COOPERATIVE AUTOMATED TRANSPORTATION (CAT)

SERVICE LAYER PLAN

November 2019

REVISION HISTORY

This document was periodically updated by the Iowa Department of Transportation (DOT). The following table provides the date and a brief description of each revision to track history.

Revision Number	Date of Revision	Description of Revision
0.1	6/4/2019	Initial version
0.1	7/9/2019	Revision 1
0.2	7/22/2019	Revision 2
0.3	8/14/2019	Initial Full Draft
0.4	10/21/2019	Revised Final Draft
1.0	11/5/2019	Final Draft
1.1	11/20/2019	Final

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INTRODUCTION

The 2014 Iowa Department of Transportation (DOT) Strategic Plan defined a vision of ***Smarter, Simpler, Customer Driven***. The 2016 Iowa DOT Transportation System Management and Operations (TSMO) Strategic Plan and accompanying Program Plan describe a TSMO-oriented approach towards managing and operating the transportation system in a way that will help achieve this vision. TSMO is an approach to optimize existing infrastructure through better integration, coordination, and a systematic implementation of key operational strategies. As stated in the TSMO Strategic Plan, *"Within Iowa DOT there are multiple disciplines, offices and regions with the responsibility and ability to deliver safe and reliable mobility at the statewide and regional level. TSMO does not replace any of the current responsibilities; instead, it offers resources and strategies to realize the full capacity of the existing transportation system, increase reliability, improve safety, and target safety and operational problem locations."* TSMO is organized into eight service layers by the Iowa DOT, as illustrated in Figure 1.

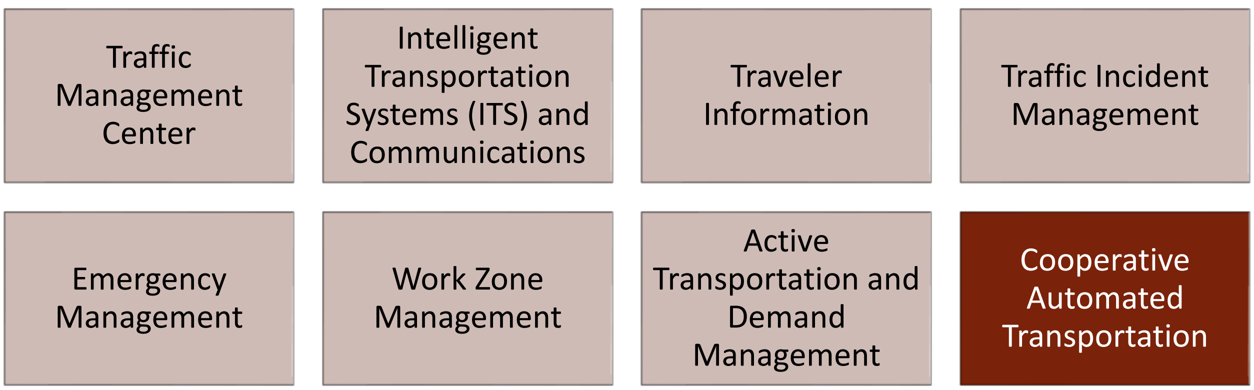

Figure 1 Iowa DOT TSMO Service Layers

This document defines the Service Layer Plan for the Cooperative Automated Transportation (CAT) Service Layer by describing challenges and opportunities, existing services and conditions, future direction, gaps and actions to bridge them, performance metrics, and estimated costs. Figure 2 summarizes how CAT, as part of the overall TSMO approach, will help Iowa DOT continue working toward its vision to be smarter, simpler, and customer driven.

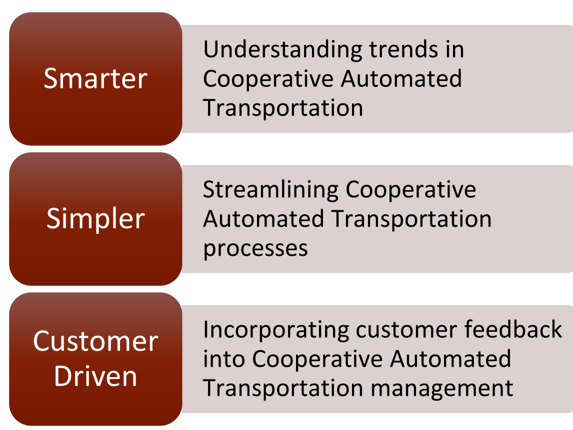

Figure 2 Cooperative Automated Transportation Contributions to Iowa DOT Vision

DEFINITION OF COOPERATIVE AUTOMATED TRANSPORTATION

The term Cooperative Automated Transportation (CAT) denotes a concept for automated transportation in Iowa that considers all modes and in which three basic elements work together:

- ***Systems*** (vehicles, infrastructure, communications);
- ***Services*** (operations, roadway design, vehicle and driver licensing, driver education and training, transit and mobility services); and
- ***Real-time automated safety features*** (on-board vehicle-based, hand-held, and dispatcher-based).

All elements work together to improve safety, mobility, and efficiency. (A glossary for many of the terms and acronyms used in this document can be found in Appendix A.

It should be noted that, in addition to autonomous vehicles, CAT addresses "connected" vehicles. Connected vehicles are equipped with networked wireless communications features that are safe and interoperable. Connected vehicles can communicate with the following:

- Other Vehicles - and is referred to as Vehicle-to-Vehicle (V2V) communications;
- Infrastructure Systems - and is referred to as Vehicle-to-Infrastructure (V2I) communications; and
- Roadway Users personal communications devices - and is referred to as Vehicle-to-Everything (V2X) communications.

According to the Federal Highway Administration, "Connected vehicles could dramatically reduce the number of fatalities and serious injuries caused by accidents on our roads and highways.[1]" Connected vehicles are part of a larger shift by the US Department of Transportation from helping people survive crashes to preventing crashes from happening in the first place.

In V2V connectivity, vehicles communicate with other nearby vehicles regarding information such as location, speed, braking, and potentially dangerous situations such as cross traffic ahead. Examples of V2V safety applications include forward collision warnings, left turn assistance, and blind spot/lane change warnings.

V2V Connectivity:

Vehicles communicate with other nearby vehicles.

V2I Connectivity:

Vehicles communicate with transportation infrastructure.

V2I connectivity means vehicles communicate with traffic signals, work zones, and other transportation infrastructure. Infrastructure that vehicles may communicate with include traffic signals, stop signs, toll booths, work or school zones, and railroad crossings. Applications include red light violation warnings, curve speed warnings, stop sign gap assistance, reduced speed zones warnings – lane closures (including work zones), roadside alerts, weather and road condition alerts, and dynamic travel guidance. Buses,

[1] https://www.its.dot.gov/cv_basics/cv_basics_what.htm

trucks, and emergency vehicles may also use V2I to request signal priority as they approach intersections. Vehicles would provide information such as speed, direction, and location to the agencies operating the network to support operational decision making, analysis, and planning.

V2X includes vehicle communication with anything that may affect the vehicle, such as V2I and V2V, but also pedestrians, bicycles, and other individual travel modes. An example of V2X may be an application that allows a pedestrian to alert nearby vehicles of his or her presence at a crosswalk.

V2X Connectivity:

Vehicles communicate with anything that may affect the vehicle.

Connected vehicles will likely communicate using either short-range low latency secure connections (e.g. Dedicated Short-Range Communications (DSRC) or Direct Cellular-V2X) or wide-area cellular-based approaches, such as 4 or 5G Long-term Evolution (LTE). Solutions may include communication hardware that broadcasts and receives data among vehicles, infrastructure and other devices in a local area, or they may include cloud-based solutions that allow data exchange among connected elements via existing and future cellular networks.

Automated vehicles leverage sensors, cameras, radar, and Light Detection and Ranging (LiDAR) capabilities to independently increase awareness of the surroundings. Note that automated vehicles may be autonomous (i.e., use only vehicle sensors) and/or may be connected (i.e., use communications systems such as connected vehicle technology, in which cars and roadside infrastructure communicate wirelessly).

Automated vehicles refer to a wide range of assistance. Figure 3 summarizes the six levels of automation as defined by the Society of Automotive Engineers (SAE). Of the six levels, levels 0 and 1 capabilities are currently available in many production vehicles. A variety of production vehicles include level 2 capabilities, with specific models from Cadillac, Tesla, and Audi approaching level 3. Levels 4 and 5 are being tested with limited real-world deployment, such as Uber and Waymo self-driving ride hailing services, but not available to the public.

Figure 3 Levels of Automation in Vehicles as defined by SAE J3016™

The distinction between levels of automation is not always simple nor well understood given that some vehicles may operate in various levels of automation based on owner/operator settings. The driver response to varying levels of automation as well as actual market delivery and actual adaptation of these capabilities is something to track and monitor in future versions of this plan.

Connectivity is an important factor in realizing the full potential benefits and broad-scale implementation of automated vehicles. In some vehicles, these technologies are expected to converge such that vehicles are both connected and automated, with integration that allows vehicles to be operated automatically and communicate with other vehicles, the roadside, and other infrastructure to make safe, efficient travel decisions. Nonetheless, some vehicles will operate automated features without connectivity while others will feature connectivity without automation. Figure 4 illustrates the integration of connected and automated vehicles.

Integrating connected vehicle technologies with automation offers several advantages over the exclusive use of vehicle sensors (i.e. radar, LIDAR, cameras, and other on-board sensing). Vehicle connectivity can provide both guidance and warnings well beyond the range of on-board sensing. This happens today when the navigation tools on our phones warn you about debris on the roadway, vehicles stopped on the shoulder, or slow traffic ahead well in advance of you seeing it or the vehicles on-board equipment sensing it. Finally, today's faster computing power, communications capabilities, and dynamic vehicle data are providing a natural transition into connecting vehicles. In contrast, the publics perceptions, tolerance, and acceptance of full automation are unknown and so for now connectivity as opposed to automated is more viable to a broader range of travelers.

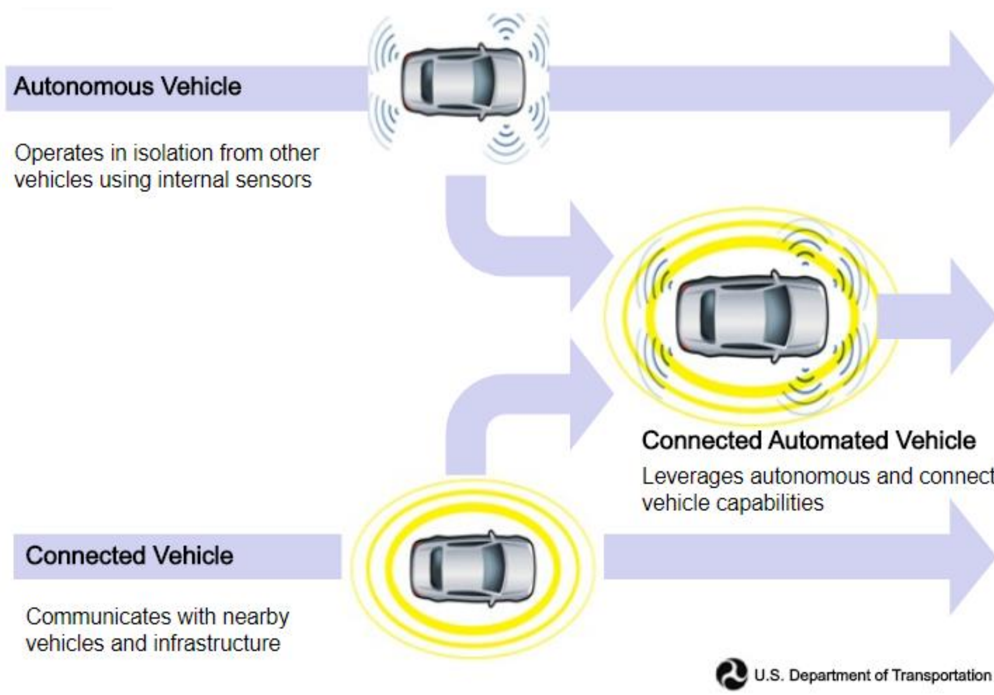

Figure 4 Conceptual Integration of Connected and Automated Vehicle Technologies

INFRASTRUCTURE TO ENABLE COOPERATIVE AUTOMATED TRANSPORTATION

The emergence of CAT, and expanded deployment in operations, will be enabled and ultimately be supported by two types of infrastructure, defined for purposes of this plan as follows:

CAT Digital Infrastructure: Digital infrastructure refers to the data, communications, and technology systems related to the electronic collection, processing, and transmission of information. Examples may include the data describing work zone related lane closures and speed reductions, as well as the database, reporting system, and the systems that communicate this data to the vehicles.

CAT Physical Infrastructure: CAT physical infrastructure refers to existing transportation infrastructure, changes or additions to the existing infrastructure, or deployments of new physical equipment or adaptations to the existing infrastructure to support CAT. Example adaptations could include modifications to lane striping or signage to support automated driving systems like lane keeping which is available on today's vehicles, structural modifications to pavement or bridges reflecting changes to vehicle paths or following distances, as well as modifying existing traffic control devices to send and receive information at rates as high as 10 times per second to improve intersection safety. Roadside units (RSUs) that broadcast and receive data using low latency communications mediums are also examples of CAT physical infrastructure.

SERVICE LAYER PLAN DEVELOPMENT PROCESS

Developing this Service Layer Plan began with a review of a variety of resources, including the Iowa DOT Strategic Highway Safety Plan, TSMO Plans, State Transportation Plan, and I-80 and I-380 Planning Studies, as well as the Iowa Code (permanent laws enacted by the Iowa General Assembly). An overview of findings from review of these documents was presented at a Visioning Workshop on July 25, 2018. This Visioning Workshop engaged Iowa stakeholders to gain a mutual understanding of CAT activities and trends across the nation before having discussions about how Iowa DOT should anticipate CAT technologies. This workshop helped with understanding the challenges and needs in Iowa.

A second workshop on September 20, 2018 involved completion of the Capability Maturity Model (CMM) for CAT with a group of Iowa DOT stakeholders. The CMM follows a process-driven approach to improve TSMO in six capability areas: culture, collaboration, organization and staffing, business processes, systems and technology, and performance measurement. This second workshop helped established a baseline for current Iowa DOT capabilities related to CAT and identified a number of recommendations and actions to advance agency practices. A third workshop was conducted on March 26, 2019 to present a preliminary structure for this Service Layer Plan and discuss the prioritization of actions to advance CAT in Iowa.

