. Instead, USDOT requested that a Model Deployment Site Plan be submitted along with the technical approach in response to the RFP. The Site Plan was required to address the following primary criteria for the test area.

First, the selected area was required to produce a sufficient number of interactions between equipped vehicles to:

- Demonstrate V2V safety applications in a real-world environment using multiple vehicle types; and
- Support estimating the safety effectiveness and benefits of V2V communication.

Second, the test area needed to support the installation of various infrastructure components, including roadside units and various types of signal controllers, in order to:

- Collect and store data V2V data;
- Test the transmission of Signal Phase and Timing (SPaT) and geometric intersection description (GID) messages in V2I safety applications; and
- Test the security credential management system.

To select the geographic area for the Model Deployment, the Test Conductor evaluated traffic patterns, traffic volumes, and crash data to identify specific roadways that could potentially produce a sufficient number of interactions and conflict situations between equipped vehicles. Another key factor was identifying intersections and roadways that could support the installation of various infrastructure components for data collection and testing exercises. Details of the criteria used by the Test Conductor are included below.

Traffic Patterns and Traffic Volumes

- **Annual average daily traffic (AADT) values were used to determine how busy the roads were in the area.** AADTs for major roadway segments and corridors were tabulated by direction and time of day. The busiest sections of the test area contained several intersections with AADTs in excess of 30,000 vehicles.
- **High volume origins and destinations were identified.** Sites included health care centers, hospitals, primary and secondary schools, institutions of higher education, and major employers. Residential areas outside of Ann Arbor were also identified. It was assumed that roadways carrying traffic to and from these destinations would result in high numbers of interactions if participants were selected from these locations.

Crash Data

- **Crash data was identified for the roadway segments in the identified test area.** Data was organized by crash type and crash location, for example the number of crashes occurring at intersections or curves. It was important to match the crash types with the V2V and V2I applications being evaluated to ensure that sufficient numbers of conflict situations could be generated on those roadway segments. For example, curves with the highest crash rates were identified as potential sites for deploying RSUs for the curve speed warning V2I application.
- **Composite crash rates for the major corridors were calculated and compared with statewide computations for similar road types.** Three of the four corridors identified in the test area met or exceeded statewide crash rates by their respective road type, indicating that these roadways were representative of types of roadways you would find throughout the state and would also potentially generate conflict situations for V2V-equipped vehicles.

Characteristics of Potential Roadside Equipment Sites

- **Signalized intersections were catalogued by traffic signal controller type and signal control system.** A variety of intersections were needed to examine the ability to transmit Signal Phase and Timing (SPaT) data from the RSU using 1) different controller types; and 2) a traffic signal network running traffic adaptive software at a series of intersections.
- **Potential RSU sites were categorized by location characteristics.** Locations with varying site characteristics were identified in in order to investigate various RSU behaviors. Potential sites for RSU installation included co-location with existing ITS, sites with alternate power (solar) and sites with communications alternatives (cellular).

The Test Conductor combined their research on traffic patterns, traffic volumes, crash data, and intersection inventories to identify potential routes. Using this approach, the Test Conductor was able to identify roadways that carried a mix of commercial vehicle, transit, and passenger vehicle traffic with high traffic volumes to maximize interactions between vehicles, while also supporting the installation of various infrastructure components to test functionality and store data. The selected area was located in the northeast corner of the City of Ann Arbor, Michigan, as shown in Figure 1 on the following page. The area encompassed 72 lane miles of roadway and included 3 major, east-west corridors through the east side of Ann Arbor, along with portions of the highways M14 and US23 surrounding the north east corner of the city.

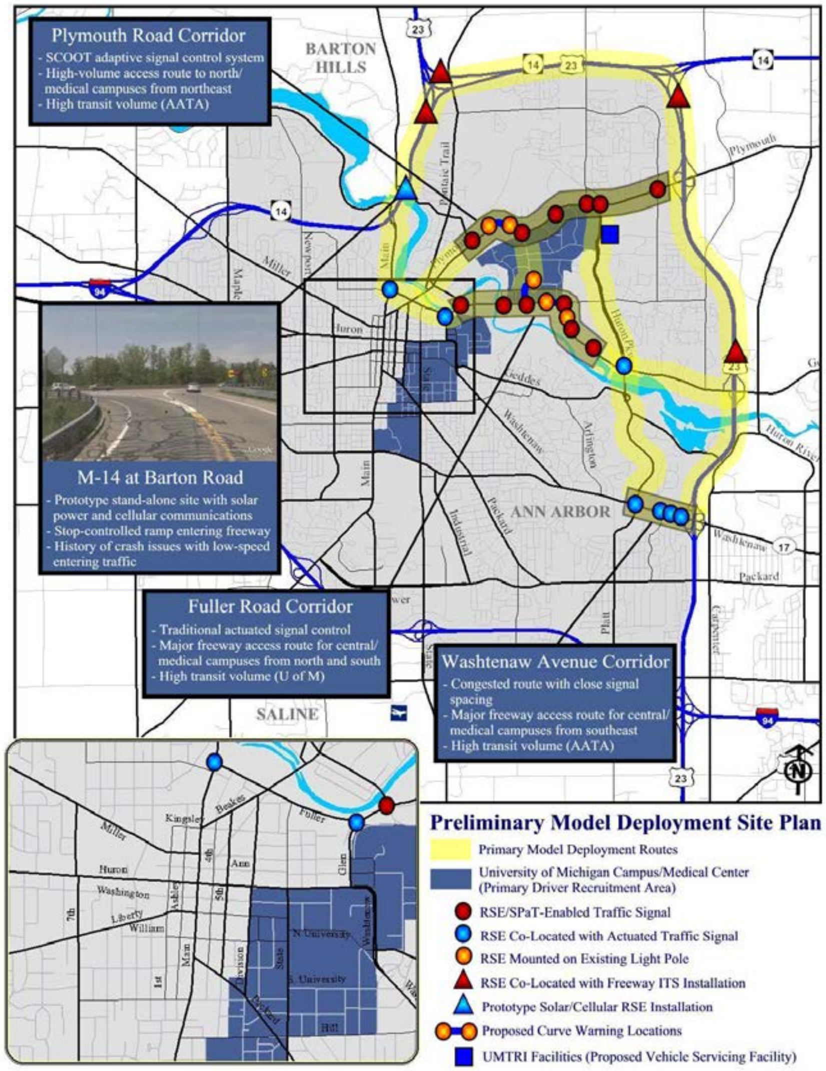
Ultimately, the site and roadways selected using this approach worked well for generating large numbers of V2V interactions. However, selecting a geographic test area can be a highly iterative process depending on the goals of the project and established criteria. Another key component in selecting the test area is correlating the area to an effective driver recruitment strategy that identifies participants that drive primarily in the selected area. For example, a high traffic volume roadway may carry people to and from the city, but if local residents were targeted in the recruiting effort instead of commuters, this may not result in as many equipped vehicle interactions as anticipated. More information about participant requirements, recruitment and selection can be found in *Section 3.4 Requirements for Light Vehicle Drivers* and *Section 3.5 Recruiting and Selecting Light Vehicle Drivers*.

Another key component of the iterative process is ensuring that the test site characteristics match the needs of all aspects of the project. For example, as further explained in *Section 3.6 Selecting Heavy Vehicle Fleets*, the specification of heavy vehicles occurred before the selection of the carriers whose fleets/routes would best serve the needs of the SPMD. Certain trucks turned out to be unsuitable for the MDGA and the truck specifications were not suitable for the actual operations of the ideal carriers in the area. Also, as described in *Section 3.7 Managing Transit Vehicle Drivers*, transit vehicle usage was constrained by union restrictions on driver hours and the inability of transit operators to allocate specific vehicles to specific routes. These types of variables should be taken into consideration as part of the geographic area selection process.

Recommendations

- Be prepared to conduct an iterative process to select the test site. Analyze the characteristics of the test area, i.e., historical crash and traffic volume data, against the performance requirements of the test. Ensure that the test site characteristics match the needs of all aspects of the pilot, particularly if involving commercial vehicles or transit. These vehicle types may be constrained by geographic area, operations and scheduling, or commercial and union restrictions.
- Closely coordinate the test area selection process with the driver recruitment strategy to ensure that selected participants will be driving primarily in the test area. This approach is likely to produce better results when examining interactions between equipped vehicles and interactions between equipped vehicles and infrastructure.

Figure 1: Planned Model Deployment Geographic Area[19]



Source: UMTRI

3.3 Estimating Number of V2V Interactions

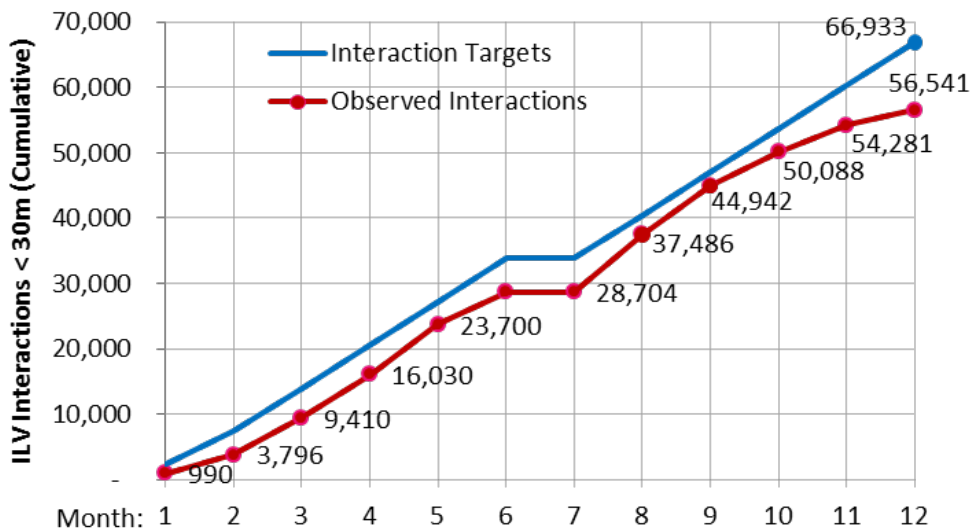
Following the initial sizing analysis and selection of the MDGA, it was critical to ensure to the greatest degree possible that the selected site would be able to generate a sufficient amount of data for evaluation. The USDOT conducted a detailed analysis to more accurately predict the number of interactions between equipped vehicles that could occur on the selected routes within the selected Model Deployment area. A regional traffic microsimulation model was developed by the Volpe

[19] Two RSUs depicted on this figure were planned but not actually installed due to network connectivity issues.

National Transportation Systems Center to estimate the number of instances where an integrated vehicle would interact with a V2V equipped vehicle under various recruitment approaches. The model used as input some 1.4 million daily trips from a representative day, including trip-taking behaviors, traffic volumes, and the location of various origins and destinations within the geographic test area.

The USDOT also developed monthly estimates of V2V interactions, or “interaction targets”, for data collection monitoring purposes. The interaction targets were used as a baseline of the number of monthly interactions needed to ensure that sufficient data was collected for evaluation purposes over the 12 month period of the Model Deployment. During SPMD, the in-vehicle data acquisition systems recorded the actual number of interactions, or “observed interactions” that occurred during each month of the Model Deployment. Figure 2 below shows monthly comparisons of predicted ‘Interaction Targets’, as generated by the model, with the actual ‘Observed Interactions’, as recorded during the Model Deployment.

Figure 2: Actual (Observed) vs. Estimated (Targets) Number of V2V Interactions



Source: USDOT

Throughout the SPMD, the observed interactions were lower than the interaction targets. Two reasons were cited for this deviation. First, the actual deployment rate of V2V-equipped vehicles did not occur as planned. The model assumed 100% deployment of the V2V-equipped vehicles on day one. However, the Test Conductor planned to deploy 33% of the VADs per month for the first three months. The ramp-up period also ended up being 4 months (to reach 95% of V2V-equipped vehicles deployed) instead of 3. Second, the interactions dropped off significantly during the last 3 months of SPMD. It was assumed that this was a result of the summer break for the Ann Arbor schools, as they were the primary source of drivers recruited (see *Section 3.5 Recruiting and Selecting Light Vehicle Drivers*).

Without the impact of either of these factors, the V2V interactions observed in SPMD would likely have exceeded the interaction targets. Overall, the traffic simulation model validated that the selected site would produce the amount of data needed for the evaluation and proved to be a reliable method for estimating the number of V2V interactions. It is important to note that although the USDOT was confident in their model, there was no sure way of knowing at the start of SPMD that the actual data collected would match the model's estimated targets. USDOT took a proactive approach, and cooperatively with the Test Conductor, developed various risk response plans aimed at increasing the volume of data generated in the event that the observed interactions were significantly below the targets.

During the Model Deployment, there were two instances where the risk response plans were initiated as a result of lower than expected volumes of interactions. First, due to a delay in the VAD deployment as discussed above, the interactions at the start of Model Deployment were less than projected. The USDOT authorized the Test Conductor to utilize staff to drive VAD equipped vehicles throughout the Model Deployment area to increase potential exposure of integrated vehicles to the VAD equipped vehicles. Second, several months into the test, the 3 integrated heavy vehicles were not generating as many interactions as were needed for evaluation purposes. This was due to the vehicles not being driven within the SPMD area as often as anticipated, as discussed in *Section 3.6 Selecting Heavy Vehicle Fleets*. As a result, the USDOT authorized the Test Conductor to utilize existing staff members with valid commercial driver's licenses (CDLs) to drive the vehicles within the Model Deployment Geographic Area on predefined routes to generate more data.

Recommendations

- Follow-up the size and scoping analysis used to select the initial test area with a more detailed traffic simulation analysis of the selected site. Use the traffic simulation analysis to develop estimates of the volume of data that will be generated. This will help confirm prior to the start of the experiment that the selected site will provide sufficient data to meet the project objectives.
- Develop quantitative performance measures with intermediate targets for the environment that can be utilized throughout the test to evaluate progress and success towards project goals.
- Develop risk response plans in the case that intermediate performance targets are not being met. Determine trigger points to determine when each response plan should be executed.

3.4 Requirements for Light Vehicle Drivers

The Test Conductor was required to recruit a minimum of 2,500 volunteer drivers. This pool was used to support the deployment of personal vehicles equipped with Vehicle Awareness Devices and Aftermarket Safety Devices. The 128 drivers of the 64 Integrated Light Vehicles were also selected from this pool.

The following minimum requirements were included in the Statement of Work. All participants driving light vehicles must:

1. Have a current, valid driver's license;
2. Drive an average daily mileage that meets or exceeds the average daily vehicle miles traveled (32 miles / day), as reported in the latest National Household Travel Survey[20]; and

[20] The February 9, 2011version of the survey was used, available here: http://nhts.ornl.gov/2001/pub/STT.pdf

3. Drive mostly in the Model Deployment Geographic Area.

These requirements were intended to identify drivers most likely to generate a large number of interactions with other V2V equipped vehicles. An additional requirement for the 128 integrated light vehicle drivers was that the selected pool of volunteers be split evenly by gender and three age groups: younger (under 30 years of age), middle-age (between 40 and 50 years of age), and older (over 60 years of age).

The Test Conductor initially identified two concerns with the average daily mileage requirement (2nd requirement listed above):

1. Requiring all participants to drive a minimum amount of miles per day could potentially eliminate some participants who drive a large number of short trips within the MDGA. For example, a participant who drives 25 miles per day all within the MDGA would not be eligible to volunteer because they did not meet the minimum of 32. However, this participant would potentially generate more V2V interactions than a participant who drives 32 miles per day during their daily commute, where maybe with only half of those miles would be driven in the MDGA. One of the challenges was defining and measuring “drive mostly” in the MDGA (3rd requirement listed above).

2. For the integrated light vehicles, identifying participants in all age and gender categories to meet the average daily vehicle miles traveled requirement may not be feasible. For example, 60 year old females typically have low numbers of miles driven and likely would not have met the minimum of 32 miles per day.

As a result, the Test Conductor requested the ‘average daily vehicle miles traveled’ requirement be removed from the contract to allow recruitment of participants based on their miles driven in the MDGA with no minimum total miles driven. USDOT granted this request, which allowed the Test Conductor to focus less on the total number of miles driven and more on the area where most of the driving was taking place.

Recommendations

- When identifying volunteer drivers, utilize metrics that focus on the volume of trips or time spent within the test area boundaries. Using metrics that focus exclusively on the total number of miles driven may not always be representative of the amount of time a driver spends within the test area. It may also be difficult to identify particular drivers within certain age or gender groups if there is a minimum miles driven requirement.

3.5 Recruiting and Selecting Light Vehicle Drivers

To meet the 2,500 recruitment requirement, the Test Conductor initially proposed recruiting the majority of drivers from the University of Michigan (UM) Hospital. The hospital employs over 20,000 workers that drive into Ann Arbor daily, which seemed adequate for obtaining the 2,500 needed volunteers. To assist with the recruitment effort, the Statement of Work allowed eligible drivers to receive $100 in compensation if selected to participate, with a maximum of 3,000 drivers being eligible for federal funds. The Test Conductor was permitted to recruit more than 3,000 volunteers, but recruitment above the 3,000 maximum would not be subsidized by the USDOT.

