THE UNIVERSITY OF ARIZONA®

Multi-Modal Intelligent Traffic Signal System

Stakeholder Input Report

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This document fulfills the MMITSS Report on Stakeholder Input on Transformative Goals, Performance Measures and User Needs as defined in the proposal and Project Plan Task 99.

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MMITSS Background

The Multi-Modal Intelligent Traffic Signal System (MMITSS) project is part of the Cooperative Transportation System Pooled Fund Study (CTS PFS) entitled “Program to Support the Development and Deployment of Cooperative Transportation System Applications.” The CTS PFS was developed by a group of state and local transportation agencies and the Federal Highway Administration (FHWA). The Virginal Department of Transportation (VDOT) serves as the lead agency and is assisted by the University of Virginia’s Center for Transportation Studies, which serves as the technical and administrative lead for the PFS.

The United States Department of Transportation (USDOT) has identified ten high-priority mobility applications under the Dynamic Mobility Applications (DMA) program for the connected vehicle environment where high-fidelity data from vehicles, infrastructure, pedestrians, etc. can be shared through wireless communications. Three of the applications (Intelligent Traffic Signal System, Transit Signal Priority, and Mobile Accessible Pedestrian Signal System) are related to transformative traffic signal operations. Since a major focus of the CTS PFS members – who are the actual owners and operators of transportation infrastructure – lies in traffic signal related applications, the CTS PFS team is leading the project described in this RFP, entitled “Multi-Modal Intelligent Traffic Signal System” in cooperation with USDOT’s Dynamic Mobility Applications Program.

Document Purpose

This document serves multiple purposes:

(1) This document fulfills the contract deliverable for the MMITSS Report on Stakeholder Input on Transformative Goals, Performance Measures and User Needs as defined in the proposal and Project Plan Task 88.

(2) It provides a written account and record of participant and presenter inputs, feedback, and discussions during the Stakeholder Meeting I held via a webinar on Monday, June 4, 2012.

(3) It provides a summary and preliminary synthesis of the Stakeholder feedback as it pertains to the MMITSS Concept of Operations (ConOps) being developed as part of the research project. As such, it provides initial information on how the Stakeholder interactions and feedback will be integrated into the MMITSS CONOPS.

(4) It provides a written record of the MMITSS Stakeholder Meeting.

As stated in the MMITSS proposal, a Concept of Operations (ConOps) captures the stakeholders views of the system being developed and is written so that it can be easily reviewed by the various stakeholder communities. The Stakeholder information presented in this document will be synthesized, resolved, and integrated within the ConOps document.

Stakeholder Meeting Elements

In this section, the administrative elements of the Stakeholder Meeting are presented. As such the methodology for developing the Stakeholder Meeting is reviewed. This is followed by overviews of the meeting agenda, invited Stakeholders and meeting participants, and final attendance. Then, a self-assessment of knowledge and expertise in the areas supporting the five MMITSS scenarios is presented to quantify the composition of participants. The plan and flow for incorporating Stakeholder feedback and information, which is based on the MMITSS Project Plan, is reviewed. Finally, information on the identification and selection of Stakeholder scenarios is presented.

Meeting Methodology

The MMITSS Stakeholder Meeting was conducted in a webinar forum using a combination of PowerPoint presentation and Group Systems' ThinkTank environment to collect input from Stakeholders. A GoToMeeting webinar session was used to present information in both formats to the participants.

ThinkTank is a web-based collaboration tool that permits a large group of participants to contribute feedback, inputs, guidance, and suggestions in a simultaneous manner using either self-identified or anonymous (and randomized) entries. It is an ideal platform for brainstorming and stakeholder meetings, because it accommodates asynchronous inputs as well as anonymous inputs. As such, the MMITSS Stakeholders can focus on those scenarios of greatest interest or applicability to their research, interest area, related problem jurisdiction, or expertise. An automatic link to ThinkTank was placed in the webinar announcement to facilitate login and participation.

ThinkTank provides a suite of team-based, decision-making tools that encourage and support brainstorming, information gathering, polling, organizing, and prioritizing of information and inputs. The user entries were made available to all participants in a real-time fashion during the actual webinar event. In addition, provisions were integrated and provided for this specific Stakeholder Meeting to enable users to continue adding inputs, comments, and feedback for an entire week after the webinar concluded. Immediately following the webinar and after the closure of ThinkTank availability (6/11/12, 11:59PM PST), a written account of participant inputs were provided to the meeting organizers. The data log contains all user inputs and entries while maintaining anonymity or self-identification as selected by the actual user. Anonymity is the default state of user inputs in a randomized ordering for each topic area. This allowed the meeting organizers to focus on "what" information and feedback was provided rather than the source of the information or feedback. Stakeholder input and feedback is presented throughout this report corresponding to scenario or agenda item section.

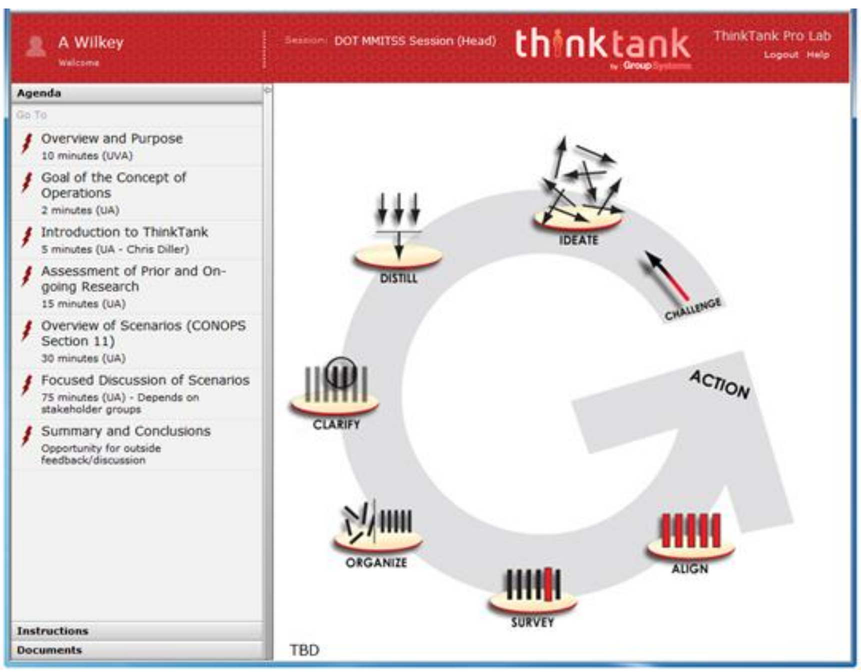


Figure 1 – ThinkTank Interface

Meeting Agenda

As stated in the MMITSS proposal, the ConOps development is based on a variety of considerations:

- Operational characteristics that can solve real-world and local traffic problems and are compatible with both infrastructure and vehicle operations,
- Technical feasibility within the constraints imposed by the enabling technologies of DSRC wireless communications and traffic signal control systems,
- Capability to provide benefits to users from the start, even when the market penetration is still small,
- Maintainability by traffic signal agency engineers and technicians, and
- Compliance with good system engineering practices.

The Stakeholder Meeting agenda, shown in Table 1, was developed to provide adequate coverage of these considerations and related topics.

Stakeholder Agenda Item	Moderator/Presenter	Time Allocation
Stakeholder Meeting Welcome and Overview	Larry Head	5 Minutes
Pooled Fund Project Overview and Purpose	CTS/PFS Panel (Melissa Lance)	10 Minutes
Concept of Operations Goal	Larry Head	2 Minutes
Introduction to ThinkTank (Collaboration Tool)	Chris Diller	5 Minutes
Assessment of Prior and Ongoing Research	Larry Head	15 Minutes
Overview of Scenarios	Larry Head	10 Minutes
Focused Discussion of Scenarios		
ISIG Scenario	Larry Head	20 Minutes
Transit Scenario	Larry Head	10 Minutes
Pedestrian Scenario	Steve Shladover/ Larry Head	10 Minutes
Freight Scenario	Larry Head	10 Minutes
Emergency Vehicle Scenario	Larry Head	10 Minutes
Other ConOps Issues		
Maintenance and Operations	Larry Head	10 Minutes
Conclusion and Next Steps	Larry Head	3 Minutes

Table 1 – Stakeholder Meeting/Webinar Agenda

Role of the Stakeholder

As it relates to the MMITSS project, the term *Stakeholder* is used to reference a potential user, operator, designer, facilitator, supplier, integrator, owner, or related functional role of the proposed system. In addition, this term is used to include experts in specific aspects of the system, including interfaces, policy and decision support, operations, support, and maintenance of the resulting system.

In the context of the MMITSS Stakeholder Meeting, the Stakeholders were asked to review a collection of scenarios and provide input, feedback, and guidance on user needs, transformative goals, and potential system performance measures. MMITSS Stakeholders provided coverage at local, state, federal, industry, and supplier levels for five transportation areas: (1) intelligent traffic signal systems, (2) transit, (3) pedestrian mobility, (4) freight, and (5) emergency vehicles.

Identified Stakeholders

Since the MMITSS research team has been working on Connected Vehicle and traffic signal systems for several years, it was possible to identify a diverse body of stakeholders having an interest in a Multi-Modal Intelligent Traffic Signal Systems. Several of these stakeholder categories are represented within the project team. For other categories, long-standing working relationships were leveraged to seek their participation and inputs during the MMITSS Stakeholder Meeting. Because of the diversity of applications included within Multi-Modal Intelligent Traffic Signal System, the initially identified and relevant stakeholder categories included:

- State DOTs – working with our own state DOTs (Arizona and California), not only the headquarters but also the district offices that have the direct responsibilities for implementing, operating and maintaining the signal systems. Other state DOTs, including, but not limited to, Michigan, New York, Texas, and Florida have specific interests that should be represented.
- Local DOTs – county and city level, including Maricopa County, City of San Jose, City of San Francisco, Harris County Texas, that have direct responsibilities for implementing, operating and maintaining signal systems.
- Transit Operators – Santa Clara Valley Transit, San Mateo County Transit, AC Transit, Valley Metro, and Houston Metro who have significant interest and concern over transit operations within signalized networks.
- Freight Movement – truck manufacturers such as Volvo Technology (a member of the project team), but also fleet operators and drivers, who would be the direct users of the system and State DOTs, such as NY DOT.
- Emergency Service Operators – county and city level, including Phoenix Fire Department, Rural Metro, Maricopa County React Teams, and other state and local emergency agencies.
- Pedestrian and bicycling interests – including visually impaired and persons with disabilities.
- Traffic signal control suppliers (Econolite, a member of the project team).
- Traffic signal control consultants and system integrators such as Iteris, Telvent, and Transcore.
- Wireless communication technology suppliers including Savari and Kapsch, who have supplied the roadside equipment for the Arizona and California test bed sites respectively, and are members of the project team.
- Automotive OEMs and first-tier suppliers such as Mercedes, BMW, Toyota, Nissan, GM, Volkswagen and Bosch who all have research laboratories within a few miles of the California test bed site.
- Academic Researchers including faculty from the University of Virginia, Texas A&M (TTI), University of Michigan, and others identified in the Assessment of Prior and Ongoing Research (Task 2.1).
- US DOT Mobility Application stakeholder groups, such as the Intelligent Network Flow Optimization (INFLO) Concept Development and Needs Identification project.

The individuals invited to the Stakeholder Meeting and their respective knowledge area(s) are shown in Table 2. It is assumed that many of these individuals have knowledge and expertise in several modalities and this classification is used solely for the purpose of ensuring good representation in the webinar.

Person, Organization	6/4/12 Attendance[1]	Expertise				
		Intelligent (Vehicle) Traffic Control	Transit Priority	Pedestrian Mobility	Freight Vehicles	Emergency Vehicles
Outside Parties						
Richard (Rick) McDonough, NY DOT	GT				X	
Nicholas Caruso, US Army - TARDEC						X
Bob Rausch, Transcore	GT	X				
Peter Koonce, City of Portland[2]	G	X	X	X		
Doug Tarico, McCain Traffic		X				
Mohammed Yousuf, USDOT, TFHRC				X		
Doug Henderson, Aegis ITS		X				X
Brian Park, UVa		X				
Gary Piotrowicz, Oakland County Michigan		X				
Nagui Rouphail, NCSU				X		
Frank Markowitz, City and County of San Francisco				X		
Lynn Weigand, Portland State University				X		
Alan R. Danaher Parsons Brinckerhoff			X			
Rebekah Karasko, North Central Texas Council of Governments	GT				X	
Walter Langford, Houston Metro			X	X		X
Glenn Hansen, Howard Co. Police (MD)						X
Chen-Fu Liao, U. of Minnesota				X		
Charles Zegeer, U. of North Carolina				X		
Greg Krueger, SAIC		X				
Hiroshi Tsuda, Nissan						
Hariharan Krishnan, GM						
Andreas Winckler, BMW						
Casey Emoto, Valley Transit Auth. (San Jose)			X			
Michael Maile, Mercedes-Benz Research	GT	X				
Andy Bata, New York City Transit			X			
John Toone, King County Metro Transit			X			
Doug Jamison, LYNX-Central Florida Regional Transportation Authority			X			
Dia Gainor, Executive Director, National Association of State EMS Officials						X
John M. Corbin, Director of Traffic Operations, Wisconsin Department of Transportation		X				X
Randy Butler, FHWA Office of Freight	GT				X	

[1] G – GoToWebinar Participant, T – ThinkTank Participant, GT – Participant in both forums
[2] Peter Koonce did not participate in the live webinar due to technology issues, but did participate in a one-on-one call and provided input to the ThinkTank system during the week following the webinar.

Person, Organization		Expertise				
	6/4/12 Attendance[1]	Intelligent (Vehicle) Traffic Control	Transit Priority	Pedestrian Mobility	Freight Vehicles	Emergency Vehicles
Ron Boenau, FTA			X			
Andy Mao, Harris County TX (Retired)	G	X				
Barb Ivanov, WSDOT					X	
Jim Tutton, Washington Trucking Assoc.					X	
Dale Tabot					X	
Madhav Chitturi, University of Wisconsin	GT					
Deb Curtis	T					
Noah Goodall, Virginia DOT	GT					
Gurprit Hansra	G					
Kate Hartman, DOT	G					
Giri Jeedigunta, Palm Beach County, Florida	GT					
Syreather Kimble,	GT					
Jianming Ma, Texas DOT	GT					
Barry Pekilis, Transport Canada	GT					
Alex Power, Texas DOT	GT					
Matt Smith, State of Michigan	GT					
Ray Starr, State of Minnesota	GT					
Karl Wunderlich, Noblis	GT					
Paul Z., City of Portland	T					
Panel Members						
Greg Larson (CalTrans)	G					
Faisal Saleem (Maricopa County in Arizona)	GT					
Ben McKeever (FHWA)[3]	GT					
Danielle Deneau (Oakland County in Michigan)	GT					
Melissa Lance (VDOT)	GT					
Hyungjun Park (UVA – Center for Transportation Studies)	GT					
Ray Derr (TRB/NSHRP)	G					
Jim Wright, AASHTO	GT					
Team Members						
Larry Head, UA	GT					
Ann Wilkey, UA	GT					
Steve Shladover, UC Berkeley/PATH	GT					
Wei-Bin Zhang, UC Berkeley/PATH						
Kun Zhou, UC Berkeley/PATH						
Gary Duncan, Econolite	GT					

[3] USDOT personnel had technical issues with GoToWebinar, but participated on the teleconference portion and provided input to ThinkTank.

