

# Traffic Management Centers

## IN A CONNECTED VEHICLE ENVIRONMENT

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### ***Task 4. Recommendations***

### *Final Summary of Recommendations*

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# 1 Introduction

This study has examined a rapidly evolving dynamic in the transportation industry with the roll-out of connected vehicle technologies. With much of the connected vehicle focus to date on field operations, security certification and emerging standards; this is the first study to examine potential impacts to agency TMC operations as a result of this evolving program and data environment.

Members of the Connected Vehicle Pooled Fund Study (PFS) recognize that the role of the TMC and TMC operations will be impacted or influenced by a future connected vehicle environment. Task 1, Review of Connected Vehicle Program Activities in Relation to Traffic Management Center Operations, aggregated and summarized key operational functions performed by TMCs and began to assess the readiness of TMCs to integrate new processes, functions, and data in a connected vehicle environment. Task 2 built on information received from an electronic survey distributed during the first task, and included more in-depth interviews with early adopters of connected vehicles. A Concept Paper developed as part of this task provides additional detail on specific connected vehicle applications and potential interactions with TMC operating environments. Task 3 identified some initial operational concepts and potential changes to the operating capabilities for TMCs in a connected vehicle-enabled data environment.

This Technical Paper summarizes the key recommendations emerging from this effort, including recommendations for the broader operations community, as well as some specific recommendations for the Cooperative Transportation Systems Pooled Fund Study.

## 2 Timing and Impact to TMCs

With the NHTSA decision not yet final (as of the time of this writing), with other key investment decisions and strategic directions awaiting outcomes of various studies and field deployments, and with ongoing speculation of the timeframe for potential connected-vehicle enabled fleet density, there are still many uncertainties surrounding a ‘go-live’ timeframe for connected vehicles. Furthermore, within the last year, there has been some significant discussion and interest in Automated Vehicles (AV); although not specifically a part of this study, the potential impact and timing of AV could modify some directions within the connected vehicle deployment scenarios. This has some obvious impacts to agency planning and procurement processes; while few are comfortable being on the “bleeding edge”, there are some agencies that have an appetite and willingness to begin integrating these new capabilities as soon as possible or feasible. In some cases, emerging applications may fit well with strong focus areas for particular TMCs (i.e., weather and winter operations focused applications for those agencies that are heavily involved in winter weather mitigation on the network, or enhanced arterial signal operations capabilities for those agencies with a large responsibility for signal operations and high volume arterial network management). In other cases, agencies may need some good lessons learned from other areas

and test beds to be able to garner internal support for investment in new processes and systems. Budget and available resources will likely drive many decisions on level of investment for agencies and TMCs. Field deployment of roadside equipment (RSE) capable of interacting with connected vehicles also will drive a lot of the investment decisions and timing for agencies.

Near-term applications will likely focus on those capabilities and data that are extensions of what agencies are already doing, that is, traffic conditions monitoring information that can help to supplement current probe data or detector data. While it is not envisioned that this data would completely replace existing sources, it is envisioned to be able to supplement existing data with additional network details. While there is no indication of a large scale, multi-agency deployment of RSEs, early applications for TMCs will likely be supported by a combination of DSRC and cellular communications. It is highly likely that RSEs will be strategically located (either isolated installations or a limited number on a specific corridor).

Near-term applications and capabilities may emerge from a limited deployment, such as has been the early efforts in Florida and Arizona, which have been focused on equipped agency-owned vehicles rather than a broader number of anonymous, general passenger vehicles. For the next few years, and until deployment density in the commercial market reaches a threshold capable of supporting TMC and agency investment in connected vehicles, applications are likely to focus on after-market installations in agency fleets (such as maintenance or transit) or public safety fleets (such as fire or law enforcement vehicles). As such, applications such as transit priority or enhanced emergency vehicle preemption could offer a lower-risk opportunity for agencies and present a relatively controlled environment to begin testing and integrating new vehicle-based data sources. These may also offer an opportunity for two-way alerts and information for TMCs to push information to instrumented vehicles. There may need to be some significant institutional coordination to enable this level of communications between TMCs and public safety fleet vehicles; real-time law enforcement or fire vehicle information is currently typically only available to their respective dispatch/communications centers.