Figure 5 illustrates how the document reviews and Iowa stakeholder outreach were used to gather information that serves as the basis for this Service Layer Plan. Internal Iowa DOT stakeholder groups were identified based on their anticipated roles with CAT to understand the challenges, needs, vision, and actions identified for CAT.

Figure 5 Illustration of the Service Layer Development Process

DOCUMENT CONTENT AND INTENDED USE

This document is intended to serve as a tactical plan for managing the CAT Service Layer in a way that is consistent with, and supportive of, the Iowa DOT TSMO Strategic and Program Plans. The TSMO Strategic and Program Plans define an overall vision for optimizing existing infrastructure through better integration, coordination, and a systematic implementation of key operational strategies, and included an approach of eight service layer plans. This document represents the CAT Service Layer Plan and therefore defines the tactical approach and action plans to accomplish CAT related aspects of the TSMO vision. The content will be used by Iowa DOT to manage operations, procurements, partnerships, developments, and deployments to accomplish the objectives defined within.

Following this introduction, the remaining sections are organized as follows:

- ***Challenges and Opportunities*** – Includes a description of transportation challenges that could be addressed by CAT, as well as a series of objectives and tactics that support TSMO strategic goals while addressing challenges.
- ***Description of Existing Conditions*** – Provides a detailed description of existing services and systems that will likely be impacted by CAT, as well as existing studies in Iowa, existing organized efforts, legal issues, and observed trends and forecasts for CAT within Iowa, in neighboring areas, and nationally.

- ***Future Direction for Cooperative Automated Transportation in Iowa*** – Describes seven elements of the future direction for implementing CAT in Iowa, together with a tactical approach for accomplishing the elements.
- ***Gap Analysis*** – Describes the analysis and criteria used to identify where services and other needs are unmet, as well as a list of actionable recommendations, specific performance measures for each service layer objective, a process for evaluating and correcting actions to meet the objectives, and a cost estimate by fiscal year that will be used to refine TSMO Program Plan budget estimates.
- ***Action Recommendations*** – Brief summaries of a series of actions to accomplish the tactics defined and advance towards the future direction for CAT in Iowa.

CHALLENGES AND OPPORTUNITIES

Iowa DOT operates programs and services by analyzing trends, strengths and weaknesses, and then capitalizing on opportunities to make enhancements. This section provides a summary of some of the challenges encountered thus far by the Iowa DOT in achieving its vision of ***Smarter, Simpler, Customer Driven*** – specifically those for which CAT may offer solutions. Following this description of challenges is a description of the opportunities presented by related TSMO service layer plans and CAT to mitigate those challenges.

CHALLENGES FACING IOWA TRANSPORTATION

Iowa DOT recognizes three areas where CAT could address existing and future needs: enhanced mobility, safety, and freight movement. These challenges are presented below, as described in the Iowa TSMO Program Plan.

- ***Mobility*** – Regarding mobility, vehicle-miles traveled (VMT) throughout Iowa increased by 38 percent from 1994 to 2017, while lane miles increased by 2.1 percent. VMT and truck freight volumes are expected to continue to increase. However, given Iowa's rural nature, safety and accessibility are generally of greater concern than travel time reliability issues.
- ***Safety*** – Over 300 fatalities occur in Iowa each year, and severe crashes are more likely to involve drivers under 25 or over 65 years of age. The average number of incidents statewide in Iowa is approximately 3,000 per month, with an average duration of about 60 minutes for blocked lanes. Each minute a lane is blocked can lead to up to 5 minutes of delay, and for each minute that a primary incident continues, the likelihood of a secondary crash increases by 2.8 percent.
- ***Freight Movement*** – The movement of freight and agricultural commodities has shaped the Iowa landscape. In addition to industries that create and ship products from within Iowa, I-35 and I-80 represent key transcontinental highways used to transport large volumes of freight every day. The state also has a strong agricultural economy with many miles of low-volume, rural roadways used for local freight transport.

An additional challenge is concern about ***funding.*** For example, gas tax revenue is impacted by increased vehicle fuel economy and use of electric vehicles. This can present challenges related to staffing and costs associated with capital projects, operations, and maintenance, potentially increasing the challenges of preparing for the transformation to CAT. The Iowa General Assembly has taken steps to address this by approving a 10 cent per gallon increase in the state's gasoline and diesel fuel taxes in 2015, and by establishing motor vehicle registration fees for electric vehicles and hybrid vehicles in 2019. The connection between CAT and electric vehicles goes beyond the concern for funding. Automated vehicle features and strategic mobility strategies often couple CAT to electrification of vehicles. Therefore, while there is no required connection there are references in this document to electrification.

COOPERATIVE AUTOMATED TRANSPORTATION OBJECTIVES

In order to address the challenges defined above, Iowa DOT is formalizing a CAT Service Layer that will work together with the other TSMO Service Layers to collectively manage and operate the Iowa transportation system. A series of TSMO strategic goals and objectives were developed based on the challenges described above, which align to a series of CAT supporting objectives that have been defined for the CAT Service Layer. Table 1 presents the CAT objectives that support the Iowa DOT TSMO strategic goals and objectives.

Table 1 Relationship of CAT Supporting Objectives to TSMO Strategic Goals and Objectives

<table>
<tr><th>TSMO Strategic Goal: Objective</th><th>CAT Supporting Objectives</th></tr>
<tr><td>1. Safety: Reduce crash frequency and severity.</td><td rowspan="3">Objective 1: Manage the Iowa digital CAT infrastructure in order to increase Iowa’s AV readiness.</td></tr>
<tr><td>2. Reliability: Improve transportation system reliability, increase system resiliency, and add highway capacity in critical corridors.</td></tr>
<tr><td>3. Efficiency: Minimize traffic delay and maximize transportation system efficiency to keep traffic moving.</td></tr>
<tr><td>4. Convenience: Provide ease of access and mobility choices to customers.</td><td>Objective 2: Ease the entry and ongoing operations of connected and automated vehicles in Iowa through appropriate physical infrastructure additions.</td></tr>
<tr><td>5. Coordination: Engage all DOT disciplines, and external agencies and jurisdictions to proactively manage and operate the transportation system.</td><td rowspan="2">Objective 3: Identify and define the business processes needed to allow and support CAT within Iowa.</td></tr>
<tr><td>6. Integration: Incorporate TSMO strategies throughout DOT’s transportation planning, design, construction, maintenance, and operations activities.</td></tr>
<tr><td>7. Security: Prepare for and mitigate potential physical and cyber security issues.</td><td>Objective 4: Secure Iowa travelers, transportation providers, residents, and physical and digital infrastructure against intentional or unintentional threats.</td></tr>
</table>

OPPORTUNITIES IN A TSMO-BASED APPROACH

Iowa DOT recognizes the potential of CAT to improve transportation efficiency, safety, and the mobility of its citizens. For example, increased data to vehicles and warnings about unsafe conditions can allow a driver or vehicle to take appropriate action, thereby reducing crashes. Similarly, a variety of applications are available or being developed that would facilitate vehicle platooning or communications with infrastructure to improve mobility and freight efficiency. Accordingly, the department has implemented CAT through pilot deployments and studies, and through engagement at the regional and national levels.

A TSMO-based framework for CAT planning recognizes that a holistic approach is necessary to allow all layers to complement and support each other. CAT requires information and services from the other TSMO services, just as it can provide information and support the other layers. An example of this approach can be seen in the recent effort by Iowa DOT to procure new and advanced traveler information and traffic management systems. There is an understanding that these systems may ultimately provide information to connected vehicles regarding traffic and travel conditions. Similarly, connected vehicles may be a source of probe data that can be used to manage traffic and inform travelers of road conditions.

The tactics in this service layer describe the relationship of CAT with the other seven TSMO Service Layers and how those relationships help to achieve the CAT objectives. The tactics help clarify the roles for management and operations activities among all eight service layers. Figure 6 illustrates at a high level the relationship of CAT services and the interaction with other TSMO Service Layers.

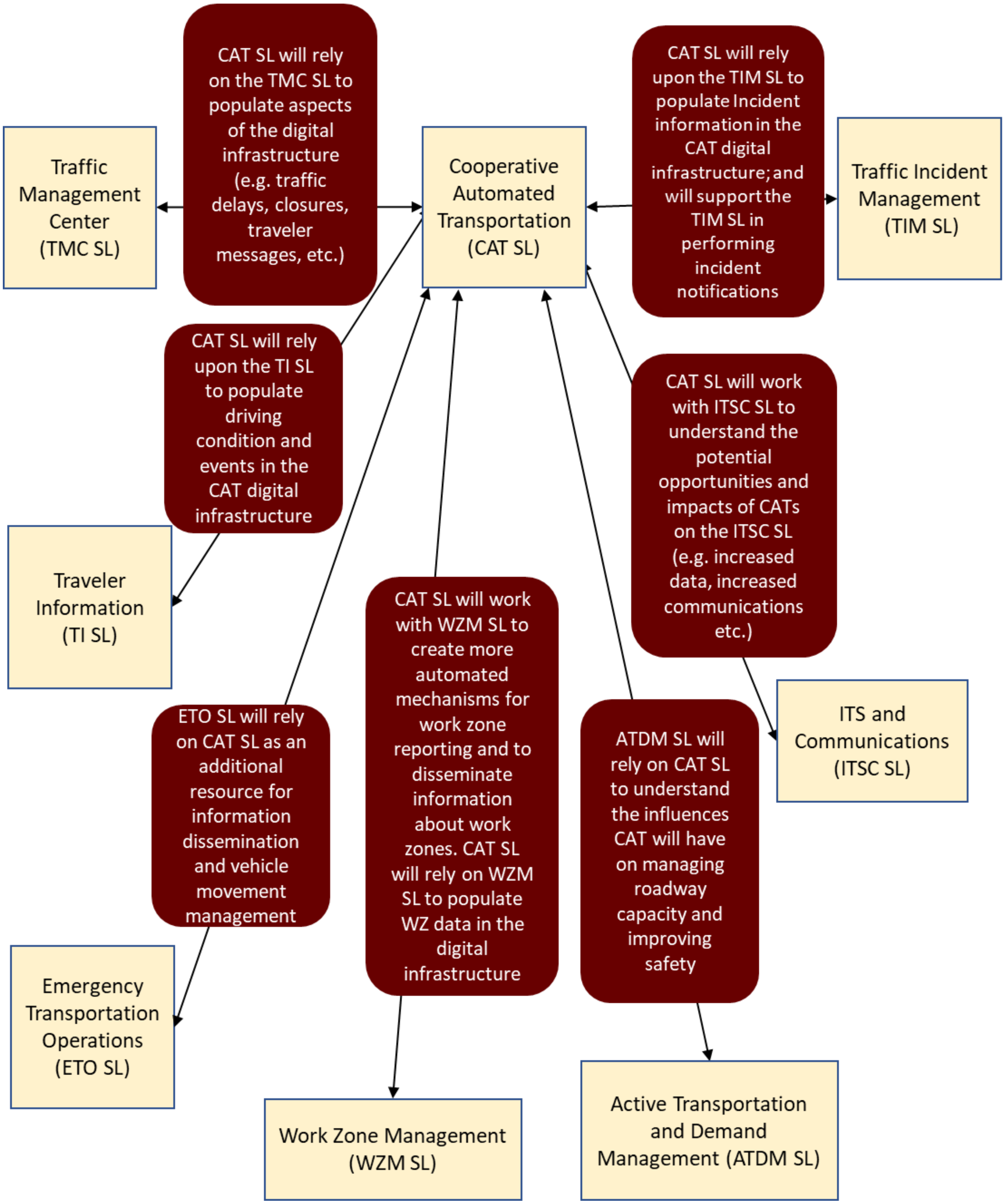

Figure 6 Example of CAT Interaction among TSMO Service Layers

DESCRIPTION OF EXISTING CONDITIONS

Defining future actions for the CAT Service Layer requires an understanding not only of the existing services and systems operated by the Iowa DOT, but also of the many supporting efforts occurring within Iowa and nationally. This section describes those existing services and systems, as well as supporting efforts.

EXISTING SERVICES LIKELY TO BE IMPACTED BY COOPERATIVE AUTOMATED TRANSPORTATION

A wide variety of services are expected to be impacted by CAT, particularly as penetration rates for Connected and Automated Vehicles (CAVs) increase. These include:

- Driver education and training services;
- Vehicle registration and licensing;
- Roadway and supporting infrastructure design;
- Transportation operations; and
- Information sharing with Iowa residents and travelers.

In the near term, additional services may be required to implement CAT. This may include the wireless exchange with CAVs of additional data and communications from roadside infrastructure.

Longer term high CAV penetration rates may lead Iowa DOT to consider phasing out or transitioning some existing service offerings. However, any phasing out of existing services should be given careful consideration to ensure that members of the traveling public have available alternatives. For instance, vehicle and personal device connectivity may increase to the point that it positively influences other TSMO service layers and/or assets maintained by Iowa DOT (e.g. Iowa DOT may consider modification or elimination of some traveler information dissemination services, such as Dynamic Message Signs (DMS) or 511.

EXISTING SYSTEMS LIKELY TO BE MODIFIED TO SUPPORT COOPERATIVE AUTOMATED TRANSPORTATION

In the near term, systems may require modification to accommodate CAT. This may include changes to the design or operations of physical systems and infrastructure. Examples of possible changes include:

- Full-depth shoulders to allow for a future CAT-designated lane when reconstructing roadways.
- Strengthening pavement design to accommodate high volumes of vehicles traveling along a more precise wheel path.
- Supporting connected infrastructure networks by installing continuous fiber, wireless communications, and/or power along corridors.
- Adding cameras, sensors, and other roadside equipment for V2I communication.

- Placing Global Positioning Systems (GPS) reference markers along the interstate medians for AV positioning during unstable satellite connectivity. This could be LIDAR in combination with known points to obtain position information.
- Installing roadside objects (technology based or non-technology based) to support navigation and guidance (e.g. signs that are readable to both AVs and humans) is one option.
- Establishing new standards for lane striping frequency, composition, or width.
- Providing pull-out areas for CAVs.