Person, Organization	6/4/12 Attendance[1]	Expertise				
		Intelligent (Vehicle) Traffic Control	Transit Priority	Pedestrian Mobility	Freight Vehicles	Emergency Vehicles
Eric Raamont, Econolite						
Ravi Puvvala, Savari						
Ramesh Siripurapu, Savari	GT					
David Kelley, SCSC	GT					
Justin McNew, Kapsch[4]						
Mike Siebert, Volvo Technology						

Table 2 – Participants and Technical Area Representation

The attendance column should be interpreted with caveats. In the case of GoToWebinar, there were 28 participants that completed the login process. However, several people from the same organization or facility could have been using a single connection. Thirty three people logged into ThinkTank, including the meeting organizers.

Stakeholder Area of Expertise

Prior to using ThinkTank to solicit and collect Stakeholder feedback, a simple survey was performed in which the participants were asked to assess their experience and/or expertise in the five scenario areas. A self-assessed score of one indicates a “novice” level of experience or expertise and a score of ten indicates a “Subject Matter Expert (SME)” level of experience or expertise. After the ThinkTank site closed for feedback entries at 12:59PM PST on 6/11/12, a tally of the results showed that 31 individuals logged into ThinkTank (not including PFP Study members). Out of these 31 Stakeholders, 25 participated in the self-assessment. The polling results are shown in Table 3 and Figure 2 shows the corresponding averages and standard deviations (Gray dot within colored-bard).

Technical Area	Average	Std. Dev.	Votes	1	2	3	4	5	6	7	8	9	10
Traffic Signal Systems	6.96	2.44	25	-	1	3	1	1	3	3	6	3	4
Transit Vehicle Priority	4.96	2.34	25	2	2	4	3	3	3	4	3	1	-
Pedestrian Mobility	4.38	1.88	24	1	2	7	2	7	1	2	2	-	-
Freight Signal Priority	3.29	2.24	24	6	6	4	1	1	2	4	-	-	-
Emergency Vehicle Preemption	5.40	2.10	25	1	-	5	3	4	3	4	4	1	-

Table 3 – Stakeholder Areas of Expertise (Self-Assessment Values)

[4] Justin McNew recently left employment with Kapsch and hasn’t been replaced by another engineer on the team by the time of the webinar.

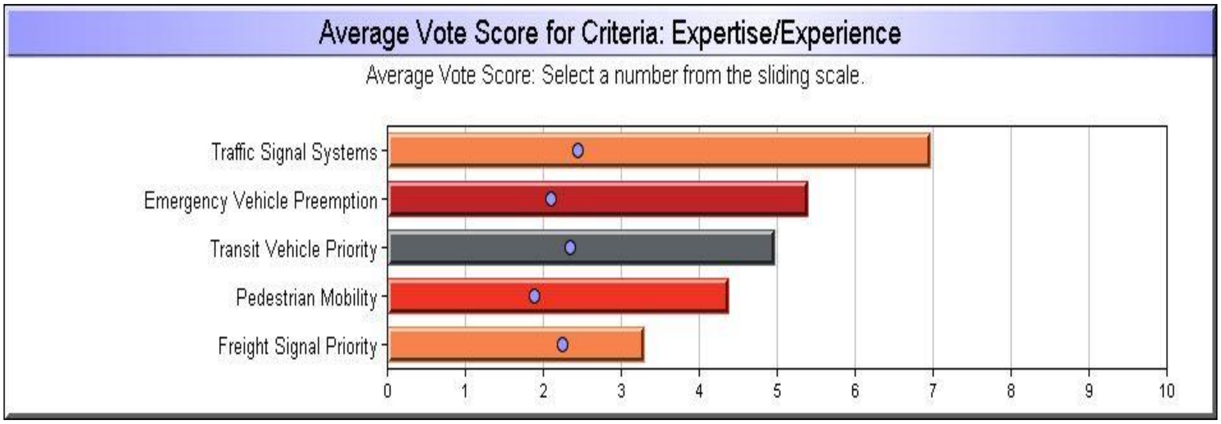


Figure 2 – Stakeholder Areas of Expertise Statistics

These results are provided as a means of characterizing the Stakeholder population and gauging the inputs, results, and feedback in subsequent polling activities during the presentation of scenarios, maintenance, and operations segments of the meeting.

Use of Stakeholder Inputs

The organization, solicitation of participant feedback, and reporting of involvement with transportation stakeholders are explicit components of the MMITSS Statement of Work and Project Plan. The Stakeholder Meeting and subsequent data collection period were used to solicit, gather, synthesize, and document input from identified stakeholders regarding the transformative goals, user needs, and system performance measurements of the initial prototypes of the multi-modal integrated traffic signal system.

In Table 4, the progression of user and expert input and feedback on the MMITSS project is presented. The intent of this information is to provide the meeting participants with an overview of how their input and information will be documented and used in subsequent efforts on the MMITSS project. Ideally, user inputs will be integrated into the Concept of Operations (ConOps) document in a manner that allows integration into the system requirements, system design, test networks, and test plans.

Task / Subtask	Goal / Purpose
Stakeholder Meeting 1	
Identify Participants	Define sufficient user input and representation across each of the five areas.
Schedule Meeting	Select a date and forum permitting the greatest participation of identified representatives. *Webinar: Monday, 6/4/12*
Conduct Stakeholder Meeting	Develop and execute brainstorming and input generating materials for soliciting and invoking user input.
Report on Stakeholder Input	
Develop Draft Report on Stakeholder Input	Integrate the various user and expert inputs, feedback, and performance measures into a single document that can be referenced and used in latter project tasks.
Solicit and Integrate PFS Member Feedback	Audit the draft stakeholder report using broad spectrum knowledge of long-term programmatic goals.
Compile Final Report on Stakeholder Input	Integrate review feedback to fine-tune the capture of user and expert inputs on the MMITSS.

Integrate User and Expert Stakeholder Information into MMITSS ConOps
Integrate ConOps into SyRS
Integrate SyRS into System Design

Table 4 – Progression of User and Expert Stakeholder Input and Feedback

Initial Scenario Selection

Solicitation of feedback was accomplished through the development, discussion, and review of representative scenarios. The classifications of MMITSS Actors comprising the five scenarios are shown in red text and groupings in Figure 3. The corresponding scenarios are shown in Figure 4. For example, a walking pedestrian is a possible actor in the *Pedestrian Mobility* scenario. The initial collection of actors and scenarios shown in Figure 3 and Figure 4 were presented during the Stakeholder Meeting and do not incorporate Stakeholder feedback at this time. As appropriate, these diagrams will be updated with the synthesized feedback and included in the ConOps document.

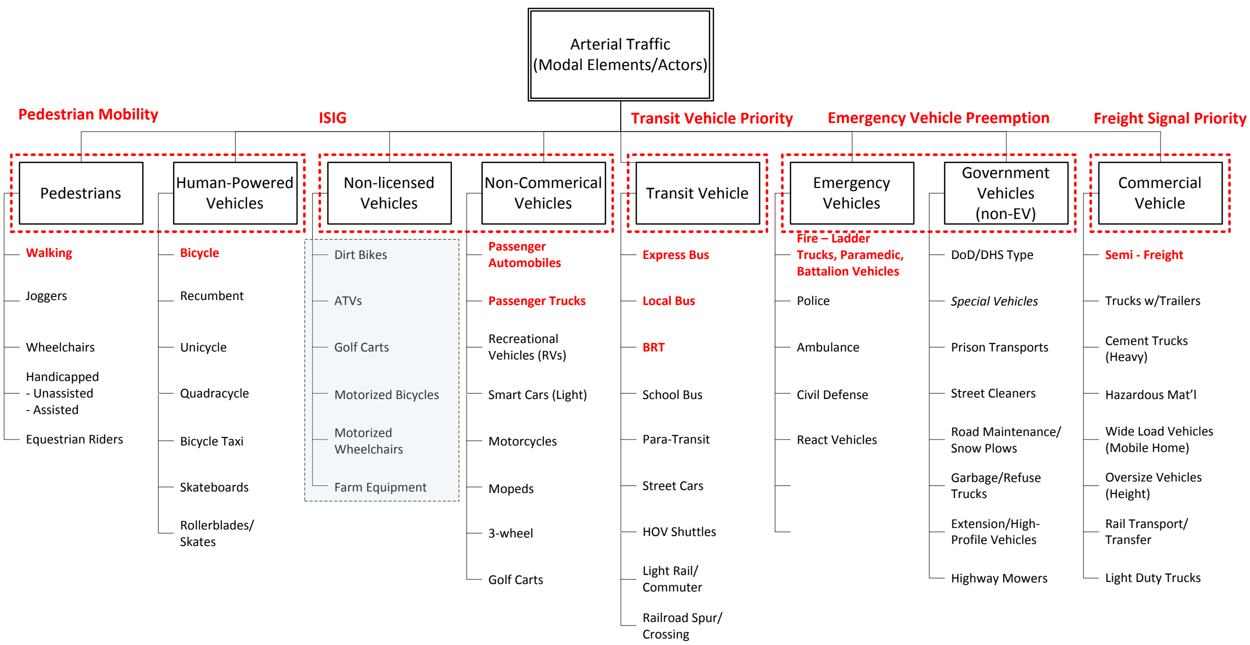


Figure 3 – Initial Collection of MMITSS Actors

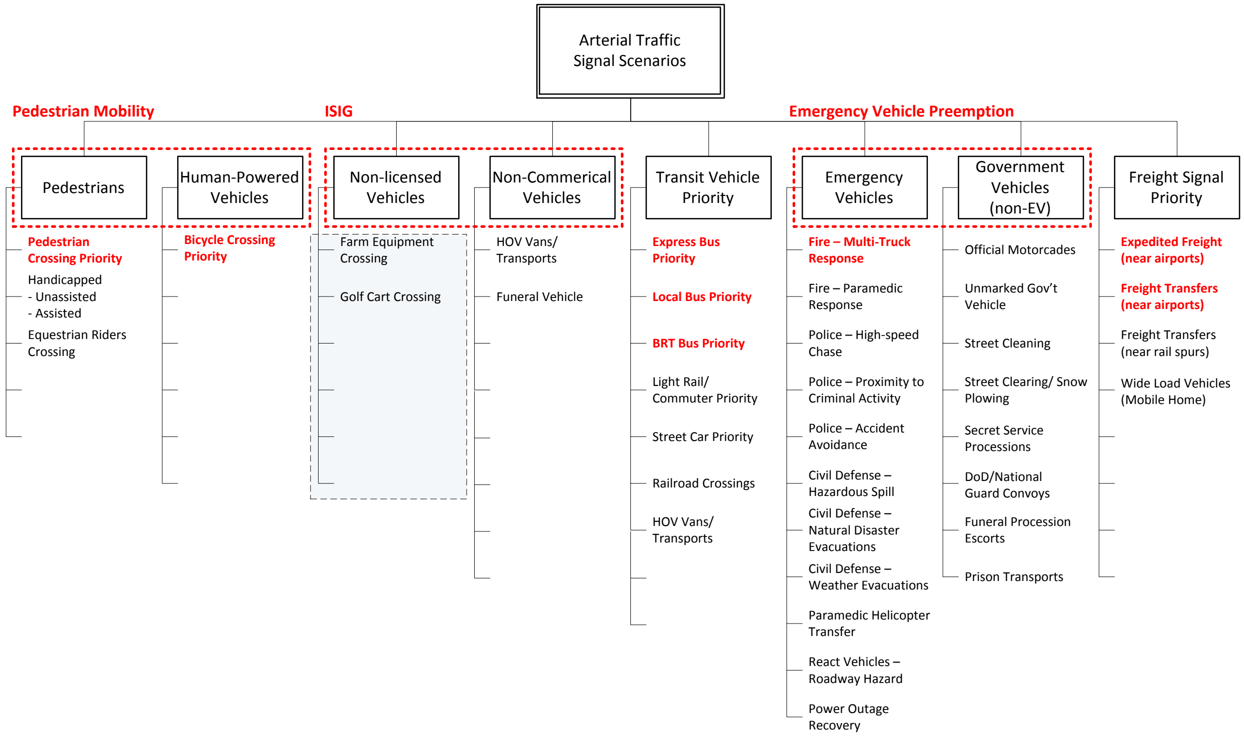


Figure 4 – Initial Collection of MMITSS Scenarios

Assessment of Prior and Ongoing Research

The purpose of the Assessment of Prior and Ongoing Research Report is to review and identify research related to multi-modal intelligent traffic signal systems (MMITSS) and identify key performance measures used in the related research. Reviewing and understanding previous and ongoing research can influence the design and operation of MMITSS as well as identify key stakeholders and related concepts of operations that have been developed previously, as well as system designs, including architectures, algorithms, and performance measures related to MMITSS. Four categories of research were considered: (1) Prior Research, (2) Ongoing Research, (3) Related Research, and (4) Standards and Technology. A summary of research was presented for the areas of Connected Vehicle Systems, Intelligent Traffic Signal Control, Traffic Signal Priority, Pedestrian Mobility, Freight Signal Priority, Emergency Vehicle Preemption, National Testbeds and Other Deployments, and National Standards.

Intelligent Traffic Signal Systems Research - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on Intelligent Traffic Signal Systems are shown below in a bulleted format. Indentations are used for cases where a Stakeholder's comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in *italic* font.

- Intelligent Traffic Signals are more than just adaptive signal control.
- Bikes should be considered to be vehicles.
  - …if they are operating in a bike lane or separated bike facility.
- Most current signal timing is based on volumes. Until there is 100 percent market penetration, connected vehicles will not be able to provide volume information. Therefore, looking into prior

research related to using travel times or speed profiles as the basis for signal timing would be important.

- It is important to remember that isolated intersection operation is not usually the optimal approach in a dense urban environment where signal operation needs to look at a larger population of signals and a managed implementation - i.e., the central systems need to optimize the network.
- A traffic signal system should include existing detection systems already in place, identify congestion hot points and implement appropriate signal timing, arterial travel-time and delay monitoring, passage of emergency vehicles through the signals with minimal disruptions to commuter traffic.
- Should the system include a “surveillance” function?
- Larry, there was a harmonization meeting with the Europeans regarding SPaT. They need the changes by end of 2013.
- Larry, there are a couple of projects in Europe regarding intelligent signal control with regard to Eco Driving.