### 3 Recommended Operational Readiness Activities

TMCs today have a wide degree of variation in structure, organization, and capabilities, even though from a functional perspective, there are several synergies. Variations in the level of staff, staffing models, operating systems, system storage support, data analysis capabilities, and support for the TMC operations all provide a challenge in how to define the change in operational processes for TMCs as a result of connected vehicle data.

Each TMC will be 'ready' for a connected vehicle environment very differently. In some cases, there may be limited appetite to integrate information from this data source, or there may be institutional barriers (e.g., lack of established partnerships or available procurement options, or limited density of supporting road side equipment) to integrating connected vehicle data. Other agencies might have a greater interest and greater ability to integrate this information into their processes and operating environment.

An important consideration is the role of the TMC in data hosting, processing and analysis. The Task 3 document identified several requirements that are anticipated as a result of Big Data and the influx of data and metadata in a connected vehicle environment. The data model for a TMC will be dependent on a number of factors, but there is an underlying assumption that the TMC will have some role and some level of responsibility for these functions. This is not unlike the current strategy where TMCs are largely responsible for archiving and managing data generated by the systems and field equipment they operate. Partnerships and relationships of various other entities with the TMC (i.e., Statewide and regional TMCs, TMCs and public safety systems, TMCs and private data sources) will influence this data model.

The following table identifies types of TMC characteristics that currently support TMC operations, and these are presented in three specific scale levels. Recognizing that a full-scale connected vehicle environment is still a ways into the future, and also accounting for continued evolution in this dynamic field, there are some recommended activities that will help to support future readiness for TMCs in a future multi-source, dynamic data environment. These recommendations are presented in the following categories:

- Geographic Scale of the Transportation Network (managed by the TMC)
- Device and Communications Infrastructure
- Staffing Levels and Skill Sets
- Data Storage Support
- Data Analysis
- System Functionality
- Operational Processes
- System Performance Reporting
- Institutional Support

Scale of Environment	Current Operational Environment	Recommended Operational Environment Adjustments for Readiness
<b>Geographic Scale of the Transportation Network</b>		
<b>Robust</b>	Large geographic area covered with potentially one or more urban areas, many jurisdictions within operational influence (i.e., statewide or very large urban area)	<ul style="list-style-type: none"> <li>Assess geographic capabilities to support jurisdictional network – one central location with satellite operations or maintenance, multiple urban centralized locations with coordination between centers, shared operational capabilities/responsibilities with non-TMC personnel by permissions levels</li> <li>Adjust or implement capabilities based on needs of geographic area</li> <li>Identify focused areas for deployment of additional infrastructure (if required), possible pilot corridors or test beds that could be expanded once integration into existing systems is successful</li> </ul>
<b>Moderate</b>	Focused on one geographic area within reasonable driving distance to be able to maintain equipment (i.e., multiple cities within one County area)	<ul style="list-style-type: none"> <li>Assess geographic capabilities to support jurisdictional network – one central location with satellite operations or maintenance, multiple centralized locations with coordination between centers, shared operational capabilities/responsibilities with non-TMC personnel by permissions levels</li> <li>Adjust or implement capabilities based on needs of geographic area</li> <li>Identify focused areas for deployment of additional infrastructure (if required), possible pilot corridors or test beds that could be expanded once integration into existing systems is successful</li> </ul>
<b>Limited</b>	Small area with limited transportation network issues to monitor/manage or limited field equipment (small urban area or rural area)	<ul style="list-style-type: none"> <li>Assess existing location of where operations are performed for the small area</li> <li>Identify focused areas for deployment of infrastructure (if even required for a smaller area)</li> </ul>
<b>Device and Communications Infrastructure</b>		
<b>Robust</b>	Large network of device and communications infrastructure, wide variety of technologies, established and reliable connectivity from the TMC to devices	<ul style="list-style-type: none"> <li>Determine current bandwidth used and dark bandwidth available for new big data</li> <li>Determine gaps in data that would be beneficial to start collecting and investments to be able to collect that data – agency-owned infrastructure or private sector data</li> <li>Identify potential density requirements for field devices to support communications with connected vehicles</li> <li>Coordinate with partners (public or private) to identify plans for communication network expansion or connectivity opportunities</li> <li>Assess current network maintenance capabilities (resources) and identify potential mechanisms to address any identified shortcomings (i.e., need additional resources, need to expand current network maintenance contract, etc.)</li> </ul>
<b>Moderate</b>	Reasonably large network of device and communications infrastructure covering a defined geographic area or spread over larger state area, consistent technologies across coverage area	<ul style="list-style-type: none"> <li>Determine current bandwidth used and dark bandwidth available for new big data</li> <li>Identify gaps in communications infrastructure to connect parts of network not already under central control</li> <li>Identify types of data currently collected by agency departments that may not already be known</li> <li>Determine gaps in data that would be beneficial to start collecting and investments to be able to collect that data – agency-owned infrastructure or private sector data</li> </ul>
<b>Limited</b>	Minimal network of device and communications infrastructure, limited types of technologies deployed, or none at all	<ul style="list-style-type: none"> <li>Determine bandwidth to support infrastructure that may be added to a new system</li> <li>Identify types of data currently collected by agency departments that may not already be known</li> <li>Determine gaps in data that would be beneficial to start collecting and investments to be able to collect that data – agency-owned infrastructure or private sector data</li> </ul>
<b>Staffing Level and Skill Sets</b>		
<b>Robust</b>	Robust agency staff or a combination of agency personnel and contracted operations personnel that supports full service TMC operations	<ul style="list-style-type: none"> <li>Identify roles and responsibilities within current structure to support new activities with new data</li> <li>Identify opportunities to shift or modify job responsibilities or personnel to match where new needs will arise – may require hiring new personnel with specialized skills or allocate resources to train current personnel</li> <li>Invest in training on latest system capabilities (if not already completed recently) or identify source of training support once needed</li> </ul>