Modifications are also expected for the design and operations of digital systems and infrastructure. New communications mechanisms for transmitting and receiving infrastructure and vehicle data may become available. Additionally, as more CAT data becomes available, Iowa DOT may need to expand data processing and archiving capabilities and the functions of the Advanced Transportation Management System (ATMS).

Longer term, with high CAV penetration rates Iowa DOT may consider phasing out or transitioning some existing service offerings. Any phasing out of existing services should be given careful consideration to ensure that members of the traveling public have available alternatives. For instance, Iowa DOT may decide to implement managed lanes on major interstate corridors to accommodate CAVs or platoons.

EXISTING COOPERATIVE AUTOMATED TRANSPORTATION STUDIES AND EFFORTS

CAT has impacted nearly every aspect of the transportation industry, and continues to be a focus of many conferences, research initiatives, model deployments, and planning scenarios. To provide a perspective on the evolving nature of CAT, this section highlights some examples of studies and efforts within Iowa and at the national level to provide a perspective on the evolving nature of CAT.

IOWA PLANNING STUDIES RELATED TO CAT

In an effort to improve interstate mobility and better understand CAT, Iowa DOT has conducted planning studies focusing on I-380[2] and I-80[3]. Both studies included public involvement, establishment of existing conditions, an examination of required improvements necessary to support CAT, evaluation of alternative modes of transportation, and a vision for infrastructure investment. The studies offered a variety of CAT-related recommendations for these corridors.

Multiple studies are being conducted through a partnership between Iowa DOT, HERE Technologies (HERE), the University of Iowa, and Iowa State University. The study has several immediate goals for advancing CAT in Iowa. To date, the group has developed an infrastructure data specification document, and is testing the effectiveness of mobile and in-dash V2X hazard alerting. Additional plans include creating a queue detection pilot program, testing tools for obtaining additional detail regarding work zone activity, and completing a CAT “proof of concept” project for commuter vehicles and trucks.

[2] I-380 Planning Study: https://iowadot.gov/i380planningstudy.
[3] I-80 Planning Study: https://iowadot.gov/interstatestudy/Home.

IOWA ADVISORY COUNCIL ON AUTOMATED TRANSPORTATION

The State of Iowa has also created an Advisory Council (Council) to facilitate the strategic development of policy, systems, and infrastructure that are necessary to support CAT. This includes members from Iowa DOT, University of Iowa, Iowa State University, Iowa Department of Public Safety, Iowa State Patrol, Iowa Economic Development Authority, Iowa City Area Chamber of Commerce, Technology Association of Iowa, Iowa Insurance Commission, Iowa Motor Trucking Association, Freight Advisory Council, Iowa League of Cities, Iowa State Association of Counties, and Department of Agriculture and Land Stewardship. As stated in its objectives, the Council is intended to:

- Function as a catalyst and forum for automated transportation systems and automated vehicle (AV) technologies.
- Discuss policy and strategies to further effective and successful research, development, testing, operation, and implementation of AVs in the state of Iowa.
- Provide coordinated feedback on AVs to both public and private entities.
- Promote testing and deployment and remove barriers.
- Provide a forum for education and outreach on automated transportation systems and AVs.

Iowa Advisory Council on Automated Transportation

Vision: "To create an AV-ready driving environment in Iowa for the safe movement of people and freight for a thriving Iowa economy."

Mission: "Lead, coordinate, and enable the advancement of automated transportation systems in Iowa."

This Service Layer Plan is being developed to be, in part, a resource for the Council, and to expand on its findings and recommendations. The council will have subcommittees made up of subject matter experts, each focused on specific AT topics, as shown in Figure 7.

Outreach and Education (crosscutting)

Infrastructure Readiness
- Digital
- Energy
- Electrification
- Planning
- Land Use
- Freight
- Security
- Institutional
- Workforce

Policy & Legislation
- Administrative
- Liability
- Insurance
- Finance
- Privacy
- Land Use Planning

Economic Development
- Workforce Development
- Employment
- Entrepreneurship
- Freight
- Commerce
- Efficiency
- Reliability
- Industry
- Manufacturing

Public Safety & Enforcement
- Regulation
- First Responder Safety
- Operator Responsibilities
- Safe Deployment
- Vulnerable Road Users

Research and Development (crosscutting)

Figure 7 Iowa Advisory Council on Automated Transportation Subcommittee focus areas

Since many states have similar groups, the Council values the opportunity to exchange ideas with them. DOT staff participation in a national dialog through the American Association of State and Highway Transportation Officials (AASHTO) will assist in keeping the Council apprised of updates from other states. The Council is open to external stakeholders and has engaged with groups such as the American Automobile Association (AAA) and insurance companies.

Engaging with community members to educate them about CAT is also very important to the Council. For instance, many car owners have an incomplete understanding of the technology within their own vehicle, and of the technology that has become available. Educating communities also provides an opportunity to learn about their concerns.

NATIONAL ORGANIZED EFFORTS

A variety of efforts are occurring nationally to support CAT.

- **CAT Coalition.** The CAT Coalition serves as a collaborative focal point for federal, state, and local government officials, academia, industry, and related associations to address critical program and technical issues associated with the nationwide deployment of connected and automated vehicles on streets and highways. Coalition membership includes representation from infrastructure owners and operators (IOOs), original equipment manufacturers (OEMs), technology and service providers, and "internet of things" (IOT) suppliers. Working groups develop and provide feedback on CAT resources; promote peer exchange and outreach efforts; and promote CAT deployments such as the Signal Phase and Timing (SPaT) Challenge and the Connected Fleet Challenge. Individual working groups that Iowa CAT stakeholders may elect to participate in include the following:
    1. **Policy, Legislative, and Regulatory (PLR) Working Group** – focusing on policy level topics;
    2. **Infrastructure-Industry Working Group** – that has an emphasis on relationships between the infrastructure owner operators and industry providers/operators; and
    3. **Planning Scenarios Working Group** – that has an emphasis on understanding impacts that CAT has on short- and long-term planning.

- **National Strategy for Highway Automation.** The National Strategy for Highway Automation is intended to serve as a roadmap for automating America's highway network from freight routes to metropolitan areas. A three-phased approach envisions a transcontinental freight automation network as the initial focus, followed by automation networks in major metropolitan areas, and ultimately, automation support for the full National Highway System. This bold effort is expected to offer many benefits in bolstering global economic competitiveness and growth, national security and preparedness, public health and safety, and corollary technological advancement. Iowa is an active leader in the development of this national strategy. This means Iowans are positioned to influence its development and to benefit from the nationwide implementation and execution.

- **AASHTO CTSO CAV Working Group.** The AASHTO Committee on Transportation System Operations (CTSO) includes a working group on CAV. This working group provides a forum for state DOT members to exchange best practices, conduct outreach, and advance CAV concepts. Through Iowa DOT's involvement in CTSO, Iowa stakeholders can leverage this working group to engage with peers in other state DOTs throughout the development of the CAT program.

- **AASHTO State AV Task Forces – Community of Practice**. Iowa DOT participates in the State AV Task Force's Community of Practice (CoP). Recognizing that several states have formed (or are in the process of forming) AV Task Forces, AASHTO created a CoP with three objectives:
  1. To cross inform others about their efforts;
  2. To understand the products being generated by members that may be of interest to others; and
  3. To discuss critical policy and technical issues, as appropriate.

  The AV Task Force's CoP meets through quarterly webinars or conference calls to exchange information. In addition, ideas are shared via an on-line dialogue facility.

- **American Association of Motor Vehicle Administrators (AAMVA) AV Working Group.** AAMVA operates an AV Best Practices working group that is defining best practices with the intent of sharing them with member jurisdictions. Examples of topics include regulation of autonomous vehicles and the testing of drivers who will operate autonomous vehicles.

- **The Connected Vehicle Pooled Fund Study (CV PFS).** This initiative involves large-scale research and demonstration projects, with an emphasis on connectivity between vehicles and infrastructure systems. Iowa stakeholders may consider tracking the products and outcomes of this effort while also evaluating membership options.

Additionally, there are several ongoing public- and private-sector efforts occurring nationally to support CAT efforts using both cloud- and roadside-based technologies:

- **AV 2.0.** In September 2017, the United States Department of Transportation's (USDOT's) National Highway Traffic Safety Administration (NHTSA), released a voluntary guidance document intended to support the automotive industry, states, and other key stakeholders. *Automated Driving Systems 2.0: A Vision for Safety (AV 2.0)* is divided into two sections: Section 1 contains voluntary guidance for the safe testing and deployment of automated driving systems (ADS); Section 2 provides best practices for state highway safety officials with regard to procedures and conditions for operation of ADS on public roadways and also clarifies federal and state roles in the regulation of ADS.

- Table 2 highlights USDOT and state responsibilities for ADS as noted in this document.

Table 2. NHTSA and State Responsibilities for ADS from USDOT AV 2.0

USDOT/NHTSA's Responsibilities	States' Responsibilities
Setting safety standards for new motor vehicles and equipment	Licensing human drivers and registering motor vehicles in their jurisdiction
Enforcing compliance with safety standards	Enacting and enforcing traffic laws and regulations
Investigating and managing the recall and remedy of non-compliances (and safety related defects) nationally	Conducting safety inspections, as needed
Communicating with and educating the public regarding motor vehicle safety issues	Regulating motor vehicle insurance and liability

- **AV 3.0.** In December 2018, USDOT released a document that builds upon AV 2.0. *Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0)* describes the six principles that guide USDOT programs and policies on automated transportation and describes five implementation strategies for how USDOT translates the principles into action.

- **Additional Resources.** The USDOT has issued a number of additional resources to support CAT activities, including V2V Notice of Proposed Rulemaking; V2I Deployment Guidance; V2I Hub; and DSRC Specification 4.1.

- **Pilot Deployments.** Large-scale Connected Vehicle Pilots and Smart City Deployments sponsored by the USDOT are occurring in Columbus, New York City, Tampa, and Wyoming.

- **Early Local Deployments.** The SPaT Challenge has been accepted by 26 states to date, with over 2,000 signals expected to be equipped in the coming years.

- **CAT Policy Frameworks.** Over 22 agencies are represented on the CAT Coalition's CAT / CAV Policy Clearinghouse via various CAT-related policies and plans: https://transportationops.org/CATCoalition/clearinghouse-cat-policy-frameworks.

LEGAL ISSUES FOR COOPERATIVE AUTOMATED TRANSPORTATION

As of July 2019, 40 states have enacted CAT legislation or a related executive order[4]. Legislation and executive orders range from specific details regarding licensing or following distances that could in some ways be restrictive, to more general exemptions that provide greater flexibility for CAT initiatives, to general authorization for testing and advisory committees.

Iowa has enacted the following laws related to CAT:

[4]Autonomous Vehicles State Bill Tracking Database. National Conference of State Legislatures. Accessed July 2019. http://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx

- House File 387 became effective on June 1, 2019 and modifies existing Iowa Code[5] to remove vehicle following distance requirements for towing to accommodate coordinated platoons.
- Senate File 302 became effective on July 1, 2019 and provides CAT-related definitions, conditions for operation, insurance requirements, expectations when involved in an accident, on-demand driverless-capable vehicle network allowances. It also addresses taxing authority, specifically prohibiting political subdivisions (cities and counties) from imposing a tax on system equipped vehicles.
- House File 767 was signed on May 16, 2019 and contains various effective dates according to the respective divisions of the bill. This bill establishes registration fees for electric vehicles.

The Iowa CAT-related laws are similar to those in other states regarding:

- Definitions of CAVs and their operators and other CAV-related terms, such as platooning (22 total states).
- Vehicle following distances for coordinated platoons (18 total states).
- Insurance and liability for CAVs (11 total states).

Additional legislative changes that other states have enacted for CAT include the following examples:

- Defining the role of passengers/operators and establishing allowances for viewing devices while in motion (12 states).
- Preventing local authorities from prohibiting CAV use (5 states).
- Registering and licensing CAVs (4 states).
- Establishing requirements for various crash scenarios, such as reporting the crash and staying at scene (4 states).
- Establishing safety standards and penalties for violations (2 states).
- Addressing vehicles without standard operating gear, e.g. steering wheel, pedals (1 state).

CAT legislation or related executive orders enacted in states bordering Iowa are described in Table 3. A full list of enacted legislation and its relationship to Iowa Code is presented in Appendix C.

[5]Iowa Code 2019. Accessed June 2019. Note: this link is to the code as it stood prior to the start of the 2019 session, a link to the updated code will be inserted when available. https://www.legis.iowa.gov/law/iowaCode

Table 3 CAT Legislation or Executive Orders in Neighboring States

State	Legislation or Executive Order	
Illinois	Executive Order 13, 2018	• Directs interagency coordination to launch and support Autonomous Illinois Initiative, led by Illinois DOT. • Creates the Autonomous Illinois Testing Program, administered by Illinois DOT.
	House 791, 2017	• Amends Vehicle Code to define autonomous vehicle. • Bans local prohibitions on autonomous vehicle use on local roadways.
Minnesota	Executive Order 04, 2018	• Establishes the Governor's Advisory Council on Connected and Automated Vehicles. • Related documentation: MnDOT CAV website.
	Executive Order 19-18, 2019	• Replaces Executive Order 19-18; • Continues the efforts of the Governor's Council on Connected and Automated Vehicles
Missouri	None	
Nebraska	Legislature 989, 2018	• Authorizes automated and driverless vehicles and on-demand driverless vehicle networks with requirements, restrictions, and limitations. • Provides powers and duties for the Department of Motor Vehicles (DMV). • Defines terms.
South Dakota	None	
Wisconsin	Senate 695, 2018	• Defines and creates traffic law exemptions for a vehicle platoon traveling in a unified manner at electronically coordinated speeds.
	Senate 698, 2018	• Revises provisions relating to distances between vehicle platoons.
	Executive Order 245, 2017	• Created Governor's Steering Committee on Autonomous and Connected Vehicle Testing and Deployment to determine how best to advance the testing and operation of autonomous and connected vehicles. • Submitted findings: June 2018 report.