Using this approach, the Test Conductor's initial driver recruitment effort to obtain a minimum of 2,500 volunteers lagged somewhat below expectations. While the pool of potential volunteers from the UM Hospital was large, there seemed to be minimal interest from employees in participating in SPMD. This may have been partly due to the participation incentive offered. The initial compensation amount of $100 may not have been sufficient enough to attract volunteers in this part of Michigan, which has a higher average annual income than the rest of the state. Subsequently, the Test Conductor requested USDOT approval to make two changes in the recruitment approach:

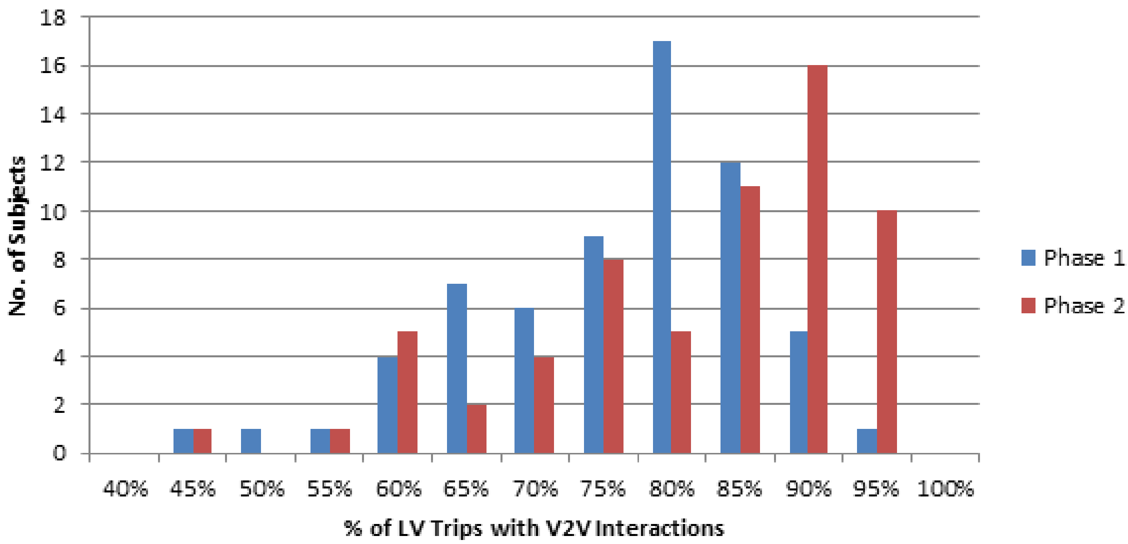
1. Increase compensation for each driver to $200
2. Refocus recruitment efforts on residents of the city of Ann Arbor, instead of primarily targeting University of Michigan Hospital employees

Within the Ann Arbor community, the Test Conductor specifically targeted the local school systems and their associated parent-teacher –student organizations (PTSO) for recruitment efforts. A program was established where each participant could donate their compensation to a local school of their choice in Ann Arbor. Overall, this revised approach of increasing compensation and recruiting through the PTSOs was very successful and generated a pool of over 4,000 volunteers by the launch of Model Deployment. There are two likely reasons for why this recruitment strategy resulted in a higher number of volunteers. First, the Test Conductor was able to conduct more in-person outreach on the Safety Pilot Program through the schools. The Test Conductor attended PTSO meetings to describe the Program and answer any questions from potential volunteers. The outreach for the initial recruitment through the UM Hospital consisted of an email sent by Human Resources, which is likely to get less attention than an in-person meeting. Second, providing participants the opportunity to donate their compensation was an enticing incentive for the community. Parents realized the significant amount of additional funding for school activities that participating in the SPMD provided. For example, 100 people donating $200 would net $20,000 in additional funding for their selected school.

As part of the recruitment and volunteer process, potential participants were required to complete a Web-based form which asked for name, address, vehicle characteristics, and the number of trips traveled per week on each of the major roads in the Model Deployment (e.g. Plymouth, Washtenaw, US-23, M-14, etc). Although the participant selection process varied for each device type, the self-reported trip data was used to prioritize drivers according to their volume of driving within the geographic area. The positive aspect of having an excess of 4,000 initial volunteers allowed UMTRI to be more selective and choose participants that reported the largest amount of driving time in the Model Deployment Geographic Area. However, there was a downside to recruiting this large of a pool of volunteers at one time. The installations for VADs extended over four months and by the time that some volunteers were contacted for participation, they were no longer interested in participating for a variety of reasons.

The Test Conductor first selected drivers for the ILVs, followed by ASDs with DAS, ASD-only, and finally VADs from the potential pool of participants. As discussed in *Section 3.1 Developing Initial Size Analysis*, two sets of naïve drivers - totaling 128 participants - were selected to drive the ILVs. For Phase 1 ILV drivers, the drivers were selected by matching potential participants with the highest number of self-reported trips, with the demographic requirements described in *Section 3.4 Recruiting and Selecting Light Vehicle Drivers*. The goal was to identify drivers with the largest number of trips per week within each demographic category in order to generate a maximum number of interactions with other equipped vehicles. For Phase 2, the Test Conductor decided to implement an alternative approach to selecting ILV drivers. Phase 2 ILV drivers were selected from the pool of existing participants driving VAD-equipped vehicles in Phase 1. For SPMD, each VAD-equipped vehicle was logging the BSMs transmitted by the device. The Test Conductor analyzed the BSMs to identify which drivers were spending the most time in the Model Deployment geographic area. The results of the analysis were used to select drivers that would be eligible to swap out their VAD and drive an integrated light vehicle for Phase 2. Figure 3 provides a comparison of the percentage of trips where the integrated light vehicles interacted with another V2V equipped vehicle for Phase 1 and Phase 2.

Figure 3: Percentage of LV Trips with V2V Interactions



Source: USDOT

As shown above, the majority of drivers of the light vehicles in both Phase 1 and Phase 2 had an interaction with another V2V-equipped vehicle in over 80% of their trips. However, the drivers in Phase 2 had more trips with a V2V interaction on average than drivers in Phase 1. This indicates that the actual trip data from the BSMs logged was a better predictor of V2V interactions than self-reported trip data from the participants. Therefore, utilizing actual driving data was an effective strategy for ensuring integrated light vehicle drivers would interact with V2V equipped vehicles on a large percentage of trips.

Recommendations

- Replicate the community-based driver recruitment strategy used in the SPMD. Understand what motivational factors are important to the community (e.g., education, jobs, safety) and incorporate these factors in the recruitment process. Utilize in-person recruitment activities whenever possible.
- Recruit participants iteratively to align with the planned device deployment schedule. This will reduce significant delays between recruitment and initial contact. Lags between recruitment and participation could cause participants to reconsider their willingness to participate for a variety of reasons or volunteers could move away from the test area making them non-viable candidates.

- When selecting and prioritizing volunteer drivers from the recruitment pool, utilize actual driving data (i.e. GPS, surveys) over self-reported driving data, if possible. SPMD demonstrated that there was a significant advantage to using the BSM data logged from VADs to identify participants for future phases.

3.6 Selecting Heavy Vehicle Fleets

As part of the SPMD contract, the Test Conductor was required to identify two heavy vehicle fleet operators to participate in the Model Deployment. Both fleets were asked to identify eight (8) of their tractors that were in operation in the Model Deployment area. The Test Conductor was responsible for installing the retrofit safety devices and data acquisitions in the sixteen selected vehicles. The USDOT also provided the Test Conductor with 3 integrated heavy vehicles, i.e., tractors, equipped with integrated V2V and V2I safety systems. The vehicles were purchased by the USDOT prior to SPMD for use in the test, and included 2 sleeper trucks and 1 non-sleeper truck. These vehicle types were chosen because they were representative of the majority of the types of heavy vehicles in use by carriers nationally in 2012. As a part of their contract, the Test Conductor was required to place these three vehicles with a fleet(s) in Ann Arbor for use in the Model Deployment Geographic Area (MDGA).

Since the specification of the trucks occurred before the selection of the MDGA, the trucks turned out to be unsuitable for the area. The placement of the two sleeper trucks with a fleet in the Ann Arbor area was a major challenge. This vehicle type is typically not used in cities due to their size, long wheel base, and lack of back glass, all of which limit maneuverability in small urban environments. This made the vehicles undesirable to many of the delivery fleets that were operating within the SPMD area. The Test Conductor spent considerable time cold calling trucking firms; and while there was interest to participate, the truck specifications were not suitable for the actual operations of the carriers. The two sleeper vehicles were eventually assigned to a long haul fleet that would travel in and out of Ann Arbor as part of larger interstate trips. The placement of the non-sleeper truck faced a similar challenge due to its longer wheel base, which again limited the maneuverability in and around the streets of Ann Arbor. This vehicle was placed with a fleet that operated on the boundaries of the MDGA along Plymouth Road.

While the non-sleeper truck collected more data than the two sleeper trucks, none of the three vehicles reached the volume of V2V interactions that were initially anticipated. As a result of the limited amount of data collected by the two sleeper vehicles, the Test Conductor requested their return from the host fleet. After their return, the Test Conductor utilized their own drivers with valid commercial driver's licenses to drive the vehicles within the MDGA on predefined routes. The naturalistic data collected from the 3 integrated and 16 retrofit heavy vehicles was augmented by data collected from controlled track tests as a part of the heavy vehicle driver clinics. This combined set of data provided enough data for the Independent Evaluator to conduct the evaluation and provide results to the USDOT.

Recommendations

- Prior to procurement of specific types of vehicles, it is important to take into account the geographic area where these vehicles will be operated. There may be constraints that impact the types or configuration of the vehicles purchased, particularly in smaller cities.

- When conducting naturalistic testing with heavy vehicles, ensure that contingency plans are in place in the event that an insufficient amount of data is being generated. This is especially important with a small sample size and when the geographic area limits the exposure of the heavy vehicles to other V2V equipped vehicles.

3.7 Managing Transit Vehicle Drivers

In addition to VADs planned for installation on transit vehicles, the SPMD also included the deployment of three (3) transit vehicles equipped with a transit safety retrofit package (TRP) system.[21] The vehicles were part of the University of Michigan's (UM) transit system, which provides transit service for University students and employees to various parts of campus. The Test Conductor selected the vehicles based on their make, model and CAN bus version, and installed the TRP devices. The TRP devices required the J1939[22] protocol; therefore, this was a critical factor in the selection process.

Five safety applications[23] were installed on the TRP devices:

- FCW - Forward Collision Warning (V2V standard application)
- EEBL - Electronic Emergency Brake Light Warning (V2V standard application)
- BSW - Blind Spot Warning (V2V standard application)
- PCW - Pedestrian in Signalized Crosswalk Warning (transit-specific application)
- VTRW - Vehicle Turning Right in Front of Bus Warning (transit-specific application)

There were two challenges with using the UM transit system. The first challenge involved selecting a driving route for the TRP equipped transit vehicles. The transit-specific applications had several requirements that dictated which route could be selected.

- *Crash scenarios in urban environments:* The two transit-specific applications addressed specific crash scenarios with transit vehicles in urban environments. These applications were chosen prior to the selection of Ann Arbor as the test site. Since Ann Arbor is primarily a suburban city with a small downtown area, it was a challenge to find routes which would encounter the potential crash scenarios addressed by these transit-specific applications.

- *Infrastructure installation:* The two transit-specific safety applications both had an infrastructure component that needed to be installed and configured. The Pedestrian in Signalized Crosswalk Warning (PCW) application required the installation of crosswalk motion sensors at the intersection to detect pedestrians. Since the call button status and pedestrian presence in the crosswalk status were packaged in the Signal Phase and Timing (SPaT) message, this also required a RSU/SPaT-enabled intersection. The Vehicle Turning

[21] The TRP system included the following elements: Transit Vehicle On-Board Equipment (OBE); Safety Applications; Crosswalk Motion Sensors; and a Data Acquisition System (DAS). For more information on the TRP System, see the following report: *Transit Safety Retrofit Package (TRP): Leveraging DSRC for Transit Safety – Fielding Results and Lessons Learned* found here: http://www.its.dot.gov/safety/pdf/trp_august2014.pdf

[22] http://standards.sae.org/j1939_201206/

[23] A complete list of the Safety Applications Tested by Vehicle Category and Device Type can be found in the Background section of this report

Right in Front of Bus Warning (VTRW) application required the installation of a customized digital map for the specific locations where the application would function.

The USDOT and the Transit Safety Retrofit Package Developer analyzed existing UM transit routes to identify options that satisfied the crash scenario and infrastructure installation requirements. A route was selected that had high volume pedestrian traffic and bus stops near the end of a block (many of the UM transit routes have mid-block stops), both of which would provide exposure to the specific crash scenarios for the two transit-specific applications. The VTRW application was deployed at 17 bus stop locations on the University of Michigan Commuter North and Commuter South routes. The PCW was deployed at the intersection of Fuller Road and Medical Center Drive, in Ann Arbor, MI, next to the University Medical Center.

The second challenge involved the volume of drivers eligible to drive the three TRP equipped transit vehicles. The University of Michigan utilized a large number of part-time and full-time drivers, increasing the pool of drivers that could potentially be assigned to the vehicles. In addition, drivers were able to bid on specific routes based on their seniority. The route selected for the TRP vehicles was not one of the highly desired routes and as a result, there was a large amount of driver turnover during the one year period.

The large number of potential drivers impacted the project in two ways. First, it increased the amount of training that had to be conducted since each potential driver had to be trained on the applications. Second, an increased number of drivers of the vehicles resulted in less exposure to the applications for each individual driver. With over 60 drivers, it could not be assumed that each of the drivers would be exposed to enough alerts. A driver-specific baseline and treatment approach could not be used due to the lack of data; instead the Independent Evaluator had to use an alert specific analysis in order to evaluate the system.

Recommendations

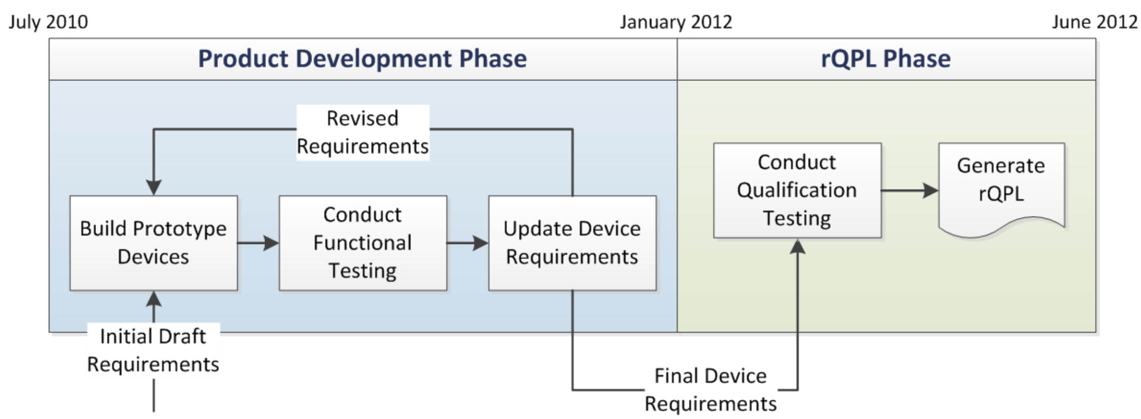
- Deploying transit-specific safety applications requires a careful analysis of the operations of the target transit agency (i.e. routes, bus stops, drivers) to ensure the vehicles will be exposed to the target populations addressed by the safety applications.
- Driver training and exposure to the safety applications are significantly impacted by the transit agency driver characteristics, and they should be planned for in all aspects of the program, especially the evaluation.

Chapter 4   DSRC Device Development

The Safety Pilot Model Deployment (SPMD) required development and deployment of thousands of dedicated short range communications (DSRC) communications devices, including VADs, ASDs, and RSUs. Prior to SPMD, only a small number of DSRC communications devices had been developed for proof of concept and small scale tests. There was little consistency within the device development industry in terms of concept, design, development and testing knowledge for DSRC communications devices. Furthermore, the companies that previously developed these devices were small organizations without extensive experience in developing significant quantities of DSRC communication devices for use in a connected vehicle environment.

As a result of these unique challenges, the USDOT took a lead role in the device development process and implemented a two-phase approach as shown below in Figure 4 .

Figure 4: DSRC Device Development



Source: USDOT

The first phase of the approach, the Product Development Phase, included an iterative process where device developers built prototype devices based on the Initial Draft Requirements. Then the USDOT conducted functional testing and updated the device requirements based on the testing results and developer feedback. This process was repeated multiple times over a 16 month period. The end result was the Final Device Requirements for the SPMD.

The second phase of the approach, the rQPL Phase, included qualification testing of the prototype devices against the final requirements, followed by the creation of a research Qualified Products List (rQPL) for each type of device (ASD, VAD, RSU). The rQPL was utilized by the Test Conductor to select the qualified device developers to supply the SPMD with various types of DSRC devices.

This chapter discusses the approach employed by the USDOT and the Test Conductor to develop DSRC communication devices for the SPMD and includes the following sections:

- **Section 4.1 Engaging the Development Community** outlines how the USDOT used contracting and communication mechanisms to encourage participation by the device developers in the Product Development Phase and mature the industry in an effort to produce sufficient numbers of devices for the Model Deployment.
- **Section 4.2 Developing Device Requirements** describes the process for generating the final device requirements used for qualification testing in the rQPL Phase.
- **Section 4.3 Executing Qualification Testing** outlines the qualification testing process used in the rQPL Phase to determine if a device was compliant with the final requirements.
- **Section 4.4 Generating the Research Qualified Products Lists** describes the collaborative processes utilized by the USDOT and the Test Conductor to generate rQPLs for VADs, ASDs, and RSUs.

4.1 Engaging the Development Community

The USDOT developed and implemented a collaborative process through which the DSRC device development community would eventually be capable of supplying devices for the Safety Pilot Model Deployment. The USDOT identified two key activities in an effort to engage and develop this relatively immature community of developers.

First, the USDOT funded a subset of the research and development costs through a set of procurements that resulted in multiple awards to device developers. The developers were tasked with producing a small number of prototype devices, roughly 2 – 5. These devices were then subjected to functional testing by the USDOT. The USDOT returned the devices to the developers with the test results for refinement and retesting, as described in the process in Figure 4 on page 50. This activity was important for engaging the device development community because the majority of device developers were small organizations, and they did not have the research and development funding to develop these devices without USDOT support. Also the business model for developing some of these devices was not well established as a relatively small number of devices were needed for SPMD, and the profit made from this activity likely would not cover the development costs. These USDOT funded contracts attracted a relatively large number of device developers to the process.

For the second activity, the USDOT encouraged an open exchange of information across the development community through the use of weekly technical coordination meetings, sample functional testing events, plugfests, and other activities aimed at rapidly increasing the developers' experience. The primary purpose of this open exchange was to ensure that the devices produced by the developers were interoperable with each other. This required all developers to interpret and implement the requirements in the same manner (see *Section 4.2 Developing Device Requirements* for more discussion of the requirements). The weekly open meetings shared lessons learned and other vital information across the development community, as well as documentation, e.g., meeting notes, example code, for the community to utilize in their development processes.

Recommendations

- Assess the level of industry knowledge and experience in the development of research devices to determine if industry is capable of producing the number of devices required for the pilot and the timeframe by which these devices will be ready. Consider various procurement or partnering approaches to encourage increased participation by numerous device developers to ensure that an adequate number of devices will be available.
- Determine the most efficient and effective activities, i.e., conference calls, workshops, working meetings, "plug fests", to engage the device community and increase industry knowledge to ensure a common understanding and interoperability of devices, applications, and infrastructure to support project objectives.

4.2 Developing Device Requirements

The USDOT developed the initial version of the device requirements for VADs, ASDs, and RSUs and provided them as input into the Product Development Phase, as illustrated in Figure 4. During the Product Development Phase, the device requirements were iteratively revised based on the results from the functional testing of the prototype devices and on input from the device developer community. At the completion of this iterative process, a final set of the requirements was generated for each of the devices deployed in the SPMD. This final set of requirements was used to qualify devices for the rQPL. The collective set of requirements for each type of device was identified in the published specification document, for example see the VAD Device Specification.[24]

The USDOT sought to mature the requirements to a point that the final set would be able generate devices that would operate throughout the SPMD with only minimal manual intervention from the Test Conductor or device supplier. As it was, the majority of devices deployed in the SPMD were still operational after one year of data collection, however, there were a number of gaps in the device requirements that impacted the Test Conductor's ability to monitor and maintain the devices throughout the Model Deployment. For example, the final requirements lacked test functionality typically needed for less mature or prototype devices, including diagnostic functions, reset capabilities, detailed status messages and status indicator lights. As a result, the Test Conductor had to utilize a variety of manual methods to monitor both the in-vehicle and infrastructure devices deployed in the field to identify device failures. In some cases, when a failed device was discovered, without having reset capabilities the Test Conductor had to physically remove the device and ship it back to the vendor to perform the device reset. This resulted in additional downtime for the affected devices which reduced the volume of data collected and increased the amount of Test Conductor support required. More discussion can be found in *Section 5.8 Monitoring and Recalling Devices*.