Transit Signal Priority Research - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on Transit Signal Priority are shown below in a bulleted format. Indentations are used for cases where a stakeholder’s comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- There are already commercially available transit signal priority/emergency vehicle preemption systems that use GPS and radio communications with the signal. It would be useful to work with these vendors to incorporate DSRC rather than try to re-invent the whole system just to use DSRC.
- Many of these applications need not be DSRC centric - but rather in an urban setting, this is more likely a broad-band communications using on-board GPS and better location etc. to support priority and preemption without localized infrastructure. A DSRC centric is not an optimal solution unless you suggest that SPaT is present!
- DSRC may have difficulty communicating around corners in downtown areas.
- There is a wide body of knowledge on transit signal priority applications. This is often the most common application sited for Connected Vehicle use.
- Since many intersections have communications lines already in place, perhaps a more robust method of using DSRC *is needed* than cascading the information intersection to intersection.

Pedestrian Mobility Research - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on Pedestrian Mobility are shown below in a bulleted format. Indentations are used for cases where a stakeholder’s comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- There *are* pedestrian applications being researched at the University of Idaho and University of Minnesota. There was a presentation at the ITS America Conference regarding a mobile APS application developed at the University of Minnesota.
- You should add the technology (from Israel) being used by FTA to detect pedestrians at intersections as part of the Safety Pilot Model Deployment in Ann Arbor.
- There are plans to include a pedestrian/transit vehicle safety application during the Connected Vehicle Safety Pilot. The goal is to study how V2I data could improve transit vehicle versus pedestrian accidents in crosswalks.

Freight Signal Priority Research - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on Freight Signal Priority are shown below in a bulleted format. Indentations are used for cases where a stakeholder's comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- Here are links to 2 Minnesota projects on truck priority at traffic signals:
    - http://www.dot.state.mn.us/guidestar/2006_2010/truck_priority.html
    - http://www.dot.state.mn.us/guidestar/2001_2005/truck_priority/truckpriorityfinal.pdf

  Synopsis of Link: This information is titled "Truck Priority at Signaled Intersections" and dated December 15, 2004. It is a report authored by Roger Plum under the authority of the Minnesota DOT. It highlights past and current efforts to enhance the efficiency of the statewide network of inter-regional corridors (IRCs) that connect production centers and population areas in the state. Three primary benefits are defined and pursued for freight signal priority: (1) enhance the level of service of time-critical freight delivery, (2) achieve safety improvements, (3) reduce the delays to vehicles (freight vehicles, passenger vehicles, etc.) using the IRCs. These benefits and goals were approached using a two-prong approach: (1) optimization of traffic signal timing parameters for an existing traffic signal system, and (2) development, installation, test, and evaluation of a truck detection system for freight signal priority. As stated in the report[5], the results of this effort were mixed. The number of trucks that stopped for the signal was reduced, but the average amount of time stopped increased for those trucks that were signaled to stop.

    - Freight is too narrow a theme. What about construction equipment, road and winter maintenance vehicles, and other types of heavy vehicles. Truck signal priority would include freight and all classes of heavy vehicles excluding transit.
      This comment suggests that the non-EV Government Vehicles shown in Figure 4 *(snow plows, road maintenance vehicles, street cleaners, garbage trucks, prison transports, etc.) should be grouped with the Freight Signal Priority.*
    - I think transit, freight, emergency, and maintenance vehicle priorities are really very similar from a technical level of traffic control. The operational priorities - business rules - dictate priorities.

Emergency Vehicle Preemption Research - Stakeholder Feedback

No stakeholder input or feedback was provided on the research presented on Emergency Vehicle Preemption during the Stakeholder Meeting or during the one-week period of time the ThinkTank website remained open for comments.

National Testbeds and Other Deployments Research - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on National Testbeds and Other Deployments are shown below in a bulleted format. Indentations are used for cases where a stakeholder's comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- It is important that the lessons learned are practical for the rank-and-file deployers - not just the "bleeding edge" agencies such as MNDOT.

[5] "Truck Priority at Signaled Intersections", MNDOT0326.00, p32

- How do we factor in possible lessons learned from the Safety Pilot (timing of this project versus Safety Pilot could be an issue)?

Other Traffic Control Issues - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented on Other Traffic Control Issues are shown below in a bulleted format. Indentations are used for cases where a stakeholder's comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- Highway-Railroad Interface
  This is grouped under "Transit" in Figure 3.
    - Agree with this topic. Signal priority to clear waiting areas for signals that cross over a rail grade crossing very important. Also, once train is occupying crossing and blocking road, signal would give priority to cross traffic until train clears crossing.
- Arterial-Freeway Interchanges
  Should (and how should) Figure 3 and Figure 4 be modified to include this category?
- Active Traffic Demand and Management
- Is it really practical to equip all of the signals in an urban environment with the DSRC/SPaT - or are we going to see advances in broad-band communications that will make this more practical?
- Perhaps learn when we need to equip and when we do not is the key research need in this regard.
- We should include interconnected traffic signals and grade crossing locations with gates/lights/traffic signals (i.e., railroad preemption).

Uncategorized Ideas - Stakeholder Feedback

Stakeholder inputs and feedback on the research presented under Uncategorized Ideas are shown below in a bulleted format. Indentations are used for cases where a stakeholder's comment pertained to another comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

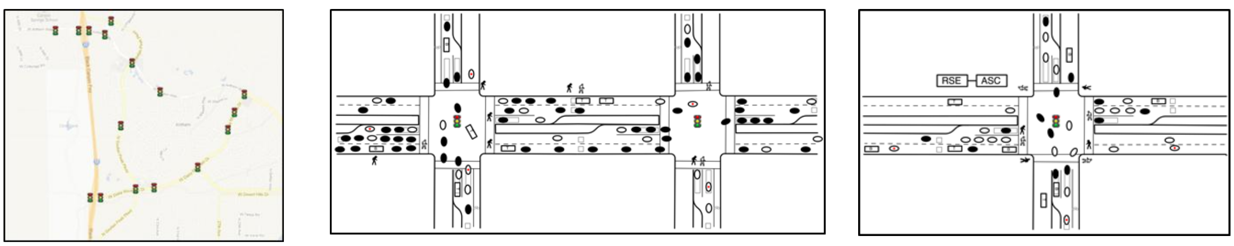
- It seems that the area of work zones and incident management when overlaid on a signal control areas is a major missing element in your list. We would want the test bed to be in a position to be able to study this further.
  These two items are not explicitly enumerated in Figure 3 and Figure 4. The topic of "work zones" could be added within "maintenance." The category of "react vehicles" was intended to include incident management (assuming the response to a traffic accident, roadway incident, etc.)
- Standards - NTCIP 1103 V3 is critical.
- Expansion of NTCIP 1202 to add support for SPaT is an outcome of the Battelle SPaT work. Funding is to be available for updating 1202. Hopefully the SPaT additions will be a focus of this funded effort.
- Do we have good technical data on the density of DSRC and vehicles around an intersection - within range?
- A NHTSA decision in 2013 could mandate V2V on new vehicles. It will not likely mandate any V2I applications. Therefore, even the equipped vehicles may not be capable of interacting with the roadside infrastructure for V2I apps. We need to identify a mechanism for getting the V2I apps into the vehicles.
- A wealth of safety information could be gained from I-to-V communication, for example operator behavior could be identified, and corrective actions taken within transit fleets using collected data.

Scenario 1 – Intelligent Traffic Signal Systems

From the perspective of the MMITSS project, Intelligent Traffic Signal System (ISIG) applications are defined to use high-fidelity data collected from vehicles through wireless communications to accurately predict lane-specific platoon flow, platoon size, and other driving characteristics. ISIG has the potential to transform how traffic signal systems are designed, implemented and monitored. ISIG also plays the role of an over-arching system optimization application, accommodating transit or freight signal priority, preemption, and pedestrian movements to maximize overall arterial network performance. As such, user inputs on scenarios related to this area will influence the MMITSS project.

Scenario 1 Description

Traffic signal control systems can be considered from a hierarchical perspective starting at an intersection at the lowest level, a section or sections (or facility such as an arterial, CBD grid, or freeway interchange) at the middle level, and the overall system at the highest level. Traditional traffic signal control concepts such as actuated phase call, phase extension, phase sequencing, pedestrian intervals, dilemma zone protection, time-based coordination, transit priority, and preemption are generally implemented at the intersection level. Section control strategies primarily address coordination (common cycle length and offsets) and time or traffic responsive pattern selection. System level control considerations generally include time-of-day patterns, traffic responsive patterns, clock synchronization, partitioning signals into section, selection of common cycle length and common phase sequencing strategies (leading, lagging, lead-lag).



System Level *Section Level* *Intersection Level*

Figure 5 – Hierarchical Levels of Traffic Signal Systems

Scenario 1 Assumptions

At the intersection level, the scenario is comprised of a single intersection with connected travelers. Some form of communication with each signal controller is assumed to exist. This communication could be a high-speed backbone such as Ethernet, a serial-multi-drop, or a local master. The purpose of this communication includes clock synchronization, uploading and downloading controller databases, time-of-day scheduled commands, manual commands, and status monitoring. It is assumed also that ISIG has a separate communication backbone as part of the connected vehicle system.

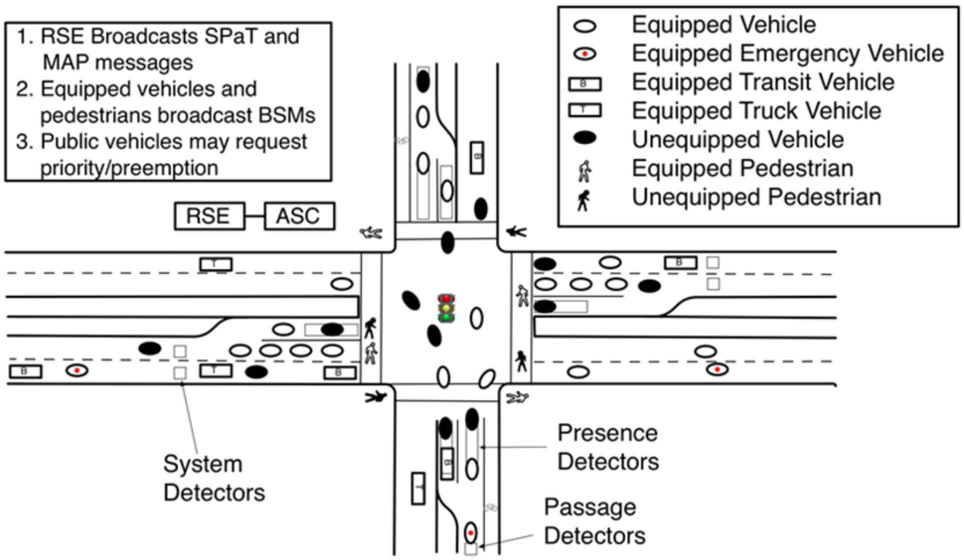


Figure 6 – Single Intersection with Connected Travelers

As shown in Figure 6, the actors at the intersection level include equipped and unequipped vehicles and pedestrians, equipped emergency vehicles, transit vehicles, and freight. The intersection accommodates roadside equipment (RSE) that can broadcast signal and phase timing (SPaT) and MAP messages. Equipped vehicles and pedestrians can broadcast basic safety messages (BSM) and public vehicles may request priority or preemption.

As shown in Figure 7, the section level is represented with only two intersections, but a section could include arterials, grids, and central business district (CBD). The actors at the intersection level include equipped and unequipped vehicles and pedestrians, equipped emergency vehicles, transit vehicles, and freight.

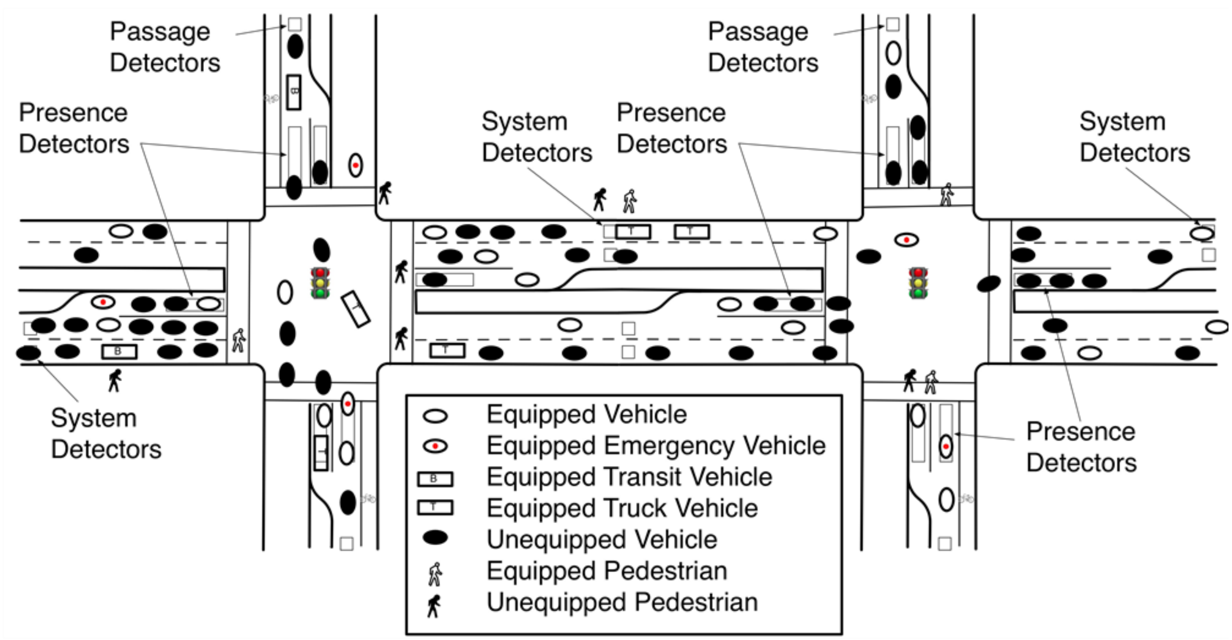


Figure 7 – Group of Intersection with Connected Travelers

As shown in Figure 8, a system or network can be comprised of multiple intersections, arterials, grid, and CBD configured with connected travelers.

