Dynamic Mobility Applications Analysis

Policy and Institutional Issues for Multi-Modal Intelligent Traffic Signal System (MMITSS)

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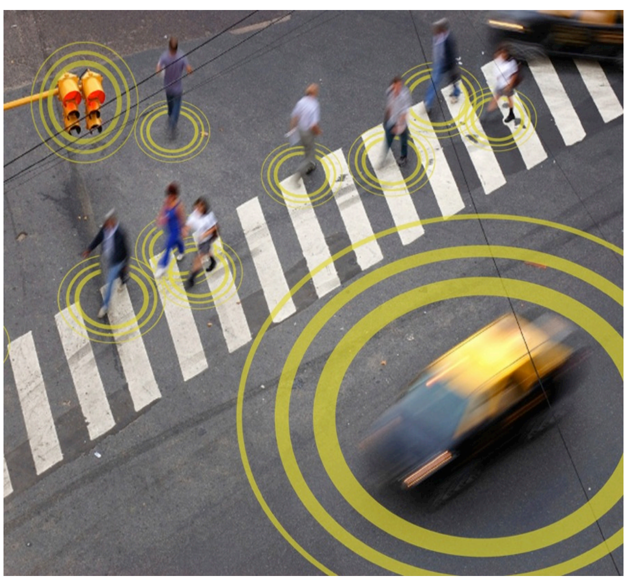

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16. Abstract

The Connected Vehicle Mobility Policy team (herein, policy team) developed this report to document policy considerations for the Multi-Modal Intelligent Traffic Signal System, or MMITSS. MMITSS comprises a "bundle" of dynamic mobility applications (DMA) that leverage existing and new connected vehicle data sets to optimize traffic signal timing for safety, emergency response, and improved mobility.

The analysis is based on the policy team's review of a wide range of materials that include:

- The MMITSS program's Concept of Operations (ConOps), Stakeholder Input Report, and System Design and Requirements documents.
- The Connected Vehicle Reference Implementation Architecture (CVRIA) diagrams for MMITSS.
- Discussions with the technical team overseeing development of the prototype applications within the MMITSS bundle and a review of the prototype documents.
- Industry best practices and standards in information technology, security and privacy, and data exchange.

As policy or institutional issues emerged during the review, they were categorized into one of four categories (not every DMA bundle had issues in all four categories) and were further paired with recommended actions for resolution, if options were available. Where they were not available, additional research is recommended. The four issue categories are:

1. High priority issues need immediate attention and resolution as they may challenge deployment, adoption, and use.
2. Medium priority issues have potentially serious consequences but clear, if challenging, paths to resolution; which should be accomplished prior to technology transfer.
3. Low priority issues have policy implications but also have solutions underway or represent current best practices that can be implemented before MMITSS applications are introduced to the marketplace.
4. Emerging issues have some probability of challenging deployment over time, as MMITSS implementations grow in complexity or geographic coverage.

In summary:

- One high-priority issue common to other DMA applications was identified and documented. The one issue is concerns of privacy of Personally Identifable Information (PII). Future MMITSS deployments will need to ensure careful attention to PII concerns.

- Four medium-priority issues were identified and documented. One issue is common to the other DMA applications. The four issues are: certification of Connected Vehicle (CV) technologies; data governance with regard to collecitng, archiving, and accessing CV data; safety of pedestrians and disabled users; and allocating signal priority among multiple agencies and private entities. All of these issues are challenging but have potential technical and policy options that can be applied to resolve them. Further research is recommended to analyze the options for their impacts and to determine the optimal recommendations.
- Nine low priority issues were identified and have been documented in this report. They include: governance (legitimacy) of "handicapped" nomadic devices; ensuring functionality throughout the product lifecycle; digital certification for data exchange with nomadic devices; credentialing for technicians; interoperability of New MMITSS components with existing systems; availability to DSRC for real-time data exchange; regional integration and optimization of signal priorities; coordination and participation; concerns of existing signal priority patent owners.
- Bicycle safety with MMITSS enabled signal systems may emerge as more important as MMITSS implementations expand to involve multiple agencies or jurisdictions which must work together effectively.

Based on the results of this analysis, the policy team does not foresee a need for any new policies to be enacted or any major issues that will stand in the way of successful market adoption and use by industry. All policy and institutional issues identified can be resolved satisfactorily, some with recommended additional research into the following topics:

- Existing guidance for collecting and storing Personal Identification Information (PII); identify whether existing policies adequately address MMITSS needs
- Legal analysis of liability for pedestrian safety, in the event of an app failure
- Case studies of bicycles and alternative technology
- Literature review of current coordinated signal timing practices
- Inventory Geographic Intersection Data management practices and identify any needed institutional changes
- Best practices in inter-jurisdictional agreements for traffic management
- Alignment with existing FHWA guidance on bicycles, coordinated signal timing

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Executive Summary

Background

The Dynamic Mobility Applications (DMA) Program is prototyping applications that are anticipated to be transformative to public sector transportation system management and modal integration. These technical research and development activities are a part of the U.S. Department of Transportation's (USDOT) advancement of new technologies in support of the emergence of Connected Vehicle (CV) environments.

The objective of the DMA research is to foster the release of high-value, open-source applications that use synthesized, multisource Intelligent Transportation Systems (ITS) data to transform surface transportation management and information. The DMA Program research is also focused on developing tools (for instance, an open source portal), metrics, and strategies to promote and facilitate additional application development by stakeholders and industry.

The Intelligent Transportation Systems Program's role within the USDOT is to facilitate high-risk/high-reward research in cooperation with industry and academia to meet transportation needs. Investments in new research are based on policy analysis that determines that the technology concepts meet threshold criteria:

- They advance the state-of-the-practice and, if successful, will deliver transformational transportation benefits to the Nation.
- They are unlikely to be pursued in industry given the nature of the risks by comparison to the required investment.
- The advancements are desired by stakeholders who will champion the transfer of results into use.
- The advancements are significant enough to take precedence over other investment choices.

A decision to pursue research is followed by development of prototypes with demonstration and testing under real-world conditions. Successful results precipitate the process of transferring new technologies into market adoption and use, which set the stage for planning and preparing for technology implementation, operations and maintenance, and upgrades and evolution. Throughout this technology lifecycle, policy and institutional issues can often become the major stumbling blocks to realizing success.

Thus, identification of and research into, the policy issues and practical options and solutions is an important step that raises the assurance that the Federal investment will result in adoption and use by agencies, organizations, the private sector, and travelers. It is an iterative process with the technical research teams—identification of policy challenges early in the development stage can change the nature of technical decisions; envisioning policy challenges throughout the lifecycle supports preparation for robust technology transfer.

Purpose of this Report: Document MMITSS Policy Issues

The Connected Vehicle Mobility Policy team (herein, policy team) developed this report to document policy considerations for the Multi-Modal Intelligent Traffic Signal System, or MMITSS. MMITSS comprises a "bundle" of mobility applications that leverage existing and new connected vehicle data sets to optimize traffic signal timing for safety, emergency response, and improved mobility.