OBSERVED TRENDS, CHALLENGES, AND FORECASTS FOR THE FUTURE

TRENDS

A number of activities are currently underway by both IOOs and OEMs that point to a future with CAT:

- ***CAT Policy Frameworks*.** Many IOOs are anticipating CAT and beginning to develop task forces, executive committees, or research initiatives to explore CAT and understand what it means for their state and agency. This has sometimes been motivated by legislation or executive orders, as indicated in the previous section. Some IOOs have already published CAT-related strategic plans, executive reports, or other documents.
- ***Early First-Generation Deployments*.** An increasing number of IOOs are deploying their initial CAT infrastructure systems. An example of a common first CAT infrastructure deployment is the broadcast of SPaT data with accompanying MAP messages. SPaT/MAP broadcasts provide data for a variety of on-board applications, including red light violation warning (RLVW) and pedestrian in signalized crosswalk warning.
- ***Expanded Deployments.*** Some IOOs that have completed first-generation systems are expanding their existing deployments to a larger network. For example, Colorado DOT, Michigan DOT and Utah DOT all have wide area deployments underway or operational that will deploy a vast network of CAT infrastructure.
- ***Autonomous Vehicle Testing on Public Roads.*** Non-traditional OEMs like Uber and Waymo continue to test autonomous vehicles in various environments. Similarly, autonomous shuttles (often referred to as driverless shuttles) are being tested and deployed (either for temporary demonstrations or long-term operations) in a variety of urban and suburban settings, including the cities of Las Vegas and Minneapolis, and the state of Utah. One critical role these demonstrations are playing is allowing the general public to ride in and experience the new technologies.
- ***Autonomous Vehicle Operations on Private Roads***. Autonomous vehicle operations are underway in locations with private roads (e.g. inside gated retirement communities) and are delivering benefits to travelers.
- ***Production Vehicle Manufacturer Announcements***. Several OEMs such as GM, Ford, and Toyota have made announcements about equipping their vehicles with connectivity and/or communications capabilities in the coming decade, either through DSRC or Cellular-V2X communications.
- ***Guiding Principles.*** Several initiatives are developing guiding principles related to CAT activities that are likely to shape the overall industry approach, and Iowa CAT stakeholders have opportunities to both provide input to the guiding principles and benefit from the direction they offer. While it is likely that additional documents will continue to define principles from both the public and private perspectives, examples of current efforts to develop guiding principles include:
    - AASHTO, the Institute of Transportation Engineers (ITE), and ITS America have drafted *Guiding Principles for Connected Infrastructure supporting Cooperative Automated*

Transportation, anticipating that these principles will be reviewed, modified, and ultimately approved by each association's membership;
  - A document titled "Safety First for Automated Driving" was published by a coalition of 11 companies that include Aptiv, Audi, Baidu, BMW, Continental, Daimler, Fiat Chrysler Automobiles, Here, Infineon, Intel, and Volkswagen. This document is described as a framework for the development, testing, and validation of safe autonomous vehicles.
  - In July 2019, Uber published a "Safety Case" that describes testing and development of their self-driving system and encourages the industry to collaborate on safety. Uber described this as an approach to provide additional transparency around their safety approach.

POTENTIAL FUTURE CHALLENGES

The list below describes some of the challenges that will likely impact future CAT deployment and operations:

- ***Communications Spectrum Uncertainty.*** Since 1999, the Federal Communications Commission (FCC) has allocated 75 MHz of the 5.9 GHz band to transportation use, with the intent of promoting the safety of automobile drivers, passengers, and possibly even pedestrians. Recently, there have been questions about the long-term status of dedicated transportation use of this spectrum.
- ***Communications Technologies.*** Since 1999, the default communications technology for the 5.9 GHz spectrum has been the use of the DSRC protocol. However, cellular V2X and 5G technologies have recently been introduced as alternates and/or supplements to DSRC. The industry now lacks universal agreement on the long-term communications technology for V2V and V2I communication. This uncertainty is impacting long-term investments from both the private and public sectors.
- ***Security of Communications***. V2I and V2V communications will ultimately require a credentials-based mechanism for securing messages. Questions remain regarding ownership, cost, and responsibility for managing a national security credentialing system to support the V2I and V2V use cases.
- ***Potential for Unsafe Proliferation of Autonomous Features***. While there is considerable industry attention to the safety of autonomous features in vehicles, the introduction of any transformational technology change introduces potential risks of safety factors not anticipated.
- ***Abuse and Misuse of Autonomous Features***. As the autonomy of vehicles incrementally increases beyond driver assist, there is potential for drivers to either misuse functions if they are not well understood or to abuse functions that are understood. Educating drivers about the facts of the autonomous features (e.g. the limits they are allowed to rely on the autonomy) can reduce the misuse, but drivers may be included to push the extent that they rely on the autonomy beyond the level it is tested and trusted.
- ***Enforcement of Autonomous Vehicles***. Autonomous vehicles will introduce new and unique challenges to law enforcement and emergency responders. It likely will not be possible to distinguish the level of autonomy by visual inspection of a vehicle traveling down the road,

creating challenges of enforcing distracted driving laws. Similarly, the testing and verification of vehicle functions is not well understood at this time.

- ***Vulnerable Road Users***. While vulnerable road users stand to benefit from increased mobility through autonomous vehicles, there are potential safety risks by removing some or all of the driver's control. The visual confirmation and often eye contact or hand gestures that enable vulnerable road users to understand the driver's intention will likely decrease or remove as vehicles increase in autonomy.
- ***Identifying and Understanding Levels of Automation***. Any specific vehicle's level of automation may vary depending upon software upgrades downloaded, driver activation (or deactivation) of features. Similarly, automation functions may be marketed as features in vehicles, with various names depending upon the manufacturer. This may create confusion for both the drivers as well as enforcement.
- ***Common Nomenclature.*** Currently no universal set of CAT related terms and definitions exists. While multiple organizations have developed or are developing these, inconsistencies remain between definitions used in legislation, technical research, vendor products, and supporting resources.

FORECASTS

The trends, activities, and challenges discussed above point to three parallel transitions that are likely to occur over the coming decades:

1. A progressive increase in the level of automation and connectivity in privately-owned vehicles – the rate of which is difficult to estimate.
2. Increased use of fully autonomous (i.e. no on-board driver controls) shared vehicles for transit, shuttles, rideshare, mobility-on-demand, and commercial vehicles.
3. Increasing enactment of legislation, policies, and regulations by federal, state, and local governments to ensure safe and equitable operations and foster better understanding by all stakeholders.

Due to many variables involved, estimates of CAV penetration rates within 10 or 25 years vary widely from 10 percent to nearly 100 percent of the vehicle fleet. It is expected that a major paradigm shift will occur at some point in the coming decades when we reach a critical mass of operational CAVs and electric vehicles. When this occurs, travel patterns are likely to change significantly, requiring significant infrastructure changes as well. However, given the fast-changing pace of new and evolving technologies, much uncertainty remains about when the CAT future will arrive or what it will look like.

FUTURE DIRECTION FOR COOPERATIVE AUTOMATED TRANSPORTATION IN IOWA

The next 10 years promises to be transitional and formative for CAT throughout the United States. During this period, the vehicles on Iowa roads will increase in automation, with growing use of commercial products available today (e.g. Cooperative Adaptive Cruise Control (CACC)) as well as new features and functions as they are introduced in production vehicles. In fact, it is possible that testing and limited operations of fully autonomous vehicles will become increasingly common, supporting specific freight or transit uses.

ELEMENTS OF THE FUTURE DIRECTION OF CAT IN IOWA

Iowa DOT will gather input and direction from the National Strategy on Highway Automation, the Iowa Advisory Council on Automated Transportation, and additional Iowa CAT stakeholders. This input is not limited solely to public agencies. For example, private sector industry is represented on the Council, and the National Strategy for Highway Automation includes a component of private sector outreach and input. The department will conduct a variety of activities in line with the identified CAT and TSMO objectives. As illustrated in Figure 8, these activities can be organized into elements of the future direction of CAT in Iowa, as follows:

- Advancing and supporting a digital CAT infrastructure that benefits from both public and private data and information;
- Supporting efforts to expand the generation and availability of AV-ready data;
- Making practical, incremental changes to the Iowa DOT physical infrastructure and digital infrastructure to support CAT;
- Developing a coordinated approach that aligns national efforts with Iowa's Automated Transportation Vision developed by the Iowa Advisory Council on Automated Transportation, which may include DOT activities and policy, legislative, and regulatory efforts;
- Informing Iowa residents about CAT, potentially through driver education, licensing, and outreach, and representing statewide needs to encourage equity;
- Increasing internal CAT readiness at Iowa DOT by updating business processes, meeting staffing and funding needs required by CAT, and educating decision makers; and
- Minimizing security threats are minimized to all CAT-related systems and activities.

In addition to the influences and actions that are expected over the next several years, Figure 8 illustrates these elements of the future direction for CAT in Iowa. Details on the seven elements of the future direction are described below, as they relate to the previously defined CAT supporting objectives.

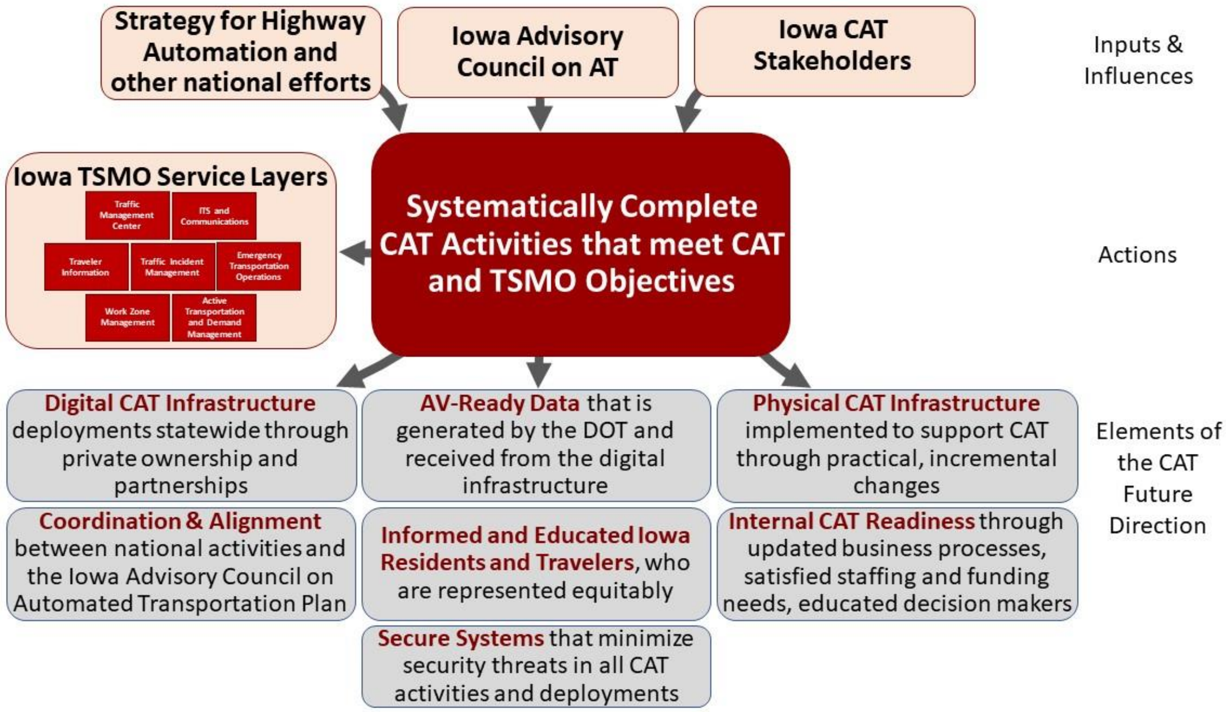

Figure 8 Future Direction for Cooperative Automated Transportation in Iowa

DIGITAL CAT INFRASTRUCTURE

The digital infrastructure will be a critical component of CAT in Iowa. Currently, the availability and maturity of digital infrastructure in Iowa is very low. However, it is likely to be deployed rapidly statewide over the next 5-10 years. This increasing availability and maturity is expected to simultaneously increase CAT functionality at a rapid rate. The department envisions this rapid growth as occurring largely through private-sector investment, ownership, and partnerships, with some ownership at the state and local public levels. Figure 9 depicts the relationship of digital infrastructure availability and maturity to proportionately enhance CAT functionality.

Iowa DOT envisions early demonstrations will help with understanding the business case as well as helping to define the respective roles of industry and DOT in funding, deployment, operations, and maintenance of the digital infrastructure. These demonstrations would be encouraged and supported by Iowa DOT but preferably led by the private sector. Demonstrations will also help identify roles where Iowa DOT adds value that third-party providers and private sector cannot.

PHYSICAL CAT INFRASTRUCTURE

Physical infrastructure is another a key element of the CAT vision in Iowa. As illustrated Figure 9, the physical infrastructure is largely built out and therefore widely available for traveler needs. The future direction for CAT will require Iowa DOT to make changes to this network to enable CAT functionality.

Some changes to the physical infrastructure will involve low or no technology improvements. These may include improvements to lane striping (e.g. widening of stripes or increased frequency of painting), signing changes, and traffic signal improvements. These changes are expected to be implemented based on a timeline developed by the National Strategy for Highway Automation and can be near-term changes that will benefit drivers of non-autonomous vehicles as well.[6]

Other changes to the physical infrastructure will involve technical solutions with a higher degree of complexity and require increased maintenance and operation. These may include roadside or cloud broadcasts of data to support V2I applications in vehicles, roadside data captures of data broadcast by vehicles for information gathering. These technology changes to the physical infrastructure are longer term changes and do offer potential benefits to vehicles with on-board applications. However, such changes are expected to be incremental, practical, and targeted to specific locations and corridors, such that availability and maturity of the physical infrastructure incurs minimal expansion while CAT functionality is steadily increased. Figure 9 shows how expansion and increased CAT functionality for the physical infrastructure is relatively less than that expected for the digital infrastructure.

To support incremental changes to the physical infrastructure, Iowa DOT envisions pilot projects will be conducted to help understand the needed changes in the physical infrastructure to support CAT. The Iowa DOT currently envisions four types of demonstrations:

1. **Proof of Concept**. Demonstrations to learn if something is possible technically or institutionally.
2. **Benefit Understanding**. Understand the direct and indirect benefits to be expected as CAT deployments progress and infrastructure investments continue, and to quantify these benefits to the extent possible in relation to TSMO goals.
3. **Cost Understanding**. Learn the costs of an activity and determine its fiscal feasibility within the current technical or institutional structure, and relate costs to the estimated benefits.
4. **Design Understanding**. Discover design changes necessary for the future CAT environment.