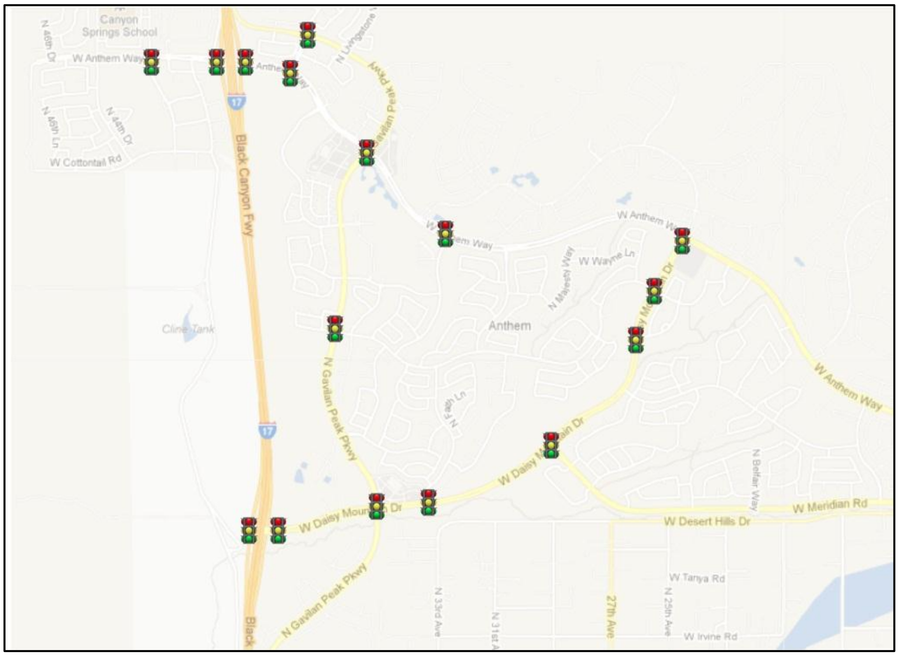


Figure 8 – System or Network with Connected Travelers

Scenario 1 Questions/Issues

During the MMITSS Stakeholder Meeting, the following questions and issues were presented for discussion and input.

Intersection level questions included:

- What ***intersection*** control operational improvements can Connected Vehicles provide?
- Which improvements ***should*** Connected Vehicles provide?
- What advice or ideas would the Stakeholders offer on ranking the potential intersection control improvements?

Section level questions included:

- What ***section*** control operational improvements can Connected Vehicles provide?
- Which improvements ***should*** Connected Vehicles provide?
- What advice or ideas would the Stakeholders offer on ranking the potential section control improvements?

System level questions included:

- What system management improvements can Connected Vehicles provide?
- Which improvements ***should*** Connected Vehicles provide?
- What advice or ideas would the Stakeholders offer on ranking the potential management improvements?

Scenario 1 Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on the scenarios describing Intelligent Traffic Signal Systems are shown below in a bulleted format. Indentations are used for cases where a user comment pertained to another user comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- **What intersection control improvements can Connected Vehicles provide?**
    - *Connected Vehicles can provide* high-speed transmission of SPaT, and of vehicle positioning.
    - All pedestrian phases (when needed).
    - Reducing and eliminating infrastructure based sensors and replacing with vehicle or human based dynamic sensors reduces costs and increases signal operation efficiencies.
        - This seems like pie in the sky to eliminate all sensors.
    - *Connected Vehicles can provide the* ability to prioritize vehicles in a multi-modal environment.
        - I think this is a logical conclusion and should be the focus.
    - Number of vehicles approaching intersection, number of vehicles leaving intersection in the respective directions, approach speeds.
    - *Connected Vehicles can provide* controller algorithm improvements by making use of individual vehicle data that can be provided via a Connected Vehicle system.
        - Seems like anonymity of the data will limit this significantly.
    - Connected Vehicles could provide measures of effectiveness, such as travel times, to monitor ongoing signal operations.
        - One particularly important area that I haven't seen much thought on (Inrix offers this) is the archival data and a notice of effectiveness as it relates to more typical conditions. Also, long term tracking of performance.
    - *Use* connected vehicle sample speeds for selecting timing program.
    - Consideration of vehicle weight, performance when traversing the intersection when setting phase length and other settings.
    - *Connected Vehicles can provide* improved oversaturated control; queue lengths easier to estimate.
    - Some of the ideas described here concern me. It would seem that some of these should be separated into what the Researchers believe to be true and what is likely to occur.
    - *It is* critical to find controller solutions that can combine Connected Vehicle data with existing sensor data to improve controller performance.
    - Connected Vehicles could provide more accurate traffic demand for different movements.
    - *Connected Vehicles can provide* detection of gridlock conditions/violations.
    - Connected vehicles can provide speed information by lane *and* accurate queue information.
    - *Connected Vehicles can provide* improved safety - dilemma zone reduction.
    - Connected Vehicles could provide improvement to detection methods.
    - Determining the number of vehicles awaiting the left hand turn - and traffic approaching to determine whether a FYA or a protected movement is warranted; detection of speeds to determine appropriate clearance intervals.
    - *Connected Vehicles can provide* better operational control during heavy rains or storms/ construction when loops and video are unreliable.
    - *Connected Vehicles can provide* better coordination between pedestrians and vehicle needs.

- For buses, you can get passenger counts, service type, schedule adherence, etc.
- *Connected Vehicles can provide a* lot more data for performance measurement.
- Added data at the intersection level should allow us to provide improved local adaptive signal control operation.

- **Which of these intersection control improvements SHOULD be included in MMITSS (ISIG)?**
  - Measures of effectiveness should be included.
  - Adaptive system timing *should be included.*
  - Development of new controller algorithms that can make use of connected vehicle data in a less than 100% penetration environment. Need to move away from our current gap based control approach.
    - Agreed. Data should be good for analysis, planning, and operations monitoring.
  - *MMITSS should include* better solutions to the dilemma zone problem through use of individual vehicle data available with a connected vehicle system.
    - It would seem there are some equity issues on this particular application. I am not saying it isn't a good idea.
  - *MMITSS should* incorporate flexible multi-objective optimization that can be altered depending on the operational conditions: bad weather, code red AQ, special event, and so on.

- **What section control improvements can Connected Vehicles provide?**
  - *Connected Vehicles can provide* measures of effectiveness *for section control improvements.*
  - *Connected Vehicles can provide* travel time/sample speeds for selecting timing programs *for section control improvements.*
  - *Connected Vehicles can provide* queue spillback detection between/among intersections.
  - *Connected Vehicles can provide* coordination control, with known platoon sizes and locations.
    - Knowing routes of vehicles requiring priority/preemption allows for prediction and planning in real-time .e.g. preparing for a left turn if several signals upstream along vehicles known route.
  - *Connected Vehicles can provide* optimization of section based on known arrival times of vehicles. *Connected Vehicles can provide* optimization based on number of commercial vehicles.
    - O-D info and schedule adherence requirements could be fed into algorithms.
  - *Connected Vehicles can provide* coordinated priority through the section by path for time critical users (freight, transit, EV).
  - *Connected Vehicles can provide* second-by-second optimization, based on real-time vehicle arrivals if high enough market penetration.
  - *Connected Vehicles can provide* pedestrian wave accommodation (special events).
  - Need O-D information (which is prohibited today) to help optimize the network/section.

- Which of these section control improvements SHOULD be included in MMITSS (ISIG)?
  - Measures of effectiveness.
  - Split or regroup intersections for coordination based on measured MOEs.

- **What system management improvements can Connected Vehicles provide?**

- *Connected Vehicles can provide* incident detection where traffic is slow or stopped for prolonged periods of time.
- *Connected Vehicles can provide* dynamic re-routing.
- *Connected Vehicles can* measure and improve progression through a corridor.
- Suggest including ramp meters to the system
- *Connected Vehicles can provide* intersection levels of effectiveness, system travel time, and intersection approach information.
- Multimodal priority is my primary interest as opposed to the auto-based ideas within this category.

- **Which of these system management improvements should be included in MMITSS (ISIG)?**
    - Incident detection.
    - On-the-fly priority corridor identification, processing predicted O-D data.
    - If the density of vehicles is present - then we can determine which areas are "busy" and where there is/is not capacity - faster detection of incidents - so we can support network optimization not just a single arterial.
    - If one were to use the in-vehicle communications - then parking information, event parking information, street closures etc. could be communicated to the individuals or selectively of we had O-D information.

Scenario 1 Performance Measures and Goals

Stakeholder inputs and feedback on performance measures and goals for the Intelligent Traffic Signal Systems are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What are reasonable, realistic, and attainable ten-year target performance measures and goals?
    - Emissions *and* fuel reductions as well as travel times or corridor throughputs.
    - Arterial travel-time, degree of saturation, or occupancy on green.
    - Per person delay versus per vehicle delay.
    - All of this depends on the density of equipped vehicles. Hence, I would not expect any significant improvements for several years - UNLESS there is a mandate for an after-market BSM device on all vehicles!
    - Can we optimize for reliable system-level throughput?
    - Travel time reduction in the network would seem to be the end-users ideal performance measure.
    - The first goal might be defining what the goal requires (i.e., a level of percentage population need to determine reasonable data on your five items). For example, if the evening rush hour needs 8% population and you are not there yet, what you 'can know' below this tipping point is what needs to be learned first.
    - Without knowing potential/capabilities from this technology, guesses are not very useful. I would think this is a follow up exercise after we prove we can do it and assess the basic operational aspects.
    - The problem with these *types of* projections *is that* you have to layer on the growth in VMT or shrinkage depending on demographics and the economy - and the cost of mobility!

- Performance Measures and Goals for Uncategorized Ideas
    - Is there any new baseline that "ten years out" we can agree on in any of this?

- Picking percentages for improvement or metrics now without knowing capabilities seems like a valueless action - too premature, any guess is good.
- Recall that "8-track" was a clear failure in less than 4 years.
  The reference is to music storage and delivery that provided transformative performance in mobile music capability but negligible performance in longevity.
- None of your measures seem to involve safety in any way, are you not short-changing yourselves as to the benefits beyond congestion?
- Can the overarching optimization algorithm also throttle data collection in real time to reduce communications costs and data storage costs?
- What is the minimum set of data required to realize these applications and can a fixed time interval reporting system feasibly accommodate these data needs?

Out of the 31 Stakeholders providing input via the ThinkTank facilitation, a total of 22 provided numerical values for ten-year goals on five, pre-defined performance improvement metrics. The acceptable range for improvement performance was bound by 0-100% referenced to present day thresholds. The summary statistics are shown in tabular form in Table 5 and graphical form in Figure 9. Note that the relationship between average and standard deviation implies a wide disparity or range between Stakeholder entries.

Intelligent Traffic Signal System Performance Improvement	Average	Std. Dev.	Votes
Reduced Overall Vehicle Delay	26.64	24.46	22
Increase Throughput	23.05	20.06	21
Reduce Queue Length	21.00	14.65	21
Reduce Extent (spatial range) of Congestion	23.38	15.28	21
Reduce Temporal Duration of Congestion	26.71	22.10	21

Table 5 – Stakeholder Input on Ten-Year Target for ISIG Performance Improvement

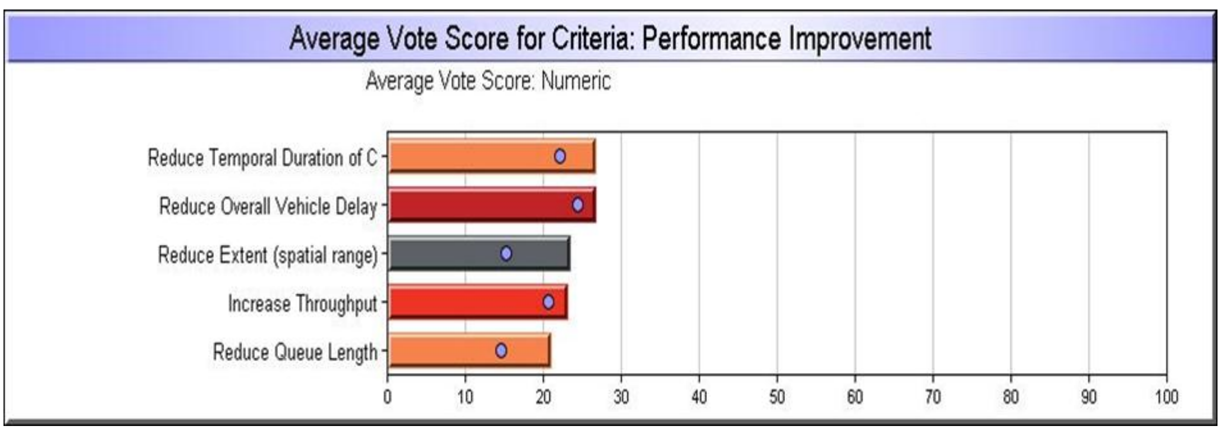


Figure 9 – Stakeholder Input Graph for Ten-Year Target ISIG Performance Improvement

Scenario 2 – Transit Vehicle Priority

Delays at signalized intersections are a considerable contribution to the journey time for public transport in urban areas. Providing transit priority at traffic signals to reduce this delay can be an effective use of Intelligent Transportation Systems (ITS) technology thereby reducing travel time and improving service quality for buses at a relatively low cost. Transit Signal Priority (TSP) is an operational strategy that facilitates the movement of in-service transit vehicles, either buses or streetcars, through traffic signal controlled intersections. As substantiated in the MMITSS Assessment of Relevant Prior and Ongoing Research report, various deployment cases of TSP systems have demonstrated that TSP is effective in improving transit service quality. The benefits of TSP include reduced intersection delay and travel time, improved schedule adherence and travel time reliability, which lead to increased transit quality of service and improved customers' satisfaction.

Transit Signal Priority (TSP) strategies allow transit agencies to manage better bus service by adding the capability to grant buses priority based on a number of different factors. For instance, transit vehicles equipped with on-board equipment can communicate information such as passenger count data, service type, scheduled arrival time, actual arrival time, and heading information to roadside equipment via DSRC.

Scenario 2 Description

Consider the section (sub-network) shown in Figure 10 with several bus routes in the network with active buses on each route. The network shows several important transit characteristics including bus routes with conflicting movements at the different intersections, near side, far side and mid-block bus stops, passengers, and other vehicles including trucks and public vehicles. Buses move along their routes based on a headway or schedule based management strategy.