The driver vehicle interface (DVI) on the ASDs illustrates another example of gaps in the final requirements. The final ASD specification did not specifically identify requirements for the ASD DVI; therefore, the suppliers had complete flexibility in the implementation of the DVI. The graphical DVI proposed by the device suppliers, i.e., a cell phone connected by a mini-USB cable, was not suitable for a one-year deployment due to theft and maintenance concerns. As such, this required the Test Conductor to perform a significant amount of rework with device suppliers to develop a simple speaker with audible tones rather than a full DVI.

[24] http://www.its.dot.gov/safety_pilot/pdf/Vehicle_Awareness_Device_Specification-r3-5--20111202.pdf

The final requirements for each of the DSRC devices were also completed later in the program schedule than originally planned. This delay was due to a very aggressive initial schedule for the Product Development Phase, as well as the need for additional iterations of building and testing devices which were not anticipated. This delay impacted the schedule for developing the rQPL and procurement of devices.

Recommendations

- Device requirements may need to be tailored on a project by project basis depending on the intended use of the devices and current device maturity level. Clearly communicate requirements to device developers and incorporate the appropriate functionality for less mature devices, such as test capabilities and functions to monitor device up-time.
- Utilize an iterative process for developing device requirements that incorporates cycles of industry input and device testing. Complete the requirement generation and QPLs prior to all device and system use. If it is anticipated that the requirements will be updated after testing based on field deployment, incorporate enough time in the schedule to procure updated components and retest.

4.3 Executing Qualification Testing

The first step in the rQPL Phase of the device development process was to perform qualification testing for each type of DSRC communication device to be deployed in SPMD. The purpose of the qualification testing was to verify that a device developer was capable of producing a device compliant with the final requirements, and therefore should be included on the rQPL as a potential device supplier. The qualification testing process required each developer to provide two prototype devices to the USDOT. The devices were tested according to a pre-defined test plan that consisted of a series of bench and field tests with a large number of pass/fail test cases. The test plans were publically released for both VADs[25] and RSUs.[26] The qualification requirements for the ASDs included not only the DSRC radio requirements, similar to VADs, but they also included requirements for the safety applications. Qualification testing was also conducted on the safety applications supported by the ASDs.

Several issues were later identified in the qualification testing process that impacted the SPMD. One example was if a device became inoperable during qualification testing, developers were allowed to substitute the inoperable device with a spare device in order to complete all the tests in the test plan. This substitution approach did not capture the device failure that occurred in the testing process and did not result in an overall failure for the device supplier. The consequence of using this approach was that device stability issues were not identified and remediated in the development process. Instead, some of these stability issues were still present in the devices eventually deployed during SPMD. This resulted in the Test Conductor and device suppliers spending additional time to diagnose and remediate those stability issues with devices that passed qualification testing and were deployed in the field.

[25] http://www.its.dot.gov/safety_pilot/pdf/Vehicle_Awareness_Device_TestDatasheet%20V10_%209242012a.pdf
[26] http://www.its.dot.gov/safety_pilot/pdf/RSE%20Evaluation%20Report%20%20Template.pdf

In order to test the safety applications, the USDOT utilized a set of performance-based tests for each application. Due to time constraints, the USDOT utilized a set of previously developed application tests. These tests were developed for applications based on radar technology instead of DSRC technology. As such, newer tests more specific to DSRC-based safety applications, specifically false warnings due to GPS inaccuracies, were not developed or executed in the qualification testing. As a result the testing did not identify the scenarios where the devices may generate false warnings. One specific example unique to a particular device developer was where the device would issue a forward collision warning alert when the other vehicle was not traveling in the same direction as the warning vehicle. If test scenarios had been developed for where the devices should not provide a warning, i.e., “no-warn scenarios”, then some of these performance issues could have been identified in the qualification testing rather than during Model Deployment.

Recommendations

- Institutionalize and formalize all testing procedures for the QPL. Provide clear and unambiguous qualification test procedures, with pass/fail criteria, as part of the test plan.
- Provide testing specifications covering the performance of all components, to allow common understanding and expectation, and allow sufficient time for iteration.
- Develop application tests that are specific to the type of technology being deployed, and place additional emphasis on false positive scenarios.

4.4 Generating the Research Qualified Products Lists

Based on the results of the qualification testing process described in the previous section, the USDOT planned to generate and publically release rQPLs for each of the device types deployed in the Safety Pilot Model Deployment, including VADs, ASDs, and RSUs. The Test Conductor was required to use the device developers listed on the rQPLs as input into their own procurement processes to select device suppliers to build devices for the SPMD. The intent was to provide the rQPLs to the Test Conductor prior to January 1, 2012 to allow sufficient time for the Test Conductor to select and contract with suppliers and for the suppliers to manufacture the volume of device needed for SPMD.

Unfortunately, none of the three rQPLs were ready for delivery by the January deadline. The final RSU v3.0 design specification developed for SPMD was delayed by several months and not released until March 2012. This caused a downstream delay in the creation of the RSU rQPL because the RSUs developers needed approximately 2 months to incorporate the changes into their design and retest the devices. As such the RSU rQPL[27] was publically released and delivered to the Test Conductor in May 2012 for use in their procurement process to identify RSU suppliers for SPMD. The Device Development Phase for VADs and ASDs also required additional time; and therefore, the rQPLs for these devices were not completed in time for the Test Conductor to utilize them in their selection process. As such, the USDOT worked collaboratively with the Test Conductor to modify the contract and initiate a joint evaluation process to select VAD and ASD suppliers for SPMD. While the Test Conductor carried out their procurement process to select the VAD and ASD suppliers, the USDOT concurrently executed qualification testing and submitted the test results to the Test Conductor as input for the final selection in their procurement processes. Further explanation of the

[27] http://www.its.dot.gov/safety_pilot/safety_pilot_qpl.htm

Test Conductor's evaluation criteria and process for selecting VAD and ASD suppliers can be found in Section 5 of *Safety Pilot Model Deployment: Test Conductor Team Report*.

The USDOT expected that this comprehensive development process would yield devices sufficiently mature to operate throughout the Model Deployment and require only minimal manual intervention by the Test Conductor or the device supplier. This result was mostly achieved because a large portion of the devices that were deployed in the SPMD were still operating at the completion of the SPMD contract (August 2014); however, in order to keep these devices in operation for this amount of time, every DSRC device deployed had to be recalled at least once during the SPMD to identify and correct issues. For example, there were software issues associated with the GPS coordinates, leap second calculations, path history, and security credentials, and there were hardware issues with batteries and power cables. The Test Conductor documented all device issues and corrective actions that occurred during the Model Deployment, which can be found in Section 7 of *Safety Pilot Model Deployment: Test Conductor Team Report*. These hardware and software updates required a significant amount of additional resources from the Test Conductor and the device suppliers. More information can be found in *Section 5.8 Monitoring and Recalling Devices.*

Recommendations

- Developing QPLs are a necessary step in developing research products that can withstand deployment in a lengthy field test. Complete all supplier evaluations prior to launch, even if the devices are not needed on day one of the deployment.
- Even with a QPL process, it may be necessary to plan for additional resources to provide troubleshooting and general device support throughout the test period. During the SPMD, delays encountered due to maturity and readiness of the devices resulted in the Test Conductor taking on more development and support activities, which constrained resources.
- Evaluate impacts of procuring devices from various vendors included on the QPL. Balance the cost of increased procurement complexity of having more device types with the cost of possible schedule impacts due to possible device production delays. Consider the impacts of having to conduct interoperability testing between large numbers of devices and schedule implications for any needed hardware or software updates.

Chapter 5 Device Deployment and Monitoring

This chapter focuses on the processes utilized for the installation and deployment of in-vehicle devices and infrastructure devices, as well as for monitoring and maintaining the devices after deployment. The Test Conductor was responsible for installing, tracking, and monitoring the in-vehicle devices and vehicle fleets for the VADs, ASDs, and RSDs. The Test Conductor team was also responsible for the installation and maintenance of the infrastructure devices and the back office infrastructure. Much of the infrastructure work was a closely coordinated effort between various subcontractors that made up the Test Conductor team, along with the City of Ann Arbor and the Michigan Department of Transportation (MDOT).

The chapter is divided into three main areas: (1) Device Testing; (2) Vehicle-based and Infrastructure-based Device Installations; and (3) Monitoring Devices. Device testing and installations, for both vehicle-based devices and infrastructure-based devices, was performed during Stage 2: Pre-Model Deployment Planning and Testing. The purpose of Stage 2 was to test, identify, and resolve all critical issues before proceeding to Stage 3: Model Deployment Execution phase in August 2012. All device monitoring and maintenance activities took places during Stage 3.[28]

This chapter includes the following sections:

- **Section 5.1 Interoperability Testing** describes the process used to verify the ability of the vehicle-based and infrastructure-based devices produced by various suppliers to exchange, decode, log, and/or forward DSRC messages.
- **Section 5.2 Pre-Model Deployment Dry Run** outlines the process used to verify installation, operation and interoperability of all hardware and software components needed for the SPMD. It highlights the importance of proper scheduling and resource management to implement multiple rounds of testing and updates.
- **Section 5.3 In-Vehicle Installation Requirements** reports on the requirements identified in the statement of work and by the Test Conductor for installing VADs and ASDs in various vehicle types.
- **Section 5.4 Installing In-Vehicle Devices** outlines the development of standardized installation procedures, the check-out procedure used to verify the functionality of the devices, and schedule requirements for individual device installs.
- **Section 5.5 Infrastructure Installation Requirements** provides general descriptions of the selected RSU locations and outlines the site configuration and installation requirements for infrastructure devices.

[28] A description of all stages of the SPMD can be found in the Background section of this document

- **Section 5.6 Installing Infrastructure Devices** outlines the three primary components of the infrastructure installations: set-up and testing of the backhaul and back office server systems; RSU installations; and traffic signal controller replacement. It describes challenges encountered during installation of RSUs, including network and IPv6 availability, data collection and redundancy, and back office needs.
- **Section 5.7 Configuration and Property Management Systems** reviews the systems implemented for enabling equipment and software refreshes, and for enabling follow-on data analysis after the deployment was completed. These systems were also used as part of the state of health monitoring systems.
- **Section 5.8 Monitoring and Recalling Devices** discusses the methods employed by the Test Conductor to monitor the health of the in-vehicle and infrastructure devices. It highlights the challenges with having to recall a large number of devices, including Test Conductor resource constraints, loss of data due to non-functioning devices, and inconvenience to the participants.
- **Section 5.9 Transitioning between Data Collection Phases** highlights key elements to include in the schedule between data collection periods, such as repairing and cleaning vehicles; harvesting data; validating functionality and performing maintenance on the devices and systems; and updating device software.

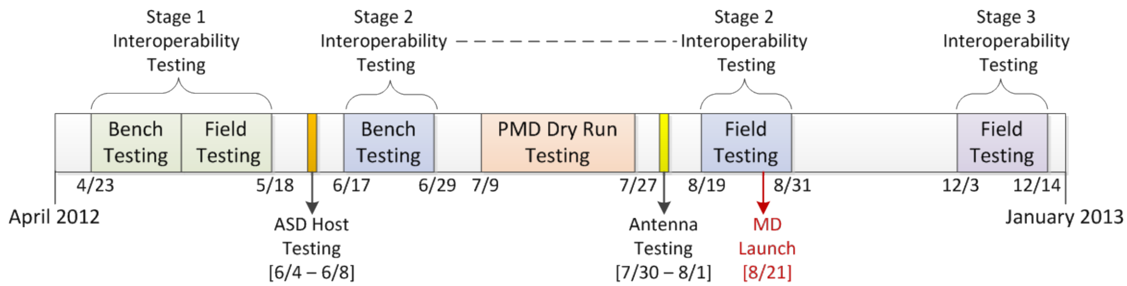
Device Testing

The Test Conductor, with support from the device suppliers, conducted four different types of testing activities to ensure that the devices and systems were ready for deployment into the Model Deployment environment.

- **Interoperability Testing** – Verified DSRC messages sent from multiple device types and multiple device suppliers were received and decoded by other device types and other device suppliers.
- **ASD Host Testing** – Verified ASDs and their safety applications generated warnings based on BSMs from other DSRC devices.
- **Antenna Testing** – Evaluated various antenna mounting locations for both GPS and DSRC antennas.
- **Pre-Model Deployment (PMD) Dry Run Testing** – Verified all deployed devices, hardware, and software components functioned as a complete system by exercising various Model Deployment functions related to communications, logging, driver training, system monitoring, and others.

Figure 5 provides a high-level timeline of each testing activity. It should be noted that interoperability testing was separated into multiple stages in order to accommodate variations in the DSRC device delivery schedules.

Figure 5: Pre-Model Deployment Testing



Source: USDOT

Note: Not shown in this diagram is the fourth and final round of bench and field testing which was conducted from February 2, 2014 – February 21, 2014.

The next two sections focus on Interoperability Testing and the Pre-Model Deployment Dry Run Testing, as these were the most resource intensive testing activities and required significant support from all device suppliers. The ASD Host Testing and Antenna Testing were smaller scale tests focused on evaluating a single function. For more details on the tests performed and the results, refer to *Safety Pilot Model Deployment: Test Conductor Team Report.*

5.1 Interoperability Testing

The Test Conductor conducted device interoperability testing to verify the ability of the vehicle-based and infrastructure-based devices produced by various suppliers to exchange, decode, log, and/or forward DSRC messages. All possible combinations of device types and suppliers were tested to verify this capability. For each stage of interoperability testing, a test matrix was developed to display the types of devices that were being tested. Table 7 is an example matrix from Stage 1.

Table 7: Devices Tested in Stage 1 Interoperability Testing

Receiving Device / **Transmitting Device**	**ASD** (Delphi)	**ASD** (Visteon)	**ASD** (Denso)	**ILV** (CAMP)	**IHV** (Battelle)
VAD (Savari)	X	X	X	X	X
VAD (Cohda)	X	X	X	X	X
ASD (Delphi)		X	X	X	X
ASD (Visteon)	X		X	X	X
ASD (Denso)	X	X		X	X
ILV (CAMP)	X	X	X		X
IHV (Battelle)	X	X	X	X	

Source: UMTRI

The initial testing schedule included one round of interoperability testing, scheduled to occur in April through May 2012, prior to the Pre-Model Deployment dry run testing. Two reasons were cited for including only one round of testing. First, it was assumed that all devices would be ready according to the device development schedule and therefore available for testing in April 2012. But more importantly, since all of the devices went through the qualification testing process, it was assumed that no major issues would be identified during the interoperability testing that would require significant updates and additional rounds of retesting.

Unfortunately, the RSUs were not ready for testing as originally scheduled due to the delay in developing the specification and rQPL, as discussed in *Section 4.4 Generating the Research Qualified Products Lists*. As a result, the interoperability testing was divided into two stages (see Figure 5 on page 58). Stage 1 only tested vehicle-based devices. Stage 1 evaluated the vehicle-to-vehicle (V2V) Basic Safety Message (BSM) compatibility between a variety of vehicle-based devices and platforms from each of the selected suppliers. It included static bench testing at the Test Conductor facilities and dynamic field testing of devices on a predefined route within the MDGA and occurred from mid-April through mid-May as originally planned. The infrastructure-based devices (RSUs) were incorporated into the Stage 2 testing. Stage 2 evaluated both vehicle-based and infrastructure-based devices against a series of seven test cases. This testing was scheduled for two weeks at the end of June. At the time of the Stage 2 bench testing in June, the vehicle-based devices could not be tested against three of the test cases that included security functions, as these devices did not support this functionality at the time. Therefore, these functions were not included in the Pre-Model Deployment Dry Run Testing in July.

It is clear that devices were not as mature as initially assumed based on the qualification testing, as evidenced by the number of changes required following the initial stages of interoperability tests. The Test Conductor tested as much functionality as possible prior to the Pre-Model Deployment Dry Run Testing, however there was still much to be done following the dry run testing in July. As a result, the Test Conductor and USDOT jointly decided that two additional stages, Stages 3 and 4, of interoperability testing were required after the SPMD launch in August 2012. The Stage 3 field testing re-assessed devices that failed in previous stages of testing and tested security functionality that was previously not supported in the Stage 2 testing. A fourth and final stage of bench and field testing was conducted to re-assess the devices after multiple firmware updates were implemented to resolve issues discovered in the field.

Several issues were identified in the interoperability testing process. First, adding additional stages of testing and not being able to adjust the project schedule or deployment launch date added risk to the project since it was unknown how the VADs and ASDs would work with the RSUs until after the devices were purchased and deployed in the field. Second, the process of conducting the interoperability testing required far more resources and time than was originally planned for this activity. The device interoperability testing verified, via a manual process, that the data elements in the BSM sent by the transmitting device were identical to the data elements in the BSM received by the receiving device. The manual verification process involved a field by field comparison of each data element in the transmitted and received BSM. Since there are a large number of fields in the BSM, this was a labor intensive process. Also, this testing was somewhat limited and did not verify the validity and accuracy of the data generated and transmitted by each supplier's device since this type of testing was assumed to be covered in other testing activities such as the device qualification testing and PMD dry run testing.

A positive aspect of the testing process was that representatives from each of the suppliers were on-site during all rounds of testing. Since these were still considered research devices without the monitoring capabilities of production scale devices, the representatives were needed to verify that their device was able to properly receive BSM data from the other devices participating in the test and also to troubleshoot any issues with their device in real-time. Several vendors did note however that the interoperability testing was not as useful as it could have been, as testing occurred at the message level, not at the byte-by-byte level. In addition, several of the suppliers recommended that a process similar to the European Telecommunications Standards Institute (ETSI) model-based interoperability testing may be useful when validating the new standards for interoperability. ETSI uses Plugfests, or interoperability events, that provide an open forum for resolving issues of non-interoperability and other technical aspects related to standards development and validation.

Recommendations

- Specify interoperability testing requirements as part of the device requirements. Utilize automated tools to perform basic data comparisons between devices in order to more efficiently conduct the testing and test a wider variety of cases.
- Define and document requirements and steps for all interoperability testing participants and data users prior to starting multiple rounds of testing, feedback, reset, and retest.
- Incorporate sufficient time in the schedule for multiple rounds of testing. If all devices are not available for testing at the same time, utilize multiple stages of testing as new devices and updates to previously tested devices become available.
- Establish agreements between vendors that all results and data will be shared between vendors that experience interoperability issues to ensure that a solution is achieved in an efficient timeframe.
- Utilize plug testing and implement multiple rounds of face-to-face interoperability testing. This will help to identify issues in the lab before the devices are deployed in the field.