Scale of Environment	Current Operational Environment	Recommended Operational Environment Adjustments for Readiness
		<ul style="list-style-type: none"> <li>• Identify skill set needs that would need to be required of TMC contract staff (if applicable)</li> <li>• Evaluate current operations and identify where additional information (alerts, images, weather conditions, location, etc.) may provide value to current services provided by TMC – verify or define how operators will use the new data to help make decisions</li> <li>• Invest in operations and maintenance staff training on new systems being integrated not in use today – in-vehicle, mobile devices, new field technology, or other type of new systems</li> <li>• Identify potential additional staff requirements (numbers) that might be needed in a broader geographic coverage area enabled by more ubiquitous data</li> </ul>
<b>Moderate</b>	Adequate staff to support service requirements, although could benefit from additional staff for value-added services	<ul style="list-style-type: none"> <li>• Identify roles and responsibilities within current structure to support new activities with new data</li> <li>• Shift job responsibilities or personnel to match where new needs will arise, or identify the need to hire new positions to fill gaps – may require hiring new personnel with specialized skills or allocating resources to train current personnel</li> <li>• Invest in training on latest system capabilities (if not already completed recently) or identify source of training support once needed</li> <li>• Evaluate current operations and identify where additional information (alerts, images, weather conditions, location, etc.) may provide value to current services provided by TMC – define how operators will use the new data to help make decisions</li> <li>• Invest in operations and maintenance staff training on new systems being integrated not in use today – in-vehicle, mobile devices, new field technology, or other type of new systems</li> <li>• Identify potential additional staff requirements (numbers) that might be needed in a broader geographic coverage area enabled by more ubiquitous data</li> </ul>
<b>Limited</b>	Limited or partial agency FTE staff not currently serving in a ‘typical TMC’ capacity due to limited staffing	<ul style="list-style-type: none"> <li>• Identify where information (alerts, images, weather conditions, location, etc.) may provide value to traveling public not currently provided by TMC – define how data will be used to help make decisions</li> <li>• Garner political support for functionality the agency would like the TMC to perform and the staffing required to do so</li> <li>• Identify potential ways to partner internally or externally to meet staffing needs, such as a shared resource between departments or agencies, or a contract to acquire the needed skill sets</li> <li>• Hire additional staff based on new functional needs and specialized skill sets required to utilize new big data, or acquire contracted services on an as-needed basis</li> <li>• Invest in operations and maintenance staff training on new systems (if applicable) being integrated not in use today – in-vehicle, mobile devices, new field technology, or other type of new system</li> </ul>
<b>Data Storage Support</b>		
<b>Robust</b>	Robust servers within TMC, partner agency IT department that provides consistent TMC system support, or robust third party platform with essentially unlimited contract for capacity limits	<ul style="list-style-type: none"> <li>• Identify if data storage will be a TMC function, or if there will be a division of responsibility for data storage</li> <li>• Verify third party contract can support additional capacity required for new big data (if applicable).</li> <li>• Consider third party contract to support new big data storage (if not already used)</li> <li>• Regardless of if third party contract for storage is used, consider upgrading agency storage technology to support consolidated system access, use, and management</li> <li>• Adjust any existing agreements for any interdepartmental sharing of storage capacity and system access/firewall/security requirements or standards</li> <li>• Initiate discussions with IT staff to begin identifying how future storage needs could be addressed, and develop a high level action plan of key steps and resources needed</li> <li>• Evaluate existing processes or policies for data archiving and management, including time limits, accessibility to archived data, processes for querying, etc. Consider modifying these processes if needed</li> </ul>