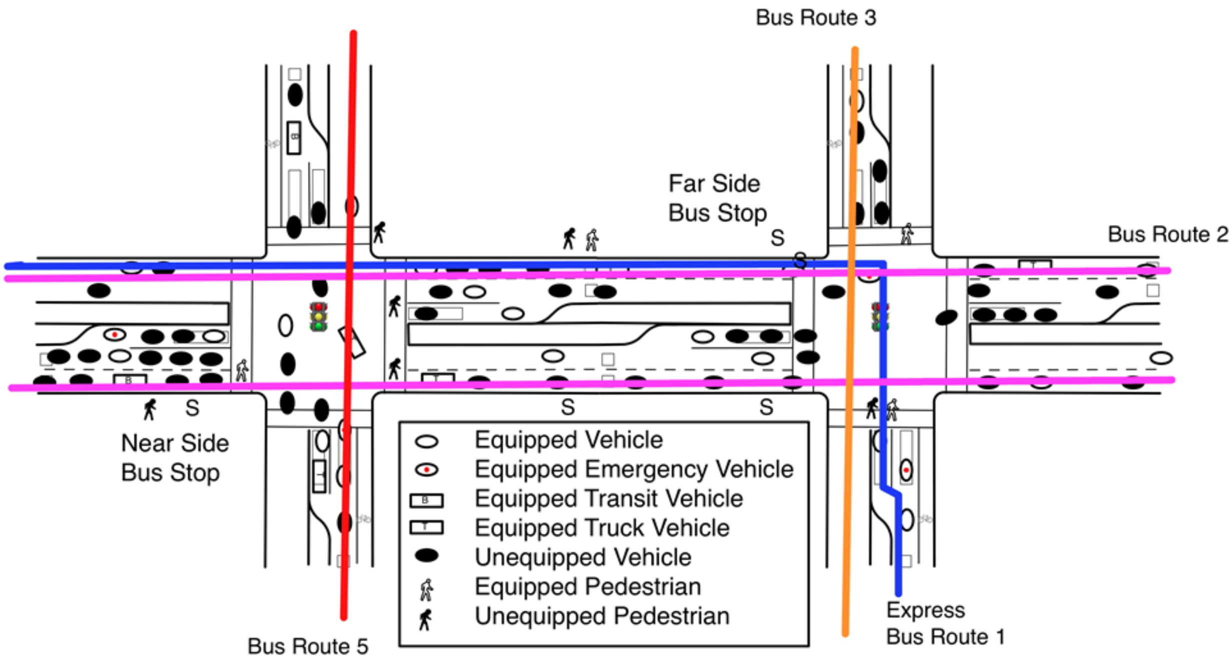


Figure 10 – Scenario 2: Traffic Control Section with Several Bus Routes

Scenario 2 Assumptions

- The dwell time at bus stops is unknown and depends on passenger boarding and alighting as well as current schedule status (e.g. a driver may dwell at a stop to ensure they are not ahead of schedule).
- The transit management system and bus has information on the bus occupancy, schedule/headway adherence, and class of service (e.g., BRT, Express, local).

Scenario 2 Questions/Issues

- What traffic signal control capabilities can be improved given Connected Vehicle information?
- What transit operations capabilities can be improved given Connected Vehicle information?
- What information is needed by the traffic signal system to make TSP decisions?
- What role should transit data play in making a priority decision? Transit data is defined to include passenger count, schedule adherence, etc. Should these decisions be made by the transit management system or on the transit vehicle or by the traffic control system?
- Should priority be granted for every qualified vehicle or should there be a budget or other allocation control mechanism?

Scenario 2 Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on the Transit Vehicle Priority scenario are shown below in a bulleted format. Indentations are used for cases where a user comment pertained to another user comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What traffic signal control capabilities can be improved given Connected Vehicle information?
    - In theory all aspects *of traffic signal control can be improved with Connected Vehicle information.*
    - *Connected Vehicle information* should provide better priority-based service to transit vehicles (compared to current first come first served approach).
        - This is exactly what I think should be an outcome achieved as a part of this project. Find ways to get public sector vehicles equipped and use information strategically to deliver better service.
    - *Connected Vehicle information* can provide priority specific to turn movement (i.e., more time needed for right turn).
    - *Connected Vehicle information* can provide priority-level relative to bus occupancy.
        - In Portland, we don't worry about the current occupancy because there is always someone downstream that the bus will pick up. That's a policy distinction that may not be appropriate everywhere.
    - *Connected Vehicle information* should provide priority only if *transit vehicle* is delayed.
        - In Portland, the bus system does this. It should be something that would be integrated with the system and in an ideal situation you would also have that data as a signal operator.
    - *Connected Vehicle information* should provide service based on vehicle type, loading, schedule delay, etc.
    - Didn't we answer this question in Scenario #1?
    - It is not so much the connected vehicle program - but the ability of the appropriate vehicles to communicate their requests in real-time to the intersection/systems to improve their passage, reduce conflicts, avoid accidents, etc.
    - *Connected Vehicle information should provide the* ability to assess speed of various vehicles requesting priority can lead to better assignment of priority in multi-modal environment.
    - Note that much of the discussion focuses on the use of near-field/DSRC communications with the intersection. Yet the scenarios shown (for a section-route) are more of a central directed function. So, it becomes the ability of the vehicle to communicate its needs to the central system so that it can "program" the route, manage potential conflicts and actually dynamically re-route the vehicle if necessary.

- Don't forget to improve pedestrian safety as related to transit vehicle movements. We need to use Connected Vehicle data to better inform the transit vehicle operator and pedestrian to avoid accidents.
  - This is an intriguing concept that I would support.

- What transit operations capabilities can be improved given Connected Vehicle information?
  - Connection protection *can be improved with Connected Vehicle information.*
  - Bus diversion *can be improved with Connected Vehicle information.*
  - *Connected Vehicle information can improve* connection protection to guarantee transfers on low frequency routes.
  - *Connected Vehicle information can provide* better tracking and monitoring of flexible fixed route and demand responsive services.
  - *Connected Vehicle information can provide* more innovative control strategies for transit vehicles (e.g., transit vehicles turning left from the far right lane).
  - *Connected Vehicle information can improve* communications between bus and transit operation center.
  - Not significant - broadband is more likely a deployment alternative in urban settings (*in comparison to the DSRC mentioned in the scenario description.)*
  - *Connected Vehicle information can improve* conversion from fixed route to para-transit/jitney service.

- What information is needed by the traffic signal system to make TSP decisions?
  - *The traffic signal system needs information on* passengers behind schedule or potentially missing connections.
  - Of course this data will be used, but when a vehicle is not 'behind' this data is also used to sharply reduce any action that might otherwise be taken.
  - *The traffic signal system needs information on* bus occupancy.
  - *The traffic signal system needs information on the* transit vehicle's route *and* turn decision (left, right, through).
  - *The traffic signal system needs information on the* vehicle type and a relative priority based on function or vehicle type - fire truck, ambulance, etc. the vehicle dynamics need to play a role.

- What role should transit data play in making a priority decision? Transit data is defined to include passenger count, schedule adherence, etc. Should these decisions be made by the transit management system or on the transit vehicle or by the traffic control system?
  - *The role* should be balanced against overall optimization -- one of many users.
  - Duh, my last answer was meant for this entry. In answer to Larry's question, the signal needs to know and will not (never) trust others in this regard in the absence of truth.
  - The request can come from the individual bus/passengers but granting of priority should be made at the infrastructure level (intersection or section or system).
  - This decision must he shared - the vehicle does not know the balance of the service requests - - so it is broader - because it involves the route, the intersection, the section - not just the intersection. The vehicle type and priority should have a greater impact - it becomes more complicated when you try to integrate freight priority!
  - I think transit data should be used. I don't think it matters where and what happens on the decision side as long as there is appropriate communication throughout the system to get the information to the right people.

- Should priority be granted for every qualified vehicle or should there be a budget or other allocation control mechanism?
  - Of course not!
  - Consider not only if the bus is ahead or behind schedule, but how the travelers are doing (if they have a logged itinerary) with respect to schedule or planned connections.
  - How do you define "qualified"?
  - Consider number of passengers on the transit vehicle.
  - The ideal priority solution would combine the needs of approaching transit vehicles with those of other road users.
  - If it is light rail, perhaps. If it is bus, then no.
  - Assign priority based on existing traffic conditions at that time.
  - There needs to be a budget. But, it is likely that the optimal solutions are route, as well as localized issues. So, broadband communications and DSRC are likely to be required.
  - If you are going to grant priorities during peak periods, this needs to be considered during the planning of operational parameters to budget these times.
  - I think this is something that is user-definable based on policies by the *transit* agency.

Scenario 2 Performance Measures and Goals

Stakeholder inputs and feedback on performance measures and goals for the Transit Vehicle Priority scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What are reasonable, realistic, and attainable ten-year target performance measures and goals?
  - Again, how do we know without assessing the basic capabilities?
  - On-time performance, number of successful connections made, ratio of transit travel time to POV travel time *are performance measures for Transit Vehicle Priority.*

- Performance Measures and Goals for Uncategorized Ideas
  - Will DSRC give us the distance needed to solve both transit signal priority under all conditions (including environmental)? *The stated range for 5.9GHz DSRC is 1000 meters (30 meters for 915MHz predecessor).*
    - Great question.
  - Intuitional trust by a multiple local agency of a transit agency that cover them seems very unlikely to occur, even in ten years. If the transit vehicle states why it needs a call (I am behind and I have xx people on board), then it seems likely that the ASC will be able to grant without understanding the need further.
  - And again, we are using delay as the measure of success rather than safety at all.

Out of the 31 Stakeholders providing input via the ThinkTank facilitation, a total of 21 provided numerical values for ten-year goals on two, pre-defined performance improvement metrics. The acceptable range for improvement performance was bound by 0-100% referenced to present day thresholds. The summary statistics are shown in tabular form in Table 6 and graphical form in Figure 11. Note that the relationship between the average and standard deviation implies a wide disparity between individual Stakeholder entries.

Transit Vehicle Priority Performance Improvement	Average	Std. Dev.	Votes
Reduced Average Transit Delay	26.95	19.33	21
Reduce Transit Delay Variability	32.67	23.31	21

Table 6 – Stakeholder Input on Ten-Year Target for Transit Vehicle Priority Performance Improvement

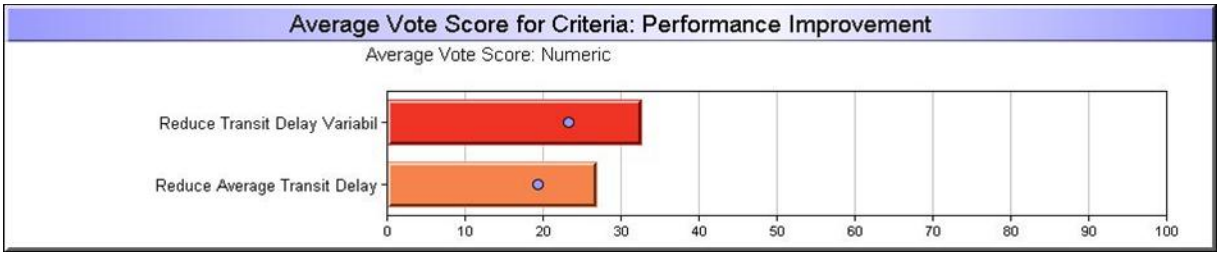


Figure 11 – Graph of Ten-Year Target for Transit Vehicle Priority Performance Improvement

Scenario 3 – Pedestrian Mobility

Mobile accessible pedestrian signal systems integrate information from roadside or intersection sensors and new forms of data from wirelessly connected pedestrian-carried mobile devices, and then wirelessly communicate with the traffic signal controller to obtain real-time Signal Phase and Timing (SPaT) information, which will then be used to inform the visually impaired pedestrian as to when to cross and how to remain aligned with the crosswalk. This permits an "automated pedestrian call" to be sent to the traffic controller from the smart phone of registered blind users after confirming the direction and orientation of the roadway that the pedestrian is intending to cross. Integration and compatibility with such systems may also support the accommodation of safe and efficient pedestrian movement of a more general nature.

Scenario 3 Description

Consider a section where pedestrians are present as shown in Figure 12. Pedestrians are traveling in the network. Some of the pedestrians have nomadic applications on smart devices and others do not. Pedestrians may or may not be disadvantage which includes visual impairment or physically challenged.

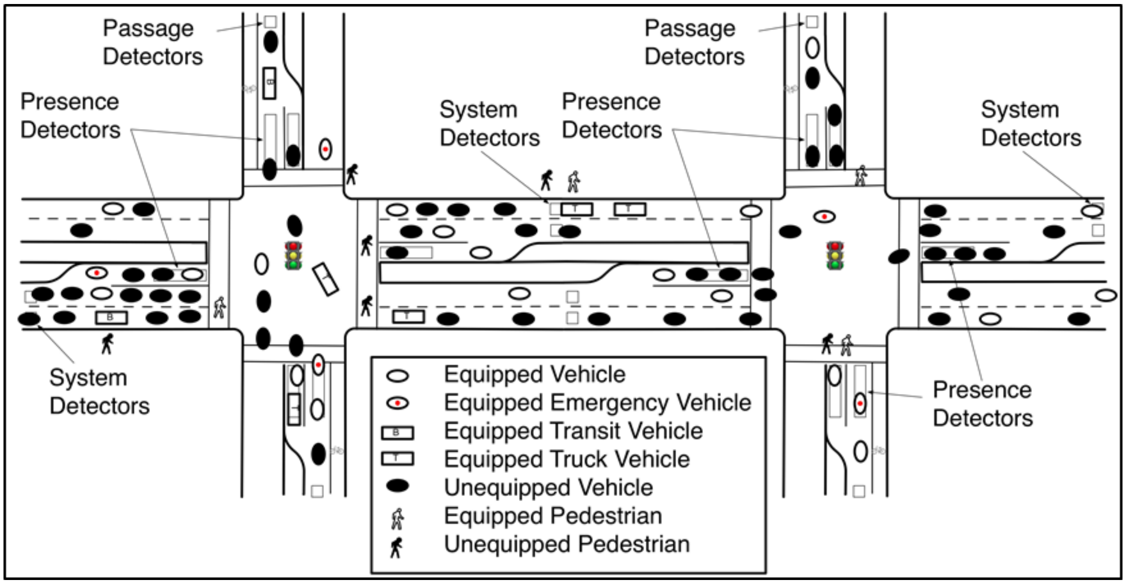


Figure 12 – Scenario 3: Pedestrian Mobility in a Network

Scenario 3 Assumptions

- The traffic signal is compatible with pedestrians that are equipped with nomadic devices as well as those that are not.
- The pedestrian service treatments do not have to be fixed intervals as part of phases.
- Pedestrians may desire to cross the street or to meet a bus at a stop (near side, far side, or mid-block).
- Pedestrians may or may not be disadvantage which includes visual impairment or physically challenged.

Scenario 3 Questions/Issues

- What communications method (DSRC, Wi-Fi, Bluetooth, 3G/4G, etc.) is best to support pedestrian applications?
- What intersection control improvements (e.g., active interval enhancements) could benefit pedestrians?
- What additional consideration could be made for disadvantaged pedestrians?

Scenario 3 Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on the Pedestrian Mobility scenario are shown below in a bulleted format. Indentations are used for cases where a user comment pertained to another user comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What communications method (DSRC, Wi-Fi, Bluetooth, 3G/4G, etc.) is best to support pedestrian applications?
  - Again, who knows without testing?
  - Advisory or "active safety" warning systems? *It* depends on the applications you are considering.
  - What about *data* security? This is subject to much corruption? Wi-Fi has the correct range and is already on most devices!