5.2 Pre-Model Deployment Dry Run

The purpose of the Pre-Model Deployment Dry Run testing was to verify that all of the hardware and software components needed for the SPMD were installed properly; were functioning according to their design specifications; and were interoperable. The dry run testing was planned to occur during the last three weeks of July 2012, following the completion of the device interoperability testing. This left approximately one month for remediation of any issues identified during the testing prior to the SPMD launch on August 21, 2012.

A total of 125 vehicle devices and 6 RSUs were installed and tested. The Dry Run tested connectivity between vehicle-based devices, RSUs, and the SCMS; as well as the connectivity between RSUs and the backhaul network. It also assessed the performance of several processes and procedures such as: retrieving log files from the various devices and transferring the data to the Independent Evaluator and the Real-Time Data Capture and Management Team for processing and analysis; state of health monitoring; device installation procedures; and driver training procedures.

However, as noted in the previous section, not all devices and processes were in place in time to be exercised in this testing. The Transit Retrofit Devices and Heavy Vehicle Retrofit Safety Devices were not ready for the Dry Run, but were included in the Stage 2 Interoperability Testing before being introduced into the Model Deployment. The six RSUs installed for Dry Run testing had limited functionality and could only offload data logs to meet the data collection goals. The fully functional RSUs were tested during the Stage 3 field testing in December 2012 (see Figure 5). Although 8 of the 64 ILVs participated in the Dry Run Testing, the data acquisition systems of these vehicles were not fully functional for the testing. As a result, the data collection and transfer process from the integrated light vehicles to the Independent Evaluator was not tested. This resulted in a number of issues being identified during SPMD with the initial transfer of data from the Integrated Light Vehicle Developer to the Independent Evaluator (see *Section 6.5 Ensuring Data Quality* for examples and more details regarding the data). These issues did not impact the overall delivery of final results from the Independent Evaluator to the USDOT; however, there were additional costs and time associated with addressing the issues in the data. Some of these issues may have been identified earlier if the data had been available during the Pre-Model Deployment testing stage.

Ultimately, the Pre-Model Deployment was not a true dry-run testing scenario and many device and interoperability issues that may have been discovered during the dry-run were identified during the actual Model Deployment. And even though there was a month between the completion of Pre-Model Deployment and Model Deployment launch, this was insufficient time to make any major changes in the devices. For example, there was an issue discovered with the unique IDs of VADs which was not able to be remediated in the time available and had to be addressed in Model Deployment. In general, there needed to be longer testing intervals during and between the cycles of qualification testing, interoperability testing, and device development. It also would have been useful to have more time for the Pre-Model Deployment Dry Run and for more time after the interoperability testing prior to the PMD Dry Run. An ideal model would be to procure devices for the interoperability testing, test the devices, analyze the results, update the devices, retest the devices on the bench, and then procure devices for the PMD Dry Run. This same process would be repeated at the end of the PMD Dry Run prior to the official launch of the pilot.

Recommendations

- Implement a full dry run that includes all installation, operation and interoperability requirements for all devices, infrastructure, and systems. Incorporate sufficient time into the schedule to ensure that all devices and systems are in a stable state prior to implementing a full dry run.
- Ensure that in-depth system testing requirements, updates, and retest cycles are well-understood, and are appropriately resourced in time and budget. Plan for several iterations of component, subsystem, and total pilot system testing within the dry run. Depending on the number of system components (devices, infrastructure, data collection and backhaul connections, security implementation, etc), this could take several weeks to several months.
- Include sufficient time between Pre-Model Deployment and the actual Model Deployment to refresh the software, procure updated parts, and conduct re-testing after the updates. During the SPMD, one month proved to be insufficient to make any major changes in the devices.
- Be prepared to encounter field issues that were not discovered during the qualification testing, interoperability testing, and dry run testing.

In-Vehicle Device Installations

The following sections focus on the installation of Vehicle Awareness Devices (VAD) and Aftermarket Safety Devices (ASD) in light vehicles. This includes ASDs with and without a Data Acquisition System (DAS). In total, over 2,700 VADs installations were performed; however, the peak number deployed concurrently during SPMD was approximately 2,300. There were 330 ASD installations completed for SPMD. At the peak of deployment, 281 ASDs were in the field - 196 ASD only and 98 ASD with a DAS. It was difficult to maintain 100% full deployment of VADs and ASDs, primarily due to ongoing device recalls, device repairs and some participant attrition. In addition to the information in these sections, further discussion on device recalls can be found in *Section 5.8 Monitoring and Recalling Devices*.

5.3 In-Vehicle Installation Requirements

The Test Conductor installed three device types in light vehicles: (1) VADs; (2) ASDs; and (3) ASDs with a DAS. For VADs, each vehicle required the installation of four primary components: an on-board unit (OBU), a DSRC antenna, a GPS antenna, and power supply. The installation process for ASDs without a DAS was identical to the VAD process, except a Driver Vehicle Interface (DVI) was also included. Vehicles with ASDs with a DAS included installation of all of the ASD components as well as the DAS module, several cameras, a forward-ranging system and a microphone. The DAS required a connection to the vehicle Controller Area Network (CAN) bus in order to collect data directly from the vehicle, e.g., turn signal status, steering wheel angle, etc. Note that collecting and interpreting the data communicated over the CAN bus required an agreement between the Test Conductor and the vehicle OEM. The agreement provided the Test Conductor with documentation regarding the data passed over the CAN bus and the rights to collect such data as it is considered proprietary by the OEMs.

The Safety Pilot Statement of Work included two basic requirements for the installation of the in-vehicle devices and associated equipment. First, installations should not void the vehicle warranty. Second, the installation should not permanently modify the vehicle. The Test Conductor developed additional installation criteria and plans for each device type based on their past experience in field operational tests. The plans called out the following general guidelines for installation:

- Assume all components must survive one full year of normal vehicle operation in the Michigan climate;
- Mount all equipment and sensors so as to be out of the way of the driver and passengers, and to be secure in a crash;
- Maximize system reliability;
- Minimize the exposed cable runs on the interior or exterior of the vehicle and secure all cabling behind trim;
- Use OEM service procedures for disassembly and reassembly;
- Make minimal, if any, modifications to the vehicle. The installation should leave no visible evidence, i.e., paint damage, once removed; and
- Replace any components damaged during the installation process.

The on-board unit (OBU) and the DSRC antenna installations did not pose major challenges as the OBU could be mounted in various locations inside the vehicle, and the DSRC antenna could be mounted internal to the vehicle on the front windshield. The major installation challenge was the GPS antenna. The ideal installation location for the GPS antenna is outside the vehicle on the apex of the roof. This location provides the most visibility to the open sky and the best overall performance. However, this installation location required either a long run of exposed cable or a hole to be drilled in the roof of the vehicle. Neither of these options met the equipment installation requirements, and therefore the Test Conductor proposed installing the GPS antenna inside of the vehicle in order to minimize the installation risk.

The challenge with proposing installation of the GPS antenna inside the vehicle was that all testing of connected vehicles prior to Safety Pilot used test vehicles, not privately owned participant vehicles, and had utilized a roof mount for the GPS antenna. Therefore, it was unknown what impact of placing the GPS antenna inside the vehicle would have on the performance level needed to support the V2V safety applications. The Test Conductor, Integrated Light Vehicle Developer, and the USDOT decided to conduct additional testing and analysis to better understand the system performance with various antenna installation locations. After extensive testing, a set of installation locations was identified for the GPS antenna that would balance the performance and the installation risk. It was decided to mount the GPS antenna externally, in locations to minimize the length of exposed cables – on the trunk lid for sedans or rear door for SUVs. These locations did not provide the same level of performance as a roof mount; however, at the time of testing, the performance at this location was deemed sufficient for Model Deployment. It should be noted that the performance of the interior mounted GPS antenna in the testing was significantly worse than the exterior mounting locations and that mounting the GPS antenna inside the vehicle would not provide the performance level needed to support the V2V safety applications.

The Test Conductor was not able to install as many in-vehicle devices as planned prior to the SPMD Launch. The additional testing and analysis had a noticeable impact on the project since installation of devices could not begin until the antenna location was finalized in early August 2012. Furthermore, the installation of the GPS antenna on the outside of the vehicle required an additional 30 – 60 minutes of installation time, in order to run the cable and to test the connection. The external GPS antenna also required a film be placed underneath the antenna to protect the vehicle paint, which also added cost to the project.

Recommendations

- If installing aftermarket equipment in privately owned vehicles, conduct an assessment to determine how various installation requirements could impact participant recruitment, data collection, device performance and other factors to better understand project impacts. Use this information to develop and customize the device installation requirements to meet the project objectives.
- Consider that the installation configuration required to generate optimal device performance, for example antenna location, may not be feasible given the installation constraints dictated by the project, i.e., no permanent modifications to a vehicle.
- Before selecting vehicle types, ensure that agreements between the Test Conductor and the vehicle OEMs can be obtained if connecting to the vehicle Controller Area Network (CAN) bus for data collection purposes. The data passed over the CAN bus and the rights to collect such data is considered proprietary by the OEMs.

5.4 Installing In-Vehicle Devices

The Test Conductor developed device installation guides for both ASDs and VADs which included installation configurations for common types of vehicles. It was initially estimated that standard installations of VADs and ASDs without DAS would require about 45 to 90 minutes. The ASDs with a DAS required more components to be installed and therefore, could take several days to complete, depending on the vehicle type.

VADs were the first in-vehicle devices to be installed. The Test Conductor originally planned to install about 245 VADs a week until the installs were completed. However, the initial installation of 2,300 VADs took about 4 months, approximately 1 ½ months longer than anticipated. The installations started in early August 2012 and were completed at the end of November. It was anticipated that approximately 500 installs would be completed by the August 21, 2012 launch date, however, only approximately 300 installs were finished in this timeframe.

There were several reasons for the delay in VAD installs. First, the installations could not begin until after the GPS and DSRC antenna testing was completed on August 1, 2012, as discussed in the previous section. Second, although the Test Conductor developed the installation guides for the most common types of vehicles selected for Safety Pilot and the device mount designs were verified during the pre-model deployment phase, there ended up being a variety of vehicle types that were not compatible with these standard procedures (e.g., convertibles, pick-up trucks). As a result, the installation configurations had to be modified during the installation to support some of the less common vehicle types. For example, with one common type of vehicle, the power supply was located on the other side of the firewall; therefore, installing a device in this type of vehicle required the power cable to run through the firewall through an existing hole into the engine compartment to access the power supply. For some types of vehicles this was not easily done and these vehicles had to be rejected from the Model Deployment if the installer could not find a suitable installation configuration. This added complexity and additional effort to the VAD and ASD installations. Finally, the Test Conductor found it difficult to contact and schedule the participants to bring their vehicles in for device installations, particularly when the installation hours were scheduled for weekdays when many participants were working. In an effort to increase the number of VAD installations and recover some of the schedule, the Test Conductor contracted with a third-party installer to augment existing installation staff to accelerate the deployment of VADs into the Model Deployment Test Environment (as discussed in *Section 1.5 Utilizing Quantitative Performance Measures*).

The installation of the ASDs was also delayed from the original installation schedule; however, this was primarily due to the delays in the device development process as discussed in Chapter 4. The installation of the ASDs was fairly straightforward since the Test Conductor had already gone through the VAD installation process and many components were similar.
One omission from the installation plans was that there were no “end-of-line” tests to validate the installation. At the conclusion of each installation, the Test Conductor performed a basic verification procedure to ensure the device was properly functioning before completing the installation. The verification procedure included the following checks:

- Device successfully powered up
- Device successfully transmits a BSM
- Device, antenna, and wiring harness are securely mounted

The verification procedure did not include checks to measure the performance of the device or the accuracy of the data being broadcast by the device once it was installed. For example, there were no checks to ensure the x, y, and z offsets of the GPS antenna from the center of the vehicle were properly measured and recorded. Also, there was no check for the broadcast range of the DSRC messages nor was there any check of the accuracy of the GPS location. As a result of the lack of verification of the performance of the device, it was not possible to describe the performance of the devices deployed in the environment. Furthermore, independent evaluation of the data collected indicates that some of the false V2V safety alerts generated in Model Deployment may have been due to poor performance by a subset of the ASDs and VADs. Optimally, one would have a test track or access to closed roads to conduct these end-of-line tests for each installation and more detailed operational tests.

Recommendations

- Consider limiting the number of vehicle makes and models to reduce the number of device installation plans required. Develop an installation plan (including device mounting) for each vehicle type and evaluate all designs for any potential common elements. Even with different makes and models this could reduce the number of unique designs required.
- Include performance testing as part of the installation verification test procedure to determine if the installation is operating as intended. Ensure access to a dedicated test facility for "end-of-line" performance and functionality tests for either all installations or a representative sample.
- Establish an online scheduling tool for participants to self-schedule their device installations. This will reduce the amount of time required to manually schedule participants and will also help balance workload for installers. Consider providing installation times during evening hours or on weekends.

Infrastructure Installations

A number of infrastructure components were installed in the Model Deployment Geographic Area. This included installation and integration of Roadside Units (RSU), traffic signal controllers (TSC) enabled with Signal Phase and Timing (SPaT), and an interface device between the SPaT signal controllers and the RSUs referred to as the "black box". These components are collectively referred to as Roadside Equipment.[29] Network connectivity from the RSUs to the infrastructure back-office was also required.

The infrastructure was needed to serve a variety of functions including:

- **Data Collection:** All RSUs were designed to listen for and record any DSRC messages transmitted from other connected vehicle and infrastructure devices within approximately 300

[29] At the time of the Safety Pilot Model Deployment, the term roadside equipment (RSE) was defined as the roadside device that facilitates communication between transportation infrastructure and vehicles and other mobile devices by exchanging data over DSRC; however, following the conclusion of SPMD, a revised RSU specification was issued (v4.0) and the term was changed from RSE to RSU. Now RSE is used to describe all infrastructure equipment at the roadside (signal controllers, backhaul connections, etc.), and RSU refers to original definition of RSE (i.e. the DSRC radio).

meters. The RSUs recorded Basic Safety Messages (BSMs) from the V2V-equipped vehicles, as well as transmitted Signal Phase and Timing (SPaT) messages, geometric intersection description (GID) messages[30] and Traveler Information (TIM) messages transmitted by nearby infrastructure devices.

- **Message Broadcast:** Several of the RSUs transmitted SPaT, GID and TIM messages. Note that the RSUs only broadcast TIMs at the locations where the Curve Speed Warning (CSW) V2I application was deployed.
- **State of Health Monitoring:** The DSRC messages captured by the RSUs were transferred via backhaul connection to a data center and utilized by the Test Conductor team to monitor the state of health of connected vehicle devices. For example, if a BSM for a specific VAD was not received by any RSU in the network over a one week period, then the Test Conductor would contact the participant to bring their vehicle in to verify that the in-vehicle device was functioning properly.
- **Security:** The RSUs provided secure Internet Protocol (IP) connections to nearby aftermarket safety device vehicles, retrofit device vehicles, and integrated vehicles to allow communications with the security credential management system for the purpose of requesting and acquiring security credentials.
- **Pedestrian Detection:** The Pedestrian in Signalized Crosswalk Warning (PCW) transit application required the installation of crosswalk motion sensors to detect pedestrians. The call button status and pedestrian presence in the crosswalk status were packaged in the Signal Phase and Timing (SPaT) message.

The Test Conductor team was responsible for the installation, state of health monitoring, and maintenance of the RSUs. This required the Test Conductor to maintain a close relationship with the City of Ann Arbor and the Michigan Department of Transportation throughout SPMD. The City of Ann Arbor and MDOT played a significant role in the site planning and equipment installation process. The City of Ann Arbor also served as the backhaul infrastructure provider while the Test Conductor operated and maintained the infrastructure back-office and monitored the network.

5.5 Infrastructure Installation Requirements

The Test Conductor contract required the installation of twenty-nine (29) RSUs and twelve (12) traffic signal controllers throughout the MDGA in Ann Arbor. The traffic signal controllers (TSC) had two basic requirements: 1) the TSCs were required to communicate Signal Phase and Timing (SPaT) data to the RSUs co-located with them; and 2) the controllers were to be installed on two distinct corridors with at least three contiguous signals. The TSCs were two different types provided by two manufacturers. Both manufacturers worked with the USDOT to develop the SPaT interface to and from the controller for their respective devices. The Test Conductor was also responsible for developing the geometric intersection description (GID) for each SPaT location.

Using these basic requirements, the Test Conductor developed an Infrastructure Implementation Plan which outlined the site configuration requirements, installation schedule, and installation roles and

[30] The format and content of the SPaT message and the GID used in SPMD can be found in SAE standard J2735, version 2009-11.

responsibilities. The plan identified four different types of sites within the SPMD for installation of RSUs, as shown in Table 8.

Table 8: RSU Planned Installations

Type	Location	No. of RSUs	Owner
Signal Corridor	Fuller	9	City of Ann Arbor
Signal Corridor	Plymouth	6	City of Ann Arbor
Signal Corridor	Washtenaw	4	MDOT
Curve Warning	Various	6 (2 per curve)	City of Ann Arbor
Freeway	US 23/M 14	5	MDOT

Source: UMTRI

Below are general descriptions of the RSU installation locations:

- **Fuller:** Corridor had existing traffic signal controllers that were replaced by new SPaT-enabled controllers.
- **Washtenaw:** Carries a mix of commercial vehicles, transit, and passenger vehicle traffic. Selected to examine the effects of closely spaced RSUs, using four signalized intersections over a length of approximately 0.5 miles.
- **Plymouth:** Corridor running traffic adaptive software. Selected to examine the ability to transmit SPaT data from a traffic signal network that is running traffic adaptive software at a series of intersections.
- **Curve Warning Sites:** RSUs were installed on light poles with NEMA enclosures to house equipment for data backhaul. The sites utilized point-to-point radios to backhaul data to adjacent signalized intersections to improve signal reliability/latency and reduce operational costs.
- **Freeway Sites:** Four of the freeway sites were co-located with existing ITS installations for backhaul purposes. The fifth site was a prototype stand-alone site that utilized solar power and cellular communications.

The Test Conductor was responsible for negotiating with the City of Ann Arbor and MDOT on the installation locations of the RSUs and TSCs. This required commitments from both the City of Ann Arbor and MDOT on schedule, resources for installations, and longer-term operations and maintenance support. Prior to selecting the sites, a field survey of each potential site was conducted for planning purposes. The survey included a general overview of the roadway geometry, existing poles, cabinets and conduit runs. All specific field and traffic cabinet requirements were documented for each site. The potential location of each RSU had to take into account: (1) line of site for all vehicle approaches while reducing overlapping RSU ranges; and (2) distance from RSU to the controller cabinet due to distance limitations based on power over Ethernet restrictions.