Scale of Environment	Current Operational Environment	Recommended Operational Environment Adjustments for Readiness
<b>Moderate</b>	No servers local to TMC, servers handled by third party with limited capacity contract, or servers are handled by functionally separate agency IT department	<ul style="list-style-type: none"> <li>Identify if data storage will be a TMC function, or if there will be a division of responsibility for data storage</li> <li>Consider third party contract to support new big data storage (if not already used)</li> <li>Regardless of if third party contract for storage is used, consider upgrading agency storage technology to support consolidated system access, use, and management</li> <li>Develop agreements for any interdepartmental sharing of storage capacity and system access/firewall/security requirements or standards</li> <li>Evaluate existing processes or policies for data archiving and management, including time limits, accessibility to archived data, processes for querying, etc. Consider modifying these processes if needed.</li> </ul>
<b>Limited</b>	No storage existing or storage capacity identified for transportation use	<ul style="list-style-type: none"> <li>Evaluate data storage needs</li> <li>Consider implementing agency storage technology or identify existing agency storage technology to use partially for transportation use</li> <li>Develop agreements for any interdepartmental sharing of storage capacity and system access/firewall/security requirements or standards</li> </ul>
<b>Data Analysis</b>		
<b>Robust</b>	Data analysis done by dedicated staff knowledgeable of traffic operations and engineering principles, analysis applied to enhance TMC operations and traffic management	<ul style="list-style-type: none"> <li>Evaluate TMCs role in data analysis</li> <li>Invest in data mining applications or software packages that could automate data analysis for better efficient use of staff time</li> <li>Regular review of data analysis performed to encourage creativity and innovation in data mining and story-telling through data comparisons</li> </ul>
<b>Moderate</b>	Data analysis by studies or planning group, not necessarily with traffic operations and engineering principles, not typically applied to real-time operations strategies	<ul style="list-style-type: none"> <li>Evaluate TMCs role in data analysis</li> <li>Consider investing in data mining applications or software packages that could automate data analysis for better efficient use of staff time</li> <li>Training or education on types of analysis that would be beneficial to justify before-and-after investments in TMC operations, devices and communications, or system enhancements</li> </ul>
<b>Limited</b>	No data analysis capabilities or resources to support this effort	<ul style="list-style-type: none"> <li>Identify resource to perform data analysis based on types of reporting required to justify current investments or support future investments</li> <li>Training or education on types of analysis that would be beneficial to justify before-and-after investments in TMC operations, devices and communications, or system enhancements</li> </ul>
<b>Operating System Functionality</b>		
<b>Robust</b>	Good customer service and system management provided through completely integrated systems	<ul style="list-style-type: none"> <li>Consolidate existing overlapping systems that may be taking up more bandwidth or from the network or staff time to operate than needed – will require investment</li> <li>Identify and integrate to new systems not currently utilized but would be beneficial for the TMC to interact with – in-vehicle displays, mobile devices, new types of field technologies</li> <li>Invest in automated functionality that could free up staff time to support new services</li> <li>New ATMS modules will likely need to be developed that require engineers familiar with connected vehicle technologies – follow systems engineering processes to develop requirements</li> <li>Training for operations staff on any new systems and capabilities</li> </ul>
<b>Moderate</b>	Moderate to good customer service and system management provided through separate systems	<ul style="list-style-type: none"> <li>Evaluate staff time involved in separate system management to determine efficiencies that could be gained with integration of systems</li> <li>Identify and integrate to new systems not currently utilized but would be beneficial for the TMC to interact with – in-vehicle displays, mobile devices, new types of field technologies</li> <li>Integrate currently separated systems for operational control of network</li> <li>Consider value-added system expansions (or replacements) that could support new types of services/functions</li> </ul>