        - The user has to enable the Wi-Fi to be on. It also makes battery life less and could be prone to issues.
    - It depends on the application.
    - All of the above *communication methods* and others not yet known. I still fail to see the need to pick the winner here when the application and the ConOps are still quite young.
    - Is there a latency requirement for pedestrians that would suggest one communications alternative over the other?
    - Because it is not reasonable to require a pedestrian to have a special device just for walking around, we should use communications that people would have anyway for consumer reasons. This would suggest 3G/4G, Bluetooth, or Wi-Fi.
    - Whatever has the best security.
    - It is probably best to test some combination of wireless technologies and see which works best. The solution could include more than one too.
    - Wi-Fi is good. It's on most smart phones and *has* enough range.
    - Probably Bluetooth or 3G/4G.
    - *The communications method* needs to be cost effective, easy to use, and made available to all pedestrian users. *It* must be a technology and solution that is also easily used by someone with limited visual capabilities.
    - It will depend on the latency necessary for the application to receive data, process it and then provide feedback to the pedestrian in a timely manner.
    - DSRC is better for safety. Wi-Fi can take too long to make the connection. 3G/4G is not always available or can be dropped.

- What intersection control improvements (e.g., active interval enhancements) could benefit pedestrians?
    - On-demand all pedestrian phases, predictive pedestrian phase lengths, *and/or* 2-minute look-ahead pedestrian movement predictions *are intersection control improvements that could benefit pedestrians.*
    - Extend phase length for slow-moving pedestrians.
    - Better knowledge of true pedestrian demand at an intersection could provide improvements at the controller level (get past our current fixed time approach).
    - Require that the handicapped have the device - keep conventional devices - but enhance available walk and clearance time to manage special cases only.
    - Meet ADA requirements with hardware less likely to get knocked over by vehicles and less likely to annoy neighbors of the signal.
    - On-demand and adaptable *intersection control improvements could benefit pedestrians.*
    - Better knowledge of vehicle positions and speeds should theoretically allow shorter cycle lengths for the same performance. That would improve pedestrian LOS more than anything else.
    - Better dynamic service time to pedestrian movements (adaptable Walk/Don't Walk) *is an intersection control improvement that could benefit pedestrians.*
    - Knowing the full crossing pattern as opposed to single approach crossing *is an intersection control improvement that could benefit pedestrians.*
    - Do not increase phase lengths for every type of pedestrians.
    - If possible, integrate severe-weather information into the phase length determination. Imagine crossing the street with a Chicago-style headwind, an icy surface, or Monsoon-type water hazard (puddle size and water flow rate). Standing on the street corner in Tucson during or after rainfall is an invitation to a “vehicle shower” or spraying. Imagine the pedestrian benefit of reducing the wait-time during inclement weather.

- What additional consideration could be made for disadvantaged pedestrians?
  - They are the only ones that it makes sense to assist!
  - Curb cut information, sidewalk closures, icy/wet crosswalk or sidewalk conditions *are additional considerations that could be made for disadvantaged pedestrians.*
    - This seems like a pretty difficult hurdle to overcome. How would you get information on icy crosswalks? Closed sidewalks would be good.
  - Log all special services and note where basic services are lacking so they can avoid *these intersections* altogether.
  - This is an area where the 'kinds' of disability need more agreement so that we can work up to saying what we will not in fact do (or cannot do).
  - Which street they are facing, which phase is currently active, *and* vehicles violating the pedestrian phase *are additional considerations that could be made for disadvantaged pedestrians.*
  - Use GPS on their phone to tell them if they are straying out of crosswalk.

Scenario 3 Performance Measures and Goals

Stakeholder inputs and feedback on performance measures and goals for the Pedestrian Mobility scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What are reasonable, realistic, and attainable ten-year target performance measures and goals?
  - Fewer injuries for the handicapped.
  - High level of equipped pedestrians.
  - Pedestrian accessibility, by level of ambulatory capability
  - Better service level or performance measure level for pedestrians without impacting vehicle travel time.
    - This is a value choice that should be made at the policy level. In Portland, there are places where we would disagree with this. Also, in the late night operations, why would one vehicle be more important than one pedestrian?
  - Improving safety for pedestrians should be a performance measure more so than reducing pedestrian delay.
    - An argument for reduce delay leads to better compliance of pedestrian signal indications.
  - This really needs to be more than just pedestrians - - fewer injuries with less wasted capacity!

- Reduce Overall Pedestrian Delay
  - Is delay the only performance measure? It may not only be about delay but more about safety. Their delay may actually be longer rather than shorter. If we find there is only one pedestrian at a light it may take longer for them to cross.
  - Can we measure the goal in term of platooning pedestrian movements in downtown areas in some useful way?

- Performance Measures and Goals for Uncategorized Ideas
  - Do not focus on the able bodied - if they are too stupid to press a simple button why give them a tool to really mess things up!

- Give consideration of *how* remote devices would interface with the traffic controller and how that might affect standards.
- I sometimes wonder if we are spending too much time staring at devices rather than looking around in our environment.
- Pedestrian Safety is more important than mobility.
- Any improvements will be very dependent on penetration. This is an area that I don't think has been researched.
- Pedestrians should not have to stare at the device to know signal status. The device should work unobtrusively and alert only when there is conflict.
- Can we measure the goal in term of platooning pedestrian movements in downtown areas in some useful way?

Out of the 31 Stakeholders providing input via the ThinkTank facilitation, a total of 15 provided numerical values for ten-year goals on a single pre-defined performance improvement metric – reduction of overall pedestrian delay. The acceptable range for improvement performance was bound by 0-100% referenced to present day thresholds.   The mean value of Stakeholder input on reduction of overall pedestrian delay was 24% and the standard deviation was 16.71.

Scenario 4 – Freight Signal Priority

Freight Signal Priority concept provides signal priority along an arterial corridor near a freight facility based upon current and projected freight movements into and out of the freight facility. The goals of freight signal priority efforts includes the reduction of potential delays, increase of travel time reliability for freight traffic, and enhance safety at intersections around the freight facility.

Scenario 4 Description

Consider a system (or sub-network) with several traffic signals along a corridor where there are a couple of routes supporting a factory or warehouse. These businesses load and unload many freight vehicles per hour in a work day with various work schedules. Assume that these trucks come from, and go to, a general facility such as a freeway, airport, rail depot, or port. Figure 13 depicts a small network with a factory/warehouse where trucks come to load and unload goods.

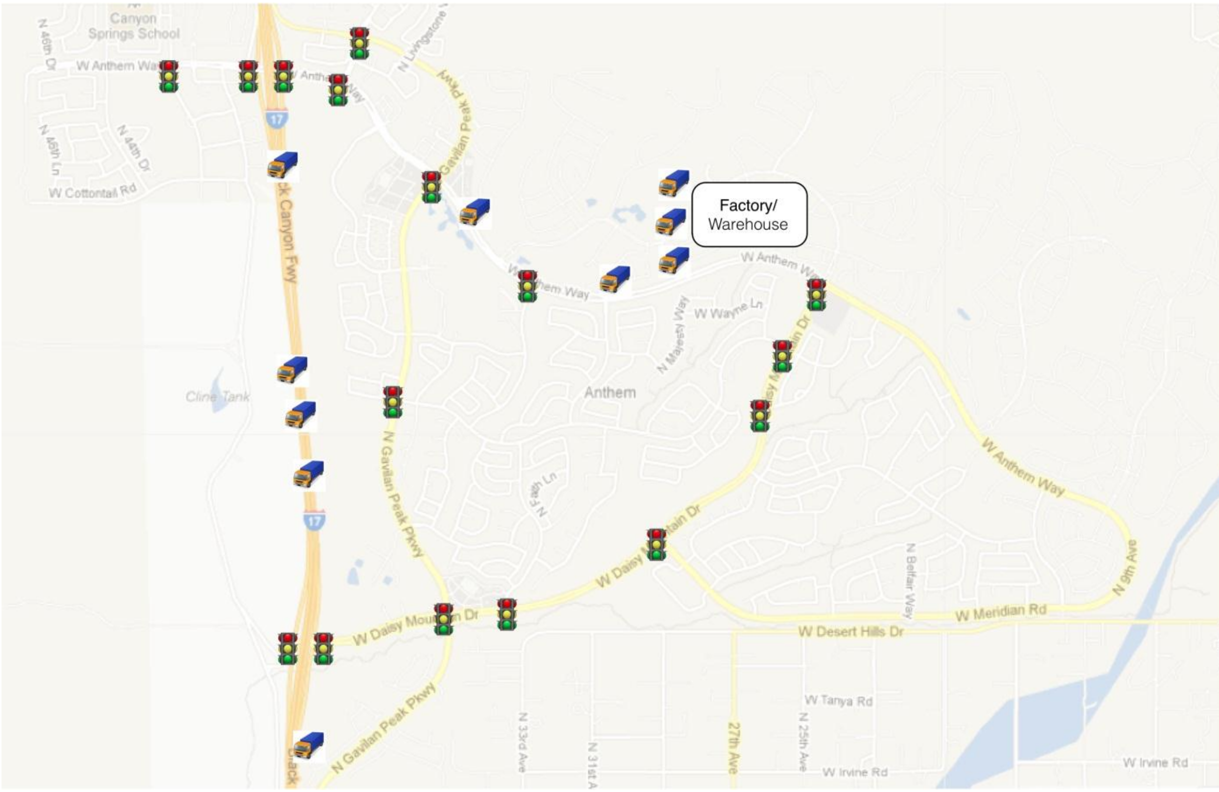


Figure 13 – Scenario 4: Freight Signal Priority

Scenario 4 Assumptions

Truck information, such as size, weight, cargo restrictions, etc., is available to OBE for the purpose of making traffic control decisions.

Scenario 4 Questions/Issues

- What traffic management strategies can be used to improve performance for Trucks?
- What connected vehicle information will enhance traffic control strategies for trucks?
- Should trucks request priority in a manner that is similar to transit and emergency vehicles? Are there other considerations that should be included in decisions?
- If the truck cargo consists of Hazardous Waste Cargo what connected vehicle information could be used to make traffic management decisions?

Scenario 4 Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on the Freight Signal Priority scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What traffic management strategies can be used to improve performance for trucks?
  - Dynamic stop bar locations *can* provide acceptable turning movement for freight *vehicles*, say sharp left hand turns.
  - *Traffic management strategies* should strive to make safety improvements for heavy vehicles approaching intersections.
  - Increased green time during peak periods of freight traffic *will* keep trucks moving.

- Avoid having trucks come to a full stop.
- MNDOT studies[6] found that providing priority to trucks increased the signal cycle length, resulting in increased delay to other vehicles that approximately cancelled out the benefit provided to the trucks.
- Travel time information provided trucks for various routes would be advantageous.
- *Strategies* similar to transit vehicles, but *they* may be at a low priority because these are run by private for-profit organizations.
- Truck intersection safety improvements at downgrade approaches especially in mountainous areas.
- *Traffic management strategies that incorporate* consideration of truck acceleration and deceleration times.
- Considerations should be made on the operations of the terminals or ports where freight is operating in and out. Example ship arrivals, train arrivals at intermodal facilities, etc. These *operations* present large areas of congestion around these facilities.
- Identify trucks and/or large and heavy vehicles through the intersection and allow appropriate passage time automatically.
- Dilemma zone elimination for trucks.
- Can multiple truck from or to (OD pairs) be treated in some useful way to increase laminar flow types?
- Given the density, one would want to platoon these vehicles to create a smoother travel through the network - basically granting them with a priority if one could work with the entry and dispatch process to group the vehicles.
- Trucks maybe should get a longer yellow indication because they are less inclined to stop.
- Truck turning radii should be taken into consideration near freight facilities when signal timing is set.

- What connected vehicle information will enhance traffic control strategies for trucks?
  - Schedule criticality, vehicle size and weight, turning radius, and acceleration/deceleration performance *information will enhance traffic control strategies for trucks.*
  - Having data on the vehicle type and potentially load or information on stopping ability could help us improve control decisions at the intersection.
  - Speed, weight, and dimensions *information will enhance traffic control strategies for trucks.*
  - When a signal knows a truck is arriving, it can adjust its assumptions for startup, clearance time, and other factors for that particular phase.
  - Current lane and direction of travel *information will enhance traffic control strategies for trucks.*
  - Maybe something on criticality of cargo, for example perishable items, medical, etc. *will enhance traffic control strategies for trucks.*
  - The expected/desired path through the network *will enhance traffic control strategies for trucks.*
  - Turn radius, speed, and lane being occupied *information will enhance traffic control strategies for trucks.*
  - Fewer emissions (e.g., priority to trucks on an uphill approach) *information will enhance traffic control strategies for trucks.*

[6] [6]"Truck Priority at Signaled Intersections", MNDOT0326.00

    - One needs more vehicle dynamics - breaking distance, mass, immediate speeds, etc. so that clearance times and progression speeds can be managed.
    - Assumptions that are being made are not realistic. In particular, in V2V we are struggling with how to identify what's being pulled – communication issues are huge. Cargo ID is also a challenge – hazmat maybe not so much, but shippers don't want to give out info on what they are carrying with a HUGE benefit. More understanding of the industry (and not what the states want) is needed.
    - Shouldn't this information already be taken into consideration by dispatchers? Is it necessary for trucks to be connected vehicles?
    - Ability to detect vehicle class, speed, etc. would enhance safety

- Should Trucks request priority in a manner that is similar to transit and emergency vehicles? Are there other considerations that should be included in decisions?
    - MNDOT had good success in using two loop detectors 30 feet apart in the approach lane. Cars were too short to trigger both loops simultaneously. It was a low cost easy way to detect trucks in advance of the intersection.
    - There should be an economic factor as well, so trucks could pay more for priority when they have a time-critical load.
    - Need to establish some measure to determine if and when trucks should be given priority.
    - No but in a safety scenario where the green could be extended for a truck that may not be able to stop.
    - Yes, *trucks should be able to request priority in a manner similar transit and emergency vehicles,* but they should be granted low priority.
    - *Trucks should request priority similar to transit and emergency vehicles* only at peaks during the day where operations of terminals cause congestion.
    - There are other considerations - suggest mandating platooning rather than random dispersion!
    - In the off-peak, yes, especially if a train or ship they are delivering to are scheduled to leave shortly.

- If the truck cargo consists of Hazardous Waste Cargo what connected vehicle information could be used to make traffic management decisions?
    - Suggest also adding oversize and overweight trucks that require permits from DOT specific to trips they make.
    - Do you really want to grant priority for HAZMAT at all intersections? Obviously there is a need to track this cargo through the network and to take this movement in account for TSP or EVP - so as not to create a dangerous situation.
    - Making traffic system operator aware of HAZMAT vehicle being present in the system/network might be of help.
    - Please keep in mind that greater than 90% of all hazmat is NOT placarded or marked. Only a very small amount should get signal treatment.
    - The type of HazMat (flammable, etc.) *is connected vehicle information that could be used to make traffic management decisions.* The more dangerous the cargo is, the higher its priority.

