

## Connected/Autonomous Vehicles and Smart Cities

The intent of System Layers is to define in further detail recommendations that would serve toward the goals of how ADOT should be operating and managing their network. This System Layer Plan is focused on:

- **Connected/Autonomous Vehicles and Smart Cities** – C/AV and Smart Cities are emerging fields within the transportation realm that utilize technology and communication platforms to communicate and interact with public infrastructure. Connected vehicles exchange data and information to increase efficiency and safety while autonomous vehicles utilize sensors and other means to automate driving tasks.

## Context of Existing Capabilities

ADOT, as an infrastructure owner and operator (IOO), is largely focused on building and maintaining roadways with the TSMO Division responsible for optimizing traffic operations. Through TSMO and interactions with the C/AV community, ADOT has prioritized specific features that will support the operation of Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) vehicles such as the use of wider 6-inch striping and regular field inspection of sign retro-reflectivity. Beyond MUTCD enhancements, ADOT has partnered with other stakeholders in the Maricopa County area to conduct pilot studies related to traveler information and basic safety messages (BSM). ADOT has also explored connected vehicles options for their specialized fleets such as Incident Reasons Units (IRU) and snowplows which can provide some level of probe data.

Within the realm of Smart Cities, ADOT has begun providing broadband access Statewide to support increased data solutions.

ADOT is in the early stages of C/AV and Smart Cities and there are many opportunities to increase ADOT involvement in the area that drive the recommendations outlined in this System Layer Plan.

## Challenges and Gaps

Through a variety of meetings, workshops, and review of existing conditions and applications utilized by the state, current issues were uncovered that provide insight into the direction that ADOT should focus on addressing. The following are some of the current issues identified as related to Connected/Autonomous Vehicles and Smart Cities:

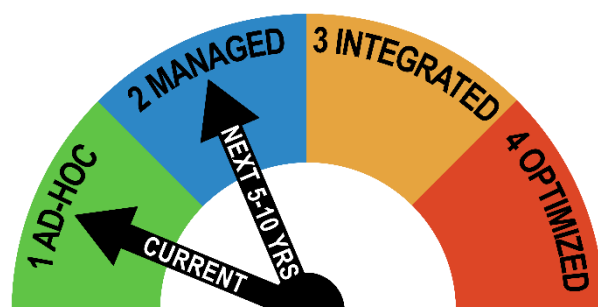
- Major advances in CAV have been driven by private sector. The public sector role in CAV remains uncertain.
- Uncertainty of communication, data standards and industry direction, how to prepare Infrastructure Owner and Operator (IOO).
- Lacking testing protocols to thoroughly evaluate the new technology and also comply with business practices.
- Technology is evolving rapidly; Challenged with keeping current on emerging technology and assessing opportunity for application.

## Future Direction

The project team conducted a series of individual workshops with ADOT for each System Layer Plan to identify the perceived existing readiness and future direction within the functional areas. The workshop included an interactive, online (JamBoard) activity in which ADOT staff provided specific feedback following a similar structure to the TSMO Capability Maturity Model (CMM) Framework. For CAV/Smart Cities, the workshop was held on May 5, 2022. A summary of the feedback is provided below.

CMM levels for consideration of ADOT staff for their current capabilities, where they see progress in the next 5 years, and where there is desire to move toward in the next 10 years.

- **Level 1 – Ad-Hoc** – Activities are ad-hoc, informal, champion-driven
- **Level 2 – Managed** – Basic strategy application is understood with limited internal accountability or coordination
- **Level 3 – Integrated** – Standardized strategy applications that are managed for performance and aligned
- **Level 4 – Optimized** – Full and sustainable program based on prioritized data-driven process of continuous improvement



A summary of the feedback for the state is that the current capabilities are at the ad-hoc Level 1 state and in the future can be moved toward the Level 2 managed state.

*A small segment of ADOT staff is aware and/or engaged in existing research such as the Connected Vehicle Pooled Fund Study or relevant National Cooperative Highway Research Program (NCHRP) projects related to CAV as well as participation in national organizations such as AASHTO and ITS America. There have also been several pilot projects to better understand CAV operational maturity and establish some relationships with other stakeholders particularly in the realm of traveler information and basic safety messages (BSM). Beyond those activities, there were some ADOT participants who felt their engagement with Institute of Automated Mobility (IAM) and ADOT's current use of 6-inch road striping are a positive move toward their goal of Level 2 on the CMM scale. Overall, the future*

*direction for ADOT relative to CAV/Smart Cities is largely one of education and exploration – to determine the functional need, scope, and involvement within the State DOT.*

## Recommendations

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This section provides a summary of important steps that will be used as building blocks for achieving the ultimate vision that extends to the five- to ten-year horizon. Because ADOT is looking at the three- to five-year horizon for implementation, these recommendations will focus on investments that are foundational technologies needed to support ADOT's future. The remaining gaps between what ADOT has today and where ADOT needs to be in the future becomes the recommended changes/additions that are needed.