Once the exact locations of RSUs were determined, the City of Ann Arbor assisted with verifying the RSU ranges prior to device installation. This was done manually, by utilizing a bucket truck to position the RSU in the appropriate location and verifying the range. The City of Ann Arbor did not require a formal approval process prior to installation of the equipment; however, they did follow the procedures for mounting traffic signals as contained in the Minimum Uniform Traffic Control Device (MUTCD) manual.

The Test Conductor saved significant time and expense on the project by selecting sites with existing communications and network capabilities available on the City of Ann Arbor's fiber optic network. This reduced the amount of new conduit that had to be installed. The freeway sites were not on the City's network as the freeway is owned by the Michigan Department of Transportation. This resulted in some major connectivity challenges for the RSUs, which are described in greater detail in *Section 5.6 Installing Infrastructure Devices.*

Recommendations

- Investigate requirements or restrictions implemented by the local or state road authority for installing roadside equipment. This is particularly important if RSUs will be mounted on existing traffic signal infrastructure, as this may limit the site selection.
- Available space in a traffic signal cabinet is typically at a premium. Prior to site selection, work with the state and local agencies to determine if it is feasible to place additional equipment in the cabinet or if additional roadside infrastructure is needed.
- Consider deploying RSUs at sites that have existing ITS installations to utilize existing power and backhaul connections. Ensure that a robust fiber optic network using IPv6 is in place to connect the RSUs to the back office facilities if collecting and transferring data. This will minimize costs and schedule impacts for new conduit installations.
- Look for opportunities to develop robust traffic signal communications networks, upgrade signal controllers with Ethernet connectivity and incorporate provisions for conduit and fiber-optic installation as part of new roadway projects. This will ensure that the infrastructure is in place for future RSU expansions.

5.6 Installing Infrastructure Devices

There were three primary components of the infrastructure installations: RSU installations; set-up and testing of the backhaul and back office server systems; and traffic signal controller (TSC) replacement. Field installation of RSUs and connection to the infrastructure backhaul for city sites was a team effort shared by the City of Ann Arbor and the Test Conductor team. Due to potential liability issues involved with the installation and testing of TSCs, and right-of-way issues involved with the installation of RSUs on property owned or controlled by local transportation agencies, the Test Conductor arranged in advance with the City of Ann Arbor to install the TSCs and RSUs for the city sites. The City was responsible for all physical aspects of the installations including mounting equipment, and connecting wires, power, and Ethernet within the controller cabinet. The Test Conductor team offered networking knowledge for backhaul of the data. Some of the work areas and tasks required more instruction and oversight from the Test Conductor team than other more routine tasks that the City performs on a regular basis, e.g., set-up and configurations, physical cabling connections in the cabinet, but ultimately the team engineered a solution together for each site.

Because of the delay in finalizing the v3.0 RSU specification and developing the rQPL, as discussed in *Section 4.4 Generating the Research Qualified Products Lists*, the RSUs were not tested during the Pre-Model Deployment and were not in place for the Model Deployment launch. As a result, the Test Conductor implemented a 2-stage RSU installation plan. In the first stage, repurposed Proof of

Concept (POC) RSUs were installed at six locations in the MDGA just prior to the SPMD launch. These RSUs were updated to offload data logs to simply meet the data collection goals after launch. The Phase II SPMD RSUs were installed in early December 2012, according to the originally developed site and installation plans. Freeway sites deployments were also scheduled for December 2012; however, as noted in the previous sections, the freeway sites were not part of the city network and therefore required other means of connecting to the network backhaul. This delayed installations by several months.

A major challenge that impacted the installation schedule for RSUs was the requirement to use Internet Protocol version 6 (IPv6). This requirement was added into the revised v3.0 RSU specification, issued in March 2012. The update was driven primarily by security requirements implemented in SPMD. This was a major change from the planning phase and greatly increased the complexity of the network routing. At the time of the SPMD, most of the world was still using IPv4. As of late November 2012, IPv6 traffic share was reported to be approaching 1%. The IPv4 and IPv6 protocols are not designed to be interoperable, complicating the transition to IPv6. Since all RSUs required a connection to the network backhaul to offload data, this required an update to the interface between the RSUs and the City of Ann Arbor backhaul network, which utilized IPv4. The resulting impact was the separation of the City's network into 'traffic only' data and 'SPMD only' data. Many service providers were also not ready to support IPv6. This was most troublesome for the freeways site since they were owned by MDOT and therefore not connected to the City of Ann Arbor's network.

Prior to installing the RSUs in the field, the City of Ann Arbor's maintenance shop was used as a working lab to set up, configure, and test the RSUs. Letting the units run for up to a week in the lab allowed the team to address and replicate any issues that may not have been detected during qualification or interoperability testing. However, after the devices were installed, several of the units that had passed both the qualification and interoperability tests, as well as the tests conducted at the lab, encountered issues in the field that were not previously detected. While these units performed as expected during testing under very limited load scenarios, when the unit was deployed at scaled model, several problems were detected related to how the RSU responded under network traffic or how the unit interacted with vehicles at on-road speeds. These types of scenarios were very difficult to replicate on the bench in order to find a solution. The lab facility also did not have the capability to test or replicate these scenarios, and therefore these tests were not included in the interoperability testing. These types of problems often resulted in RSUs being removed from the field and sent back to the supplier for a manual reset.

Once the RSUs were installed, the amount of data collected became the most significant challenge. During the site planning exercises, the RSUs were expected to have a range of 300 meters. However, once deployed, many RSUs exhibited ranges much larger than 300 meters. Based on how the RSUs were located in the field, there was overlap of the RSU ranges resulting in significant duplication of data. Even with only 1,000 vehicles deployed, the amount of data collected in a week was measured in Terabytes. This required high-bandwidth backhaul connections to offload data from the RSUs and there were times when this was a challenge for the Ann Arbor network. Warehousing and processing also became a significant challenge with these large amounts of data.

One area that did not have a significant impact on the project was the installation of new signal controllers. The City of Ann Arbor was initially concerned with the requirement to install different signal controllers from what existed in their current system and how this would impact the day-to-day operations of the system. The signal software some updates to handle the Ethernet based new controllers and retain the adaptive signal timing coordination algorithm and capabilities throughout the project, but ultimately there was little impact on traffic operations.

Recommendations

- Establish strong partnerships with state and local agencies responsible for the operations and maintenance of roadways and related equipment. Implementing new technologies will require additional resources for attaining technical competency for the installation and maintenance of equipment.
- Consider hiring an engineering firm to coordinate all installation requirements and implementations between various transportation entities, infrastructure suppliers and the Test Conductor. This will alleviate any one organization having to take on additional responsibilities, further constraining limited resources.
- As part of the infrastructure installation plan, identify if RSU will collect data, how this data will potentially be used, e.g., how could BSMs be used for operations applications, asset management, etc., and how this impacts site selection. Develop a strategy for dealing with the potential duplication of RSU logged data. If offloading and storing data, consider alternatives to purchasing large volumes of IT hardware, e.g., cloud services.
- Conduct testing prior to infrastructure installation through the use of staging sites. After initial installations are complete, utilize the staging site to test firmware updates implemented by the device manufacturers to address any issues later identified in the field. Testing at the staging sites will help ensure that updates are ready to be rolled out prior to installing on all infrastructure.

Monitoring Devices

With thousands of device deployed in the field, along with many complex and varying infrastructure installations, the Test Conductor played an important role in monitoring and tracking issues and defects within the deployed technology. This included establishing two separate Property and Configuration Management Systems to track all assets and their respective configurations – one for infrastructure-installed components, the other for vehicle-installed components. Once the devices were deployed in the field, the Test Conductor implemented state of health monitoring for all devices. The following sections focus on the systems used to enable equipment and software refreshes, and monitoring the health of the in-vehicle and infrastructure devices.

5.7 Configuration and Property Management Systems

The Test Conductor was required to implement a property management system and a configuration management system to track and manage the in-vehicle and infrastructure devices during deployment. The property management system recorded and tracked all physical property that was acquired by or provided to the Test Conductor as Government Furnished Equipment (GFE). It tracked the assignment of each device to the participant (for in-vehicle devices) or to its location in the field (for infrastructure devices). The configuration management system provided hardware tracking for ***all of the devices*** deployed in the field (both in-vehicle and infrastructure) and software tracking for the various versions of software deployed on each device. In addition to the ASD and VAD in-vehicle devices, this included entries for the RSD, TRP, IHV, and ILVs, even though these devices were not built or installed by the Test Conductor.

The intent of the property and configuration management systems was to efficiently and effectively enable equipment and software refreshes. Each device was assigned a unique ID. During property management check-in, a barcode was affixed to the device and linked to the device unique ID. The device barcode was scanned during the in-vehicle installation process and linked to the vehicle VIN in the configurations database. When a particular device was detected as having an issue, the configuration management system served as a way to identify all of the other devices with the same hardware and/or software so that all devices could be recalled at once when a solution was determined. This link was also critical for conducting follow-on data analysis after the deployment was completed, so that specific system alerts and warnings could be associated with specific devices and software configurations. This link was particularly important in SPMD because devices were swapped out of vehicles, reconfigured or updated with new software, and then placed in other vehicles. The unique ID assigned to each device was also important because it was broadcast in the BSM and therefore critical to the state of health monitoring system (see discussion in *Section 5.8 Monitoring and Recalling Devices*).

Due to the sheer volume of in-vehicle devices and incremental roll-out, one of the biggest challenges was keeping track of various versions of software and device configurations installed on different batches of devices delivered from the vendors. Many early batches of devices that were deployed had to be recalled so that their software and configurations could be updated. For example, approximately 2 weeks after SPMD launch, the Integrated Light Vehicle Developer identified an issue with one supplier’s VADs which impacted the integrated light vehicles. The GPS parameters in the VAD were configured in such a way that it generated a lot of noise in the GPS coordinates for the VAD. This noise in the GPS coordinates resulted in the integrated light vehicles misinterpreting the location of the VAD and subsequently issuing false warnings. Resolving this issue required a change to the configuration parameters in the VAD. Since the supplier was still in the process of delivering VADs to the Test Conductor, the supplier updated the parameters in future deliveries of VADS; however, those VADs that were already deployed were configured with the old parameters. As such the Test Conductor had to utilize the configuration management system to identify the devices to recall and update the parameters. Later in the project it would be necessary for the Independent Evaluator and the Integrated Light Vehicle Developer to analyze the warnings generated by the ILVs. During this evaluation process it was important to know the software and GPS parameter configuration for the VAD at the time that a warning was issued by the ILV. Therefore, the Test Conductor had to provide a database linking the device ID, software version, configuration parameters and installation parameters to the IE and ILV Developer in order to complete their analysis.

One issue that arose during SPMD was how the information was entered into the configuration and property management systems. The initial information input into the system was entered via a manual process. This manual process often involved the installers writing down the configuration information on a hardcopy, paper template and then later entering the information into the system. This increased the probability that human errors were propagated into the system. Human error entries were found in the recording of the x, y, and z offsets in the location of the GPS antenna as well as in the vehicle VINs, device IDs, and driver IDs. The Test Conductor subsequently had to verify all of the entered information during the data download process when the vehicles were brought to the Test Conductor facilities. The system was then updated to reflect the accurate information. Based on this experience, it is advised that in future projects to automate as many entry functions as possible. This will minimize the amount of manual input into the system and reduce entry errors. Implementing a quality control process as part of the management systems is critical to verify that information input manually is error free.

Recommendations

- Establish a robust property management and configuration management system prior to starting installation of devices. Ensure that asset and configuration management, control, and auditing of all devices and project equipment is conducted throughout the pilot. This is critical for a large number of deployed devices.
- Within the property and configuration management systems, automate as many entry functions as possible. This will minimize the amount of manual input into the system and reduce entry errors. Implement a quality control process to verify that the information input manually is error free.
- Ensure the property and configuration management systems are linked in such a way to support detailed evaluation and analysis of potential impacts of various software versions and installation configurations on the overall system performance.

5.8 Monitoring and Recalling Devices

During the Safety Pilot Model Deployment it was necessary to monitor the health of the in-vehicle and infrastructure devices to identify any performance issues that needed to be addressed by the Test Conductor. State of health monitoring for in-vehicle devices was conducted by the Test Conductor via two methods:

- **Data Acquisition Systems** – Nearly 200 vehicles were equipped with Data Acquisition Systems (DAS), including ASD-equipped vehicles, TRP-equipped vehicles, RSD-equipped vehicles, and the IHVs. The DAS sent device diagnostic information in near real-time through the use of a cellular modem. The diagnostic information was used to determine the device health. The 64 Integrated Light Vehicles also had cellular-based health monitoring; however, the Test Conductor was not responsible for monitoring these vehicles.
- **RSU Monitoring** – RSUs recorded BSMs that were transmitted by in-vehicle devices as the vehicles passed by the RSUs. Each vehicle-based device had a unique ID (as discussed in *Section 5.7 Configuration and Property Management Systems*) that was included in the BSM. The Test Conductor analyzed the recorded BSMs to identify any in-vehicle devices that did not transmit a BSM over an extended period of time, typically 1 week. This approach was used for monitoring the thousands of VADs and ASD-equipped vehicles without a DAS.

Using the Data Acquisition Systems method was far more effective at monitoring the in-vehicle devices than the RSUs monitoring method. This was a result of the DAS having real-time communications and diagnostic information. The RSU monitoring method required the Test Conductor to first analyze the data, and then individually contact drivers of vehicles to verify when they were last driving in the Model Deployment Geographic Area. There was no way of knowing if the device was malfunctioning or if the participant was simply not driving the vehicle. This was a time consuming and inefficient approach to monitoring the health of the in-vehicle devices.

To monitor the state of health for the infrastructure, the RSUs generated a heartbeat message once a minute that was sent to the back-office servers. Using the heartbeat as a diagnosis tool was somewhat limited. The heartbeat messages only contained information about the status of available internal storage on the RSU, which was not enough to effectively monitor the health of the RSU. The message did not indicate the health of each individual component operating within the RSU, such as SPaT transmission, network connectivity and backhaul connectivity, and radio and GPS status. Failure to receive a heartbeat only indicated that the RSU was no longer powered or online. This required further field investigation since there was no tool to diagnose the state of health remotely.

Although somewhat rudimentary, the state of health monitoring processes proved to be critical to the Model Deployment. Based on the DSRC device development process outlined in Chapter 4, it was assumed that the in-vehicle devices would not require a significant amount of maintenance during the Model Deployment. It was anticipated that the VADs and ASDs would only need to visit the Test Conductor once every few months to have data downloaded off the device. However, it turned out that the devices encountered many issues after being deployed in the field. The Test Conductor would have had no way of detecting these issues except for the state of health monitoring processes in place. Every VAD and ASD deployed in SPMD was recalled and required a software update at least once during the test period to resolve issues detected in the field.

There were several challenges with the monitoring and recall process. First, there was the inability to quickly detect, assess, or diagnose many of the issues that occurred in the field. This seems to be a combination of the monitoring process as noted above and also the lack of device test functionality as described in *Section 4.2 Developing Device Requirements*. Once an issue was detected, often times this required the device be brought back to the Test Conductor (for in-vehicle devices) or the Test Conductor visit the field to diagnose the problem (for RSUs). In some cases, when a failed device was discovered, the Test Conductor had to physically remove the device. Since both the Test Conductor and the USDOT assumed that the devices would be stable and expected only a small number of failures, a relatively small number of spare units were purchased as back-up units. This was primarily due to the high cost of the spare units. Therefore, the Test Conductor did not have enough spare units to simply change out any devices that were not functioning appropriately with a spare. Sometimes the device had to be removed from the vehicle, diagnosed, and reinstalled at a later date.

The need to recall every device in SPMD negatively impacted the Test Conductor by pulling resources from other activities and increasing overall costs. In addition, it also impacted the participants by requiring them to return to the Test Conductor facilities more frequently for device updates. And finally, when the device was not functioning properly, it was not collecting data for analysis purposes. For example, issues with the state of health and the stability of the RSUs resulted in the loss of over 1 month of BSM data when the log files on the RSUs were full of data and therefore unable to store additional BSMs.

Recommendations

- Develop state of health monitoring requirements and supporting processes for each type of device utilized in the test. Implement remote monitoring and device reset capabilities to reduce the number of devices that need to be physically recalled from the field.

- Develop a plan and process for efficiently recalling devices in the event that numerous updates are required. Clearly communicate to volunteer drivers that they may be contacted to bring in their vehicles at any point during the pilot if problems are detected.
- Analyze the need to purchase spare devices. If the budget allows, procure a sufficient inventory of spares to replace non-functional units as part of the recall process plan. Work with suppliers to determine replacement times to better estimate how many spares would be required.

5.9 Transitioning between Data Collection Phases

As discussed in *Section 3.1 Developing Initial Size Analysis*, the Safety Pilot Model Deployment was divided into two distinct phases for the purpose of collecting data from the integrated light vehicles. Phase 1 covered the first six months of the Model Deployment – from August 2012 through February 2013. Phase 2 covered the last 5 months – from March 2013 through August 2013. There was one month between the two phases of data collection to prepare the light vehicles for redeployment in Phase 2.

Although the Integrated Light Vehicle Developer was responsible for maintaining the fleet, the Test Conductor was responsible for repairing and cleaning the integrated light vehicles prior to their deployment to the Phase 2 drivers. These activities required more time than anticipated due to the large number of vehicles that received damage during Phase 1. Only 25 of the 64 vehicles were listed in good condition after the first phase. One vehicle was damaged beyond repair requiring it to be decommissioned. As a result, 63 integrated light vehicles were available for re-deployment in Phase 2 of the test. Note that the damage to the vehicles was not attributable to the V2V systems installed, instead, the Test Conductor and the USDOT speculated that the participants did not maintain or care for their vehicles in the same way they would their own personal vehicles. For example, rental cars often have more damage than personal vehicles, and this may have been a similar phenomenon.

In addition to repairing and cleaning the vehicles, the one month gap was initially intended to harvest the data from the vehicles and validate the functionality of the systems prior to redeployment. However, following early analysis of the Phase 1 data, it was decided that the month should also be utilized to update the V2V systems. One issue that the analysis revealed was that there were more false alerts generated by the systems than anticipated. Unfortunately, significant updates to the applications between phases were not part of the original experimental plan and therefore there was only enough time to make basic updates based on a high-level analysis of false alerts. Even these basic updates to the application software required some limited verification testing to ensure the V2V systems were properly functioning. The short amount of time between the phases constrained the activities of the Test Conductor and the ILV developer.