The analysis is based on the policy team's review of a wide range of materials[1] that include:

- The MMITSS program's Concept of Operations (ConOps), Stakeholder Input Report, and System Design and Requirements documents.
- The Connected Vehicle Reference Implementation Architecture (CVRIA) diagrams for MMITSS.
- Discussions with the technical team overseeing development of the prototype applications within the MMITSS bundle and a review of the prototype documents.
- Industry best practices and standards in information technology, security and privacy, and data exchange.

As policy or institutional issues emerged during the review, they were categorized into one of four categories (not every DMA bundle had issues in all four categories) and were further paired with recommended actions for resolution, if options were available. Where they were not available, additional research is recommended. The four issue categories are:

1. *High priority* issues need immediate attention and resolution as they may challenge deployment, adoption, and use.
2. *Medium priority* issues have potentially serious consequences but clear, if challenging, paths to resolution; which should be accomplished prior to technology transfer.
3. *Low priority issues* have policy implications but also have solutions underway or represent current best practices that can be implemented before MMITSS applications are introduced to the marketplace.
4. *Emerging* issues have some probability of challenging deployment over time, as MMITSS implementations grow in complexity or geographic coverage.

One high priority issue, four medium priority issues, nine low priority issues, and one emerging issue were identified and documented in this report.

High Priority Policy Issue

One issue was found to be potentially high priority:

- <u>Privacy of Personally Identifiable Information</u>: Collecting and storing PII may be necessary for performance measurement and is of potential concern to users. This is also true of other DMA bundles. The prototype demonstrations of MMITSS have safeguarded privacy by

[1] See references in Appendix A.

aggregating data and de-identifying PII. As deployment moves forward, stakeholders need to ensure that privacy concerns are addressed and privacy poilcies and approaches are transparent to the public.

Medium Priority Policy Issues

Four issues are potentially medium priority; all may require further research into options for resolution.

- Certification: Connected vehicle technologies will potentially be available from a variety of sources, including imbedded systems provided by vehicle original equipment manufacturers (OEMs), aftermarket devices, and smart phones. The diverse CV technology landscape that is likely to emerge raises potential issues about the trustworthiness of the data generated, and the need for a certification framework to ensure that all devices meet industry-wide minimum performance standards. A variety of efforts are underway to address the technical and policy issues related to certification.
- Data Governance: Stakeholders disagree substantially on appropriate data governance practices, especially regarding the appropriate extent of collecting, archiving, and accessing CV data.
- Safety of Pedestrians and Disabled Users: Individuals relying upon nomadic devices for their personal safety when crossing an intersection could be injured if the system provides incorrect information due to malfunction, hacking, or inaccurate/out-of-date geographic intersection data.
- Signal Priority Allocation: Multiple agencies and private entities with competing agendas will need to cooperatively allocate signal priorities to different vehicle and traveler classes.

Low Priority Policy Issues

These issues have either been resolved or have clearly identified solutions that are technical rather than policy oriented:

- Governance (Legitimacy) of Handicapped Nomadic Devices: A technical solution has emerged to allow nomadic devices with fraudulent handicapped registrations to be locked out of MMITSS systems, and certification of all nomadic devices is expected to be consistent with the overall approach to the CV environment. As such, this issue is considered resolved.
- Ensuring functionality throughout the lifecycle: This includes resolving coordination and participation issues by agencies and private entities with multimodal regional goals and priorities, and crafting agreements and data standards across multiple jurisdictions.
- Digitial Certification for Data Exchange with Nomadic Devices: Nomadic devices and applications may require data certification.
- Credentialling for Technicians: It will be important to ensure only properly trained technicians have access to the system.
- Interoperability of New MMITSS Components with Existing Systems: MMITSS requires a variety of component types to work together effectively.

- Availability of DSRC for Real-Time Data Exchange: The real-time, safety-critical components of MMITSS rely on Dedicated Short-Range Communications (DSRC) for data exchange.
- Regional Integration and Optimization of Signal Priorities: Agencies and entities operating a MMITSS in a regional context may be challenged to identify and negotiate towards a system optimized for regional mobility, safety, and efficiency.
- Coordination and Participation: This institutional issue is concerned with whether transit agencies, traffic management, and freight companies can work cooperatively to manage surface traffic, without being hampered by existing operating, funding, or business rules. This type of coordination is one that is highlighted for discussion when developing regional or statewide ITS architectures.
- Concerns of Existing Signal Priority Patent Owners: Existing signal priority patent owners may inquire whether MMITSS algorithms build upon their IP although developers recognize the algorithms as new IP.

Emerging Policy Issue as MMITSS Deployment Expands

One issue may become more important as MMITSS implementations expand to involve multiple agencies or jurisdictions which must work together effectively. This issue does not require immediate study, but should be considered in long-term planning for MMITSS implementations:

- Safety of Bicyclists: If expanded to include bicyclists, MMITSS systems will need to accommodate cyclists' unique requirements, which differ from those of either pedestrians or motorists. Cyclists relying upon bike-specific nomadic devices for their personal safety when passing through an intersection could be injured if the system provides incorrect information due to malfunction or hacking.

Conclusions and Next Steps

It is expected that this report will support a dialogue with stakeholders by promoting discussions and comments on:

- Any additional policy or institutional issues that may present challenges to successful emergence of MMITSS technology and practice, which are not documented but for which new or additional research and analysis is recommended.
- Whether policy options identified for resolution of the issues are appropriate.

The issues that require options for resolution will either be addressed by:

- Ongoing research that applies across all DMA bundles as well as other applications (for instance, privacy)
- Further research which is recommended in this white paper.

The emerging bicyclist safety issue can be assessed over time to ensure it does not pose significant barriers to deployment.

Finally, it should be noted that data privacy and security have been raised as key policy concerns for all of the dynamic mobility applications. Privacy has been highlighted as a high concern for MMITSS. USDOT research is ongoing in this area to develop options to address these new DMA applications as well as to standardize security for future applications that have yet to emerge. To develop optional approaches for security and privacy, analysis using National Institute of Standards and Technology (NIST) standards (Special Publication 800-53[2] Rev 4) is underway to assess any policy or institutional challenges[3]. This analysis explores the minimal data set that is necessary for MMITSS functionality, and to assess any public concerns or policy challenges associated with the data set. Where MMITSS is transferred to market adopters, the private sector is expected to play a major role in setting privacy and data access policies. However, where MMITSS is used by government entities at the State and local level, there will likely be additional reviews of practices for data collection, access, and storage; handling of any personally-identifiable information; and/or security practices.

[2] http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf

[3] USDOT research and analysis results are made available through the ITS Joint Programs Office website at www.its.dot.gov.

Chapter 1 Introduction

This report documents policy considerations for *Multi-Modal Intelligent Traffic Signal Systems* (MMITSS). MMITSS applications integrate signal prioritization for multiple transportation modes, improving arterial flow and pedestrian safety.