For example, a design understanding demonstration could focus on design for a major interstate corridor such as I-80 to understand whether pullouts are needed to support AVs and how AVs might handle them. As another example, a proof of concept demonstration could experiment with fiber or other uses of conduit to support CAT.

[6] Preparing Local Agencies for the Future of Connected and Autonomous Vehicles; Iowa State University for the MN LRRP. http://www.dot.state.mn.us/research/reports/2019/201918.pdf

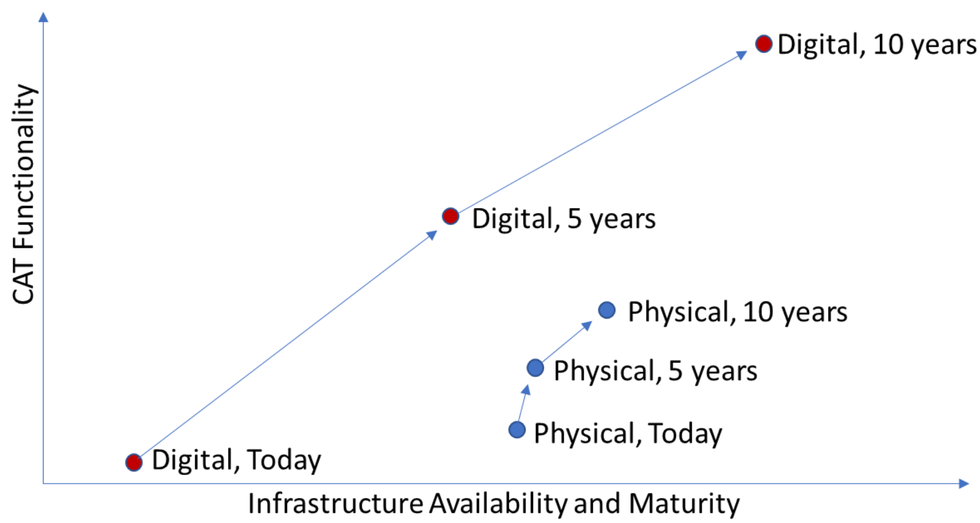

Figure 9 Future Direction for Expansion of CAT Physical and Digital Infrastructure in Iowa

AV-READY DATA

Iowa DOT recognizes the importance of data to support CAT and intends to systematically increase the accuracy and level of detail of DOT-generated AV-ready data. This AV-ready data will directly support, contribute to, and be generated by the digital infrastructure. At the same time, Iowa DOT will make accommodations to receive non-DOT data from the digital infrastructure to increase TSMO capabilities. Iowa DOT recognizes the importance of augmenting data systems and availability in a way that is sustainable and formalized throughout the department.

For example, an agreed-upon goal for the Iowa DOT is to have statewide AV-ready work zone data available within 10 years. This will begin soon as a pilot with staff focusing on work zones that have higher crash rates to get comfortable with the data and understand what it takes to generate, validate, process, and disseminate the data. Iowa DOT is also participating as a pilot state in the FHWA Work Zone Data Initiative, which is expanding the availability of work zone activity data and supports this goal for AV-ready work zone data. Once the cost of generating AV-ready work zone data (or any data for the digital infrastructure) is understood, Iowa DOT may release a position statement describing the department's vision of the respective roles of the DOT and private sector.

COORDINATION AND ALIGNMENT WITH NATIONAL AND LOCAL COOPERATIVE AUTOMATED TRANSPORTATION GUIDANCE

Deployment of physical and digital CAT infrastructure and AV-ready data described in the previous sections is expected to ultimately harmonize with both national and local CAT guidance, recognizing that this guidance is evolving as well. A variety of national organizations such as USDOT, AASHTO, AAMVA, and the CAT Coalition provide guidance and recommendations for the deployment of CAT. Further, as part of its phased deployment, the National Strategy for Highway Automation is expected to develop a variety of resources to help agencies prepare for future automation. One such resource would be a "roadmap" that identifies priorities for CAT investment and minor modifications to business practices to support CAT. Iowa DOT will align local interests and input from the Iowa Advisory Council on Automated Transportation with available information and guidance from these national organizations to develop an approach for CAT that addresses three primary questions:

- What CAT activities should be pursued?
- Where should these CAT activities be pursued?
- When should these CAT activities be pursued?

INFORMED AND EDUCATED IOWA RESIDENTS AND TRAVELERS

Iowa DOT envisions helping Iowa residents understand the role of CAT in transportation, including the benefits, the potential risks, and the challenges. As new technologies are introduced and deployed, this knowledge base will help to reduce confusion and misinformation. In addition, Iowa residents may not understand the role of Iowa DOT in evaluating and supporting CAT through research, deployment, and infrastructure changes. Active information campaigns from Iowa DOT and partner public agencies will allow residents to make informed decisions about the future of transportation in the state, and counteract misinformation before it spreads, providing residents with a greater sense of confidence in CAT and preparing them for the changes that they will see on and to the roadways.

Recognizing that industry will likely focus CAT deployments on select geographic areas (e.g. metropolitan areas) or travel modes/sectors as motivated by profitability, Iowa DOT sees its role as guiding deployment in a way that represents all Iowa travelers, including 'non-CAVs', to ensure that benefits are as equitable as possible. In short, the DOT hopes to ensure that CAT support is appropriate, that integration is safe and efficient, and that equity is a priority regardless of location, demographics, or mode of travel.

Another opportunity for Iowa DOT in this area is to support the department's Motor Vehicle Division (MVD) in developing new or modified training and education to help drivers understand not only their changing roles and responsibilities, but also how to interact with other vehicles that are semi- or completely automated. In addition, cars with driver-assistance technologies may impact testing and licensing of drivers and vehicles.

INTERNAL CAT READINESS

Iowa DOT anticipates supporting CAT by making internal adjustments (to reflect changing staffing and funding needs, for instance) and by updating its business processes. Demonstrations of the physical and digital CAT infrastructure, as well as AV-ready data, will help Iowa DOT to understand the resources needed to support CAT on a larger scale, including specific staff expertise and funding requirements. Additionally, these demonstrations will help identify changes that need to be made to business processes, policies, and procedures. For example, a design-focused demonstration may provide a window into the future, allowing roadway designers to future-proof updates to design manuals. Increased staff awareness about future CAT needs is crucial since roadway designs remain in place for many years.

Additionally, Iowa DOT envisions supporting the Iowa Advisory Council on Automated Transportation with helping to provide the resources and research needed for making key decisions about possible changes to Iowa Code, administrative rules, or policy documents. This may involve engaging a wide variety of stakeholders, including decision makers and the legislature. It is envisioned that this engagement will result in policies, laws, and regulations that not only support CAT in Iowa, but that also ensure equity and strike a balance between safety, freedom of the marketplace, and traveler choice.

SECURE SYSTEMS

Iowa DOT understands the importance of protecting against intentional or unintentional threats and will ensure that appropriate security measures are in place for CAT activities and deployments. The department plans rigorous testing with mechanisms in place to prepare for potential security threats, per available standards and protocols.

PROPOSED TACTICS TO ACHIEVE THE FUTURE DIRECTION FOR CAT

A series of tactics has been developed to move Iowa DOT toward the focus areas for CAT in Iowa as described above. Table 4 presents these seven CAT tactics as they relate to the CAT supporting objectives.

Table 4 CAT Tactics to achieve both CAT and TSMO Objectives

CAT Supporting Objectives	CAT Tactic
Objective 1: Manage the Iowa digital CAT infrastructure in order to increase Iowa's AV readiness.	**Tactic 1:** Continue pilot demonstrations as a mechanism to explore partnerships that will establish the ***digital infrastructure*** for CAT in Iowa, with an approach that makes use of Iowa DOT data sources but also includes private data, as needed, to supplement data for which Iowa DOT is the authoritative source.
	Tactic 2: Systematically increase the accuracy and granularity of DOT generated ***data*** to accomplish 'AV-ready' data to contribute to the digital infrastructure, and also receive non-DOT data from the digital infrastructure in a way that is sustainable and formalized throughout the department.
Objective 2: Ease the entry and ongoing operations of connected and automated vehicles in Iowa through physical infrastructure additions.	**Tactic 3:** Conduct investigations and demonstrations that increase Iowa DOT's understanding and educate Iowa DOT project designers of changes needed to the ***physical infrastructure*** design processes to prepare Iowa's infrastructure for AVs.
Objective 3: Identify and define the business processes needed to allow and support CAT within Iowa.	**Tactic 4:** Participate in national activities and support the outcomes from Iowa Advisory Council on Automated Transportation Plan to facilitate an ***aligned, consistent, coordinated process*** to establishing CAT business processes, policies, legislation, regulations, and infrastructure in Iowa.

CAT Supporting Objectives	CAT Tactic
	Tactic 5: Define business process needs and systematically implement actions that will ensure Iowa ***residents and travelers*** are informed, educated, trained, and represented equitably as CAT expands throughout Iowa.
	Tactic 6: Support efforts to update business processes, satisfy staffing and funding needs, and conduct ***internal*** outreach and education to promote CAT within Iowa DOT, to decision makers, and the legislature.
Objective 4: Secure Iowa travelers, transportation providers, residents, and physical and digital infrastructure against intentional or unintentional threats.	**Tactic 7:** Ensure all CAT activities and deployments have undergone rigorous testing and have mechanisms in place to ensure ***security***.

GAP ANALYSIS

The tactics necessary to achieve the future direction and objectives for CAT in Iowa were examined alongside existing activities to identify general gaps. The gaps resulting from that analysis are presented in this section.

GAPS, ISSUES, AND OTHER CHANGES NEEDED

Each tactic addresses a key area of the future direction. To achieve these tactics, Iowa DOT must address the gaps identified in Table 5.

Table 5 Identified Gaps for the CAT Supporting Objectives

CAT Tactics	General Gap Areas
Tactic 1: Continue pilot demonstrations as a mechanism to explore partnerships that will establish the ***digital infrastructure*** for CAT in Iowa, with an approach that makes use of Iowa DOT data sources but also includes private data, as needed, to supplement data for which Iowa DOT is the authoritative source.	**Gap 1:** CAT digital infrastructure is not fully ready to support CAT activities in Iowa.
Tactic 2: Systematically increase the accuracy and granularity of DOT generated ***data*** to accomplish 'AV-ready' data to contribute to the digital infrastructure, and also receive non-DOT data from the digital infrastructure, in a way that is sustainable and formalized throughout the department.	**Gap 2:** Gaps exist in the data to support highway automation (i.e. AV ready data).
Tactic 3: Conduct investigations and demonstrations that increase Iowa DOT's understanding and educate Iowa DOT project designers of changes needed to the ***physical infrastructure*** design processes to prepare Iowa's infrastructure for AVs.	**Gap 3:** Iowa's physical transportation infrastructure is not yet ready to fully support automated vehicles.
Tactic 4: Participate in national activities and support the outcomes from Iowa Advisory Council on Automated Transportation Plan to facilitate an ***aligned, consistent, coordinated process*** to establishing CAT business processes, policies, regulations, and infrastructure in Iowa.	**Gap 4:** There is no consistently agreed CAT deployment approach defined for national or Iowa activities.
Tactic 5: Define business process needs and systematically implement actions that will ensure Iowa ***residents and travelers*** are informed, educated, trained, and represented equitably as CAT expands throughout Iowa.	**Gap 5:** Iowa residents and travelers have not been trained or educated about CAT capabilities and risks.

CAT Tactics	General Gap Areas
Tactic 6: Support efforts to update business processes, satisfy staffing and funding needs, and conduct ***internal*** outreach and education to promote CAT within Iowa DOT, to decision makers, and the legislature.	**Gap 6:** Iowa DOT internal business processes do not fully address all topic areas needed to support agency-wide CAT activities.
	Gap 7: Iowa DOT workforce skills do not match to all capabilities needed to support CAT.
Tactic 7: Ensure all CAT activities and deployments have undergone rigorous testing and have mechanisms in place to ensure ***security***.	**Gap 8:** Nationally, the CAT community is still learning about the threats and risks of CAT activities.

ACTION RECOMMENDATIONS

The actions presented in Table 6, Table 7, and Table 8 are derived from a combination of stakeholder input and the results of a workshop conducted at the Iowa DOT called "Capability Maturity Model for CAT". Actions are organized by the suggested timeframe for initiating each activity with near-term actions presented in Table 6, medium term actions in Table 7, and longer-term actions in Table 8. Actions are also presented with a recommended priority level as either 'high' 'medium' or 'low' reflecting the criticality of initiation for the actions at the current time (i.e. high priority actions are both critical to start as soon as possible and ready to initiate actions, medium or low priority may still be critical but timing may be better if deferred).

Note that the Iowa Advisory Council on Automated Transportation is developing a plan that includes its own set of prioritized actions and recommendations. The prioritized actions below are not expected to wholly align with those of the Iowa Advisory Council on Automated Transportation given the specific TSMO focus for Iowa DOT within this service layer, as well as the broader stakeholder representation and focus areas for the Iowa Council.

Table 6 describes the actions that the Iowa DOT is recommended to initiate within the next three years. As it happens, all of these actions are also high priority. Note that many of these actions are major endeavors which the department may implement incrementally or iteratively. As such, these actions are generally expected to be ongoing and overlap with additional actions that are initiated at a later date.

See Appendix B for a table relating each action to the objective, tactic, and gap.