Recommendations

- Plan for varying levels of damage and repairs to the vehicles throughout the course of the experiment. Implement a plan and schedule for checking the vehicles for damage to the equipment. Develop risk log and mitigation strategies for damage that may occur to the vehicle.
- If providing vehicles to test participants, develop potential approaches or incentives to discourage and limit damage to the vehicles. Minimizing damages to vehicles will help to

ensure that data collection will remain on schedule in order to support project performance measures.

- In a two phased experiment, it is important to provide sufficient time between the phases to allow for a full refresh of the systems and vehicles. The refresh period should account for software update cycles, device hardware maintenance, and addressing physical damage to the vehicles.

Chapter 6 Data Management

One of the primary objectives of the Safety Pilot Program was to collect data to support the 2013 NHTSA agency decision on light vehicles. In support of this objective, the Independent Evaluator (IE) worked with the Test Conductor to develop the experimental design and define data needs, prepare driver surveys, coordinate data transfer, and share information about data analysis as needed for a successful Model Deployment. The Test Conductor also provided technical support to the IE in processing the field test data and performing quality assurance. These activities were intended to prepare the data for analysis by the Independent Evaluator during the final stage of the Model Deployment – the Post-Model Deployment Evaluation.

Both subjective and objective data were needed to meet the objectives of the independent evaluation. Subjective data was gathered from surveys, interviews and focus group sessions with test subjects. Objective data was collected using in-vehicle data acquisition systems installed on a total of 186 vehicles, including 64 integrated light vehicles, 100 light vehicles equipped with Aftermarket Safety Devices, 16 heavy vehicles with Retrofit Safety Devices, 3 heavy vehicles with Integrated Safety Devices, and 3 transit vehicles with TRPs. The objective data consisted of both video data and numerical data. The numerical data included in-vehicle sensor data, remote sensor and radar data, environmental data, and data from V2V sensory components using DSRC and relative positioning. Since the Test Conductor supplied the data acquisition systems for the ASD, RSD, and TRP vehicles, they were also responsible for harvesting, processing and transferring data from these vehicles to the Independent Evaluator. Similarly the Integrated Light Vehicle Developer supplied the DAS units for the integrated light vehicles and was responsible for harvesting, processing, and transferring data from the ILVs to the IE (see Figure 6 on page 77).

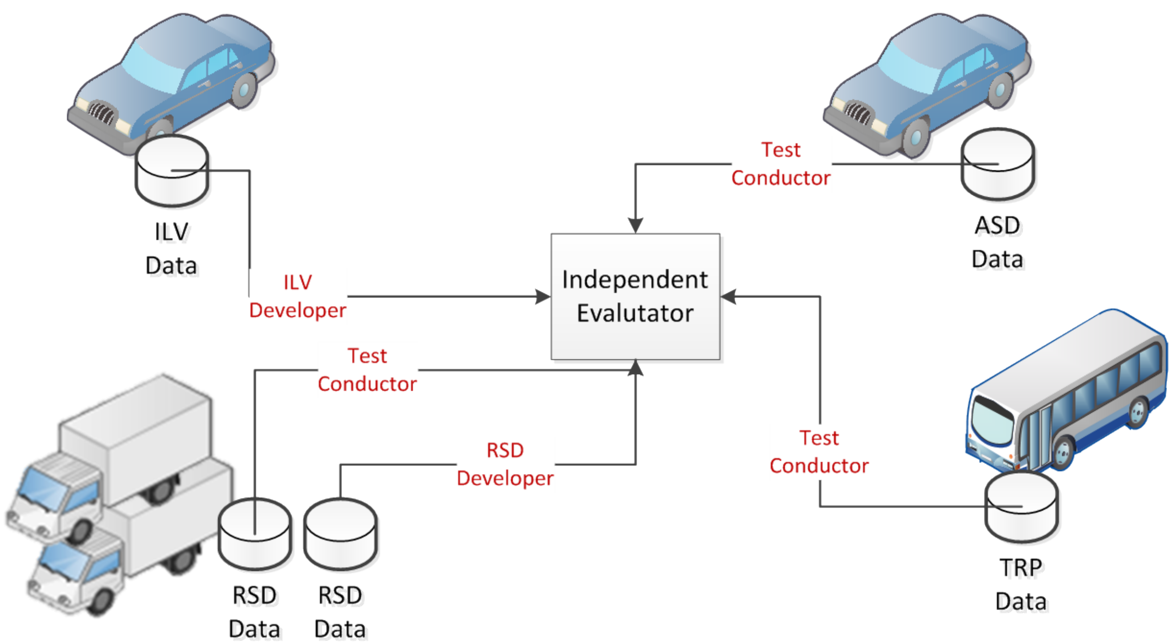
In addition to the data needed for the evaluation, other forms of data were generated by and collected from a variety of sources and systems within the Model Deployment, including BSMs gathered by the RSUs from passing vehicles, signal phase and timing messages transmitted by RSUs, and communication messages with the SCMS. Weather data and traditional traffic data was also collected from previously existing systems in order to understand the context in which the Model Deployment was conducted. The Test Conductor was responsible for collecting all of this additional data characterizing the Model Deployment environment and delivering it to the USDOT and the Independent Evaluator.

This chapter describes the processes that were utilized to define, collect and analyze Safety Pilot Model Deployment data and includes:

- **Section 6.1 Approach to Data Collection** explains the USDOT's rationale for collecting and storing all data generated from the Model Deployment. It highlights the resulting archival and management requirements, as well as several unanticipated benefits from archiving all data.
- **Section 6.2 Defining Data Requirements** discusses the importance of clearly specifying data requirements to ensure that the data collected will meet the research needs. Examples of misinterpretation of the data needs and requirements are discussed.

- **Section 6.3 Developing a Common Data Structure** considers the benefits and challenges of integrating various sets of in-vehicle data collected by proprietary data acquisition systems, which were developed independently by three different contractors.
- **Section 6.4 Harvesting and Transferring Data** outlines the methods that were utilized to transfer large quantities of data from the vehicle or infrastructure, to the organization harvesting the data, and then to the Independent Evaluator.
- **Section 6.5 Ensuring Data Quality** describes the importance of generating and reviewing fully formatted data samples from the various systems before deploying vehicles. This section lists several of the data quality issues encountered after the start of the Model Deployment.
- **Section 6.6 Data Sharing** discusses the concept of making all collected data available to others – including outside researchers, stakeholders, and the public. It highlights the challenges associated with sharing data and the resulting impacts to the project from a device supplier perspective.

Figure 6: IE Relationship to Vehicle DAS/Data Collector



Source: USDOT

Additional information about the identification of data needs, data collection and management, and data transfer and processing from the perspective of the Test Conductor can be found in Section 4 and Section 7 of the *Safety Pilot Model Deployment: Test Conductor Team Report*.

6.1 Approach to Data Collection

Two of the four primary goals[31] of the Safety Pilot Model Deployment focused on the collection and use of data:

- Support the 2013 NHTSA agency decision by obtaining empirical data on user acceptance and system effectiveness
- Demonstrate real-world connected vehicle applications in a data-rich environment
- Establish a real-world operating environment for additional safety, mobility, and environmental applications development
- Archive data for additional research purposes.

With such a wealth of data sources, it was anticipated that the data generated by SPMD could support a wide range of research topics, in addition to supporting the 2013 NHTSA agency decision. However, since the SPMD was the first of its kind deployment of connected vehicles, the USDOT did not know exactly what types of data would be available, what data would be needed to support future research, or even what potential research questions may be developed during or after the Model Deployment. Therefore, the USDOT decided to retain ***all data*** collected during SPMD, rather than only the data needed for the NHTSA decision. This allowed the flexibility to determine at a later date, even after the Model Deployment ended, how best to utilize the data to support identified research areas, as well as preserve the data for potential research not yet identified. Below are several examples of additional research topics:

- Safety application performance and effectiveness;
- Driver acceptance of safety applications;
- Security system performance;
- Viability of aftermarket devices; and
- Signal Phase and Timing message performance.

Using an approach that collected *all* data – as compared to only collecting the data needed to answer the research questions – resulted in archiving and managing an extremely large volume of data. To illustrate, over 60,000 hours of video and 2.3 billion database records were captured from the data acquisition systems alone. This volume of data required additional IT infrastructure and also additional resources from the Test Conductor and USDOT to perform the necessary data management. These data management functions included transferring data, removing redundant data, and storing and archiving data.

There were several unanticipated benefits from archiving all data from the Model Deployment, including allowing additional analyses to be conducted that were not originally envisioned at the start of the SPMD. For example, vehicle OEMs utilized the BSM database to conduct an analysis of false alerts generated by the safety applications and categorize them based on the root cause of the false alert. This analysis utilized the BSMs collected by the RSUs from all the in-vehicle devices, i.e., VADs, ASDs, to determine instances where degradations in performance of in-vehicle devices resulted in the safety applications generating a false alert. Also, the BSM data collected by the RSUs was used by

[31] More information about the overall Safety Pilot Program can be found in the Background section of this report on page 10.

the Test Conductor to monitor the health of the in-vehicle devices, as discussed in *Section 5.8 Monitoring and Recalling Devices.* Finally, the Test Conductor also analyzed the maximum range of in-vehicle device BSMs that were received by RSUs. These three analyses would not have been possible had the USDOT and Test Conductor not decided to retain all the BSM data collected by the RSUs at an early point in the SPMD.

Recommendations

- Assess the data collection approach in terms of types of data and data volumes that will be collected. Develop a plan for collecting and storing the data, including the sizing of IT hardware and data management processes.

6.2 Defining Data Requirements

Detailed data collection requirements were not developed for the in-vehicle data acquisition systems (DAS) installed in the Safety Pilot Model Deployment. These data acquisition systems were well established systems that were successfully utilized in numerous prior field tests, and as a result it was assumed that they would be able to capture all the necessary in-vehicle data required by the Independent Evaluator. Therefore, in lieu of detailed data requirements, the Independent Evaluator provided only general, high-level guidelines for the data collected to support the independent evaluation of the Safety Pilot.

While the guidelines were useful as input to the suppliers of the data acquisition systems, they were not specific enough to ensure that the data collected by the DAS could be analyzed in the manner that was envisioned by the Independent Evaluator. The language used in the guidelines was somewhat ambiguous, leaving the requirements open to interpretation by the developers. For example, the statement “the DAS should collect data surrounding the vehicle” was envisioned to mean “the DAS should have side-facing cameras”, but in hindsight it is clear that such phrases could be interpreted in multiple ways.

As the IE and the DAS suppliers discussed the data collected and the planned analyses, the team agreed that it would have been beneficial to include the intended use of the data as a part of the high-level requirements. Providing the intended use of the data would give the DAS suppliers more information to use in customizing the implementation in the Model Deployment and it would have reduced the risk of a misunderstanding of the data collection needs. As an example, the Independent Evaluator needed a forward radar unit to determine the presence of potential threat vehicles in the path of the host vehicle. The data descriptions in the general guidelines stated that the “range, range rate, and relative location of surrounding objects” was needed and that the radar needed to specify if the target was “in path”. However, what was actually needed was to know if the target is “in-lane”. Because of the Independent Evaluator’s previous extensive experience with automotive grade radar, it was believed that this was implied. However, the radar selected by the supplier did not provide this same level of accuracy, as radar used for research is typically not at the same levels of accuracy as automotive grade radar. If it had been specified that the radar data was needed to determine the location of other vehicles that are an imminent threat to the host vehicles, then the discrepancy may have been avoided. As a result of this discrepancy, the IE had to perform additional analysis on the data in order to determine if the target was “in-lane”. Describing the intended use of the data may be particularly helpful in a research environment where new technical concepts are being explored.

A data collection pilot was not performed during the Safety Pilot Model Deployment, but this is critical for future pilots. As part of the data collection pilot, the data should have been collected, examined, and transferred using a limited number of vehicles, but with the exact technology that would be used during the actual experiment. Data samples were also not collected during the interoperability tests. This meant that the first time data was collected was during the first data harvest.

Recommendations

- Define all data needs and develop a uniform data format up-front. Specify data types, format, and device specifications in the procurement documents.
- Allow the data evaluator to provide detailed data requirements to the data collection entities as a part of the planning process. Consider including “business definitions” or the intended use of the data to reduce the risk of discrepancy in understanding of data needs (e.g. “a way to determine if there is an in-lane, lead vehicle” instead of “forward radar data”).
- Collaborate with and inform stakeholder groups about data and analysis needs and requirements. Create checkpoints for collaboration between the contractor and the evaluator prior to the equipment selection to ensure that the data collected will meet the research needs.
- Conduct a data collection pilot test to validate end-to-end data acquisition, transfer, processing, and quality assessment processes.

6.3 Developing a Common Data Structure

There were three contractors responsible for supplying data acquisition systems that would collect data from various in-vehicle devices. Each of the three contractors developed a proprietary system that utilized a distinct structure of data tables and formats for storing the video and numerical data collected. Since these three systems were developed independently, different design choices were made and different data collection approaches were utilized in the development of these data acquisition systems.

During the Model Deployment, the IE explored the option of integrating all of the data collected by the three systems into a single common data structure. This was considered for three key reasons. First, integrating the data would make it easier to analyze as the analysis and queries could be executed on a single data structure instead of three separate data structures. Second, custom applications (such as data viewers to display video and numerical data on the same screen) developed to interact with the data would only have to be implemented once instead of three different implementations (one for each data structure). Finally, data quality may have been improved because the same data validation checks would be universally applied to all three data sets and they would need to conform to the same validation rules.

After a significant amount of analysis by the IE, it was determined that creating a single data structure to integrate all of the data would be technically challenging for a number of reasons:

- The same conceptual attribute was recorded in different units - for example the brake pressure (decimal) was recorded in one system while the brake indicator (binary) was recorded in another.

- There were a number of attributes collected by one system which did not have equivalent attributes in the other systems. This would have resulted in a sparsely populated final database with a large number of null values in many of the fields.
- The size of the integrated data structure would have been much larger than the three distinct data structures. This would have required additional computational resources to manage.
- Finally, the most compelling reason for keeping the data structures separate was that each DAS developer considered their data structure part of their intellectual property and therefore unique to their system. This means documentation describing each data element in detail was not readily available.

Therefore, the IE determined that in the end, it was more cost effective to keep the data structures distinct and interact with each one separately. This decision did not negatively impact the Safety Pilot Model Deployment as the IE was able to successfully conduct the safety analyses on each of the data sets separately and still meet the delivery schedule established by the USDOT.

Recommendations

- Common-ize as many related data elements across suppliers as is reasonable and practical. This includes data structure, primary keys, units, naming schemes, and formats.
- When strategizing data collection, storage, and merging approach, it is best to think specifics rather than in general, particularly when it comes to how datasets will interface with each other, i.e., synchronization. The cost of integrating disparate data sources should be weighed against the cost of managing and analyzing the data as separate entities, particularly if there are issues with the data structure being considered intellectual property.

6.4 Harvesting and Transferring Data

As discussed in beginning of Chapter 6, data was generated and collected from a variety of devices and systems in the SPMD. The Test Conductor was responsible for harvesting, processing and transferring data from the ASD, RSD, and TRP-equipped vehicles to the Independent Evaluator. Similarly the Integrated Light Vehicle Developer was responsible for harvesting, processing, and transferring data from the ILVs to the IE (see Figure 6 on page 77).

The contractors responsible for harvesting in-vehicle data collected by the data acquisition system utilized two different methods: 1) in-person, manual downloads and 2) over-the-air via cellular communications. In-person, manual downloads were performed by a technician and involved removing the hard drive from the DAS and replacing it with an empty one. This process occurred once a month. The vast majority of the both the numerical and video data collected by the DAS was retrieved in this manner. Limited amounts of numerical data was transferred from the vehicle to the contractor's back office system via an over-the-air cellular modem built into the DAS; however, due to size limitations, this could not be done with the video data captured by the DAS. The primary purpose of transferring some data over-the-air was to provide feedback on the health of the data acquisition system, which is discussed in *Section 5.8 Monitoring and Recalling Devices*. The over-the-air transfer also provided some limited metrics to ensure that the system was properly recording data, for example, metrics such as the number of safety alerts generated by each application and the number of communication events with other in-vehicle DSRC devices.

To accommodate the DAS data retrieval process, drivers of vehicles equipped with data acquisition systems were required to schedule monthly appointments to bring their vehicle to the Test Conductor facilities for the data download process. Scheduling and interfacing with the participants required additional resources on the part of the Test Conductor; however, an added benefit was that the Test Conductor and device developers could access the vehicles to check for damage and also make any necessary software or hardware updates to the DSRC devices while the data download process was occurring. Visually inspecting the vehicles and devices for damage was an important part of the Model Deployment as this type of damage could not be detected through remote diagnostics. The Test Conductor was able to inspect the devices for damage, for example, some ASDs suffered from water damage from leaks in participant's vehicles and required replacement. There were also several ILVs that had extensive amounts of physical damage which needed to be repaired. The physical vehicle damage and impacts to the project are discussed in *Section 5.9 Transitioning between Data Collection Phases.*

Finally, one of the contractors responsible for data collection did experiment with over-the-air downloading for all data, including video. The early tests of this capability were promising; however, since this was new functionality, it was not able to be fully tested prior to Model Deployment. Due to data loss concerns and other unintended impacts, this capability was not utilized.

In addition to the in-vehicle data collected by the DAS units, the RSUs also collected a large amount of data by storing every BSM and SPaT message that was transmitted within listening range. These messages were stored in the internal memory of the RSU until they were transferred to a back office system via the City of Ann Arbor's fiber optic backhaul network. This data transfer process occurred at least once a month. At one point during the Model Deployment, the back office system that received this data had to be taken off-line to remediate some issues. This impacted the RSUs because they eventually ran out of memory to store the SPaT and BSMs received and therefore stopped collecting data. Until the connection to the back office was restored, the data had to be manually downloaded from the RSU by physically connecting a laptop to retrieve the stored data. This was challenging since the RSUs were mounted approximately 25 feet off the ground and over public roads. Ensuring a functional back office connection to the RSUs is a critical requirement to ensure that no data is lost.

Recommendations

- Explore methods for implementing over-the-air downloads of data to minimize impacts on resources and participants. This may need to be balanced with needing to physically interact with the vehicles to ensure state of health of the vehicle and equipment.
- Ensure RSUs have an adequate connection to a back office system if being used to collect and transfer DSRC messages received from vehicles. Consider processes for parsing redundant data to reduce storage requirements.