ADOT desires to look at potential recommendations in the following areas:

- Vehicle to Everything (V2X) Communications
- Basic Safety Message (BSM)
- ML (Machine Learning)/AI Integration
- Enhance Mobile Apps
- Mobility-as-a-Service (MaaS)
- Mobility on Demand (MoD)

**Table 1** provides recommendations that can assist ADOT in improving their readiness level to move toward Level 2 capabilities for C/AV and Smart Cities on a statewide basis and working toward Level 3 capabilities in the future. While many of the recommendations are independent and can be accomplished in a short timeframe, ADOT should focus on a few key recommended activities (denoted in bold) to ensure adequate resources are available and generate the greatest benefits in progressing their readiness level.

Table 1 – C/AV and Smart Cities System Layer Plan Recommendation Summary (STIP level information)

PROCESS Recommendation Title	Description	Steps and Outcomes	Context for Recommendation	Recommended Champion	Recommended Stakeholder Involvement in Implementation	Total Funding Required	Annual Funding Required	Contracting Mechanism
<b>DATA MANAGEMENT</b>								
Develop TSMO Data Governance and Management Plan	Develop a data governance and management plan to prepare for increased data from connected vehicles and third-party data providers. The plan should address data sharing, storage, management, and cybersecurity along with roles and responsibilities for each.	<i>Steps and Outcomes have been incorporated in the <b>Develop TSMO Data Governance and Management Plan</b> action item in the <b>Data and Performance Management System Layer Plan</b></i>	TSMO has several data repositories - FMS loop detection, crash data, TOC incidents, etc. Each has separate environment and additional sources are being added without integration such as INRIX and RITIS.	TSMO Systems Technology Group Manager	ITG; all TSMO Group Managers	\$250K	None	Out-source (through RFP or TSMO On-Call)
Continue Evaluating Third Party Data Use	Explore opportunities for the ADOT TOC to use third party data (Waze, INRIX, RITIS) to better monitor statewide road and travel conditions, slowdowns, and recurring safety hazard locations including incident management. TOC should use third-party data for incident detection/notifications to have TOC verify and get information to traveling public sooner than they learn about it on the road.	<i>Steps and Outcomes have been incorporated in the <b>Continue Evaluating Third Party Data Use</b> action item in the <b>Data and Performance Management System Layer Plan</b></i>	ADOT has limited real-time detection capabilities outside of the metro area freeways. Third party providers can generate data to show atypical conditions (such as bottlenecks, slowdowns, decreases in travel time) to alert ADOT of potential crashes or incidents on the state highway system. Other state DOTs have found this incredibly valuable for incident notifications and awareness of potential incidents in areas where ADOT currently does not have detectors, cameras, or other real-time monitoring infrastructure.	TSMO Systems Technology Group Manager	Traffic Management Group Manager, ADOT TOC operators, other TSMO staff as needed, TSMO RTEs, District TEs, new ATDM Coordinators as identified in the ATDM System Layer Plan	Third party data has already been acquired by the state	On average \$500K for each third party data agreement statewide (currently INRIX is \$650K per year and RITIS is \$275K per year)	Out-source – either RFP or TSMO On-Call assignment