Scenario 4 Performance Measures and Goals

Stakeholder inputs and feedback on performance measures and goals for the Freight Signal Priority scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What are reasonable, realistic, and attainable ten-year target performance measures and goals?
  - Delay management *is a realistic performance measure.*
  - Freight/goods reliability by time of day and condition (rain, special event, etc.) *are realistic performance measures.*
  - Should not just measure truck delay, but also *the* total delay at the intersection? Decreasing the truck delay can increase delay to other vehicles.
  - Accident rates at intersections, minimized stops - so stops are a good measure. I am not sure that travel time is the measure - waiting time is. But, where you place the waiting time is important - at start or end is the best - not at random *locations* throughout the network?
- Performance Measures and Goals of Uncategorized Ideas
  - With all due respect, you have a school there that dumps vehicles out. Use that *situation* like someone might use the corridor in Long Beach that loads and offloads shipping containers form the harbors. Set up a test that note the clearance time pre/post to clear the day's load out and compare that with the impact on the cross street in some way.

Out of the 31 Stakeholders providing input via the ThinkTank facilitation, a total of 19 provided numerical values for a ten-year goal on a single pre-defined performance improvement metric – reduction of overall truck delay. The acceptable range for improvement performance was bound by 0-100% referenced to present day thresholds. The mean value of Stakeholder input on reduction of overall pedestrian delay was 27.63% and the standard deviation was 25.35.

Scenario 5 – Emergency Vehicle Preemption

Preemption of traffic signals is a technique used to give a very high level of priority to a preemption request. Generally, preemption is used for highway-rail road crossings where a traffic signal is near a railroad crossing (within 200 feet), or for emergency vehicles (fire, ambulance, or other first responder), and sometimes for transit priority. The NEMA definition of preemption is "The transfer of the normal control of signals to a special signal control mode for the purpose of servicing railroad crossings, emergency vehicle passage, mass transit vehicle passage, and other special tasks, the control of which require terminating normal traffic control to provide the priority needs of the special task." Recent research has considered "priority" for these vehicles in place of preemption since traditional preemption logic is generally limited to considering one vehicle at a time.

Advanced Emergency Vehicle (EV) preemption systems are similar functionally to current signal preemption systems, but may be viewed as a replacement of optical, 900 MHz, and other technologies used for signal preemption with integrated V2V and V2I communication systems. These systems would adjust preemption and signal recovery cycles to account for non-linear effects of multiple emergency responses through the same traffic network.

Scenario 5 Description

Consider a sub-network where there is an incident, e.g. a building fire, at some location as depicted in Figure 14. Emergency vehicles are responding to the incident from a variety of directions. As they approach the incident, the commander will direct vehicles to stage in a logic manner to support the incident. For example, one fire truck might go to the corner to run a fire hose from a hydrant to a vehicle at the scene. A ladder truck might approach from a different direction to avoid wind or other conditions to have a clear approach to the incident. The vehicles, fire along with police and other first responders, will form a perimeter around the incident. This perimeter might change over time as the incident is managed.

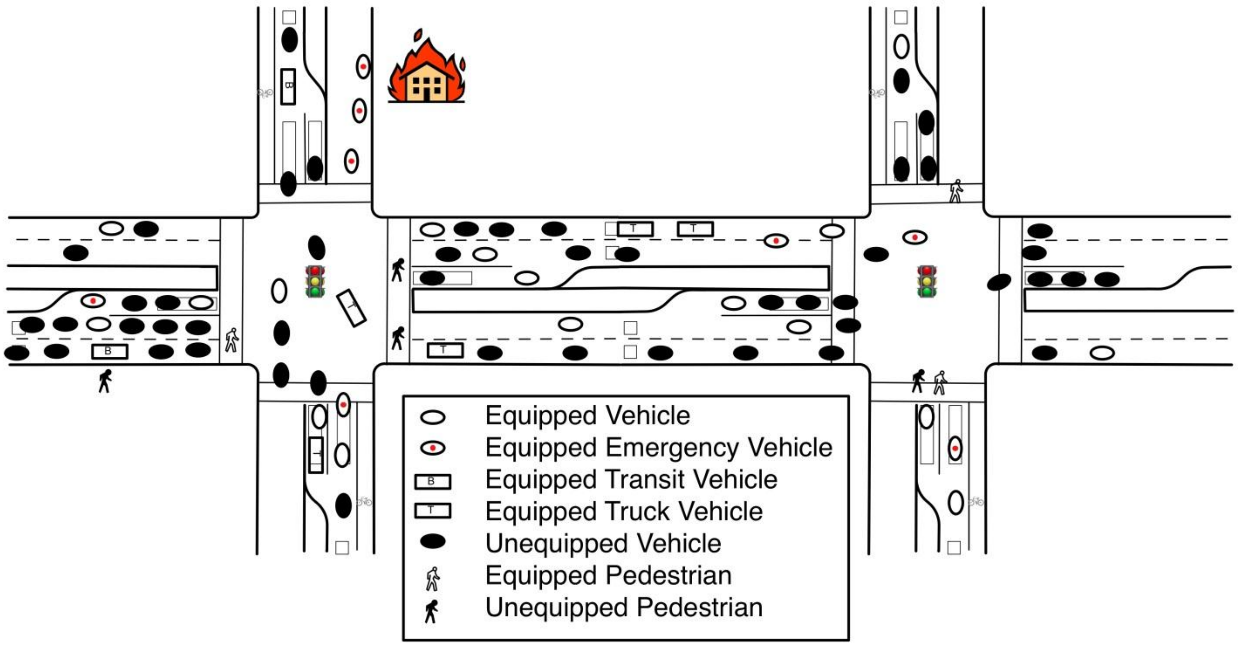


Figure 14 – Scenario 5: Emergency Vehicles Preemption

Scenario 5 Assumptions

- Emergency vehicles will enter equipped intersections from various directions and approaches.
- Multiple priority requests may occur at one intersection in a short period of time.

Scenario 5 Questions/Issues

- How can connected vehicle information improve preemption/priority?
- How should priority among several requesting vehicles be determined? What information should be considered?

Scenario 5 Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on the Emergency Vehicle Preemption scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- How can connected vehicle information improve preemption/priority?
    - Preemption could be improved by taking into account the vehicle's planned route. For example, optical preemption affects all the signals within some distance straight ahead of the emergency vehicle, even if the vehicle will be turning at the nearest intersection. Instead, you could preempt the signal around the corner (assuming you can get DSRC to work around corners with buildings!).
    - *Connected vehicle information s*hould be able to better facilitate route priority for emergency vehicles.
    - CV allows for arbitrary phase order, which should speed up coordinated system recovery after preemption.

- Two-way communication with the EV driver to let them know status of request *could improve preemption/priority*.
- Alerting vehicles of impending conflicts - and routing complete O-D solutions for each vehicle. Again, this needs broadband communications and network management (traffic) so that EVP is not just a local issue.
- As vehicle pass by the RSU of the signal control and ask for preemption or priory they will state their agency affiliation (in the DSRC messages). The RSU should gather this for DOT use to know who has arrived on scene (the way they came in). This is vital in some incidents to know very quickly and relate to other (IC and back office).
- Existing road conditions will be better known with connected vehicles.
- *Connected vehicle information can* better handle priority service for all types of Emergency Vehicles (fire versus police versus ambulance, etc.).
- *Connected vehicle information can improve preemption/priority by* providing route information back to EV operators so they can make better informed dynamic re-routing decisions (such as if approaching a rail crossing that is under control).
- *Connected vehicle information can provide* better handling of priority at intersections when multiple EVs arriving from multiple directions and at different times.
- Ideally we should handle emergency vehicle service as a priority over preemption. Knowledge of EV type and need would help making the priority service decision.
- *Connected vehicle information* can eliminate field infrastructure for some existing technology.
- *Connected vehicle information* can eliminate preemption in non-emergency situations.
- *Connected vehicle information can provide* dynamic mainline/progression routing from vehicle to scene.
- *Connected vehicle information can* ensure that pre-emption is used by only approved vehicles.
- Have the EV OBE transmit its location, heading, vehicle class, and incident location they are responding to. Then, the traffic signal can make a decision based on vehicle class which vehicle to give priority to.
- Vehicle O-Ds *and* complete paths can be used to anticipate system-level effects/response.
- *Connected vehicle information can provide* quicker transition into and out of preemption.

- How should priority among several requesting vehicles be determined? What information should be considered?
  - Vehicle class/type, incident location and type, severity of incident etc. will help the traffic control decide whether to grant priority or not and if yes, which EV to give priority to.
  - *Priority contention for several requesting vehicle should consider* adherence to predicted route.
  - Mostly vehicle type, ability to stop, and predicted time-to-intersection *should be considered in determining priority.*
  - EMTs first, followed by Fire *should be considered in determining priority.*
  - There must basically be an off-line discussion of priority - i.e., the region needs to establish a priority scheme for its operations (not just vehicles - but vehicle and mission) so that the prioritization can take place at a higher level and even alternate routes can be suggested or required. EVP is not just a localized problem - it needs to be handled for routes!
  - Vehicle type versus class of emergency being serviced *should be considered in determining priority.*

- Link *priority decision* to data from emergency dispatch regarding the level of the emergency response (e.g., fire versus a cat stuck in the tree).

Scenario 5 Performance Measures and Goal

Stakeholder inputs and feedback on performance measures and goals for the Transit Vehicle Priority scenario are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What are reasonable, realistic, and attainable ten-year target performance measures and goals?
  - Response time improvement.
  - Improved system recovery from preemption.
  - Reduction in response time
  - Reduced response times
  - Accessibility measures -- how far can a single vehicle reach from its home base, reliably across the network within a specific response threshold?
  - Reduced accident of EVP actions at intersections is about the only measure. We already have EVP and route EVP which grants green-waves, etc. About the only benefit that could be added is to route other vehicles away from the area. How does one measure those?

- Performance Measures and Goals of Uncategorized Ideas
  - Where does NTCIP 1211 play with the solutions for EVP and TSP when using Connected Vehicles?
  - Not all response vehicles arrive at the same time, by design, nor do they come/leave at the same speed or stage at the same places. See IEEE work for some concept to perhaps steal or reuse.
  - A major problem in emergency vehicle coordination credentials and rights is those “out of home service” vehicles come and operate in the region during regional problem (seasonal fires are good example). We need a solution that accepts this reality and the different equipment types that often need to cooperate.
  - I think people are being far too optimistic on gains for EVP.
  - In general, performance measures should be based on impacts to non-priority vehicles.

Out of the 31 Stakeholders providing input via the ThinkTank facilitation, a total of 18 provided numerical values for ten-year goals on two, pre-defined performance improvement metrics. The acceptable range for improvement performance was bound by 0-100% referenced to present day thresholds. The summary statistics are shown in tabular form in and graphical form in.

Emergency Vehicle Preemption Performance Improvement	Average	Std. Dev.	Votes
Reduce Overall Emergency Vehicle Delay	29.33	24.10	18
Reduce Delay Variability	26.18	17.90	17

Table 7 – Ten-Year Target for Emergency Vehicle Preemption Performance Improvement

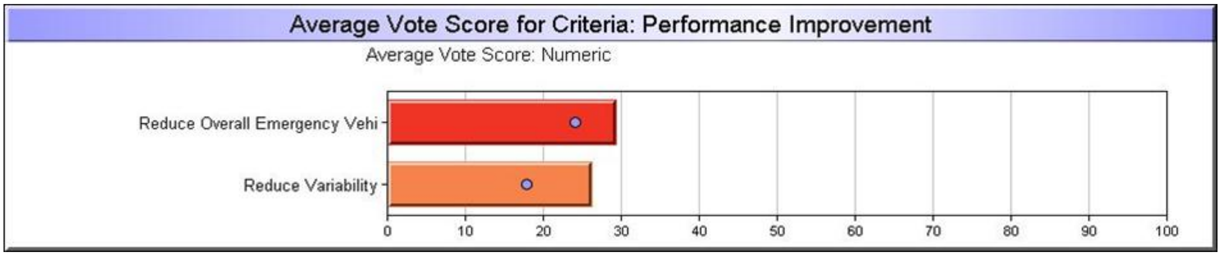


Figure 15 – Graph of Ten-Year Target for Emergency Vehicle Preemption Performance Improvement

Other Areas, Scenarios, and Considerations

In addition to the five focus areas (ISIG, Transit Vehicle Priority, Pedestrian Mobility, Freight Signal Priority, and Emergency Vehicle Preemption), other areas of concern to the MMITSS project were discussed briefly during the Stakeholder Meeting. Some of these additional areas are covered in the Assessment of Prior and Ongoing Research Report and will continue to receive some level of coverage throughout the development of the MMITSS Concept of Operations document. In this section, these topics are mentioned briefly with respect to their relevance to the MMITSS project.

Highway railroad crossings can impact the MMITSS ConOps. At highway railroad crossings, the trains cannot stop in the short distance required in the case of a queue or a vehicle that has not been cleared from the railroad tracks. The use of Connected Vehicle technology could allow for estimation of the queue length and help manage the track clearance timing. In addition, when the train has safely cleared the roadway, the nearby traffic signal could serve the standing queues in an efficient manner assuming the queue length could be estimated.

Freeway arterial interchanges have a distinct influence on the MMITSS ConOps. Various MMITSS operations will impact the flow of vehicles on freeways and vice versa. Freeway arterial interchanges can incorporate multiple components of MMITSS including freight signal priority, ISIG, emergency vehicle access near hospitals, fire stations, and police stations, and the impacts of pedestrian crossings at the intersection of freeway exit ramps and arterials.

The impacts of special classes of users such as motorcades supporting dignitaries, motorcades for wide-loads and heavy equipment transports, and funeral processions must be assessed and captured within the MMITSS ConOps document.

Compatibility of special traffic management conditions such as emergency evacuations (storms, chemical spills, terrorist episodes, etc.) and special events (sporting events, concerts, parades, marathons, etc.) must be accounted for in the MMITSS ConOps.

Other Areas/Consideration - Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on other MMITSS areas, scenarios, and considerations are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What other traffic areas/scenarios should MMITSS consider?
  - Weather/roadway flooding *should be considered.*
  - Weather conditions affecting signal clearance durations *should be considered.*

  - Special events (without being told explicitly that it’s a special event) *should be considered.*

- Highway and Railroad Crossings Considerations
  - Prior knowledge of train arrival at crossings to be able to perform pre-preemption and post-preemption timing plans.
  - Better exchange of data between rail side and controller to ensure the safe and efficient operation of signals at an active rail crossing.
  - Interconnected grade crossings and traffic signals where queue space must be forced off due to potential train/vehicle collision - railroad preemption.
  - At-grade, non-equipped crossings remains a big issue to Federal Railroad Administration that may benefit from DSRC but I am not sure how as I type this.
  - Reconfiguration of at-grade crossings, especially those near traffic signals, must be designed for all vehicles, not just cars.