6.5 Ensuring Data Quality

Due to the accelerated schedule for the launch of Model Deployment, the Test Conductor and DAS suppliers were not able to generate fully formatted data samples from their data acquisition systems prior to the start of SPMD. The DAS units were being installed and software was being updated very close to the launch of the Model Deployment; therefore, fully formatted data samples, i.e., data identical in structure to that captured in the Model Deployment, were not able to be produced in time for review, testing,and evaluation during the Pre-Model Deployment Dry Run prior to launch. As a result, there were a number of data quality issues identified after the start of Model Deployment, including the following specific examples:

- Numerical data was intended to be captured every 10^{th} of a second; however, there were numerous instances where records were missing from the database
- Vehicle speed was recorded as impossibly high numbers (e.g. 175 mph)
- Units of certain database fields were incorrect (e.g. meters / second instead of miles per hour)
- Many trips had to be flagged as invalid because another different driver was driving the vehicle than the one in the study
- There was a delay in the synchronization of the video and numerical data by about 1.5 seconds due to a lag in the recording of the numerical data by the DAS

Some of the data quality issues were caused by simple errors in the code, while others were caused by complex interactions between the DAS and the in-vehicle systems transmitting the data. The issues were typically identified when the DAS suppliers and Independent Evaluator were conducting analyses of the safety applications and they identified data quality issues that led to erroneous results. Some of these issues may have been detected during the Pre-Model Deployment Dry Run Testing if the schedule would have allowed for a full and complete test of all devices and processes. All of these data quality issues had to be addressed in the post-processing of the data before the data analysis could be completed, otherwise these issues could have had significant impacts on the final analysis results. A few issues presented major challenges that required the entire set of Model Deployment data (for one vehicle/device type) to be re-processed in order to remediate the issue.

In addition to executing automated quality control checks, more frequent interactions between the recipient of the data and the generator of the data would have been helpful to detect issues and inconsistencies in a timely manner. For example, the Independent Evaluator noted that they were not always observing that the brake pedal was suppressing the Forward Collision Warning (FCW) alerts. There was discussion about if this was the design intent or if there was another potential explanation, however, the issue was not pursued further since it was unclear at that moment what was causing the issue. In hindsight, it was being caused by the synchronization delay issue noted above. If there was more discussion between the Independent Evaluator and DAS suppliers on a more regular basis, this error may have been discovered earlier. This should not be considered a substitution for thorough quality assurance checks, but even with very good quality assurance, unexpected issues always arise, particularly in a research environment. Having a more open and accessible method of sharing information would have benefited both the IE and the DAS suppliers.

These data quality issues impacted the project primarily by requiring additional resources from the various teams to develop procedures to remedy the issues and by delaying the delivery of the data to Independent Evaluator for analysis. The delays in the delivery of the data to the Independent Evaluator constrained the analysis schedule and delayed the delivery of the final results of the analysis to the USDOT.

Recommendations

- Examine fully populated data samples prior to launch of a field test to ensure that the data and formats provided are compatible with the analysis approach. Allow adequate time for review of the samples and for any changes that may be required to the devices if data formats are not as anticipated.

- Define the timing of the data quality checks and the specific checks to be conducted as a part of the data requirements and specifications using data issues from previous field tests as a baseline.
- Implement automated system of checks on the data in near-real time to identify and flag data quality issues.
- Data vendors should keep an operational, identical copy of the evaluation database for quality assessment purposes.

6.6 Data Sharing

From the start of the SPMD, the USDOT planned to make data collected and archived from the Model Deployment available to other researchers, both within the USDOT and outside organizations, to enable those researchers to conduct other analyses. It was also anticipated that data would be shared publically via the Research Data Exchange.[32] The USDOT intended to share, at a minimum, the BSMs that were collected as a part of the Model Deployment; however, this was challenging because BSM data included trip origins and destinations, along with a unique ID for each participant. This is considered personally identifiable information (PII) and is protected from release to the public by a federal law. As a result, the *raw* BSM data could not be immediately shared with suppliers, the public or other stakeholders that were not approved by the Institutional Review Board to have access to PII data as a part of the SPMD.

To be able to share the Safety Pilot BSM data set with the research community, the USDOT needed to develop a de-identification process to remove individual BSMs that could be used to identify the driver or the vehicle. The development of this de-identification process was challenging because it was not simple to specify exactly which BSMs (e.g. near work, near home, commonly visited places, etc.) could be used to identify the driver or the vehicle and should be removed from the data set. Therefore, the USDOT conducted research to develop a de-identification process which identified the BSMs to remove from the data set. The development of this de-identification process required a significant amount of time and resources on the part of the USDOT and its contractors, which delayed the public release of one day of BSM data until early in calendar year 2014, approximately 6 months after the conclusion of the Model Deployment.

Not having immediate access to the raw data and having to wait several months for the sanitized data had the greatest impact on device suppliers. As discussed in *Section 5.8 Monitoring and Recalling Devices,* it was not anticipated that so many devices would require software updates after being deployed. As issues began to appear unexpectedly in the field, some suppliers requested raw BSM data from the Test Conductor to support the analysis and debugging of the issues identified with certain in-vehicle devices. However, the Test Conductor could not provide complete BSM data back to the device suppliers for the same reason it could not be released to the public. Suppliers were trying to find solutions to these issues as quickly as possible to support software refreshes, but some situations encountered in the field cannot be easily replicated on a bench. For example, one particular supplier's device stopped working entirely (i.e. crashed) when another supplier's device would

[32] https://www.its-rde.net/showds?dataEnvironmentNumber=10014

incorrectly transmit data values in the BSMs, and this would only happen in a certain geographic locations in the Model Deployment or in proximity to other devices. This issue could not be replicated on the bench due to the unique characteristic of the Model Deployment environment; however, the use of actual field data may have been useful in the process of resolving the issue.

Recommendations

- Identify all of the potential privacy issues at the beginning of the project and develop plans to address them early in the project if the intent is to release data to the public in a timely manner.
- Develop a plan and process for distributing supplier data back to the supplier for analysis and problem identification.

APPENDIX A. Summary of Recommendations

Report Section	Recommendations
Section 1.1 Defining Scope and Prioritizing Critical Activities discusses the importance of prioritizing the critical activities that are necessary to support the primary objectives of the research program.	• Utilize a modular project structure to reduce non-critical component impacts to launch. Prioritize the program's objectives and link them to specific tasks and activities within the project. During the planning phase, identify the level of effort required and resource requirements for each task to ensure adequate resources are available to accomplish the established objectives. • For each modular project element, conduct a needs analysis and involve any stakeholder during the initial planning stages, even those who may be initially deemed low probability of participating. • If new project elements are considered, carefully assess and weigh the impacts to primary objectives, while maintaining objectives and integrity of the research of the new element. • Ensure that all contractors are aware of the prioritized objectives and the relationships of the critical supporting tasks and activity dependencies during the planning phase.
Section 1.2 Identifying Schedule of Deliverables discusses the importance of scheduling deliverables to align with the project critical path and with key project activities. It highlights the dangers of front-loading deliverables early in the project, resulting in constrained resources and compromised quality of key deliverables.	• Identify all project deliverables at the start of the project and prioritize which are critical for the success of the project. Directly link deliverables to specific activities or milestones to ensure that multiple revisions of deliverables are not required. Ensure that due dates for contracted deliverables are not heavily front-loaded unless necessary to execute the work. • Develop an initial 'at a glance' project checklist to quickly assess deliverable dates and progress for high-level project check-ins. • Analyze the non-critical deliverables to determine the appropriate delivery schedule based on related activities and potential resource constraints.

Report Section	Recommendations
Section 1.3 Developing Practical Project Management Tools highlights the critical nature of requiring a consistent level of detail in project schedules and work plans for all contractors and tasks in order to efficiently monitor the project.	• Provide clear direction in the contracts and cooperative agreements in regards to the project management expectations. Require consistent level of detail of the project management deliverables from each contractor participating in the program. All project management plans should contain at least 3 levels of a work breakdown structure. • Develop a master project management plan (PMP) immediately after the program planning stage to facilitate detailed planning at a sufficient work breakdown structure (WBS) level of detail. Maintain plan, track linages, critical paths, and contingencies throughout. This is particularly crucial if there is inflexibility with key milestone dates or project end dates. • Define the requirements for internal program management tools early in the overall program development. Be prepared to modify the requirements, if necessary, to meet changing management and reporting needs. Develop a plan in advance for modifying and implementing changes to the program management tools. • Develop, maintain, and monitor a "Readiness Checklist" to ensure that all critical tasks are completed prior to pilot launch. Include all critical tasks and required completion timing for each task as part of the checklist. • Repeat the good practice of tracking and monitoring risks. Develop and maintain a risk management plan during the planning phase. Identify critical risks that could have severe impacts on the project. Develop a serious of risk response plans with triggers and responses for each identified risk. • Develop a System Engineering Plan (SEMP) early in the project and follow it throughout the program. Include critical gate reviews for all devices and systems.
Section 1.4 Developing GFE Management Plans outlines potential issues associated with procuring and transferring major Government Furnished Equipment (GFE), specifically focused on vehicle purchases.	• If providing vehicles or other major equipment as GFE under a contract, develop a plan describing how the GFE will be acquired, transferred, managed, and deployed over the course of the project. • When procuring high-value equipment through the federal acquisition process, be aware that non-standard options and foreign made equipment can significantly impact the procurement and delivery schedule. If the schedule is constrained, investigate alternative means of specifying or acquiring the necessary equipment.

Report Section	Recommendations
Section 1.5 Utilizing Quantitative Performance Measures explains the importance of developing, utilizing, and tracking performance measures, and developing and implementing response plans if performance falls below target levels, to ensure that overall objectives of the project are met. This section includes several examples of performance measures developed and monitored for the SPMD.	• Develop quantitative measures of performance and incorporate them into the Statement of Work and other procurement materials to ensure the contractor understands how their performance will be measured. If the performance measures are not known at the time of writing the SOW, indicate that they will be developed after award of the procurement and utilized throughout the contract. An alternative approach could be to allow the contractor to propose performance measures as part of their proposal. • Limit the measures developed and tracked to those that are directly linked to the program objectives, otherwise resources will be spent on measuring information that may not be critical to the program's success. • Indicate in the Statement of Work that potential corrective responses will be jointly developed for use in the event that the measures of performance are below the established targets.
Section 1.6 Preparing for Project Closeout describes the provisions for inventorying and decommissioning equipment (including plans for removal and decommissioning in-place) used in the SPMD.	• Develop decommissioning plans that include the disposition of all government purchased equipment well in advance of when the contractors will need to initiate those plans. Be aware of any acquisition cost thresholds on equipment that could determine ownership following the end of the project. • Develop transition and sustainability plans for converting a test environment into a live deployment. Identify roles, responsibilities, and funding sources for continuing to operate and maintain the environment. Ensure that updates can be made to any contracts to keep the environment intact if so warranted.
Section 1.7 Developing a Communications Plan discusses the critical nature of establishing communication guidelines to coordinate interrelated activities between teams. This is particularly important for projects that involve a multi-modal effort with a large number of contracts and cooperative agreements, each responsible for various components of the project.	• With closely related contracts, utilize a single contracting officer's representative (COR) or ensure close communications between CORs in order to coordinate the interrelated activities across the contracts. Note that as more distinct contracts are added to a program, more overhead is required to manage and coordinate. • Develop a communication management plan that identifies guidelines and establishes a structure for managing overall project communications, including meeting schedules, email communications protocols, and main points of contact. • Identify a process for addressing inquiries into business sensitive information as a part of the guidelines of the communication plan. For example, contractors should notify their USDOT COR if business sensitive information is being requested and the request can be evaluated. • Adopt a formal mechanism to ensure that key practices and specific lessons learned are captured and implemented in future projects or future phases of the existing project.

Report Section	Recommendations
Section 1.8 Identifying Cooperative Tasks focuses on the level of coordination and communication required at the technical, day-to-day level.	• Clearly define in writing the USDOT requirements and contractor responsibilities for all collaborative activities that involve multiple parties. • Identify all key events, such as milestones and deliverables, which may require an increased level of communications between various contractors leading up to that event. • Plan and conduct in-person working meetings leading up to all key events as a way to coordinate activities and quickly resolve any issues. Ensure that all the key project stakeholders are involved in the meetings to ensure real-time decision-making.
Section 1.9 Sharing Program Documentation highlights the magnitude of documentation produced, reviewed, and approved by a project of this size, as well as the importance of sharing results and documentation with other teams in an expedient manner. It identifies the resource intensive nature of multiple reviews and challenges with managing this level of documentation.	• Develop an accessible, easy-to-use and complete document repository that USDOT staff can use to support the management of the program. Processes for effectively managing document version control should be implemented. Include resources to ensure the repository is maintained throughout the project and can be used for future use or analysis. • Utilize technical project briefings and coordination meetings to share information across contracts and agreements with the technical staff involved in the project in a consolidated format. • Develop a matrix to assign reviews of specific topics to specific program managers so that the results and information can be filtered and distributed to the appropriate staff. This will help to prevent everyone having to review every document produced by a project.

Report Section	Recommendations
Section 2.1 Developing One Message outlines the approach for providing a consistent message regarding the promotion of Safety Pilot. It discusses the importance of establishing roles, responsibilities, and processes for handling media requests, as well as establishing guidelines for potentially sensitive information.	• Contractually stipulate level of effort and focus of outreach. Determine what role and responsibilities the USDOT and contractors will have when working with the media and incorporate appropriate language into the contracting agreements. Ensure that the balance between outreach to industry, local media, and national media is understood, and that each participant's responsibilities and limitations are well understood by all participants. • Develop a key message that is agreed upon by all parties at onset of project and establish clear guidelines on what information can be shared with various stakeholders and the public. Identify sensitive policy and program topics in advance. • Develop a full complement of materials in advance of the pilot launch, such as talking points, project presentations, FAQs, press kits, and fact sheets. This will help to establish and maintain one consistent message. • Define a process for handling, tracking, and documenting media requests. Ensure that it is agreed upon by all team members. Designate points of contact to serve as media liaisons. • Consider hiring a public relations agency to work directly with the USDOT under its own contractual vehicle to dedicate efforts towards proactive involvement, such as monitoring media coverage, developing responses to media inquiries, anticipating media needs, and developing creative content with sensitive information. • Provide guidance to study participants regarding their interactions with the media, particularly if communications regarding the program are sensitive.
Section 2.2 Conducting Outreach and Engaging Stakeholders describes the importance of developing an outreach plan and highlights components of a successful effort. Several cautions such as resource constraints and sustaining a media presence through the project are discussed.	• Ensure that all key stakeholders are actively addressed in outreach activities. Develop a focused outreach plan that identifies all stakeholders, the message appropriate for each stakeholder and the method in which you will reach the stakeholders. Review the plan with the project team and obtain buy-in on the levels of outreach needed for each stakeholder. Periodically review the plan to ensure that the types and levels of outreach selected for each stakeholder are appropriate. • Include a well-organized, high-profile launch event, and dedicate sufficient resources to this effort. Be prepared to maintain momentum throughout the project by establishing a plan to use a variety of tools to support the interests and needs of various stakeholders and audiences. After the prominent launch event, be sure to follow-up with other high visibility elements, to increase recognition of ongoing activities. • Implement performance measures to gage the impacts of particular outreach strategies. In cases where resources are constrained, evaluation tools could determine what types of media are most effective for reaching the target audience.

Report Section	Recommendations
Section 2.3 Showcasing the Environment summarizes the various showcase activities carried out by the Test Conductor, including development of showcase facilities at the University of Michigan and conducting demonstrations of connected vehicle applications in real-world conditions.	• For maximum effectiveness, ensure that any showcase is interactive and includes a prominent field demonstration component. These elements should be in place early in the deployment for stakeholders to be able to experience the environment soon after launch. This could include a closed course demonstration or outfitting a vehicle for on-road demonstrations through the environment. • Develop incentives and events to draw the industry decision makers and leaders to the deployment site to observe the technology in live operations. • Establish a team dedicated to coordinating and conducting tours and demonstrations of the test site and facilities. Institute a liaison between the technical team and the outreach team to better support group visits and demonstrations.
Section 3.1 Developing Initial Size Analysis outlines the analysis used to initially size the experiment, in terms of duration, number of test subjects, and number of equipped vehicles required. This information established the minimum requirements included in the Request for Proposal (RFP).	• Conduct an analysis using prior field test data to properly scope the size of a new test to meet the data collection and evaluation objectives. Do this early in the planning process as test size can have major impacts on scope and budget, and can be difficult to modify once the experiment has started. • After establishing the minimum values required to meet established data collection and evaluation objectives, consider adding more vehicles or devices to act as 'spares' to ensure that the minimum number of devices required will be operational during the entire test.
Section 3.2 Selecting the Geographic Area describes the approach to defining the geographic area of the Model Deployment, including factors such as traffic patterns and traffic volumes, and crash data used to identify roadways that could potentially produce a sufficient number of interactions and conflict situations between equipped vehicles. It also discusses identifying intersections and roadways to support installation of various infrastructure components for data collection and testing exercises.	• Be prepared to conduct an iterative process to select the test site. Analyze the characteristics of the test area, i.e., historical crash and traffic volume data, against the performance requirements of the test. Ensure that the test site characteristics match the needs of all aspects of the pilot, particularly if involving commercial vehicles or transit. These vehicle types may be constrained by geographic area, operations and scheduling, or commercial and union restrictions. • Closely coordinate the test area selection process with the driver recruitment strategy to ensure that selected participants will be driving primarily in the test area. This approach is likely to produce better results when examining interactions between equipped vehicles and interactions between equipped vehicles and infrastructure.

Report Section	Recommendations
Section 3.3 Estimating Number of V2V Interactions explains how a traffic simulation model was used to validate that the selected site would produce the amount of data needed for evaluation. It also highlights the importance of 1) developing performance targets for measuring progress towards project goals and 2) risk response plans in the case that targets are not met throughout the project.	• Follow-up the size and scoping analysis used to select the initial test area with a more detailed traffic simulation analysis of the selected site. Use the traffic simulation analysis to develop estimates of the volume of data that will be generated. This will help confirm prior to the start of the experiment that the selected site will provide sufficient data to meet the project objectives. • Develop quantitative performance measures with intermediate targets for the environment that can be utilized throughout the test to evaluate progress and success towards project goals. • Develop risk response plans in the case that intermediate performance targets are not being met. Determine trigger points to determine when each response plan should be executed.
Section 3.4 Requirements for Light Vehicle Drivers provides a summary of minimum requirements that needed to be met in order to qualify to drive an integrated vehicle or to have a device installed in a personal vehicle as part of the SPMD.	• When identifying volunteer drivers, utilize metrics that focus on the volume of trips or time spent within the test area boundaries. Using metrics that focus exclusively on the total number of miles driven may not always be representative of the amount of time a driver spends within the test area. It may also be difficult to identify particular drivers within certain age or gender groups if there is a minimum miles driven requirement.
Section 3.5 Recruiting and Selecting Light Vehicle Drivers outlines the recruitment approach for obtaining and selecting over 2,500 volunteer drivers for VADs, ASDs, and ILVs. It describes the change in approach between Phase 1 and Phase 2 for selecting the ILV drivers, in an effort to increase interactions with other V2V equipped vehicles.	• Replicate the community-based driver recruitment strategy used in the SPMD. Understand what motivational factors are important to the community (e.g., education, jobs, safety) and incorporate these factors in the recruitment process. Utilize in-person recruitment activities whenever possible. • Recruit participants iteratively to align with the planned device deployment schedule. This will reduce significant delays between recruitment and initial contact. Lags between recruitment and participation could cause participants to reconsider their willingness to participate for a variety of reasons or volunteers could move away from the test area making them non-viable candidates. • When selecting and prioritizing volunteer drivers from the recruitment pool, utilize actual driving data (i.e. GPS, surveys) over self-reported driving data, if possible. SPMD demonstrated that there was a significant advantage to using the BSM data logged from VADs to identify participants for future phases.
Section 3.6 Selecting Heavy Vehicle Fleets discusses the importance of coordinating the site selection with development of specifications for heavy vehicles and commercial fleets.	• Prior to procurement of specific types of vehicles, it is important to take into account the geographic area where these vehicles will be operated. There may be constraints that impact the types or configuration of the vehicles purchased, particularly in smaller cities. • When conducting naturalistic testing with heavy vehicles, ensure that contingency plans are in place in the event that an insufficient amount of data is being generated. This is especially important with a small sample size and when the geographic area limits the exposure of the heavy vehicles to other V2V equipped vehicles.