PROCESS Recommendation Title	Description	Steps and Outcomes	Context for Recommendation	Recommended Champion	Recommended Stakeholder Involvement in Implementation	Total Funding Required	Annual Funding Required	Contracting Mechanism
<b>PERFORMANCE MEASURES</b>								
Track CAV Pilot Outcomes	Identify anticipated expectations for CAV pilot projects - such as safety benefits, workforce preparedness, infrastructure readiness, and policy engagement - and measure results.	<p><b>Steps:</b> Work with TSMO staff involved in CAV efforts and document the purpose and identify the key performance benefits expected. For each project, collect (or request) data that supports the anticipated benefits and generate quarterly performance reports. A summary of overall CAV impact/benefit should inform new pilots or changes to ongoing efforts.</p> <p><b>Outcomes:</b> Defined internal direction on goals and expectations that will assist in developing pilots and other efforts.</p>	ADOT has partnered with several partner agencies on CAV pilots and have standalone efforts through MAG. An understanding of the potential agency benefit from the pilots should be developed. Examples include: virtual RSU with Verizon, CAV pooled fund studies, etc.	TSMO Systems Technology Group Manager	Partner agencies involved in pilots to provide data as necessary.	-	-	In-house
<b>STAFFING STRUCTURE</b>								
Create an Internal CAV Committee (Statewide/Regional)	Identify dedicated staff, including a CAV team lead/champion within the TSMO Division, to engage in CAV efforts and carry out a program of activities.	<p><b>Steps:</b> Work with TSMO groups to identify current CAV pilots as well as future CAV efforts. Identify key users within each TSMO group and establish an internal committee that can coordinate on a quarterly basis. Identify a single TSMO staff to champion and organize CAV efforts within ADOT. The champion will lead progress in the CAV realm and coordinate both internally and externally with partners on policy, pilot projects, data, and performance measures.</p> <p><b>Outcomes:</b> A defined internal committee that is focused on expanding CAV and can lead/review efforts.</p>	ADOT's TSMO Division was developed without a dedicated CAV group. While the Systems Technology group currently handles most CAV efforts, CAV advances and pilot efforts are widespread and involve more than a single ADOT TSMO group. Multiple people involved in traffic signals, traffic incident response, work zone applications, and others may need to be engaged.	TSMO Systems Technology Group Manager	TSMO Group Managers and other functional managers (safety, road weather, incident response, etc)	-	-	In-house



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<b>STAFFING STRUCTURE</b>								
Facilitate CAV Education	Educate staff on CAV technology, infrastructure, policy, applications.	<p><b>Steps:</b> Identify national and regional educational material that is available to DOTs with a focus on self-directed opportunities. Obtain resources (primarily weblinks) and distribute to TSMO groups. Set an annual training goal and track staff progress in the training completion.</p> <p><b>Outcomes:</b> Improved staff knowledge of CAV applications and operations.</p>	CAV remains an emerging technology. Most TSMO staff have not had hands-on experience with any CAV applications and would benefit from targeted education and training. This should include opportunities available through NCHRP, AASHTO, ITS, and other national resources.	TSMO Systems Technology Group Manager	None	-	-	In-house
<b>PROCESS STRUCTURE</b>								
<b>Develop a CAV Strategic Vision/Plan</b>	Create a CAV Strategic Vision/Plan to identify near-term funding, resources, and program needs to support Level 1 and 2 vehicles.	<p><b>Steps:</b> Work with each TSMO group to determine potential CAV applications and needs. Research national DOT direction to ensure consistency in industry. Establish an agency/division CAV vision and goals specific to CAV adoption and deployment. Identify general cost requirements and potential funding sources within ADOT. Determine if any new business processes are required to support CAV.</p> <p><b>Outcomes:</b> A formal vision document that addresses ADOT's future CAV involvement and provides input to other initiatives.</p>	ADOT has participated in pilot CAV efforts and has gained some insight into the future application. Some work has been done by ADOT in assessing maturity level and researching best practices. A strategic plan will be needed to determine how the new technology will align with existing business practices and how it will be supported.	TSMO Systems Technology Group Manager	TSMO Group Managers	\$200K	\$0	Out-source - ADOT TSMO On-call

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<b>PROCESS STRUCTURE</b>								
<b>Develop a CAV Integration Plan</b>	Identify how Level 1 and Level 2 CAV efforts advance or supplement other areas of the ITS Master Plan.	<p><b>Steps:</b> Finalize the CAV Strategic Vision/Plan. Review outcomes of the CAV pilot performance measures and select priority CAV applications. Determine industry need from agency/division as IOO and quantify available capacity to support widespread CAV deployment. Create integration/deployment plan with timeframes/schedules and range for each priority application.</p> <p><b>Outcomes:</b> A formal planning document that outlines ADOT's potential CAV deployment.</p>	Integration and use of CAV in established ADOT infrastructure and processes will require evaluation and development of new standards and approaches. An integration plan would assist in planning the technical rollout of CAV.	TSMO Systems Technology Group Manager	TSMO Group Managers to provide input on integration.	\$200K	\$0	Out-source - ADOT TSMO On-call

INFRASTRUCTURE DEPLOYMENT Recommendation Title	Description	Steps and Outcomes	Context for Recommendation	Recommended Champion	Recommended Stakeholder Involvement in Implementation	Total Funding Required	Annual Funding Required	Contracting Mechanism
<b>LIFECYCLE REPLACEMENT</b>								
Identify CAV Requirements for ITS Equipment Replacements	Consider Level 1 and Level 2 CAV needs when replacing signal controllers, and backbone communications.	<p><b>Steps:</b> Identify the industry trends in terms of messaging and V2I communications. Establish an ADOT-specific approach to connected vehicle communication and data exchange relative to traffic signals, DMS, and other devices. Determine what equipment changes are required, which manufacturers supports changes, and establish an approach for lifecycle replacement using maintenance funds.</p> <p><b>Outcomes:</b> Internal guidance on what equipment changes are desired/required when performing routine maintenance.</p>	Connected vehicles have the potential to communicate with infrastructure (V2I) to receive safety messages or signal arrival. Agency infrastructure will be a part of the system.	TSMO Systems Maintenance Group Manager	-	-	-	In-house