Scale of Environment	Current Operational Environment	Recommended Operational Environment Adjustments for Readiness
		<ul style="list-style-type: none"> <li>• New ATMS modules will likely need to be developed that require engineers familiar with connected vehicle technologies – follow systems engineering processes to develop</li> <li>• Training for operations staff on any new systems and capabilities</li> </ul>
<b>Limited</b>	Limited systems capable of managing transportation network	<ul style="list-style-type: none"> <li>• Consider implementing a central control system, or systems, for devices and communications infrastructure</li> <li>• Identify partner departments that could share/leverage central system control and develop requirements that meets the needs of all interested agency departments</li> <li>• Build into any new systems that they are standards-based applications and can be supported through the adjustments that will be required as the connected vehicle data stream and system matures</li> <li>• Training for staff new systems and capabilities</li> </ul>
<b>Operational Processes</b>		
<b>Robust</b>	Automated entry with verification	<ul style="list-style-type: none"> <li>• Identify new automated processes that could be integrated into systems to support new services based on new data sources and types</li> <li>• Modify or streamline existing processes based on new data sources and types</li> <li>• Expand current processes that are now able to be enhanced through new data sources</li> <li>• Identify how new data and reporting could be beneficial to other agency departments or other partner agencies</li> </ul>
<b>Moderate</b>	Combination of automated and manual entry processes	<ul style="list-style-type: none"> <li>• Identify new automated processes that could be integrated into systems to support new services based on new big data</li> <li>• Evaluate manual processes to determine which ones could be automated to increase staff and operational efficiency</li> <li>• Expand current processes that are now able to be enhanced through new data sources</li> </ul>
<b>Limited</b>	Largely manual entry processes	<ul style="list-style-type: none"> <li>• Identify what services TMC would need to perform based on new data coming in and what new or changed processes will be required</li> <li>• Consider implementing some automated processes to support real-time conditions reporting at a minimum to alert the operations staff that a situation warrants monitoring – could be through public safety systems or maintenance rather than traffic systems</li> </ul>
<b>System and Performance Reporting</b>		
<b>Robust</b>	Regular and automated system/activity reporting	<ul style="list-style-type: none"> <li>• Identify new reporting metrics that would be beneficial to support new MAP-21 and other performance requirements to justify future investments</li> <li>• Begin reporting on the ‘before’ environment today for metrics that were previously not reported on to be able to report on the ‘after’ once big data is accessible</li> </ul>
<b>Moderate</b>	Periodic system/activity reporting done by combination of automated system and manual collection	<ul style="list-style-type: none"> <li>• Identify additional metrics that would justify future investments to political environment</li> <li>• Begin reporting on the ‘before’ environment today for metrics that were previously not reported on to be able to report on the ‘after’ once big data is accessible</li> <li>• Invest in data analysis systems to produce automated metrics on system status, system use, operations management, and incident-based reporting</li> </ul>
<b>Limited</b>	No system/activity reporting	<ul style="list-style-type: none"> <li>• Identify metrics that would justify future investments to political environment</li> <li>• Begin reporting on the ‘before’ environment today to be able to report on the ‘after’ once big data is accessible</li> </ul>
<b>Institutional Support</b>		
<b>Robust</b>	Essentially unconditional support from upper management for investments	<ul style="list-style-type: none"> <li>• Develop or use nationally-provided educational material for what big data and Connected Vehicle applications can mean to an agency and a traveler</li> <li>• Package reporting of metrics to justify future investments – focused on public consumption only</li> <li>• Coordinate with other entities that might have this responsibility (i.e. statewide or regional operations)</li> </ul>
<b>Moderate</b>	Some interference from political environment for	<ul style="list-style-type: none"> <li>• Develop or use nationally-provided educational material for what big data and Connected Vehicle applications can mean to an agency and a traveler</li> </ul>

Scale of Environment	Current Operational Environment	Recommended Operational Environment Adjustments for Readiness
	investments	<ul style="list-style-type: none"> <li>Promote effectiveness of TMC or traffic operations capabilities either already provided or could be provided if investments can be identified – focused on agency consumption as well as public consumption</li> <li>Coordinate with other entities that might have this responsibility (i.e. statewide or regional operations)</li> </ul>
<b>Limited</b>	Challenges internal to agency to prove value for investments	<ul style="list-style-type: none"> <li>Develop or use nationally-provided educational material for what big data and Connected Vehicle applications can mean to an agency and a traveler</li> <li>Promote effectiveness of TMC or traffic operations capabilities either already provided or could be provided if investments can be identified – focused on agency consumption only (public consumption will come later once agency decision-makers are on board with concepts)</li> <li>Coordinate with other entities that might have this responsibility (i.e. statewide or regional operations)</li> </ul>