MMITSS is one of several connected vehicle applications that the Intelligent Transportation Systems Joint Program Office (ITS JPO) of the US Department of Transportation (USDOT) and its partners are prototyping as part of its Connected Vehicle Program. The ITS JPO is advancing new connected vehicle technologies through innovative research, and MMITSS applications are being piloted in Arizona and California.

Dynamic Mobility Applications

In the future, cars, trucks, buses, roads, and smartphones will talk to each other. They will share valuable safety, mobility, and environmental information over a wireless communications network that is already transforming our transportation system as we know it. This system of connected vehicles, mobile devices, and roads will provide a wealth of transportation data, from which innovative applications will be built. These applications will make travel not only safer, but more efficient and greener.

The USDOT's Dynamic Mobility Applications program is exploring these possibilities, specifically focusing on reducing delays and congestion and thus significantly improving mobility. The following six mobility application bundles are being prototyped to make this possible:

- *Enabling Advanced Traveler Information Systems (EnableATIS)* provides a framework to develop multisource, multimodal data into new advanced traveler information applications and strategies.
- *Freight Advanced Traveler Information System (FRATIS)* provides freight-specific route guidance and optimizes drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips.
- *Integrated Dynamic Transit Operations (IDTO)* facilitates passenger connection protection, provides dynamic scheduling, dispatching, and routing of transit vehicles, and promotes dynamic ridesharing.
- *Intelligent Network Flow Optimization (INFLO)* aims to optimize network flow on freeway and arterials by: informing motorists of existing and impending queues and bottlenecks; providing target speeds by location and lane; and allowing the capability to form ad hoc vehicle platoons of uniform speed.
- *Multi-Modal Intelligent Traffic Signal Systems (MMITSS)* is a comprehensive traffic signal system for use on complex arterial networks that include passenger vehicles, transit, freight, and emergency vehicles, as well as pedestrians.

- *Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)* involves advanced vehicle-to-vehicle safety messaging over dedicated short-range communications to improve the safety of emergency responders and travelers.

The USDOT's Connected Vehicle Mobility Policy team is performing the analysis needed to document policy and institutional issues and recommend options for resolution for each of these bundles in separate reports.

Policy Considerations for New Connected Vehicle Technologies

Throughout the process of developing new connected vehicle applications, various policy or institutional issues can become stumbling blocks. Examples include changes brought about by an application and its operations that could possibly affect established norms for liability; governance interoperability of hardware, software, and data; and other issues that may preclude adoption and use.

Policy analysis is an iterative process that proceeds in concert with research and development. Hence, identification of policy challenges early in the development stage can change the nature of technical decisions. Envisioning policy challenges throughout the life cycle enables smooth technology transfer and system deployment.

The USDOT's Connected Vehicle Mobility Policy team is performing the analysis needed to document policy and institutional issues for each of these bundles as well as to identify and recommend options for resolution in separate reports. This report addresses those considerations for MMITSS. The remainder of this report is structured as follows:

- Chapter 2 Description of MMITSS
- Chapter 3 Policy Analysis Approach for Analyzing New Connected Vehicle Applications
- Chapter 4 Policy Analysis Results on MMITSS Applications
- Chapter 5 Considerations for Stakeholders Deploying or Using MMITSS
- Chapter 6 Conclusion
- Appendix A Source Materials
- Appendix B List of Acronyms

Chapter 2 Description of MMITSS

The MMITSS bundle combines information from connected travelers and infrastructure-based detection systems to optimize intersection operations. It does this by integrating dynamic data on area traffic conditions with messages from a variety of approaching vehicles—emergency, freight, passenger vehicles, and transit—and with safe-crossing requests from pedestrians, bicycles, and other non-motorized travelers.

Currently, signal timing can be affected only by very simple requests: a pedestrian pushes a crosswalk button; an emergency vehicle signals the next traffic signal to cycle in its favor; a late transit bus approaches a red signal and requests priority, or a vehicle stops at a red light over a loop detector. In comparison, the rich data available in a connected vehicle environment will support substantially more complex and integrated decision options—initially by planners and later by the MMITSS applications, as directed by traffic management considerations. For example, vehicles eligible for signal priority (e.g., transit or freight vehicles) can communicate their location and additional relevant information to the roadside infrastructure which can further consider requests for service from nomadic devices/applications carried by pedestrians and other non-motorized travelers which will transmit the traveler's location, any special needs (e.g., desire to cross a particular intersection and need for extended time to cross). These request-for-service messages will contain a richer set of information about the mode, vehicle or traveler class, priority level, and desired time of service. Local authorities will have the ability to optimize for their local conditions by setting policy that determines relative priorities for various modes—e.g., a heavily loaded bus that is running late can be given higher priority than a freight vehicle that is empty, but an emergency vehicle can be given coordinated priority at a series of signals. MMITSS also provides for local traffic management systems (TMS) and fleet management systems (FMS) to work together.

The overall system will thus be able to "communicate" with equipped vehicles and travelers within range of infrastructure-based equipment and sense the presence of unequipped travelers and vehicles at fixed detector locations. Combined with traffic congestion data supplied by other components of the connected vehicle system, this will facilitate real-time traffic management. The conceptual architecture is shown in Figure 2-1.

MMITSS Applications

MMITSS consists of five applications, described below.