Table 6 Action Recommendations to Initiate within the Next Three Years (Note: numbering is for reference and does not imply priority)

#	Identified Actions	Priority		
		H	M	L
1	***CAT Pilots – Digital Infrastructure.*** Conduct and document evaluations of CAT pilots, with an emphasis on exploring partnerships that will establish the digital infrastructure and prepare Iowa for the deployments aligned with the National Strategy on Highway Automation. Pilot projects are envisioned to include: • **Proof of Concept**. Demonstration to learn if something, either technical or institutional, is possible. • **Cost Understanding**. Learn the costs to do something and understand if the DOT is able to accomplish it within the current technical or institutional structure.	✓		
2	***Identify CAT-Ready Data Needs.*** Define "AV-ready" CAT data needs for which DOT would be the authoritative source (e.g. work zone data, traffic signal data, data describing the location and messages of static roadway signs to support potential in-vehicle signing applications).	✓		
3	***CAT-Ready Data Plan.*** Develop a plan for accomplishing the identified "AV-ready" data needs for key areas in alignment with the National Strategy for Highway Automation and communicate progress to automobile manufacturers.	✓		

#	Identified Actions	Priority		
		H	M	L
4	***Research and Investigations of Physical CAT Infrastructure Needs and Impacts.*** Investigate modifications or additions to the physical infrastructure to support CAT.	✓		
5	***Regional & National Focus.*** Participate actively in the National Strategy on Highway Automation component development and perform physical and digital infrastructure enhancements to align with nationally-approved targets for deployment.	✓		
6	***Explore AV Licensing, Registration, and Titling Processes.*** Explore, understand the needs, and ultimately implement the selected approach for identifying the highly automated vehicles (HAVs) licensed in Iowa for personal or commercial use. Identifying these HAVs will help to inform Iowa DOT of how many HAVs are operating and the general trends for their operation in the state, as well as understanding HAVs involvement in crashes and moving violations. This action should seek consistency with national approaches, incorporate recommendations in the AAMVA Jurisdictional Guidelines for Safe Testing and Deployment of Highly Automated Vehicles, and build upon the "Recommendations for Administrative Rulemaking" as produced by the Iowa AV Legislative Working Group.	✓		
7	***Public Outreach and Education.*** To ensure the safe and appropriate operation of CAT in a traditional and evolving transportation environment, educate Iowa residents and travelers in both urban and rural areas of Iowa about current and upcoming CAT topics. • Educate residents to help them understand the role of CAT, the benefits, and the potential risks and challenges such that they can make informed decisions about the future of transportation in the state. • Assess the need to support and collaborate on efforts to create, implement, and require driver education, training, and licensing specific to CAT to help Iowa drivers understand the evolving vehicle capabilities and limitations, and better prepare for safe operations. • Leverage media and other organizations to expand outreach.	✓		
8	***Business Cases.*** Develop Iowa DOT centric business cases for specific CAT investments, including benefit-cost analyses. Consider factors such as: • Alignment with the National Strategy on Highway Automation. • Alignment with the Iowa Advisory Council on Automated Transportation. • Input from the CAT industry, including private vendors, service providers, consultants, and others. Public section industry providers will also be consulted to ensure consistency with neighboring states and related programs. • Needs based analyses of safety and mobility challenges. • Developing a business case tailored specifically to key decision makers (e.g. legislators and the Iowa Transportation Commission) to allow them to understand the role of CAT in TSMO. • Consideration of all Iowa travelers and an overall goal of equity regardless of location, demographics, or mode of travel, to the extent possible.	✓		

#	Identified Actions	Priority		
		H	M	L
9	***CAT Task Force and Decision-Maker Outreach.*** Establish an internal Iowa DOT CAT task force to promote outreach on technical and institutional CAT topics to all DOT divisions. • Update commissioners on CAT efforts and actively engage them in CAT pilot demonstrations. • Encourage legislators and Iowa Transportation Commission members' involvement in the Advisory Council on Automated Transportation.	✓		
10	***CAT Near-term Workforce Development & Staff Retention.*** Develop and implement a near-term plan for workforce/staffing changes needed during the CAT transition period. Implement business processes to recruit, train, and retain employees to meet specific CAT needs in the near-term. • Identify core staff technical capacities needed during the development of CAT digital and physical infrastructures and also to create and implement business process and technical changes during the CAT transition period. • Initiate activities to train current staff for CAT or consider staff hires when needed. • Examine characteristics that have helped retain DOT staff historically, to identify workforce development and retention strategies. • Encourage and utilize existing training opportunities (e.g. Iowa State University is developing a certificate degree in CAT).	✓		

Table 7 describes the actions that are recommended for Iowa DOT to initiate within 3-5 years. These actions vary from low- to high-priority and are placed within this timeframe given the expected maturity of systems and technology and expectations of the private sector and travelers, for example.

Table 7 Action Recommendations to Initiate in 3-5 Years, along with a priority (Note: numbering is for reference and does not imply priority)

	Identified Actions	Priority		
		H	M	L
1	***Digital Infrastructure Performance.*** Determine the expected coverage of the digital CAT infrastructure, especially Iowa DOT-provided data such as work zone or traffic signal data and establish performance metrics to gauge quality and progress of coverage.		✓	
2	***CAT-Ready Data Collection.*** Initiate activities for outsourcing and coordinating CAT-related data collection.	✓		
3	***Plan and Implement Physical CAT Infrastructure.*** Based on the investigations and research, establish a methodical approach to incrementally deploying the changes to existing infrastructure and the addition of new infrastructure to support the needed CAT Physical Infrastructure.	✓		

	Identified Actions	Priority		
		H	M	L
4	***Understand CAT Functionality in Iowa Vehicles.*** Utilize Iowa DOT MVD vehicle registration to establish and implement procedures to increase understanding of vehicle fleet capabilities and needs on Iowa roadways. • Consider tracking penetration of Level 1 and 2 automation capabilities to the extent possible to confirm those that may have been optional to improve estimates. • Explore other options to compile an understanding of where automated vehicles are operating within the Iowa roadway network.	✓		
5	***Freight Considerations and Truck Platooning.*** Support activities such as a benefits assessment and external collaboration to encourage national freight automation activities. Pursue public and private collaboration to achieve truck platooning, recognizing the anticipated positive impact on state economic competitiveness.			✓
6	***External Collaboration.*** Develop new and formalize existing collaboration with external entities as follows. • Engage metropolitan planning organizations (MPOs), regional planning affiliations (RPAs), cities, and counties to a greater extent for incorporating CAT into policy and planning. • Develop a statewide plan for how to engage and keep the public and key stakeholders interested in CAT on an ongoing basis. • Establish procedures for testing, training, and approvals for vehicles with high levels of automation. • Engage nationally to promote changes that encourage freight automation activities, such as modification of driver hour restrictions in automated trucks.		✓	
7	***Communicate CAT Plans and Status***. Identify approach to share CAT developments with private sector, including automobile manufacturers, tier-one suppliers, and travelers.		✓	
8	***Encourage Performance Measure Standards.*** Stimulate dialogue with peers on establishing meaningful and practical performance measurement requirements for operations as a foundation for CAT performance management.		✓	
9	***Safety Performance Measures.*** Collaborate with law enforcement on crash/incident reporting procedures to identify specific crash scenarios possibly influenced by CAT and prepare to measure performance as market penetration increases. • Use the results of early Iowa and national CAT deployments (e.g. SPaT Challenge, national CV Pilots) as a foundation for establishing safety performance measures.		✓	
10	***Traveler Reactions.*** Outreach to travelers to understand and evaluate the comfort levels and feeling of benefits and drawbacks of CAT implementations as a measure of overall performance.		✓	
11	***Funding.*** Review and “modernize” funding programs for sustainable support of CAT projects, studies, capital improvement, and operations when appropriate.		✓	

	Identified Actions	Priority		
		H	M	L
12	***Internal Education.*** Educate project planners, designers, and TMC operators on CAT technology. Specific goals include: • Ensure that CAT related physical infrastructure changes originate from traveler or transportation provider needs and align to the National Strategy on Highway Automation and Iowa Advisory Council on Automated Transportation. • Consider "future proofing" measures as much as possible to avoid replacing or reconstructing CAT investments, and conversely to make informed decisions that prevent short-term measures that are not actually needed. • Encourage risk-managed changes to the design and development of traditional infrastructure to accommodate anticipated impacts of CAT.	✓		
13	***Security.*** Initiate cybersecurity discussions with the Office of the Chief Information Officer (OCIO) related to CAT to understand Iowa DOT role and responsibility.	✓		
14	***SCMS Preparation.*** Track national security credential management system (SCMS) progress and prepare to support SCMS within Iowa.		✓	

Finally, Table 8 describes an additional action that is recommended for Iowa DOT to initiate within the 6-10-year timeframe. This action is rated as a lower priority and is placed in this timeframe given its focus on long-term workforce development.

Table 8 Action Recommendation to Initiate in 6-10 Years (Note: numbering is for reference and does not imply priority)

#	Identified Actions	Priority		
		H	M	L
1	***CAT Long-term Workforce Development.*** Develop and implement a long-term plan for workforce/staffing changes needed to support CAT after the initiation period. • Identify core staff technical capacities needed during the time period where the digital and physical infrastructures are more mature and increasing in deployments. • Identify core staff needed for the ongoing operations, monitoring, and performance management of CAT business processes. • Initiate activities to consider staff hires and/or training for CAT.			✓

PERFORMANCE MANAGEMENT

TSMO performance management is essential for understanding progress toward the seven TSMO goals and for guiding programmatic decisions related to resource allocation, technology deployment, planning, and tactics. Performance management provides the foundation for outcome-based program management, measuring how well the program is performing and adapting to improve desired outcomes. Each of the four CAT supporting objectives is most closely tied to one or more of the seven TSMO goals, and each CAT objective is in turn tied to the CAT tactics previously described. Performance management depends on this explicit cascade relationship, and Table 9 summarizes these items.

Table 9 Relationship Among TSMO Goals, CAT Objectives, and CAT Tactics

TSMO Goals	CAT Objectives	CAT Tactics
Safety **Reliability** **Efficiency**	**Objective 1:** Manage the Iowa digital CAT infrastructure in order to increase Iowa's AV readiness	**Tactic 1:** Establish digital infrastructure **Tactic 2:** AV-ready data improvement
Convenience	**Objective 2:** Ease the entry and ongoing operations of connected and automated vehicles in Iowa through appropriate physical infrastructure additions.	**Tactic 3:** Improve physical infrastructure
Coordination **Integration**	**Objective 3:** Identify and define the business processes needed to allow and support CAT within Iowa.	**Tactic 4:** Align with related national and state efforts **Tactic 5:** Inform residents and travelers **Tactic 6:** Internal outreach and education
Security	**Objective 4:** Secure Iowa travelers, transportation providers, residents, and physical and digital infrastructure against intentional or unintentional threats.	**Tactic 7:** Ensure CAT security

Overall, the CAT objectives are expected to primarily address the transportation system challenges relating to mobility, safety, freight movement. Performance measures should be the most relevant and feasible quantification of evidence for outcomes strongly linked to a goal. Each of the four objectives – which are linked to a goal – may be adapted to a specific outcome, then measures can be carefully defined to track progress toward those outcomes.

However, CAT itself is a broad set of tactics, and performance measures are best tied to outcomes, not necessarily tactics, activities, or outputs. This lends some difficulty to defining excellent performance measures specific to CAT. For example, Iowa traffic fatalities is a very important outcome performance measure, and while it is expected to improve as CAT proliferates in the decades to come, that measure is affected by many other influences and is not specific to CAT. In time, what DOT may be able to measure specific to CAT and safety are crashes involving advanced driver assistance systems (ADAS) or automated driving systems (ADS), by level of automation, ADAS or ADS feature involved, severity, etc. This is entirely contingent on new data availability and relies on collaboration with law enforcement on reporting procedures.

In the near term, performance measures related to CAT are expected to be as imperfect as the future of CAT is uncertain. Measures should be adjusted to reflect peer and national standards as they continue to evolve, and specific performance measures chosen are expected to vary for each pilot, demonstration, and action for the time being. From the CAT objectives and tactics previously described, example measures include any of the following.

- **Objective 1 – Digital Infrastructure:** CAT-capable communications infrastructure coverage by road classification; AV-ready work zone data, percent available by Traffic Critical Project / Intelligent Work Zone (TCP/IWZ) designation; measures related to those found in the ITS & Communications Service Layer Plan such as availability, uptime, and latency

- **Objective 2 – Ease of Entry:** given the emphasis on physical infrastructure, associated measures for asset management should be considered; consider a very specific measure such as percent of 6-inch wide pavement marking, its condition, by road classification

- **Objective 3 – Business Processes:** presence of code, regulation, rule, or enforcement activity incompatible with neighboring jurisdictions; favorable public perception of CAT, by CAV and non-CAV residents and travelers; internal agency level of education on CAT

- **Objective 4 – Security:** because CAT introduces new security and privacy issues, carefully measure vulnerabilities, threat prevention, and fallback readiness

Other related outcomes measures may align with the Federal final rule for national performance management measures, which specifically addresses system, freight and air quality performance targets for the National Highway Performance Program. However, improvements related to CAT are expected to be incremental and have minimal impacts on systemwide performance measures in the short-term.

As with each TSMO Service Layer Plan, the definition, implementation, and tracking of performance measures should be done in coordination across the Operations Division and in accordance with improvement priorities.

FIVE-YEAR SERVICE LAYER COST ESTIMATE

This section provides a high-level cost estimate based on the 23 actions identified above and numbered in Table B-1 in Appendix B that will be initiated in the first five years.

INTERNAL ACTIONS

Of the 25 actions, eight (listed below) are expected to be accomplished using mostly internal staff time. Thus, they are not included in the estimate. Note also that many are major endeavors, with implementation taking many years, as noted above.

- Freight Considerations and Truck Platooning
- Communicate CAT Plans and Status
- Encourage Performance Standards
- CAT Task Force and Decision-Maker Outreach
- Funding
- CAT Near-term Workforce Development & Staff Retention

- Security
- SCMS Preparation

One additional internal action (CAT Long-term Workforce Development) is recommended for initiation in 6-10 years (as the CAT physical and digital infrastructure are more mature and understood) and is expected to require significant funding and/or changes to internal staffing approaches to accommodate impacts of CAT. A cost estimate for this action is not included in this cost estimate.

INVESTMENTS IN THE CAT DIGITAL AND PHYSICAL INFRASTRUCTURE

Significant Contract Support and Procurement Actions. Iowa DOT investments and upgrades to the digital and physical infrastructure comprise the four actions noted below, and it is likely these actions will have the highest estimated costs and are expected to require significant contract support and procurement.

- CAT Pilots – Digital Infrastructure
- Research and Investigations of Physical CAT Infrastructure Needs and Impacts
- Plan and Implement Physical CAT Infrastructure
- Regional & National Focus

Investments and upgrades to the digital and physical infrastructure will drive CAT service layer costs, which will vary significantly based on the scale of these efforts combined with the availability of grant funding and private-sector investment.