## 4 Coordination with Other Concurrent Efforts

A key challenge facing agencies in this dynamic evolution is the sheer number of concurrent activities, research and planning being carried out by numerous different entities. USDOT has had a leadership role in foundational application, policy and safety research, test bed operations, and national efforts to build a dialogue among key partners (both public and private) as well as initiating the Reference Implementation Architecture. AASHTO also has recently undertaken some important planning activities in partnership with USDOT/FHWA, most notably the Strategic Plan (2009), Infrastructure Deployment Analysis, and the current Footprint Analysis. Test beds and demonstration sites throughout the country and yielding some impressive early outcomes and valuable lessons learned. The CTS represents an important effort in bringing partners together to address specific issues and research needs of most interest to state and regional transportation operations entities. From a technical association standpoint, ITS America has (and will continue to have) a role in providing a forum for ongoing connected vehicle collaboration and demonstration, and there is a significant focus on connected vehicle technology demonstration planned for the 2014 ITS World Congress in Detroit. Very recently the Institute for Transportation Engineers established a formal committee for Connected and Autonomous vehicles. There are a lot of discussions and activities happening among a lot of different entities, which makes it challenging to keep pace with how fast information is emerging.

The following subsections identify those connected vehicle activities that have the potential to produce important information for TMCs to factor in to their future planning. Included with these brief descriptions are specific recommendations for the CTS relative to TMC issues.

### 4.1 AASHTO National Connected Vehicle Field Infrastructure Footprint Analysis

In partnership with FHWA, AASHTO formed a team to conduct a national connected vehicle infrastructure footprint analysis. This analysis, although still in progress, is an important collaborative effort that will influence near-term considerations and potential research focus areas. This work will

include a set of deployment scenarios that would be likely candidates for early adoption by state and local agencies. The USDOT/FHWA have not deemed any particular set of applications as a starting point, but rather this effort is considering a broad range of connected vehicle applications and scenarios, including safety mobility and environmental applications. It is the first effort that also is providing some rough order of magnitude cost estimates and a consolidated set of field deployment scenarios and concepts. The scope of the Footprint analysis is primarily focused on infrastructure, so the deployment scenarios include those applications that have a field infrastructure deployment component (i.e., it does not include scenarios for V2V, although this infrastructure support was presumed). The final report is projected to be complete in January, so it may be publicly available by March.

The Footprint analysis is important for several reasons:

- Future deployment by state and local agencies will drive several considerations for TMCs, including available data, geographic coverage of situational awareness, and locations for operational strategy implementation, among others. Historically, system operations have ‘followed’ deployment, so the level and density of future deployment will be a major influence for any changes to TMC operating processes. TMC Operations.
- An objective of the National Footprint Analysis is to identify needs related to workforce and training. These are also two important needs that have emerged from this TMC study. The connected vehicle environment will likely influence and shape new technical workforce and training requirements for agencies, including those that have a direct relationship to TMC operations.
- Deployment scenarios are envisioned to identify some specific implementation needs and timeframes, as well as potentially help agencies and USDOT to prepare for a national launch footprint for enabling infrastructure. Deployment scenarios are being developed to be applicable to a wide range of agencies, in terms of size, capabilities and modes
- The Footprint analysis acknowledges the need for TMCs to invest in much more robust data collection, management and warehousing capabilities to support a future connected vehicle environment. There also is acknowledgment that it is premature to estimate costs or specific sizing requirements at this time. <sup>1</sup>

**Recommendations:** Maintain close coordination with the Footprint Analysis effort (representatives are also part of the CTS Pooled Fund Study) and ensure that TMC needs are captured as part of this Footprint and Recommendations. Any follow-on activities to the Footprint Analysis (including deployment coalitions and/or peer exchange forums) should include representation and involvement from CTS members.

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<sup>1</sup> National Connected Vehicle Field Infrastructure Footprint Analysis, Deployment Concepts. Section 4.3. Final Version 2, September 20, 2013.