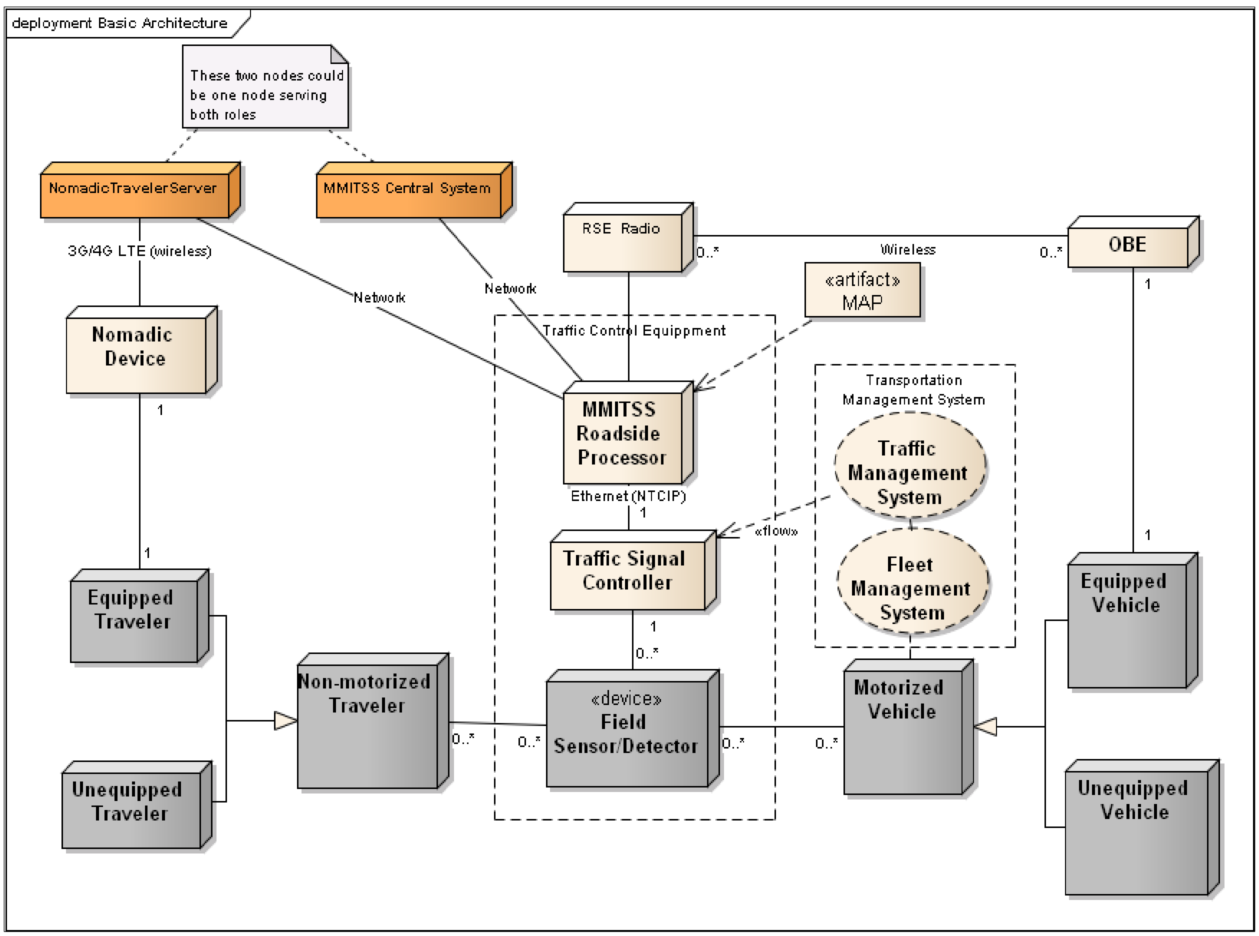
ITSS: Intelligent Traffic Signal System

The Intelligent Traffic Signal System application adjusts signal timing in response to traffic conditions and signal priority requests from pedestrians and vehicles. It uses vehicle location and movement information from connected vehicles as well as infrastructure measurement of non-equipped vehicles to improve the operations of traffic signal control systems.

The application uses vehicle information to adjust signal timing for an intersection or group of intersections in order to improve traffic flow, including allowing platoon flow through an intersection or a section of intersections. The application serves as an over-arching system optimization application, accommodating transit or freight signal priority, EV priority, and pedestrian movements to maximize overall arterial network performance.

The infrastructure-based traffic signal control equipment consists of the traffic signal controller and possibly an RSE (roadside equipment)—a general communications processing node that coordinates messages from the various modes of traveler into traffic signal controller inputs. The RSE contains (deploys) the MAP, which is the digital description of the intersection geometry and associated traffic control definitions. MMITSS has provisions to include weather sensors in the future.

Figure 2-1. MMITSS Conceptual Architecture



PEDM: Pedestrian Mobility

This application will improve pedestrian mobility, particularly in the case of disabled pedestrians. It will integrate the location and movement of vehicles with location data and crossing requests from newly developed nomadic devices to be carried by pedestrians. The app will be able to inform pedestrians when to cross and how to remain aligned with the crosswalk, based on real-time Signal Phase and Timing (SPaT) and MAP (intersection geometry) information. In some cases, priority will be given to pedestrians, such as persons with disabilities that need additional crossing time, or in special conditions (e.g., weather) where pedestrians may warrant priority or additional crossing time. This application will enable a "pedestrian call" to be routed to the traffic controller from a nomadic device of a registered person with disabilities after confirming the direction and orientation of the roadway that this pedestrian is intending to cross.

EVP: Emergency Vehicle Priority

The Emergency Vehicle Priority application provides very high priority for emergency first responder vehicles and can subsequently clear standing queues before returning to normal operation. It will improve safe and efficient movement through intersections, both for emergency vehicles and for surrounding traffic.

FSP: Freight Signal Priority

The Freight Signal Priority application provides traffic signal priority for freight and commercial vehicles traveling in a signalized network. Significantly heavy or lengthy vehicles take longer to stop and restart than passenger vehicles, so reducing stops will improve overall throughput at intersections. The goal of the freight signal priority application is to reduce stops and idling, to increase travel time reliability for freight traffic, and to enhance safety at intersections.

MMITSS Demonstrations

MMITSS is being tested in Arizona and California. The Arizona test bed is the Maricopa County DOT (MCDOT) SMARTDrive Field Test Network north of Phoenix, Arizona. It consists of six intersections equipped with Savari StreetWAVE RSE (roadside equipment) units, modern Econolite ASC/3 (Advanced Signal Controllers), and a fiber optic Ethernet backbone. Each intersection is also configured with advance and stop bar detection on all movements. Users consist of passenger vehicles, light commercial vehicles, pedestrians, bicyclists, school buses, and emergency vehicles but do not include transit vehicles.

The MCDOT test bed provides an excellent environment for the development and testing of connected vehicle applications. Traffic flow (demand) during the day is extremely light, allowing testing of a wide variety of control strategies. There is a heavy morning peak flow for commuters, but by 9:00 am the typical flow is very low. In addition, special classes of vehicles can be used or simulated—e.g., emergency vehicles (Daisy Mountain Fire, MCDOT REACT, Maricopa County Sheriff, etc.) and transit (Valley Metro). Similarly, trucks can be simulated by regular vehicles with special configuration of on board equipment parameters.

The California testbed is a two-mile-long section of “El Camino Real,” a state highway and major arterial connecting South San Francisco to San Jose through the heart of Silicon Valley. The test bed itself is in Palo Alto and includes ten signalized intersections operated by Caltrans. All ten intersections will be equipped with 2070 Controllers and Savari 5.9 GHz DSRC RSEs. One intersection has a T1 backhaul connection and the other testbed intersections will have wireless backhaul connections. Users will include local transit agencies, freight companies, and light-duty vehicles including experimental vehicles owned by PATH[4] and by local automotive research laboratories.