The biggest driver of costs for Iowa DOT are expected to be the number and scale of these demonstration efforts. Availability of grant funding or private-sector partnerships and investment will also have a major impact on the funding of demonstration efforts.

Minor Contract Support and Procurement. Each of the remaining actions are envisioned for initiation within the first five years and are estimated to require minor contract support or funding of less than $100,000.

- Within 3 years
  - Identify CAT-Ready Data Needs
  - Initiate Development of a CAT-Ready Data Plan
  - Public Outreach and Education
  - Business Cases
- Within 3-5 years
  - Digital Infrastructure Performance
  - CAT-Ready Data Collection
  - CAT Tracking
  - Extend Collaboration
  - Safety Performance Measures
  - Traveler Reactions
  - Internal Education

Excluding digital and physical infrastructure investments and upgrades, the estimated cost of the CAT Service Layer Plan is estimated to be about $200,000 per year for the first five years.

Taking into account the flexibility of timing for initiating these activities, the total cost of these 11 actions is estimated to be about $200,000 per year for the first five years.

APPENDIX A: GLOSSARY OF TERMS AND ACRONYMS

AAA	American Automobile Association
AAMVA	American Association of Motor Vehicle Administrators
AASHTO	American Association of State Highway and Transportation Officials
ADS	**Automated Driving Systems**. Automotive technology that is continuing to evolve to provide increasing levels of automation on vehicles.
AV	**Automated Vehicle.** A vehicle in which at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. Vehicles that provide safety warnings to drivers (forward crash warning, for example) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation (e.g., the necessary data are received and processed, and the warning is given, without driver input). Automated vehicles may use onboard sensors, cameras, GPS, and telecommunications to obtain information in order to make their own judgments regarding safety-critical situations and act appropriately by effectuating control at some level.[7]
CAT	**Cooperative Automated Transportation**. Cooperative Automated Transportation (CAT) enables all modes of transportation to work together to improve safety, mobility, and operations efficiency through interdependent vehicle and systems automation and information exchange. CAT includes all modes (automobile, truck, plane, van, bus, rail, ferry, bicycle, scooter, pedestrian, etc.), systems (vehicles, infrastructure, information, communications, etc.), and applications (traffic management, fare collection, mobility services, trip planning, etc.).
CAV	**Connected and Automated Vehicle.** Connected and Automated Vehicles (CAVs) are manufactured vehicles of all classes (passenger vehicles, trucks, buses, motorcycles, scooters, etc.) and levels of automation operated and connected within a CAT environment. CAVs can be used in a CAT environment for purposes including but not limited to personal transportation, freight, transit, passenger transportation, and mobility services.
CMM	Capability Maturity Model

[7] USDOT, NHTSA. Preliminary Statement of Policy Concerning Automated Vehicles. 2016. https://www.nhtsa.gov/staticfiles/rulemaking/pdf/Autonomous-Vehicles-Policy-Update-2016.pdf. Accessed: February 2018.

Connected Vehicles	**Connected Vehicles.** Vehicles that are equipped with safe, interoperable networked wireless communications and include capabilities for V2V, V2I, and V2X communications.
CTSO	**Committee on Transportation System Operations.** An AASHTO committee with a focus on supporting members' activities related to transportation operations.
Digital CAT Infrastructure	**Digital Cooperative Automated Transportation Infrastructure.** CAT digital infrastructure refers to the data, communications, and technology systems related to the electronic collection, processing, and transmission of information. Examples may include the data describing work zone related lane closures and speed reductions, as well as the database, reporting system, and the systems that communicate this data to the vehicles.
DMS	**Dynamic Message Signs.** Signs located in proximity to roads, parking garages, transit stops, or other locations that are capable of displaying varying messages, often including graphics and/or colors.
DMV	Department of Motor Vehicles
DOT	Department of Transportation
DSRC	**Dedicated Short-Range Communications.** A communications protocol developed to address the safety critical issues associated with sending and receiving data among vehicles and between moving vehicles and fixed roadside access points. These provide low-latency data-only V2V and V2I communications for use in applications such as Electronic Fee Collection (EFC), crash avoidance, In-Vehicle Signing and Cooperative Adaptive Cruise Control (CACC).[8]
IOO	**Infrastructure Owner and Operator.** Agencies that own and operate transportation related infrastructure, including but not limited to roads, bridges, tunnels, turnpikes, right-of-way, etc.
IOT	**Internet of Things.** A network of physical objects—devices, vehicles, buildings, machines, and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. In its simplest terms, the IoT is about physical "things" with the ability to sense, actuate, and communicate.[9]
Advisory Council on Automated Transportation	**Advisory Council on Automated Transportation.** An Advisory Council created in the state of Iowa to facilitate the strategic development of policy, systems and infrastructure that are necessary to support CAT.

[8] USDOT. Glossary of Terms for Connected Vehicles 2009 to Present. http://connectedvehicle.itsa.wikispaces.net/Glossary+of+Terms+for+EU-US+cooperation+in+ITS Glossary of Terms for EU-US Cooperation, 2009-Present-Version 7, 2012. Accessed Jan. 1, 2017.
[9] Driverless.global. Terms for Driverless Vehicle Systems. https://driverless.global/resources/glossary. Accessed Jan. 1, 2017.

LIDAR	**Light Detection and Ranging.** An expensive, but extremely accurate technology, which is effectively a Laser based version of Radar and used in autonomous vehicles. The LIDAR unit usually sits on top of the vehicle roof to enable unhindered 360-degree view of the area surrounding the vehicle. 64 lasers spin at about 900 rpm and create a detailed 360-degree 3D map of the surrounding environment in order to view all obstacles in real time. This unit bounces laser beams off object surfaces up to 100m around the autonomous vehicle and then builds a 3D picture from this raw data via the vehicles microprocessor, to accurately determine the identity and distance of the object.[9]
OEM	**Original Equipment Manufacturer.** Refers to the industry providers and suppliers of vehicles, vehicle applications, or equipment that supports vehicles.
Physical CAT Infrastructure	**Physical Cooperative Automated Transportation Infrastructure.** CAT physical infrastructure refers to existing transportation infrastructure, changes or additions to the existing infrastructure, or deployments of new physical equipment or infrastructure to support CAT. Examples may include modifications to lane striping or signage to support automated driving systems, structural modifications to pavement or bridges reflecting changes to vehicle paths or following distances, as well as existing traffic control devices that sensed by automated vehicles.
PLR	**Policy, Legislative, and Regulatory.** Acronym refers specifically to the CAT Coalition working group on Policy, Legislature, and Regulatory (PLR).
SCMS	**Security Credential Management System.** Security system for cooperative vehicle-to-vehicle crash avoidance applications using 5.9 GHz DSRC wireless communications.[10]
Service Layer Plan	**Service Layer Plan.** A series of eight documents developed by Iowa DOT, each of which present the challenges and opportunities, existing services and conditions, future direction, gaps and actions to bridge them, performance metrics, and estimated costs within a given TSMO focus area.
SL	Service Layer
SPaT	**Signal Phase and Timing.** The signal state of the intersection and how long this state will persist for each approach and lane that is active, according to the SPaT Benefits Report. The SPaT message sends the current state of each phase, with all-red intervals not transmitted. Movements are given to specific lanes and approaches by use of the lane numbers present in the message. In a connected vehicle environment, the message is sent from the roadway infrastructure to approaching vehicles.[8]
TIA	Technology Association of Iowa

[10] FHWA. Connected Vehicle Terms OSADP. https://www.itsforge.net/index.php/information/glossary-of-terms. Accessed Jan. 1, 2017.

TSMO	**Transportation System Management and Operations.** An approach towards managing and operating the transportation system in a way that will help realize the full capacity of the existing transportation system, increase reliability, improve safety, and target safety and operational problem locations.
V2I	**Vehicle-to-Infrastructure Communications.** Vehicles use wireless communications to exchange information with nearby traffic signals, work zones and other transportation infrastructure.
V2V	**Vehicle-to-Vehicle Communications.** Vehicles use wireless communications to exchange information with other nearby vehicles such as location, speed, braking, and potentially dangerous situations such as cross traffic ahead.
V2X	**Vehicle-to-Everything Communications.** Vehicles use wireless communications to exchange information with nearby devices that may affect the vehicle, such as V2I and V2V, but also pedestrians, bicycles, and other infrastructure.

APPENDIX B: MASTER RELATIONSHIP TABLE FOR CAT SERVICE LAYER PLAN

Table B-1 depicts the relationship between the various elements presented throughout this service layer plan. Specifically, the table traces the link from the CAT Supporting Objectives developed for this service layer to the TSMO Strategic Goals and Objectives that are consistent for all Iowa DOT service layer plans. These objectives correspond to CAT tactics, general gap areas, and then to specific actions that were identified in the CAT Capability Maturity Model workshop. Each action is associated with a priority and relative cost. The relative cost was estimated based on the assumption that the action is: $ = accomplished mostly by internal staff time; $$ = accomplished largely by internal staff with minor contract support or procurement that is <$100k; $$$ = requires significant contract support and/or procurement >$100k.

Table B-1 Relationship of CAT Supporting Objectives to TSMO Strategic Goals and Objectives, and Tactics to Achieve those Objectives