Report Section	Recommendations
Section 3.7 Managing Transit Vehicle Drivers highlights the challenges encountered with incorporating transit vehicles into the pilot site. This includes operations of a transit agency and taking into account driver schedules, routes, designated bus stops, and driver training.	• Deploying transit-specific safety applications requires a careful analysis of the operations of the target transit agency (i.e. routes, bus stops, drivers) to ensure the vehicles will be exposed to the target populations addressed by the safety applications. • Driver training and exposure to the safety applications are significantly impacted by the transit agency driver characteristics, and they should be planned for in all aspects of the program, especially the evaluation.
Section 4.1 Engaging the Development Community outlines how the USDOT used contracting and communication mechanisms to encourage participation by the device developers in the Product Development Phase and mature the industry in an effort to produce sufficient numbers of devices for the Model Deployment.	• Assess the level of industry knowledge and experience in the development of research devices to determine if industry is capable of producing the number of devices required for the pilot and the timeframe by which these devices will be ready. Consider various procurement or partnering approaches to encourage increased participation by numerous device developers to ensure that an adequate number of devices will be available. • Determine the most efficient and effective activities, i.e., conference calls, workshops, working meetings, "plug fests", to engage the device community and increase industry knowledge to ensure a common understanding and interoperability of devices, applications, and infrastructure to support project objectives.
Section 4.2 Developing Device Requirements describes the process for generating the final device requirements used for qualification testing in the rQPL Phase.	• Device requirements may need to be tailored on a project by project basis depending on the intended use of the devices and current device maturity level. Clearly communicate requirements to device developers and incorporate the appropriate functionality for less mature devices, such as test capabilities and functions to monitor device up-time. • Utilize an iterative process for developing device requirements that incorporates cycles of industry input and device testing. Complete the requirement generation and QPLs prior to all device and system use. If it is anticipated that the requirements will be updated after testing based on field deployment, incorporate enough time in the schedule to procure updated components and retest.
Section 4.3 Executing Qualification Testing outlines the qualification testing process used in the rQPL Phase to determine if a device was compliant with the final requirements.	• Institutionalize and formalize all testing procedures for the QPL. Provide clear and unambiguous qualification test procedures, with pass/fail criteria, as part of the test plan. • Provide testing specifications covering the performance of all components, to allow common understanding and expectation, and allow sufficient time for iteration. • Develop application tests that are specific to the type of technology being deployed, and place additional emphasis on false positive scenarios.

Report Section	Recommendations
Section 4.4 Generating the Research Qualified Products Lists describes the collaborative processes utilized by the USDOT and the Test Conductor to generate rQPLs for VADs, ASDs, and RSUs.	• Developing QPLs are a necessary step in developing research products that can withstand deployment in a lengthy field test. Complete all supplier evaluations prior to launch, even if the devices are not needed on day one of the deployment. • Even with a QPL process, it may be necessary to plan for additional resources to provide troubleshooting and general device support throughout the test period. During the SPMD, delays encountered due to maturity and readiness of the devices resulted in the Test Conductor taking on more development and support activities, which constrained resources. • Evaluate impacts of procuring devices from various vendors included on the QPL. Balance the cost of increased procurement complexity of having more device types with the cost of possible schedule impacts due to possible device production delays. Consider the impacts of having to conduct interoperability testing between large numbers of devices and schedule implications for any needed hardware or software updates.
Section 5.1 Interoperability Testing describes the process used to verify the ability of the vehicle-based and infrastructure-based devices produced by various suppliers to exchange, decode, log, and/or forward DSRC messages.	• Specify interoperability testing requirements as part of the device requirements. Utilize automated tools to perform basic data comparisons between devices in order to more efficiently conduct the testing and test a wider variety of cases. • Define and document requirements and steps for all interoperability testing participants and data users prior to starting multiple rounds of testing, feedback, reset, and retest. • Incorporate sufficient time in the schedule for multiple rounds of testing. If all devices are not available for testing at the same time, utilize multiple stages of testing as new devices and updates to previously tested devices become available. • Establish agreements between vendors that all results and data will be shared between vendors that experience interoperability issues to ensure that a solution is achieved in an efficient timeframe. • Utilize plug testing and implement multiple rounds of face-to-face interoperability testing. This will help to identify issues in the lab before the devices are deployed in the field.

Report Section	Recommendations
Section 5.2 Pre-Model Deployment Dry Run outlines the process used to verify installation, operation and interoperability of all hardware and software components needed for the SPMD. It highlights the importance of proper scheduling and resource management to implement multiple rounds of testing and updates.	• Implement a full dry run that includes all installation, operation and interoperability requirements for all devices, infrastructure, and systems. Incorporate sufficient time into the schedule to ensure that all devices and systems are in a stable state prior to implementing a full dry run. • Ensure that in-depth system testing requirements, updates, and retest cycles are well-understood, and are appropriately resourced in time and budget. Plan for several iterations of component, subsystem, and total pilot system testing within the dry run. Depending on the number of system components (devices, infrastructure, data collection and backhaul connections, security implementation, etc), this could take several weeks to several months. • Include sufficient time between Pre-Model Deployment and the actual Model Deployment to refresh the software, procure updated parts, and conduct re-testing after the updates. During the SPMD, one month proved to be insufficient to make any major changes in the devices. • Be prepared to encounter field issues that were not discovered during the qualification testing, interoperability testing, and dry run testing.
Section 5.3 In-Vehicle Installation Requirements reports on the requirements identified in the statement of work and by the Test Conductor for installing VADs and ASDs in various vehicle types.	• If installing aftermarket equipment in privately owned vehicles, conduct an assessment to determine how various installation requirements could impact participant recruitment, data collection, device performance and other factors to better understand project impacts. Use this information to develop and customize the device installation requirements to meet the project objectives. • Consider that the installation configuration required to generate optimal device performance, for example antenna location, may not be feasible given the installation constraints dictated by the project, i.e., no permanent modifications to a vehicle. • Before selecting vehicle types, ensure that agreements between the Test Conductor and the vehicle OEMs can be obtained if connecting to the vehicle Controller Area Network (CAN) bus for data collection purposes. The data passed over the CAN bus and the rights to collect such data is considered proprietary by the OEMs.

Report Section	Recommendations
Section 5.4 Installing In-Vehicle Devices outlines the development of standardized installation procedures, the check-out procedure used to verify the functionality of the devices, and schedule requirements for individual device installs.	• Consider limiting the number of vehicle makes and models to reduce the number of device installation plans required. Develop an installation plan (including device mounting) for each vehicle type and evaluate all designs for any potential common elements. Even with different makes and models this could reduce the number of unique designs required. • Include performance testing as part of the installation verification test procedure to determine if the installation is operating as intended. Ensure access to a dedicated test facility for “end-of-line” performance and functionality tests for either all installations or a representative sample. • Establish an online scheduling tool for participants to self-schedule their device installations. This will reduce the amount of time required to manually schedule participants and will also help balance workload for installers. Consider providing installation times during evening hours or on weekends.
Section 5.5 Infrastructure Installation Requirements provides general descriptions of the selected RSU locations and outlines the site configuration and installation requirements for infrastructure devices.	• Investigate requirements or restrictions implemented by the local or state road authority for installing roadside equipment. This is particularly important if RSUs will be mounted on existing traffic signal infrastructure, as this may limit the site selection. • Available space in a traffic signal cabinet is typically at a premium. Prior to site selection, work with the state and local agencies to determine if it is feasible to place additional equipment in the cabinet or if additional roadside infrastructure is needed. • Consider deploying RSUs at sites that have existing ITS installations to utilize existing power and backhaul connections. Ensure that a robust fiber optic network using IPv6 is in place to connect the RSUs to the back office facilities if collecting and transferring data. This will minimize costs and schedule impacts for new conduit installations. • Look for opportunities to develop robust traffic signal communications networks, upgrade signal controllers with Ethernet connectivity and incorporate provisions for conduit and fiber-optic installation as part of new roadway projects. This will ensure that the infrastructure is in place for future RSU expansions.

Report Section	Recommendations
Section 5.6 Installing Infrastructure Devices outlines the three primary components of the infrastructure installations: set-up and testing of the backhaul and back office server systems; RSU installations; and traffic signal controller replacement. It describes challenges encountered during installation of RSUs, including network and IPv6 availability, data collection and redundancy, and back office needs.	• Establish strong partnerships with state and local agencies responsible for the operations and maintenance of roadways and related equipment. Implementing new technologies will require additional resources for attaining technical competency for the installation and maintenance of equipment. • Consider hiring an engineering firm to coordinate all installation requirements and implementations between various transportation entities, infrastructure suppliers and the Test Conductor. This will alleviate any one organization having to take on additional responsibilities, further constraining limited resources. • As part of the infrastructure installation plan, identify if RSU will collect data, how this data will potentially be used, e.g., how could BSMs be used for operations applications, asset management, etc., and how this impacts site selection. Develop a strategy for dealing with the potential duplication of RSU logged data. If offloading and storing data, consider alternatives to purchasing large volumes of IT hardware, e.g., cloud services. • Conduct testing prior to infrastructure installation through the use of staging sites. After initial installations are complete, utilize the staging site to test firmware updates implemented by the device manufacturers to address any issues later identified in the field. Testing at the staging sites will help ensure that updates are ready to be rolled out prior to installing on all infrastructure.
Section 5.7 Configuration and Property Management Systems reviews the systems implemented for enabling equipment and software refreshes, and for enabling follow-on data analysis after the deployment was completed. These systems were also used as part of the state of health monitoring systems.	• Establish a robust property management and configuration management system prior to starting installation of devices. Ensure that asset and configuration management, control, and auditing of all devices and project equipment is conducted throughout the pilot. This is critical for a large number of deployed devices. • Within the property and configuration management systems, automate as many entry functions as possible. This will minimize the amount of manual input into the system and reduce entry errors. Implement a quality control process to verify that the information input manually is error free. • Ensure the property and configuration management systems are linked in such a way to support detailed evaluation and analysis of potential impacts of various software versions and installation configurations on the overall system performance.

Report Section	Recommendations
Section 5.8 Monitoring and Recalling Devices discusses the methods employed by the Test Conductor to monitor the health of the in-vehicle and infrastructure devices. It highlights the challenges with having to recall a large number of devices, including Test Conductor resource constraints, loss of data due to non-functioning devices, and inconvenience to the participants.	• Develop state of health monitoring requirements and supporting processes for each type of device utilized in the test. Implement remote monitoring and device reset capabilities to reduce the number of devices that need to be physically recalled from the field. • Develop a plan and process for efficiently recalling devices in the event that numerous updates are required. Clearly communicate to volunteer drivers that they may be contacted to bring in their vehicles at any point during the pilot if problems are detected. • Analyze the need to purchase spare devices. If the budget allows, procure a sufficient inventory of spares to replace non-functional units as part of the recall process plan. Work with suppliers to determine replacement times to better estimate how many spares would be required.
Section 5.9 Transitioning between Data Collection Phases highlights key elements to include in the schedule between data collection periods, such as repairing and cleaning vehicles; harvesting data; validating functionality and performing maintenance on the devices and systems; and updating device software.	• Plan for varying levels of damage and repairs to the vehicles throughout the course of the experiment. Implement a plan and schedule for checking the vehicles for damage to the equipment. Develop risk log and mitigation strategies for damage that may occur to the vehicle. • If providing vehicles to test participants, develop potential approaches or incentives to discourage and limit damage to the vehicles. Minimizing damages to vehicles will help to ensure that data collection will remain on schedule in order to support project performance measures. • In a two phased experiment, it is important to provide sufficient time between the phases to allow for a full refresh of the systems and vehicles. The refresh period should account for software update cycles, device hardware maintenance, and addressing physical damage to the vehicles.
Section 6.1 Approach to Data Collection explains the USDOT's rationale for collecting and storing all data generated from the Model Deployment. It highlights the resulting archival and management requirements, as well as several unanticipated benefits from archiving all data.	• Assess the data collection approach in terms of types of data and data volumes that will be collected. Develop a plan for collecting and storing the data, including the sizing of IT hardware and data management processes.

Report Section	Recommendations
Section 6.2 Defining Data Requirements discusses the importance of clearly specifying data requirements to ensure that the data collected will meet the research needs. Examples of misinterpretation of the data needs and requirements are discussed.	• Define all data needs and develop a uniform data format up-front. Specify data types, format, and device specifications in the procurement documents. • Allow the data evaluator to provide detailed data requirements to the data collection entities as a part of the planning process. Consider including “business definitions” or the intended use of the data to reduce the risk of discrepancy in understanding of data needs (e.g. “a way to determine if there is an in-lane, lead vehicle” instead of “forward radar data”). • Collaborate with and inform stakeholder groups about data and analysis needs and requirements. Create checkpoints for collaboration between the contractor and the evaluator prior to the equipment selection to ensure that the data collected will meet the research needs. • Conduct a data collection pilot test to validate end-to-end data acquisition, transfer, processing, and quality assessment processes.
Section 6.3 Developing a Common Data Structure considers the benefits and challenges of integrating various sets of in-vehicle data collected by proprietary data acquisition systems, which were developed independently by three different contractors.	• Common-ize as many related data elements across suppliers as is reasonable and practical. This includes data structure, primary keys, units, naming schemes, and formats. • When strategizing data collection, storage, and merging approach, it is best to think specifics rather than in general, particularly when it comes to how datasets will interface with each other, i.e., synchronization. The cost of integrating disparate data sources should be weighed against the cost of managing and analyzing the data as separate entities, particularly if there are issues with the data structure being considered intellectual property.
Section 6.4 Harvesting and Transferring Data outlines the methods that were utilized to transfer large quantities of data from the vehicle or infrastructure, to the organization harvesting the data, and then to the Independent Evaluator.	• Explore methods for implementing over-the-air downloads of data to minimize impacts on resources and participants. This may need to be balanced with needing to physically interact with the vehicles to ensure state of health of the vehicle and equipment. • Ensure RSUs have an adequate connection to a back office system if being used to collect and transfer DSRC messages received from vehicles. Consider processes for parsing redundant data to reduce storage requirements.

Report Section	Recommendations
Section 6.5 Ensuring Data Quality describes the importance of generating and reviewing fully formatted data samples from the various systems before deploying vehicles. This section lists several of the data quality issues encountered after the start of the Model Deployment.	• Examine fully populated data samples prior to launch of a field test to ensure that the data and formats provided are compatible with the analysis approach. Allow adequate time for review of the samples and for any changes that may be required to the devices if data formats are not as anticipated. • Define the timing of the data quality checks and the specific checks to be conducted as a part of the data requirements and specifications using data issues from previous field tests as a baseline. • Implement automated system of checks on the data in near-real time to identify and flag data quality issues. • Data vendors should keep an operational, identical copy of the evaluation database for quality assessment purposes.
Section 6.6 Data Sharing discusses the concept of making all collected data available to others – including outside researchers, stakeholders, and the public. It highlights the challenges associated with sharing data and the resulting impacts to the project from a device supplier perspective.	• Identify all of the potential privacy issues at the beginning of the project and develop plans to address them early in the project if the intent is to release data to the public in a timely manner. • Develop a plan and process for distributing supplier data back to the supplier for analysis and problem identification.

APPENDIX B. List of Acronyms

AADT	Annual Average Daily Traffic
ACAS	Automotive Collision Avoidance Systems
ASD	Aftermarket Safety Device
BSM	Basic Safety Message
BSW	Blind Spot Warning
CAMP	Crash Avoidance Metrics Partnership
CDL	Commercial Driver's License
CMS	Configuration Management System
COR	Contracting Officer's Representative
CSW	Curve Speed Warning
DAS	Data Acquisition System
DNPW	Do Not Pass Warning
DSRC	Dedicated Short-Range Communication
DVI	Driver-Vehicle Interface
EEBL	Emergency Electronic Brake Light
ETSI	European Telecommunications Standards Institute
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards
FTA	Federal Transit Administration
GFE	Government Furnished Equipment
GID	Geometric Intersection Description
GPS	Global Positioning System
IHV	Integrated Heavy Vehicle

ILV	Integrated Light Vehicle
IMA	Intersection Movement Assist
IE	Independent Evaluator
IP	Internet Protocol
IPv6	Internet Protocol Version 6
IRB	Institutional Review Board
ISD	Integrated Safety Device
ITS	Intelligent Transportation Systems
ITS JPO	Intelligent Transportation Systems Joint Program Office
IVBSS	Integrated Vehicle-Based Safety Systems
LCW	Lane Change Warning
LTA	Left Turn Assist
MDGA	Model Deployment Geographic Area
MDOT	Michigan Department of Transportation
MUTCD	Minimum Uniform Traffic Control Device
NHTSA	National Highway Traffic Safety Administration
NCRC	North Campus Research Complex
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
PCW	Pedestrian in Signalized Crosswalk Warning
PII	Personally Identifiable Information
PMS	Property Management System
POC	Proof of Concept
PTSO	Parent-Teacher-Student Organization
RFP	Request for Proposal
RSD	Retrofit Safety Device
rQPL	Research Qualified Products List
RSE	Roadside Equipment

RSU	Roadside Unit
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SEMP	Systems Engineering Management Plan
SOW	Statement of Work
SPaT	Signal Phase and Timing
SPMD	Safety Pilot Model Deployment
SwRI	Southwest Research Institute
TFHRC	Turner-Fairbank Highway Research Center
TIM	Traveler Information Message
TRP	Transit Safety Retrofit Package
TSC	Traffic Signal Controller
UM	University of Michigan
UMTRI	University of Michigan Transportation Research Institute
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VAD	Vehicle Awareness Device
VIN	Vehicle Identification Number
VTRW	Vehicle Turning Right in Front of Bus Warning

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