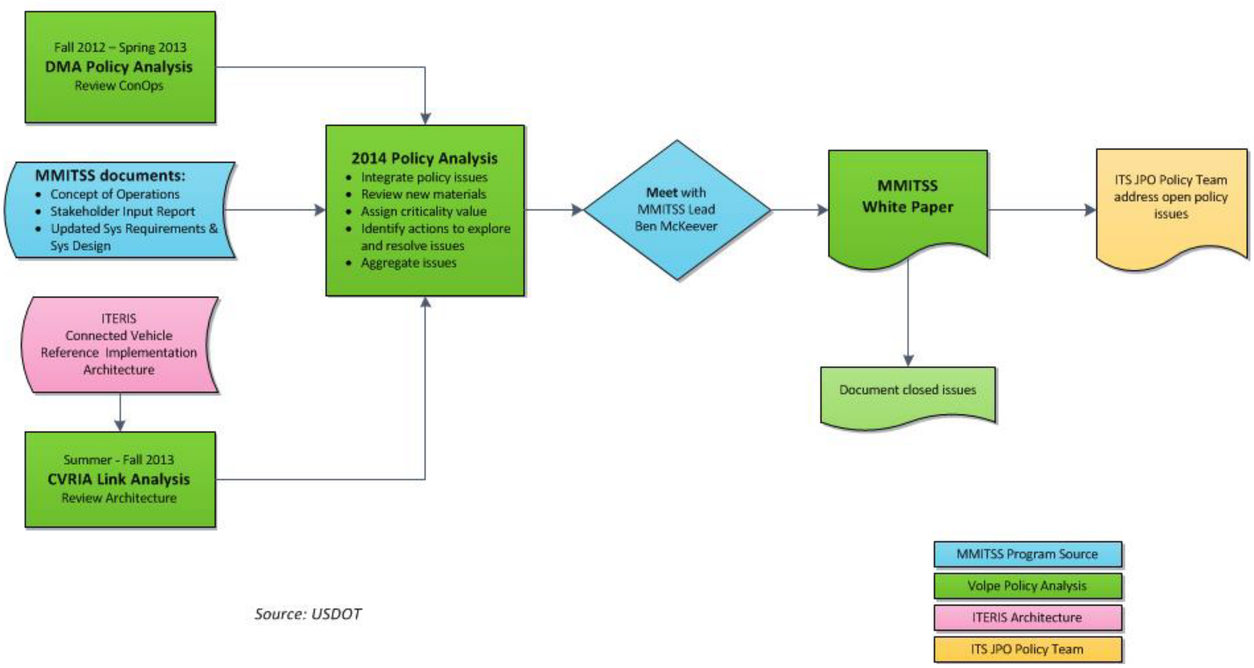
The California test bed is heavily traveled. Caltrans maintains strict operating constraints, including requiring a fixed cycle length, to ensure traffic performance is maintained. The network is ideal for testing in heavy (congested) traffic conditions. PATH and Caltrans have been operating a Transit Signal Priority system in the network for several years.

[4] Partners for Advanced Transportation Technology, a research group administered by the Institute for Transportation Studies at the University of California, Berkeley. http://www.path.berkeley.edu/

Chapter 3 Policy Analysis Approach for Analyzing New Connected Vehicle Applications

The policy analysis for this report was conducted in multiple steps, illustrated in Figure 3-1, along with the other steps in producing the report and the various sources of information used throughout the process.

Figure 3-1. MMITSS Policy Analysis Process



Source: USDOT

- Review Operations Concept: The Volpe Center policy team reviewed the original Operations Concept for MMITSS. The team documented potential policy issues at each stage of the development and deployment process, identified known policy options and solutions, and recommended areas for further investigation. The final Operations Concept was also reviewed to see if new policy issues had emerged, and to see if identified issues were still present or had been resolved.

- Review Connected Vehicle Reference Implementation Architecture: The policy team conducted a detailed analysis of the Connected Vehicle Reference Implementation Architecture[5]. The CVRIA provides a set of system architecture viewpoints that describe the functional, physical, and logical interfaces; enterprise relationships; and communications dependencies for each technology and application within the connected vehicle environment. These viewpoints serve as a common reference to help identify and prioritize standards development and to support policy considerations for the connected vehicle environment.

  The policy team used the CVRIA viewpoints to identify both the entities sharing data in each application, and the specific data elements being transmitted. By doing so, the team was able to identify potential issues for MMITSS.

- Integrate Results: Having completed the Operational Concepts analysis and the CVRIA analysis, the policy team undertook a process of integrating the results of those two efforts. This was important because the Operational Concepts analysis tended to focus on broader issues, while the CVRIA analysis in many cases identified issues that related to specific types of data being exchanged between specific entities within a given application. Integrating the results from both analyses enabled the policy team to develop a complete picture of all the potential issues for the MMITSS bundle.

- Review New Materials: Additional materials for MMITSS were reviewed and assessed against the results of the first level analysis. Recognizing that the work to define prototypes added detail (and in some cases modifications) to the existing ConOps and System Requirements documents, the team incorporated a review of newly produced materials on the prototype demonstrations.

- Eliminate Non-Policy Challenges: After integrating the results of the two efforts, the policy team identified and eliminated issues that were purely technical or logistical in nature and therefore did not have direct policy impacts. For example, the issue of malicious hacking of hardware or software is not included in the analysis because it is a common issue in today's world, and it is currently being addressed through technical solutions that are expected to apply, overall, to connected vehicle environments. Separate technical working groups are identifying the security policies that will be needed in support of the technical solutions; this policy team will, in the future, identify whether MMITSS may require any further tailoring of those policies to support operations.

- Prioritize Policy Issues: The team assigned a priority to each of the remaining issues on the following basis:

  a. *High priority* issues need immediate attention and resolution as they may obstruct deployment.

  b. *Medium priority* issues have potentially serious consequences but clear, if challenging, paths to resolution. These should be resolved prior to technology transfer.

  c. *Low priority issues* have policy implications but also have solutions underway. These solutions can likely be implemented before Dynamic Mobility Applications are introduced to the marketplace.

[5] http://www.standards.its.dot.gov/DevelopmentActivities/CVReference accessed April 2014.

d. *Emerging* issues have some probability of obstructing deployment over time, as DMA implementations grow in complexity or geographic coverage.

- Identify Issues Common to Other DMA Bundles: The team differentiated between policy issues that were unique to a single DMA bundle, and issues common to multiple DMA bundles. Issues common to multiple DMA bundles may need to be resolved at the level of the DMA program or the Connected Vehicle program (e.g., privacy policy), rather than within the individual bundle development efforts. Thus, the final set of issues includes a mix of unique and common issues of several priority levels.
- Meet with Technical Team: After completing the preceding steps, the policy team summarized the policy issues and discussed them with the MMITSS technical lead and team. This provided the technical lead and team the opportunity to agree or disagree about the veracity and priority of each issue, and to provide more information on each issue—information the policy team used to refine the policy analysis and conclusions.
- Stakeholder Outreach: Once the results were discussed with the technical team, the draft report was shared with external stakeholders for validation. All comments were incorporated into this final draft.
- Document Results: This report includes the results of that analysis and identifies issues that have been resolved and concerns that are recommended for additional USDOT research.

Chapter 4 Policy Analysis Results on MMITSS Applications

This chapter describes the policy issues identified for the MMITSS bundle along with their assigned priority status.