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost+
					H	M	L	<3 Years	3-5 Years	6-10 Years	
Objective 1: Manage the Iowa digital CAT infrastructure in order to increase Iowa's AV readiness.	**Safety:** Reduce crash frequency and severity **Reliability:** Improve transportation system reliability, increase system resiliency, and add highway capacity in critical corridors **Efficiency:** Minimize traffic delay and maximize transportation system efficiency	**Tactic 1:** Continue pilot demonstrations as a mechanism to explore partnerships that will establish the ***digital infrastructure*** for CAT in Iowa, with an approach that makes use of Iowa DOT data sources but also includes private data, as needed, to supplement data for which Iowa DOT is the authoritative source.	**Gap 1:** CAT digital infrastructure is not fully ready to support CAT activities in Iowa.	***CAT Pilots – Digital Infrastructure*.** Conduct and document evaluations of CAT pilots, with an emphasis on exploring partnerships that will establish the digital infrastructure and prepare Iowa for the deployments aligned with the National Strategy on Highway Automation. Pilot projects are envisioned to include: • **Proof of Concept**. Demonstration to learn if something, either technical or institutional, is possible. • **Cost Understanding**. Learn the costs to do something and understand if the DOT is able to accomplish it within the current technical or institutional structure.	✓			✓			$$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost[+]
					H	M	L	<3 Years	3-5 Years	6-10 Years	
	to keep traffic moving			***Digital Infrastructure Performance.*** Determine the expected coverage of the digital CAT infrastructure, especially Iowa DOT-provided data such as work zone or traffic signal data and establish performance metrics to gauge progress of coverage.		✓			✓		$$
		Tactic 2: Systematically increase the accuracy and granularity of DOT generated ***data*** to accomplish 'AV-ready' data to contribute to the digital infrastructure, and also receive non-DOT data from the digital infrastructure, in a way that is sustainable and formalized throughout the department.	**Gap 2:** Gaps exist in the data to support highway automation (i.e. AV ready data).	***Identify CAT-Ready Data Needs.*** Define "AV-ready" CAT data needs for which DOT would be the authoritative source (e.g. work zone data, traffic signal data, data describing the location and messages of static roadway signs to support potential in-vehicle signing applications).	✓			✓			$$
				CAT-Ready Data Plan. Develop a plan for accomplishing the identified "AV-ready" data needs for key areas in alignment with the National Strategy for Highway Automation and communicate progress to automobile manufacturers.	✓			✓			$$
				CAT-Ready Data Collection. Initiate activities for outsourcing and coordinating CAT-related data collection	✓				✓		$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost+
					H	M	L	<3 Years	3-5 Years	6-10 Years	
Objective 2: Ease the entry and ongoing operations of connected and automated vehicles in Iowa through appropriate physical infrastructure additions.	**Convenience:** Provide ease of access and mobility choices to customers	**Tactic 3:** Conduct investigations and demonstrations that increase Iowa DOT's understanding and educate Iowa DOT project designers of changes needed to the ***physical infrastructure*** design processes to prepare Iowa's infrastructure for AVs.	**Gap 3:** Iowa's physical transportation infrastructure is not yet ready to fully support automated vehicles.	***Research and Investigations of Physical CAT Infrastructure Needs and Impacts.*** Investigate modifications or additions to the physical infrastructure to support CAT.	✓			✓			$$$
				Plan and Implement Physical CAT Infrastructure. Based on the investigations and research, establish a methodical approach to incrementally deploying the changes to existing infrastructure and the addition of new infrastructure to support the needed CAT Physical Infrastructure.	✓				✓		$$$
				Understand CAT Functionality in Iowa Vehicles. Utilize Iowa DOT MVD vehicle registration to establish and implement procedures to increase understanding of vehicle fleet capabilities and needs on Iowa roadways. • Consider tracking penetration of Level 1 and 2 automation capabilities to the extent possible to confirm those that may have been optional to improve estimates. • Explore other options to compile an understanding of	✓				✓		$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost[+]
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				where automated vehicles are operating within the Iowa roadway network.							
				Freight Considerations and Truck Platooning. Support activities such as a benefits assessment and external collaboration to encourage national freight automation activities. Pursue public and private collaboration to achieve truck platooning, recognizing the anticipated positive impact on state economic competitiveness.			✓		✓		$
Objective 3: Identify and define the business processes needed to allow and support CAT within Iowa.	**Coordination:** Engage all DOT disciplines, and external agencies and jurisdictions to proactively manage and operate the transportation system	**Tactic 4:** Participate in national activities and support the outcomes from Iowa Advisory Council on Automated Transportation Plan to facilitate an ***aligned, consistent, coordinated process*** to establishing CAT business processes, policies, , regulations, and infrastructure in Iowa.	**Gap 4:** There is no consistently agreed CAT deployment approach defined for national or Iowa activities.	***Regional & National Focus*.** Participate actively in the National Strategy on Highway Automation component development and perform physical and digital infrastructure enhancements to align with nationally-approved targets for deployment.	✓			✓			$$$
				Explore AV Licensing, Registration, and Titling Processes. Explore, understand the needs, and ultimately implement the selected approach for identifying the highly automated vehicles (HAVs) licensed in Iowa for personal or commercial use. Identifying these HAVs will help to inform Iowa DOT	✓			✓			$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost[+]
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				of how many HAVs are operating and the general trends for their operation in the state, as well as understanding HAVs involvement in crashes and moving violations. This action should seek consistency with national approaches, incorporate recommendations in the AAMVA Jurisdictional Guidelines for Safe Testing and Deployment of Highly Automated Vehicles, and build upon the "Recommendations for Administrative Rulemaking" as produced by the Iowa AV Legislative Working Group.							
				External Collaboration. Develop new and formalize existing collaboration with external entities. • Engage MPOs, RPAs, cities, and counties to a greater extent for incorporating CAT into policy and planning. • Develop a statewide plan for how to engage and keep the public and key stakeholders interested in CAT on an ongoing basis. • Establish procedures for testing, training, and approvals for vehicles with high levels of automation.		✓			✓		$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost+
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				• Engage nationally to promote changes that encourage freight automation activities, such as modification of driver hour restrictions in automated trucks.							
				Communicate CAT Plans and Status. Identify approach to share CAT developments with private sector, including automobile manufacturers, tier-one suppliers, and travelers.		✓			✓		$
				Encourage Performance Measure Standards. Stimulate dialogue with peers on establishing meaningful and practical performance measurement requirements for operations as foundation for CAT performance measurement.		✓			✓		$
				Safety Performance Measures. Collaborate with law enforcement on crash/incident reporting procedures to identify specific crash scenarios possibly influenced by CAT and prepare to measure performance as market penetration increases. • Use the results of early Iowa and national CAT deployments (e.g. SPaT Challenge, national CV Pilots)		✓			✓		$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost[+]
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				as a foundation for establishing safety performance measures.							
		Tactic 5: Define business process needs and systematically implement actions that will ensure Iowa ***residents and travelers*** are informed, educated, trained, and represented equitably as CAT expands throughout Iowa.	**Gap 5:** Iowa residents and travelers have not been trained or educated about CAT capabilities and risks.	***Public Outreach and Education*.** To ensure the safe and appropriate operation of CAT in a traditional and evolving transportation environment, educate Iowa residents and travelers in both urban and rural areas of Iowa about current and upcoming CAT topics. • Educate residents to help them understand the role of CAT, the benefits, and the potential risks and challenges such that they can make informed decisions about the future of transportation in the state. • Assess the need, support and collaborate on efforts to create, implement, and require driver education, training, and licensing specific to CAT to help Iowa drivers understand the evolving vehicle capabilities and limitations, and better prepare for safe operations.	✓			✓			$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost^{+}
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				• Leverage media and other organizations to expand outreach.							
				Traveler Reactions. Outreach to travelers to understand and evaluate the comfort levels and feeling of benefits and drawbacks of CAT implementations as a measure of overall performance.		✓			✓		$$
	Integration: Incorporate TSMO strategies throughout DOT's transportation planning, design, construction, maintenance, and operations activities	**Tactic 6:** Support efforts to update business processes, satisfy staffing and funding needs, and conduct ***internal*** outreach and education to promote CAT within Iowa DOT, to decision makers, and the legislature.	**Gap 6:** Iowa DOT internal business processes do not fully address all topic areas needed to support agency-wide CAT activities.	***Business Cases.*** Develop Iowa DOT centric business cases for specific CAT investments, including benefit-cost analyses. Consider factors such as: • Alignment with the National Strategy on Highway Automation. • Alignment with the Iowa Advisory Council on Automated Transportation. • Input from the CAT industry, including private vendors, service providers, consultants, and others. Public section industry providers will also be consulted to ensure consistency with neighboring states and related programs. • Needs based analyses of safety and mobility challenges.	✓			✓			$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority H	Priority M	Priority L	Timeframe Suggested to Initiate <3 Years	3-5 Years	6-10 Years	Relative Cost+
				• Developing a business case tailored specifically to key decision makers (e.g. legislators and the Iowa transportation commission) to allow them to understand the role of CAT in TSMO. • Consideration of all Iowa travelers and an overall goal of equity regardless of location, demographics, or mode of travel, to the extent possible.							
				CAT Task Force and Decision-Maker Outreach. Establish an internal Iowa DOT CAT task force to promote outreach on technical and institutional CAT topics to all DOT divisions. • Update commissioners on CAT efforts and actively engage them in CAT pilot demonstrations. • Encourage legislators and Iowa Transportation Commission members involvement in the Advisory Council on Automated Transportation.	✓			✓			$
				Funding. Review and "modernize" funding programs for sustainable support for CAT		✓			✓		$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority H	Priority M	Priority L	Timeframe Suggested to Initiate <3 Years	3-5 Years	6-10 Years	Relative Cost[+]
				projects and studies, capital improvement, and operations when appropriate.							
			Gap 7: Iowa DOT workforce skills do not match to all capabilities needed to support CAT.	***CAT Near-term Workforce Development & Staff Retention.*** Develop and implement a near-term plan for workforce/staffing changes needed during the CAT transition period. Implement business processes to recruit, train, and retain employees to meet the specific CAT needs in the near-term. • Identify core staff technical capacities needed during the development of CAT digital and physical infrastructures and also to create and implement business process and technical changes during the CAT transition period. • Initiate activities to train current staff for CAT or consider staff hires when needed. • Examine characteristics that have helped retain DOT staff historically, to identify workforce development and retention strategies. • Encourage and utilize existing training opportunities (e.g. Iowa State University is	✓			✓			$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost^{+}
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				developing a certificate degree in CAT).							
				***Internal Education*.** Educate project planners, designers, and TMC operators on CAT technology. Specific goals include: • Ensure that CAT related physical infrastructure changes originate from traveler or transportation provider needs and align to the National Strategy on Highway Automation and Iowa Advisory Council on Automated Transportation. • Consider “future proofing” measures as much as possible to avoid replacing or reconstructing CAT investments, and conversely to make informed decisions that prevent short-term measures that are not actually needed. • Encourage risk-managed changes to the design and development of traditional infrastructure to accommodate anticipated impacts of CAT.	✓				✓		$$

CAT Supporting Objectives	Established TSMO Strategic Goal / Objectives	CAT Tactic	General Gap Areas	Identified Actions	Priority			Timeframe Suggested to Initiate			Relative Cost[+]
					H	M	L	<3 Years	3-5 Years	6-10 Years	
				CAT Long-term Workforce Development. Develop and implement a long-term plan for workforce/staffing changes needed to support CAT after the initiation period. • Identify core staff technical capacities needed during the time period where the digital and physical infrastructures are more mature and increasing in deployments. • Identify core staff needed for the ongoing operations, monitoring, and performance management of CAT business processes. • Initiate activities to consider staff hires and/or training for CAT.			✓			✓	$$
Objective 4: Secure Iowa travelers, transportation providers, residents, and physical and digital infrastructure against intentional or unintentional threats.	**Security:** Prepare for and mitigate potential physical and cyber security issues	**Tactic 7:** Ensure all CAT activities and deployments have undergone rigorous testing and have mechanisms in place to ensure ***security***.	**Gap 8:** Nationally, the CAT community is still learning about the threats and risks of CAT activities.	***Security.*** Initiate cybersecurity discussions with OCIO related to CAT to understand Iowa DOT role and responsibility.	✓				✓		$
				SCMS Preparation. Track national security credential management system (SCMS) progress and prepare to support SCMS within Iowa.		✓			✓		$

APPENDIX C: ENACTED LEGISLATIVE CHANGES FOR CATS

As of July 2019, 40 states have either enacted CAT-related legislation or an executive order, as shown in

Figure C-1, per the Autonomous Vehicles State Bill Tracking Database that is available from the National Conference of State Legislatures [11]. Table C-1 provides a description and links to specific examples of enacted CAT legislation in other states that modify code, as well as text in Iowa Code that relates to the modification enacted in other states. Updated information and legislative language can be found using the Autonomous Vehicles State Bill Tracking Database.

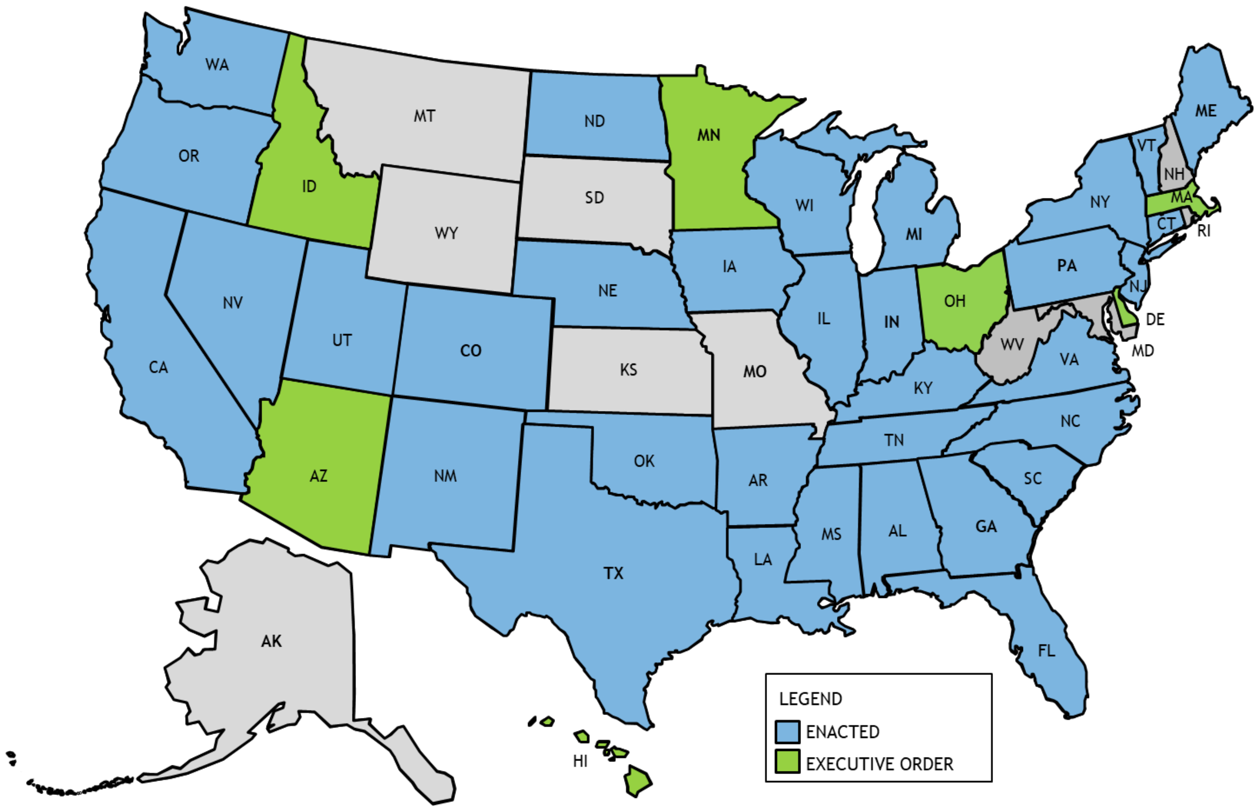

Figure C-1 States with Enacted CAT Legislation as of July 2019

[11] Autonomous Vehicles State Bill Tracking Database. National Conference of State Legislatures. Accessed June 2019. http://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx

Table C-1 CAT Legislation in Other States and Related Iowa Code as of July 2019

New CAT Need	Related Iowa Code	Related Laws in Other States
Define CAV terms (e.g., automated driving system, automated technology, automated mode, autonomous vehicle, driving mode, dynamic driving task, minimal risk condition, operational design domain)	321.1	AL.2; AR; CO; CT; DC; FL.1; FL.2; GA; IL; MI.1; MI.2; NC; ND.2; NE; NV.1; NV.2; NY; TN.1; TN.2; TX; VT
Define CAV-related Truck Platooning (connected automated braking system, connected platooning system, coordinated platoon, driver-assistive truck platooning technology)		FL.2; FL.3; GA; IN; MS; NV; OR; TX; UT.1; UT.2
Modify definitions of owner and operator to relate to CAVs	321.1.48.	AL.2; CT; MI; NV; TX
Conditions required to register an automated vehicle	321.23	GA; NV
Require licensed driver in automated commercial vehicle	321.174	KY
Automated vehicles exempt from licensing requirements	321.176	TN; UT.2
Allow operation of an automated vehicle without an occupant and/or licensed driver	321.218	AL.2; FL.1; GA; MI.1; MI.2; NC; ND.2; NE; NV; TN; TX
Require licensed driver in automated vehicle		CO; CT; DC; FL.1; FL.2; NV
Require automated vehicle to remain on scene of any crash	321.263	NE
Require more stringent reporting for crashes involving an automated vehicle	321.266	NE; NV; TN; UT.2
CAV truck platooning minimum following requirement	321.308	AL.1; CA; FL.3; GA; IN; KY; MI; MS; NC; ND.1; NV; OK; OR; SC; TN; TX; WI
Direction to develop safety standards and performance requirements	Similar references exist in the Iowa Code but do not link to CAVs	CA; NV
Direction to comply with existing state and/or federal law		CO; FL.1; ND.2; NE
Specifies fine for automated vehicles violating laws or regulations		NV
No explicit change to Iowa Code needed for CAT needs below given existing language within Iowa Code		
Insurance requirements and liability for CAVs	321.20B; 321.55	AL.2; CT; DC; FL.1; GA; NE; NV.1; NV.2; TN; UT.2; VT
Address liability of automated technology manufacturers, mechanics and repair shops, original manufacturers, vehicle manufacturer and/or upfitters		DC; MI.1; MI.2; MI.3; MI.4; NV.1; NV.2
Add an automated vehicle endorsement for operators	321.189	NV
Prevent local authorities from prohibiting CAV use	321.235	IL; NC; NV; TN.1; TN.2; TX
Provisions for automated vehicles to be used in for-hire and transit services	321.241	NE; NV
Allow vehicle occupants to view devices while automated vehicle is in motion	321.276; 321.180B.6; 321.194.2.b (2)	NV; TN; VA
Automated vehicles without steering wheel, accelerator pedal, or brake pedal	321.430	CA.1; CA.2