## 4.2 2014 ITS World Congress

The upcoming 2014 World Congress in Detroit, Michigan aims to heavily emphasize a broad range of connected vehicle related applications and demonstrations. An open solicitation by the organizers requested innovative applications and ideas be further developed and showcased at this international event. The proximity to local test beds in southeast Michigan, as well as the willingness of Detroit area transportation agencies to actively participate in field demonstrations for the Congress is expected to result in more active demonstrations than past conferences. There is a category within the showcase particularly relevant to this effort called “TMCs of the Future”, which may provide some insights as to new or envisioned TMC capabilities in a highly mobile, connected and even autonomous data environment.

**Recommendations:** For those able to attend the Congress, participate in technology demonstrations, including the TMC of the Future session.

## 4.3 USDOT 2015 V2I Guidelines for Public Agencies

The purpose of the Public Agency Guidelines activity is for the USDOT to identify, assess, develop, package, and test documentation and tools that will serve as a guide to public agencies in successfully planning, deploying, operating, and maintaining the infrastructure portion of vehicle-to-infrastructure (V2I) systems. FHWA is planning to issue V2I Deployment Guidance in 2015, which will leverage outputs from several concurrent efforts, including pilot tests and key research activities (such as the NCHRP Benefit Cost Analysis for State and Local DOTs, certification processes, security credentialing and outcomes from the Footprint Analysis). This Guidance is expected to include a “toolbox” for deployment, any specific regulatory implementation requirements (pending outcomes of the NHTSA decision), and non-regulatory implementation guidance.

**Recommendations:** CTS members should consider participating in the outreach activities during the development of this Guidance, and should consider inviting USDOT representatives involved to participate in an upcoming CTS in person meeting. This 2015 Guidance Workgroup will likely be soliciting feedback on draft deliverables and feedback on gaps that the Guidance should address. Some of the specific gaps that could be provided from this TMC study include:

- Staffing and technical skill needs to support a TMC in a connected vehicle environment
- Multi-source, real-time data sharing among regional transportation management partners
- Data management needs and requirements for TMCs in a connected vehicle environment
- Operating system needs and guidance on migrating to new and expanded operating systems
- Integration of other crowd-sourced data (i.e., next gen social media) with connected vehicle data to support transportation system operations
- Applications of connected vehicle data beyond TMC and real-time operations

## 4.4 Connected Vehicle Reference Implementation Architecture

The Connected Vehicle Reference Implementation Architecture (CVRIA) was recently released in draft form by the USDOT and the CVRIA team. It provides an important link between connected vehicles and the National ITS Architecture, and as such can serve as an important tool for agencies to support planning, integration and policy development efforts. The CVRIA is application focused rather than being functionally focused, and therefore there may be some functional areas that TMCs are interested in implementing (that are not already being performed) that will require customized reference in the CVRIA and the National ITS Architecture. For example, the National ITS Architecture discusses areas like HOV Lanes or HOT Lanes Management and these areas are not considered in the CVRIA but individual components are. While there have not been extensive research programs to consider how connected vehicles may play into HOV/HOT Lanes, there are components that can be discussed in these larger areas that may not appear in the CVRIA the same way they did in the National ITS Architecture.

The CVRIA, being focused primarily on connected vehicle applications, introduces some instances where some of the back-end coordination between centers needs to be defined in greater detail. Incorporating or merging components of the CVRIA into the National ITS Architecture would be beneficial to ensure that these backend linkages are documented.

The CVRIA also does include some higher level system requirements for the applications; however, additional detailed requirements and concept work will be required to actually support in implementing a system. The CVRIA work does provide a good starting point for further system development and can be used as a reference in developing functional requirements for the design and integration of a system.

**Recommendations:** CTS members should review this CVRIA and provide input to the CVRIA team in terms of how the TMC is captured within the CVRIA as well as provide insights as to how this reference architecture can best be used by TMCs and agencies. Most applicable applications to TMCs will be in the Road Weather applications group of the Environmental Applications; several applications groups within the Mobility and V2I Safety Applications, and a limited number within the Support applications. Input from those closest to TMC operations will provide valuable feedback to the CVRIA team, and will result in a better tool to use for future planning.