Table 4-1. MMITSS Policy Issues

Issue	Priority	Common to Other DMA Bundles?
Privacy of PII	High	Yes
Certification	Medium	Yes
Data Governance	Medium	Yes
Safety of Pedestrians & Disabled Users	Medium	No
Signal Priority Allocation	Medium	No
Bicyclist Safety	Emerging	No
Governance (Legitimacy) of "Handicapped" Nomedic Devices	Low	Yes
Ensuring Functionality Throughout the Lifecycle	Low	Yes
Digital Certification for Data Exchange with Nomadic Devices	Low	Yes
Credentialing for Technicians	Low	Yes
Interoperability of New MMITSS Components with Existing Systems	Low	Yes
Availability of DSRC for Real-Time Data Exchange	Low	Yes
Regional Integration and Optimization of Signal Priorities	Low	No
Coordination and Participation	Low	No
Concerns of Existing Signal Priority Patent Owners	Low	No

Policy Issues Common to MMITSS and Other Mobility Applications

Certain policy issues that are significant for MMITSS are also relevant to other mobility applications. They include to following:

High Priority Issue Common to DMA Bundles

The analysis identified one potential high priority policy issue that is common to many dynamic mobility application bundles, including MMITSS.

- Privacy of PII: Managing PII linked to connected vehicle apps is a challenge to the entire DMA (and CV) program. Although basic safety messages (BSM) do not use PII, they do use GPS which may be employed (using expensive and sophisticated equipment and algorithms) to re-identify a driver and/or the vehicle used and its specific routes. The proposed security solution for connected vehicle environments presents a very high barrier to such an activity (a high level of financial investment, time, and computing capabilities). This security solution is independent of communications media, but analysis acknowledges that use of today's cellular or Wi-Fi data may carry additional PII such as MAC addresses (media access control address which is a unique identifier assigned to network interfaces for communications) or cell phone numbers, allowing for more direct identification (DSRC communications do not require such identifiers).

  Privacy assessments are being conducted for all mobility applications, including MMITSS. Privacy is an important concern, and USDOT factors it into all of the prototype application development projects; a recent paper proposes a means for protecting PII while preserving the ability to estimate travel times[6]. Additionally, NHTSA is pursuing further research analyzing the privacy and data protection approaches of each DMA bundle and to identify the likelihood of tracking and to identify solutions for connected vehicle environments, as a whole.

  In the case of MMITSS, additional policy options may be needed to address "uses of data after collection." To operate properly, the MMITSS apps collect location and motion data on all equipped vehicles and individuals approaching an equipped intersection. If such data were immediately released (destroyed), the privacy concern would not arise. However, stakeholders convened to discuss MMITSS expressed fundamental disagreement about whether connected vehicle data should be archived (for research purposes) or disposed of immediately. The current program position is that data is expected to be archived and shared for evaluating performance measures, among other uses. It is expected that when MMITSS data is aggregated and used nothing is saved; if it is saved agencies should implement proper security protocols to ensure privacy. The USDOT is pursuing work to de-identify PII to ensure safety and privacy while maintaining data availability for performance measures. The MMITSS applications are currently being designed to function properly while minimizing the amount of user PII required and de-identifying any PII that is required.

  The overall technical solutions and policies developed for connected vehicle environments

[6] Travel Time Observation in Privacy Ensured Connected Vehicle 1 Environment Using Partial Vehicle Trajectories and Extended Tardity (June 2014). Khoshmagham, Feng, Zamanipour, and Head. University of Arizona.

may require further tailoring or additional policies to address the uses of collected and archived MMITSS data and to ensure data privacy throughout the deployment phases of MMITSS applications. While current MMITSS deployments have taken steps to protect PII, future deployments need to ensure careful attention to privacy and PII concerns.

Medium Priority Issue Common to DMA Bundles

The analysis identified two potential medium priority policy issues that are common to many dynamic mobility application bundles, including MMITSS.

- Certification: Connected vehicle technologies will potentially be available from a variety of sources, including imbedded systems provided by vehicle OEMs, and aftermarket devices from a variety of manufacturers. Although dedicated aftermarket CV devices may be produced, it is highly likely that, CV hardware, firmware and applications will be added to smartphones. The diverse CV technology landscape that is likely to emerge raises potential issues about the trustworthiness of the data generated, and the need for a certification framework to ensure that all devices meet industry-wide minimum performance standards.

  Various efforts are underway to define the key elements of a robust certification framework for CV devices and applications, and to develop certification implementation models. For example, the 2015 FHWA Vehicle-to-Infrastructure Deployment Guidance and Products document describes certification issues related to policies, technical requirements, implementation support and oversight. The document also describes a four-layer certification process that addresses a system's physical/environmental robustness; communication protocol capabilities; interface performance (e.g., proper message syntax and format); and overall application (i.e., system-level functioning). Other work efforts are developing a roadmap and specific tasks that will be required to create a certification environment for connected vehicle technologies. This work is addressing policy questions related to certification by, for example, describing the factors that need to be considered when determining which entities (e.g., OEMs, industry associations, third-party suppliers, government) might be the most appropriate to handle each of the four certification layers. USDOT has engaged with industry stakeholders to get their input on both technical and policy-related certification issues.

- Data Governance: Stakeholders in the MMITSS development process have articulated a range of conflicting opinions regarding data collection, archiving, and access. Some stakeholders object to any data retention due to privacy concerns. Others expect data to be archived and available for performance measurements and research purposes. It is expected that when MMITSS data is aggregated and used nothing is saved; if it is saved agencies should implement proper security protocols to ensure privacy. Agencies within a single jurisdiction likely will have little trouble developing data governance policies, but regional MMITSS implementations may require regional data policies. If needed, USDOT may find a role in providing guidance and best practices information to assist with regional coordination or at least ensure that jurisdictional policies do not preclude regional interoperability and planning.

Low Priority/ Resolved Issues Common to DMA Bundles

- Governance (Legitimacy) of 'Handicapped' Nomadic Devices: This is a digital parallel to the use of handicapped placards for parking cars. A technical solution has emerged to allow nomadic devices with fraudulent handicapped registrations to be locked out of MMITSS systems. It is important to note that all nomadic devices are expected to be consistent with the overall certification approach. This issue has been resolved.