- Freeway Arterial Interchanges Considerations
  - Ramp meter spill back and ramp meter priority *should be considered.*
  - Alternate routes for EVP and incident mitigation *should be considered.*

- Special classes of users including motorcades (dignitaries, funerals, etc.)
  - Should we be giving priority to these special classes of vehicles/situations or rely on the overall system improvements to better serve these special cases?
  - Yes - EVP routes - most systems can support this now - the connected vehicle simply adds the en-route tracking.

- Special traffic management conditions such as emergency evacuations, special events, etc.
  - This is an important area, maybe check into the experiences of recent evacuation events for insights.
  - *This is* just a better opportunity to communicate into the vehicles if they have in-vehicle displays.
  - Incident detour traffic management *should be considered.*
  - Don't forget the pedestrians in the concept of "traffic."

- Uncategorized Ideas
  - Signal operations while signal is under maintenance or in flash *should be considered.*
  - As mentioned in another post, work zone and many other events overlaid with signal operations in a clear way remains to be developed and the test beds should support this need.

Cross-Cutting Issues

In addition to the five distinct scenario areas, there are issues that are shared or cross-cutting to some extent between two or more of the scenarios with respect to the MMITSS project scope. In this section and during the Stakeholder Meeting, two categories of cross-cutting issues were discussed: (1) Maintenance and Operation Issues, and (2) Policy Issues. These issues are addressed in individual subsections and the Stakeholder inputs are included.

Maintenance and Operations Issues

The MMITSS Concept of Operations should include provisions for system maintenance of the resulting conceptual design, testbed, and resulting system. As such, the Stakeholders were asked to provide feedback and input on what additional maintenance and operations issues should be addressed in MMITSS. Stakeholder inputs and feedback on MMITSS maintenance and operations issues are shown below in a bulleted format. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- Any DSRC used for safety applications will make maintenance of the DSRC a high priority item, which may be difficult with limited maintenance staff. It also may involve different staff skills than currently employed for signal maintenance.
- This is a completely new requirement (i.e., communications management) for transportation agencies and may be somewhat challenging for some agencies. We need both operational and performance expectations identified.
- Communications issues for remote, rural locations and smaller communities *are maintenance and operations issues that need to be included in the MMITSS ConOps.*
- Do the agencies have the communications expertise to support this stuff?
- Certification of equipment is essential; ongoing calibration and easy swap maintenance is required.
- Beware of high levels of availability - traffic cabinets and traffic field equipment often takes serious time to fix - sometimes days!
- Most of our traffic signals do not have internet connectivity. Providing such internet connectivity for every roadside DSRC will be a big issue.
- If you get the internet, you also get time sync. How many intersections would benefit from a simple external time sync and not any internet connection? Is this a real problem or one that clearly will get solved by other means over the ten year time frame?
- *MMITSS project* may need to provide performance measures as to repose and turnaround time to maintenance of an equipped intersections due to safety implications.

Policy Issues

Although policy issues were limited in discussion time during the Stakeholder Meeting, it was important to raise and vet policy related topics and issues as they pertain to the MMITSS project. One specific and important policy issue is that of data archiving. Although important to lawyers after the occurrence of an accident, archived data can provide verification and validation of system performance, algorithm performance, and simulation input.

During the Stakeholder Meeting, the following questions were posed to the Stakeholders for stimulating feedback and inputs:

- What and which data should be archived?
- How often (frequency) should data be downloaded for archiving?
- How long should the data be archived?
- What are the security requirements and issues related to archived data?
- What is the jurisdiction of the archived data?
- Who authorizes release of the data?
- Who authenticates the data?
- What entity is responsible for archived data and archiving costs?

Policy Issues - Stakeholder Feedback/Inputs

Stakeholder inputs and feedback on MMITSS Policy Issues are shown below in a bulleted format. Indentations are used for cases where a user comment pertained to another user comment. Clarifications and/or responses by the MMITSS project team are shown in italic font.

- What and which data should be archived?
  - All of it - this effort helps us collect data to analyze the signal and traffic operations that will help answer the questions you asking beforehand that we really can't intelligently answer at this point.
  - Keep data disaggregate but anonymous.
  - Data should be open and shared.
  - *Keep all data* (everything) in a standardized format.
  - *MMITSS project* needs to be careful about what data is archived due to FOIA. *You* do not want to get called into court for every traffic accident.
  - *MMITSS project will* want to keep performance measure data.

- How often (frequency) should data be downloaded for archiving?
  - 24/7
  - Real-time 24x7 continuously
  - *It* depends on type of data. Follow Section 1201 for real-time data.
  - Government generated date *is equivalent to* public data and should be freely available. We can also expect private concerns to merge/fuse the data to provide added value!

- How long should the data be archived?
  - *The data should be archived* long enough for folks to use it throughout the R&D process of connected vehicles.
  - Indefinitely.
  - When stripped of PII, keep data around to support longitudinal performance assessment.
  - I may be on the fringe here, but I don't think a signal should have to archive much, if any, data to operate effectively. The goal should be to "forget" as much data as soon as possible to protect privacy.
  - A signal's internal logic should be enough to manage traffic effectively. I don't see any need to store vehicle data at the signal-level. Data should be "forgotten" as soon as possible.

- What are the security requirements and issues related to archived data? What is the jurisdiction of the archived data? Who authorizes release of the data? What entity is responsible for archived data and archiving costs?
  - Each agency/company should have their own policy on security and privacy of data.
    - With respect to comment #1, there will need to be a uniform policy on security and privacy nationwide. I don't think leaving it up to each agency will work.
  - Security *protection* from hackers *should be included in the security requirements for archived data*.
  - Privacy of data will be a critical issue to public acceptance of the end system.
  - I am not sure we have agreed on who owns data being broadcast by vehicles, individuals, and fleets. Consequently, maybe we don't have any authority to capture or archive data?

    - There should be no implied ownership. If it is publically collected, it is freely available to the public and that needs to be part of the O&M costs associated with the data. A better question - who will bear the cost of creating and maintaining the database?

- Who authenticates the data?
    - The integrity of the data must be guaranteed - but everyone should have access - no restrictions! The major issue is who certifies the integrity of the data.
    - How do we police the accuracy of the data provided? Bad data can make the archive worthless!
    - Quality of the data is key.

Next Steps

Feedback, clarifications, and requests for change from the PFS Panel Members were received on 7/26/12 via email. Minor modifications were made to the document and additional information was added to the Summary section. The “draft” watermark and terminology on the cover sheet have been removed. As such, this is the final document version to be submitted to the PFS Panel.

In addition to the administrative aspects of finalizing this document, synthesized versions of the Stakeholder inputs will be used to refine the original scenarios and spawn the development of additional scenarios for use during the ConOps meeting to be held in Washington, DC on Wednesday, 7/18/12. The “synthesized” terminology implies that the specific Stakeholder input will be evaluated, applied within the context of the MMITSS project scope, ranked in terms of impact, augmented with information from the Assessment of Prior and Ongoing Research Report, and integrated accordingly within the ConOps document and related project documentation.

Synthesized versions of the Stakeholder inputs on the five scenarios presented during the Stakeholder Meeting will be used populate Section 11 (Operational Scenarios) of the ConOps document. The latter sections of the Stakeholder Input Report will be used to augment the information in various sections of the ConOps document such as Section 9 (Operational Environment), Section 10 (Support Environment), and Section 12 (Summary of Impacts).

Summary / Conclusions

The MMITSS project team has deemed the Stakeholder Meeting a success. In summary, 55 participants were invited to the MMITSS Stakeholder Meeting (See: Table 2). These participants included representatives from federal, state, and local transportation departments, transit operations, freight vehicles and movement, emergency management, and traffic equipment suppliers and solution providers. There were 35 participants in attendance using either GoToWebinar or ThinkTank or both. Of these 35 participants, 14 were not on original invitation list (names listed in italic font in the table) and are assumed to be invited or referred by others. The ThinkTank session for the MMITSS Stakeholder Meeting remained open and active for a week after the meeting to permit participants to offer post-meeting comments. Five *new* participants[7] accessed the ThinkTank forum after the conclusion of the Stakeholder Meeting. The unaltered division by topic of Stakeholder inputs, comments, and feedback is shown in Table 8.

Stakeholder Agenda Item	Initial Comments	Sub-Comments	Total Comments
Assessment of Prior and Ongoing Research	34	5	39
Intelligent Traffic Signal Systems Scenario	64	10	74
Transit Signal Priority Scenario	44	5	49
Pedestrian Mobility Scenario	45	4	49
Freight Signal Priority Scenario	47	0	47
Emergency Vehicle Preemption Scenario	36	0	36
Other Areas/Considerations	18	0	18
System Maintenance Issues	10	0	10
Policy Issues	23	0	23
TOTALS	**321**	**24**	**345**

Table 8 – Division of Stakeholder Inputs

The Stakeholder webinar format allowed a broad and expert group of participants to consider the design of a multi modal intelligent traffic signal system and to provide valuable input to the project team. There are several themes that evolved from the webinar. First, there seems to be consensus that there is clearly a need for an intelligent traffic signal control system that considers multiple modes of travel in an integrated and cooperative system. The participants were in agreement that the connected vehicle environment offers a data rich environment that can lead to system and performance enhancements. The provided data will assist greatly in the assessment and verification of performance improvements. Numerous comments reiterated the need to share and protect this data.

While the scenarios were presented by mode (vehicles, transit, pedestrians, freight, and emergency vehicles), the participants suggested that priority control is very similar for transit, freight, and emergency vehicles. There was one participant that noted that the Freight Priority assumptions might not be consistent with the industry operating principles since data may not be readily shared due to competitive advantage considerations.

Next, there was some concern about the dependence on DSRC technology and the emerging capabilities of 3G/4G wireless communications. These other communication systems may satisfy the communication needs of a MMITSS, perhaps better than DSRC. These comments should impact the development of the Concept of Operations and System Requirements so that the System Designs considered have sufficient separation between the functionality and the communication technologies that might be used in the future implementations. In addition to the technical aspects of the communications interface utilized in the MMITSS project, several Stakeholders provided comments and cautions on equipment maintenance, system availability, and adequate staffing and training.

Throughout the flow of the Stakeholder Meeting and corresponding written comments, the underlying relationship between the MMITSS project and other safety-related applications was noted by many of the meeting participants. These safety-related comments spanned the pedestrian, transit, EV, and freight

[7] As of the evening of 6/4/12, 28 participants had accessed the ThinkTank forum. As of 11:45PM PST on 6/11/12, 33 participants had accessed the ThinkTank forum.

scenarios. The significance of this occurrence was great enough to warrant further discussion of the topic at the next meeting scheduled for July 18, 2012.

Performance measures, metrics, and goals represent another topic area that will be pursued in the follow-on meeting. There was a clear divide on which performance measures should be evaluated and whether any performance measures should be identified in a project with such a research bent. Whereas some of the suggested measures may be outside the scope of this effort, the authors are in agreement that a subset of performance measures should be defined, maintained, and evaluated to show potential benefits and possible difficulties of operating in a connected vehicle environment.

Overall, the comments from the Stakeholders have provided valuable input into the system design process. The development of the Concept of Operations will further distill the Stakeholder input into system features. The project team will consider the input from the Stakeholders, including review of the basic assumptions and role of rapidly evolving and transforming communications technologies.

Appendices

Appendix A: Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AC	Alameda-Contra Costa (Transit)
ADA	Americans with Disabilities Act (1990)
AQ	Air Quality
APS	Accessible Pedestrian Signals
ASC	Actuated Signal Controller
ATDM	Active Traffic and Demand Management
ATV	All-Terrain Vehicle
BMW	Bavarian Motor Works
BRT	Bus Rapid Transit
BSM	Basic Safety Messages
CBD	Central Business District
CONOPS	Concept of Operations
CTS	Cooperative Transportation System
CV	Connected Vehicle
DMA	Dynamic Mobility Applications
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
EMS	Emergency Medical/Management Services
EV	Emergency Vehicle
EVP	Emergency Vehicle Preemption
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FYA	Flashing Yellow Arrow
GHz	Giga Hertz (10^9 Hertz)
GM	General Motors
GPS	Global Positioning Systems
HOV	High Occupancy Vehicle
IC	Information Center
ID	Identification
INFLO	Intelligent Network Flow Optimization
IRC	Inter-Regional Corridor
ISIG	Intelligent Traffic Signal System
ITS	Intelligent Transportation System
LOS	Level of Service
MD	Maryland
MHz	Megahertz (10^6 Hertz)
MMITSS	Multi-Modal Intelligent Traffic Signal System
MNDOT	Minnesota Department of Transportation
MOE	Measures of Effectiveness
NCHRP	National Cooperative Highway Research Program
NCSU	North Carolina State University
NEMA	National Emergency Management Agency
NHTSA	National Highway Traffic Safety Administration
NTCIP	National Transportation Communications for ITS Protocol
NY DOT	New York Department of Transportation
OBE	On-board Equipment
OD	Origin-Destination
OEM	Original Equipment Manufacturer
PATH	Partners for Advanced Transportation Technology
PFP	Pooled Fund Project

PFS	Pooled Fund Study
PI	Principal Investigator
PII	Personally Identifiable Information
PMP	Project Management Plan
POV	Privately Owned Vehicle
PST	Pacific Standard Time
R&D	Research and Development
RFP	Request for Proposal
RSE	Roadside Equipment
RSU	Roadside Unit
RV	Recreational Vehicle
SAIC	Science Applications International Corporation
SIE	Systems and Industrial Engineering
SME	Subject Matter Expert
SPaT	Signal Phase and Timing
SVN	Subversion (PFP Repository with Version Control)
SyRS	System Requirements
TARDEC	Tank and Automotive Research, Development and Engineering Center
TFHRC	Turner-Fairbank Highway Research Center
TRB	Transportation Research Board
TSP	Transit Signal Priority
TTI	Texas Transportation Institute
TX	Texas
UA	University of Arizona
UC	University of California
USDOT	United States Department of Transportation
UVa	University of Virginia
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VDOT	Virginia Department of Transportation
VMT	Vehicle Miles Traveled
WSDOT	Wisconsin Department of Transportation

Appendix B: Original Distribution List

Panel/Team Member	Organization
Danielle Deneau (P)	Oakland County, Michigan
Ray Derr (P)	TRB/NCHRP
Gary Duncan	Econolite
Larry Head	University of Arizona
David Kelley	SCSC
Melissa Lance (P)	VDOT
Greg Larson (P)	CalTrans
Ben McKeever (P)	FHWA
Hyungjun Park (P)	UVA
Ravi Puvvala	Savari
Eric Raamont	Econolite
Steve Shladover	UC Berkeley - PATH
Mike Siebert	Volvo Technology
Ramesh Siripurapu	Savari
Ann Wilkey	University of Arizona
Jim Wright (P)	AASHTO
Wei-Bin Zhang	UC Berkeley - PATH
Kun Zhou	UC Berkeley - PATH