## 4.5 Test Beds

There are a number of active (and planned) test beds throughout the country that are doing real-world testing and analysis of a number of connected vehicle related applications. The Michigan test bed is perhaps the longest established of these, but additional test beds in Virginia, Florida, California, Arizona, New York and Tennessee are establishing a network of affiliated test bed sites where technologies can be tested and demonstrated in various network environments. Outcomes from these test bed sites will provide valuable insights on technology performance, compatibility of network and vehicle infrastructure, potential partner/supply chain dynamics, and will greatly shape the future evolution of connected vehicle and related technologies.

Much of the focus of these test beds is on field and vehicle interactions; there is a tremendous opportunity to leverage the test bed concepts to extend to a focused demonstration on TMC interactions with these new data sources and capabilities.

**Recommendations:** The CTS, in partnership with the TMC Pooled Fund Study, should consider developing a TMC-specific test bed or set of TMC/operations center concepts to be able to demonstrate, test and evaluate as part of one of the already established test beds. Capabilities could focus on incident, network, or weather data (as examples) being transmitted to the TMC, TMC operating process modifications incorporating this new data, potential system logic to process data into usable information for the TMC, and how the TMC could push information out to travelers, partner agencies, etc. This could be a valuable next step in the test bed process, and will help to greatly inform more specific impacts and considerations for TMCs in a connected vehicle environment.

## 5 Recommendations for Advancing the Dialogue and Research Next Steps

The following present additional recommendations for the CTS PFS to consider as follow-on activities to this effort. Several of these involve collaboration with other entities also involved in concurrent efforts or, like the TMC Pooled Fund Study, actively engage on TMC-specific needs and issues.

**Establish a Dialogue on TMC Operations Issues with Private Industry.** Notable findings in this effort point to the need for next-generation operating systems capable of ingesting, processing and translating a potentially large amount of data points about events and situations, and making that data usable and actionable in a real-time TMC operating environment. A good percentage of operating systems in use today will not be capable of that kind of logic processing, verification, and decision support without modifications or entirely new systems. There are several TMCs still working with multiple legacy systems that are not fully integrated, which can make applying multiple new data sources a significant challenge.

Industry needs to be a partner in future operating environments, and it will be important for groups such as the CTS PFS, TMC PFS, future AASHTO Coalition and others to foster a partnership with the system developers to be establishing the next-generation system requirements. Standards will be at the forefront, more so than today, in a connected vehicle environment. Requirements and operational needs for future operating systems will require direct input from TMCs, as will specific requirements for open architecture standards. It is recommended that the CTS collaborate with other key entities (including FHWA, AASHTO and the TMC Pooled Fund group) to ensure that TMC needs are well represented in the industry discussions regarding future operations systems.

**Redefine TMC Staffing and Resource Needs to Align with New Connected Vehicle Data Environment.** This is one area where the CTS also can collaborate with the TMC Pooled Fund group to develop guidance on future TMC staffing needs and required skill sets in a connected vehicle environment. There will need to be some additional research, test bed activity and lessons learned from early adopters to

more fully define specific skill set and resource needs; much of the current connected vehicle test bed activity has not actively involved TMC staff nor has it fully extended to system operations. TMC staff and skill set needs would include those to support system operations, data management, information technology (development), and potentially traveler information/communications. Other staff skill needs, such as maintenance, may or may not be directly linked to TMCs, although future technologies will likely foster a closer relationship in those areas where functions are very separate and distinct.

**Assess Agency Data Needs that New Data Can Support.** This recommendation focuses more on ‘inreach’ within agencies than outreach. New data from connected vehicles has the potential to be used well beyond real-time operations, and support other critical transportation agency functions such as long-range or corridor planning, construction traffic control plan requirements, infrastructure maintenance, asset management, performance management, information management, among others. Support from other agency departments also could help to justify investment in systems that gather and manage this data if it can be demonstrated that it will add value to multiple entities’ business processes. These discussions can provide important information to TMCs about data storage, access, query and other data management needs. These data needs can also extend to partner agencies, such as local or regional transportation management, transit operations, or law enforcement/public safety.

**Initiate the dialogue with public safety partners.** With such a significant emphasis on incident management and the potential enhancements to TMCs’ capabilities to support more coordinated incident management in a connected vehicle environment, there will need to be some effort to engage the public safety and responder communities. More granular and specific data about such parameters as incident location, responders on scene, impacts to the network during incident response, among others, have the potential to significantly alter the current public safety/transportation data paradigm. It will be important to address concerns from public safety/incident responders about data privacy and how this new data will be used.