- Ensuring Functionality Throughout the Lifecycle: Pedestrians—particularly disabled pedestrians—may increasingly trust and rely upon nomadic devices for safety in crossing streets. Thus, nomadic devices must be completely reliable in terms of interoperability with local MMITSS software and hardware and, ideally, will operate predictably regardless of geographic location within the US. As MMITSS systems evolve over time, it will be important for older nomadic device models and applications to remain interoperable with MMITSS and capable of updates. FHWA is developing guidance to address issues of reliability and updates; and the MMITSS technical reference documents will provide further detailed requirements. If necessary, guidance can also be developed to ensure consistency with ADA requirements[7] (although it is expected that developers and manufacturers will put these requirements into practice).
- Digital Certification for Data Exchange with Nomadic Devices: Due to the anticipated use of nomadic devices for pedestrian safety in a roadway, nomadic devices will need to use security certificates to provide trusted and authenticated data (similar to vehicle basic safety messages). This is a key part of connected vehicle safety application and the process for the devices and applications to access these certificates (both in the initialization phase as well as for updates/refresh) is being addressed at the global level for the range of Connected Vehicle applications.
- Credentialling for Technicians: It will be important to ensure that only properly trained technicians have access to MMITSS systems controls and software. Resolution of this institutional issue can draw from existing best practices. Further, many agencies have instituted such processes for their employees who have access to mission-critical or secure systems.
- Interoperability of New MMITSS Components with Existing Systems: MMITSS requires a variety of component types to work effectively together: nomadic devices, vehicle on-board equipment, and a range of different roadside sensors. It is likely that each type of component will be produced by multiple manufacturers, yet they must all be fully interoperable for the system to function. The MMITSS prototype is being developed in compliance with standards typical of modern signal control systems. If the private sector follows standards set in the prototype, a relatively high degree of regional interoperability is expected.
- Availabiilty of DSRC for Real-Time Data Exchange: The real-time, safety-critical components of MMITSS rely on DSRC for data exchange. If needed, other components of MMITSS data can be handled by Wi-Fi or other communications media under the expectation that all safety critical data exchange be required to use DSRC. Communications infrastructure installation can be costly, especially in rural areas where there are long distances to cover. However, areas without reliable wireless connectivity also tend not to have as much need for complex, networked traffic signalization. For this reason, this issue was listed as a low priority. Given that it is common across other mobility applications, USDOT is developing technical reference materials for agencies describing how to integrate MMITSS with existing technology. These references will also provide criteria for determining priority intersections.
- Agency Concerns about Cost of Infrastructure Upgrades: Agencies may be reluctant to make

[7] Americans with Disabilities Act of 1990, 42 USC 12101 et seq.

decisions about or invest in MMITSS or other CV applications due to the upfront costs of installation and training. The Connected Vehicle Policy program is developing benefit-cost information to share with agencies, to address the concern and assist in identifying tradeoffs.

Policy Issues Unique to MMITSS

Medium Policy Issues Unique to MMITSS

- Safety of Pedestrians and Disabled Users: In a MMITSS environment, equipped pedestrians—such as those with disabilities—may be able to make special requests (for instance, for extended timing of the cross-signal). The MMITSS ConOps assumes institutional opportunities for disabled persons to obtain ‘authorized’ and certified nomadic devices which will communicate with intersection equipment (and possibly with connected vehicles) to identify the disabled person’s location relative to the intersection. For example, if a person points an authorized device in the desired direction of travel, sending a signal request message (SRM) and an Alternative Basic Safety Message (ABSM) to roadside equipment, it triggers the requested signal phase. A malfunctioning or hacked nomadic device, however, might provide instructions to enter a street at a dangerous time, due to incomplete or lagging communication between the device and the system. This places a high degree of importance on the accuracy and security of Personal Information Device (PID)-based data, which could theoretically fail due to interoperability problems, human error, or human distraction.

  As with all CV apps that affect personal safety, many different components will contribute to the reliability and safety of a nomadic device, including designers, manufacturers, and users. Specific to MMITSS, additional institutional and policy needs are expected to include the following:

  - It will be important to ensure that all data sources are reliable and up-to-date, including sources of intersection geometry (GID) and data on road conditions (both traffic and weather). In a connected vehicle context, pedestrians will rely upon mapping apps to guide them safely through intersections. The concern is that a time lag may occur between intersection construction and reconfiguration and an update of relevant apps. During the lag, MMITSS apps (and other connected vehicle apps) have the potential to misdirect travelers within the intersection. For example, the Pedestrian Mobility component of MMITSS is intended to guide disabled pedestrians rather precisely across a street, based on GID data[8]. It will be important for cities implementing MMITSS to recognize the safety issues tied to prompt GID updates and to provide the institutional guidance necessary for meeting this need.
  - Because MMITSS offers special provisions for pedestrians with disabilities, devices will need to be “authorized” or “registered” and are expected to be consistent with the certification approach. A credentialing system similar to the handicapped parking

[8] “The Pedestrian Mobility application will integrate traffic and pedestrian information from roadside or intersection detectors and new forms of data from wirelessly connected, pedestrian (or bicyclist) carried mobile devices (nomadic devices) to request dynamic pedestrian signals or to inform pedestrians *when to cross and how to remain aligned with the crosswalk based on real-time Signal Phase and Timing (SPaT) and MAP information.*” [emphasis added] From Connected Vehicle Reference Implementation Architecture at http://www.iteris.com/cvria/html/applications/app50.html#tab-3.

placards[9] offers one policy option at the local level, but how such a system would be configured to support Nation-wide usage remains a question.

- Guidance or certification may be needed for both device designers and app developers, especially with regard to notifying the device owner when failure mode occurs.

- Signal Prioritiy Allocation[10]: MMITSS is designed with multiple levels of signal priority, which can be assigned to specific vehicle and traveler classes: emergency vehicle, transit vehicle, truck, passenger vehicle (e.g., for coordination of a platoon), or pedestrian crossing request. It also includes algorithms for deciding priorities in real time, based on prevailing conditions such as relative speed, emergencies, disabilities, and weather conditions. Public and private MMITSS partners will have competing goals but must come to agreement on assigning vehicle classes to specific priority levels and on conditions for granting different priorities – including signal priority. Such partners might include transit agencies, fire and police departments, and freight companies. Negotiations have the potential to be stymied by increasingly complex decision trees.

  Partner entities may need to look beyond their internal traffic goals and locally-based performance metrics to identify and negotiate regional goals that optimize benefits for all, in both everyday and emergency situations. Inter-agency agreements may need to address conditions in which priorities can be changed or overridden and what entity could make such changes. Priority negotiations could quickly become too complex for an affordable system to manage.

  In order to assure the success of early MMITSS implementations, USDOT may consider providing guidance to assist in developing regional compacts or agreements based on best practice case studies.

Emerging Policy Issue Unique to MMITSS

The analysis identified the need for inter-agency and inter-jurisdiction cooperation as a policy issue that may rise in importance as MMITSS is deployed. Early MMITSS implementations are likely to be quite local and may involve only a few agencies which have pre-existing agreements and channels of communication. With expansion into regional contexts, cooperation will become more complex. Three areas of cooperation were identified as key to the success of MMITSS over time:

- Bicyclist Safety: Bicycles have travel hazards and requirements distinct from pedestrians. They are required to follow motor vehicle requirements but are more vulnerable than motor vehicles in the event of an encounter, are relatively slow moving, and can tip over easily when required to react or stop abruptly. Bicycles may require more green time at a signal, as they do not travel as fast nor start as instantaneously as a motor vehicle. In addition, cyclists' hands are not available for controlling a nomadic device. Bicycles do not always trigger loop detectors, and pedestrian call buttons are not relevant to bicycle movement through an intersection. Bicycles are particularly vulnerable in two intersection situations: (1) when turning left into oncoming traffic and (2) when proceeding straight while traveling next to motor vehicles turning right.

[9] Disabled parking permits are issued by the states, based upon doctor recommendations.
[10] While signal priority *per se* is not common to other connected vehicle bundles or applications, the resulting need for inter-agency and agency-private sector cooperation and planning is common to many applications.