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<b>LIFECYCLE REPLACEMENT</b>								
<b>Upgrade / Improve Connected Infrastructure Networks</b>	Improvement of hardware, software, and communication channels/infrastructure to adjust to connected and autonomous vehicles (CAV) on the transportation network to collect and process big data and disseminate real-time information to travelers.	<p><b>Steps:</b> 1. Identify issues to disseminate real-time information.</p> <p>2. Determine where the system has technology gaps.</p> <p>3. Investigate new ways to utilize existing infrastructure combined with new technologies.</p> <p>4. Assemble the flow diagram that establishes communication between the various infrastructure components including data transmission and reception.</p> <p>5. Ensure the infrastructure and cyber security of connected infrastructure, especially in mobile and cloud interfaces that connect users to the infrastructure.</p> <p>6. Develop a comprehensive data management strategy.</p> <p>7. Identify the responsibilities and roles of individuals involved in multi-agency collaborations and public-private partnerships.</p> <p>8. Ensure that the project meets all specifications and is fully implemented when complete.</p> <p><b>Outcomes:</b> More connected system between end users and infrastructure.</p>	<p>Connected infrastructure using sensors and other ITS technology allows for real-time situational awareness for both agencies and road users. It also allows for inclusive data sharing integrated into intelligent road transportation and traffic management systems.</p> <p>For connected and autonomous vehicles to communicate with one another and with their surroundings, reliable, secure, and quick communication is essential.</p>	TSMO Systems Technology Group Manager	ADOT, MCDOT, MAG, and local agencies	\$100K	\$50K	In-house and Out-source

INFRASTRUCTURE DEPLOYMENT Recommendation Title	Description	Steps and Outcomes	Context for Recommendation	Recommended Champion	Recommended Stakeholder Involvement in Implementation	Total Funding Required	Annual Funding Required	Contracting Mechanism
Improve Roadway Marking Consistency	Update lane markings in rural areas (primarily in weather prone areas) to be consistent with MUTCD Guidance and ADOT Standards.	<p><b>Steps:</b> Work with Districts to identify areas that are prone to higher precipitation rates or other weather concerns. Conduct annual striping inspection/evaluation using existing procedures with a focus on long-line striping width and retroreflectivity (following applicable MUTCD Guidance). Increase priority for restriping those areas that are identified both as weather concerns and fall below the width or retroreflectivity threshold. Develop work order requests for the statewide striping contractor under existing practice.</p> <p><b>Outcomes:</b> Increased pavement marking widths, retroreflectivity, and consistency for the benefit of CAV.</p>	Advances in vehicle safety through ADAS rely on in-vehicle vision. Striping and signing is the basis for many manufacturer's systems.	TSMO Operational Traffic & Safety Group Manager	-	-	-	Out-source - Procurement (Striping On-call)
<b>EXPANSION OF ADOT TECHNOLOGY DEPLOYMENT</b>								
None								
<b>DEMONSTRATED TECHNOLOGIES FOR ADOT DEPLOYMENT</b>								
None								
<b>EMERGING TECHNOLOGY FOR ADOT PILOTING</b>								
Continue to Participate in CV Pilot Projects	Continue to participate in regional efforts on pilot projects to gain better understanding of CV technologies, applications, and integration requirements.	<p><b>Steps:</b> Coordinate with MAG, MCDOT, and others on regional efforts. Determine CV needs relative to ADOT facilities. Identify stand-alone, small-scale CV project that address specific use cases. Develop scope and identify funding. Monitor results per the "CAV Pilot Expectations".</p> <p><b>Outcomes:</b> Increased experience and knowledge of CAV based on pilot efforts.</p>	ADOT is currently conducting pilot projects for traveler information, pushing BSMs, and evaluating uses cases (MAG region). ADOT should continue to conduct these types of efforts to expand knowledge.	TSMO Systems Technology Group Manager	Partner agencies involved in pilots to provide data as necessary	-	-	In-house

## Performance Measures

Due to the nature of the CAV industry and the level which ADOT currently operates (Level 1), there are no specific performance measures within this SLP to actively track. Once ADOT has completed the recommended steps and developed a roadmap for CAV implementation and involvement, it is anticipated that relevant performance measures will be identified.