The MMITSS ConOps states that detecting and classifying cyclists at or near signalized intersections is a major challenge, at the present time[11]. It will be important to ensure that further technical MMITSS planning continues to include specific consideration of bicycle movements, identifying signal decision trees that involve left turns, in particular. In addition, technical and policy analysis concludes that it will be important to consider support developing requirements for a bicycle-specific certified nomadic device that would be hands-free and would generate a bicycle BSM and possibly a Signal Request Message (SRM) to the roadside equipment (the SRM could be configured to indicate the cyclist's intention to turn left, right, or continue straight, allowing the traffic signal controller to call the appropriate phase).

Alternatively, other technical options exist that may be leveraged to support bicycle movement. For instance, the intersection infrastructure may be equipped with microwave, radar, or other technology to detect bicycles and other relatively small vehicles approaching an intersection in roadways, dedicated lanes, or sidewalks. While these options do not provide greater awareness of the presence of bicyclists to other road users through an ABSM, these options do support identification of bicyclists within an intersection.

Low Priority Unique Issue to MMITSS

- Regional Integration and Optimization of Signal Priorities: Regional optimization of signal priorities is not a new challenge, and effective MMITSS deployments will require cross-jurisdictional coordination as it is needed today. The process by which that coordination happens is likely to be the same. Agencies and entities operating a MMITSS in a regional context may be challenged to identify and negotiate towards a system optimized for regional mobility, safety, and efficiency. As part of that move, agencies and private entities may need to abandon or modify existing hardware or software in favor of regionally interoperable standards. Guidance by the FHWA is under development (both planning and implementation) to assist with such transitions.
- Coordination and Participation: This institutional issue is concerned with whether transit agencies, traffic management, and freight companies can work cooperatively to manage surface traffic, without being hampered by existing operating, funding, or business rules. Transit agencies, for example, may have little involvement with highway issues or with freight management. Freight companies are driven by different priorities and agendas than public service agencies. As with the other issues under this heading, guidance from existing transportation management coalitions could be very helpful in assisting with new MMITSS implementations. Additionally, this institutional issue is one that is highlighted for discussion when developing regional or statewide ITS architectures.
- Concerns of Existing Signal Priority Patent Owners: Signal priority may, over time, replace existing signal priority systems installed in many jurisdictions. Signal priority patent owners might claim intellectual property rights to any type of automated signal management system. It is expected that this potential can be resolved through legal research and, if warranted, creation of a licensing process.

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[11] Section 11.3.3 "Equipped Bicyclist," *Multi-Modal intelligent Traffic Signal System: Concept of Operations. Updated Final Report.* December 4, 2012. Page 48.

Chapter 5 Conclusion

The policy team has documented five potentially important (high and medium priority) policy issues for the MMITSS application. The following topics will be the focus of additional policy research and stakeholder outreach:

- Existing guidance for collecting and storing PII; identify whether existing policies adequately address MMITSS needs
- Legal analysis of liability for pedestrian safety, in the event of an app failure
- Case studies of bicycles and alternative technology
- Literature review of current coordinated signal timing practices
- Inventory Geographic Intersection Data management practices and identify any needed institutional changes
- Best practices in inter-jurisdictional agreements for traffic management
- Alignment with existing FHWA guidance on coordinated signal timing

One emerging issue – bicyclist safety – may become more important as MMITSS technology transfer and market adoption move forward.

Nine low prioritie issues were identified and have been documented in this report. These issues have been resolved or have identified solutions and will not be pursued further. They are documented herein in case stakeholders raise them in the future and need to know how the DMA program has addressed them.

It is expected that this report will support a dialogue with stakeholders. Stakeholders may comment on:

- Any additional policy or institutional issues that may present challenges to successful emergence of MMITSS technology and practice, which are not documented but for which new or additional research and analysis is recommended
- Whether policy options identified for resolution of the issues are appropriate

Based on the results of this analysis, the policy team does not foresee any major policy or institutional challenges that will stand in the way of successful implementation, adoption, or use of MMITSS.

APPENDIX A. Source Materials

In conducting this analysis, the policy team used the following documents and information sources about MMITSS:

1. *Multi-Modal intelligent Traffic Signal System: Assessment of Relevant Prior and Ongoing Research. Final Report. Version 2.0. June 15, 2012.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by University of Arizona (Lead), University of California PATH Program, Savari Networks, Inc., SCSC, Econolite.

2. *Multi-Modal intelligent Traffic Signal System: Stakeholder Input Report. Version 2.0. August 3, 2012.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by Dr. Larry Head, Dr. Steve Shladover, Ann Wilkey.

3. *Multi-Modal intelligent Traffic Signal System: Concept of Operations. Updated Final Report. December 4, 2012.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by University of Arizona (Lead), University of California PATH Program, Savari Networks, Inc., SCSC, Econolite, Volvo Technology.

4. *Multi-Modal intelligent Traffic Signal System: Final System Requirements Document. Version 4.0 March 7, 2013.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by University of Arizona (Lead), University of California PATH Program, Savari Networks, Inc., SCSC, Econolite.

5. *Multi-Modal intelligent Traffic Signal System: System Design. Version 2.0. June 26, 2013.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by University of Arizona (Lead), University of California PATH Program, Savari Networks, Inc., SCSC, Econolite, Kapsch, Volvo Technology.

6. *Policy Analysis for the Connected Vehicle Dynamic Mobility Applications. Draft Report. April 12, 2013.*

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by Volpe National Transportation Systems Center.

7. *MMITSS Connected Vehicle Reference Implementation Architecture physical viewpoints, at:* http://www.iteris.com/cvria/html/applications/applications.html

    Prepared for the United States Department of Transportation, Research and Innovative Technology Administration, Intelligent Transportation Systems Joint Program Office. Prepared by Iteris. [accessed April and May 2014]

APPENDIX B. List of Acronyms

ADA	Americans with Disabilities Act
BSM	Basic Safety Message
ConOps	Concept of Operations
CV	Connected Vehicles
CVO	Connected Vehicle Operations
CVRIA	Connected Vehicle Reference Implementation Architecture
DMA	Dynamic Mobility Applications
DSRC	Dedicated Short-Range Communications
EnableATIS	Enabling Advanced Traveler Information Systems
EVP	Emergency Vehicle Priority
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information System
FSP	Freight Signal Priority
GID	Geographic Intersection Data
IDTO	Integrated Dynamic Transit Operations
INFLO	Intelligent Network Flow Optimization
ITS	Intelligent Transportation Systems
ITSS	Intelligent Traffic Signal System
JPO	Joint Program Office
MCDOT	Maricopa County Department of Transportation
MMITSS	Multi-Modal Intelligent Traffic Signal Systems
OEM	Original Equipment Manufacturer
PATH	Partners for Advanced Transportation Technology
PEDM	Pedestrian Mobility
PID	Personal Information Device
PII	Personally Identifiable Information
RSE	Roadside Equipment
R.E.S.C.U.M.E	Response, Emergency Staging and Communications, Uniform Management, and Evacuation
SPaT	Signal Phasing and Timing
TSP	Transit Signal Priority
USDOT	United States Department of Transportation

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