AASHTO
AASHTO INNOVATION INITIATIVE

AASHTO Innovation Initiative

[Proposed] Nomination of Innovation Ready for Implementation

Sponsor

Nominations must be submitted by an AASHTO member DOT willing to help promote the innovation. If selected, the sponsoring DOT will be asked to promote the innovation to other states by participating on a Lead States Team supported by the AASHTO Innovation Initiative.

1. Sponsoring DOT (State): Colorado

2. Name and Title: John Lorme, Division of Maintenance and Operations
   Organization: Colorado Department of Transportation
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   City: Denver
   State: CO
   Zip Code: 80204
   Email: john.lorme@state.co.us
   Phone: 303-365-7156

If further information is needed, please contact the below representatives:
Ashley Nylen, ashley.nylen@state.co.us, 303-512-5533
Tyler Weldon, tyler.weldon@state.co.us, 303-512-5503

Innovation Description (10 points)

The term “innovation” may include processes, products, techniques, procedures, and practices.

3. Name of the innovation:
Autonomous Truck-Mounted Attenuator (ATMA)

4. Please describe the innovation.
A common countermeasure used by many state departments of transportation is the use of truck mounted attenuators in work zone and maintenance operations. These vehicles are designed to absorb the impact from an unsuspecting, distracted or unengaged motorist that comes upon a work zone or maintenance operation. Recognizing the grave danger in our work zones, in 2018, the Colorado Department of Transportation (CDOT) embarked on a program to remove the employee (the vehicle operator) from these vehicles that are designed to be struck in crash. The Autonomous Truck-Mounted

Attenuator (ATMA) program at CDOT has retrofitted two truck mounted attenuator vehicles in CDOT's fleet with automated driving system technology, allowing for vehicle operation without a human. The technology is a leader/follower system supporting CDOT's paint striping operations on designated state highways, featuring the lead vehicle as a CDOT paint striping (that is manned) and the follower vehicle (sometimes referred to as the 'trail' vehicle) as the autonomous truck mounted attenuator (that is unmanned. The ATMA follows or replicates the leader's (paint striping truck's) maneuvers. The leader vehicle is continuously transmitting highly accurate speed, position, and heading information to the follower so that the follower can replicate the leader's path while maintaining a specified gap distance (set by the human operator). Radar and other sensors on the front and side of the follow vehicle provide obstacle detection capabilities and may stop the follower vehicle if an object is detected in the vehicle's intended path. Emergency stop buttons in the leader vehicle provide a method to stop the follower, and push buttons on the exterior of the follower vehicle provide a method of stopping and shutting the vehicle down in case of emergency.

5. What is the existing baseline practice that the innovation intends to replace/improve?

CDOT, like many other transportation organizations, use class 7 or 8 trucks with rear-mounted attenuators – also known as crash cushions – in mobile work zones to act as a barrier to absorb or deflect vehicles that would otherwise hit people or equipment. The ATMA is intended to improve safety by replacing a human operated truck with an autonomous truck that does not require a human to be seated in a vehicle that is designed to get struck. More specifically, the primary objective of the attenuator is to protect the workers in the back of the lead operations vehicles from potential impact with passing vehicles. In other words, the operators of a traditional attenuator risk harm, injury, and potential death from vehicle crashes. The ATMA effectively removes the need for human drivers in the follower, decreasing the overall potential exposure risk of the operator in a vehicle designed to be struck.

6. What problems associated with the baseline practice does the innovation propose to solve?

As described in question five, the ATMA removes drivers from the follower truck during highway maintenance operations. As a result, there is a tremendous decrease in exposure risk to the operator during operations; namely, the risk of potential injury or death to the individuals who would otherwise man the attenuator is greatly diminished. The ATMA is an example of how CDOT is pursuing cutting-edge technology to improve highway management and increase safety of our roadways for the people who manage and maintain them.

7. Briefly describe the history of its development.

Unlike many infrastructure owner operators (IOOs), CDOT has experienced incident after incident and crash after crash in work zones that has posed significant danger to employees and the public. Recognizing this danger, CDOT recognized an opportunity that was ripe for innovation, in which technology enabled the removal of our employee from a risky and dangerous environment. As such, CDOT has taken a phased approach to build an ATMA program within the department that will be sustained and well-integrated into daily operations. The phased, programmatic approach has allowed CDOT's ATMA program to successfully integrate the new technology into the department's maintenance operations and learning from that integration, while providing minimal risk to the public and CDOT staff. CDOT's phased approach is briefly discussed below.

Phase one (2018-2020) consisted of the pilot deployment of CDOT's first ATMA in CDOT Region 4 (north-central Colorado: Greeley/Agate/Limon area). The pilot deployment period allowed CDOT to build the programmatic aspects (program setup and administration, program goal setting, procurement, installation and planning) while going through the State's regulatory framework to receive approval to operate on the public roadway. In the May 2018, CDOT received Colorado's Autonomous Mobility Task Force approval to operate on roads with annual average daily traffic (AADT) of less than 2,500 vehicles

per day. CDOT leveraged 2018 – 2019 to understand the integration of the technology into the daily crew's operation, while continuing to build the programmatic approach to the ATMA program. This included understanding the relevant divisions within the department that support elements of the program, evaluating program success and lessons learned, while refining the future program roadmap. In 2019, the ATMA received several upgrades to the hardware and underlying automated driving system of the vehicle.

In 2020, CDOT entered into the second phase of the program, which featured several core elements growing out the program: (1) operational expansion of the ATMA to roads with AADT of less than 5,000 statewide, and (2) expansion and deployment of a second ATMA to the CDOT maintenance operations in southwestern Colorado known as Region 5. Expansion to Region 5 follows the same framework deployment conducted in Region 4, with installation of the equipment, testing and validation, training, pilot testing by CDOT, and lastly, integration into daily operation.

8. What resources—such as technical specifications, training materials, and user guides—have you developed to assist with the deployment effort? If appropriate, please attach or provide weblinks to reports, videos, photographs, diagrams, or other images illustrating the appearance or functionality of the innovation (if electronic, please provide a separate file). Please list your attachments or weblinks here.

CDOT has developed several resources that support the ATMA deployment internally to the department. However, it is worth noting that additionally, CDOT took the lead to start a pooled fund group dedicated to advancing the deployment and research of autonomous maintenance vehicles. CDOT serves as the lead state, administering the Autonomous Maintenance Technology Pooled Fund TPF-5(380), which features a membership of 14 states that collectively work to advance the research, deployment and understanding of autonomous maintenance vehicles in work zone operations. The member states range from those in the ideation phase of bringing an ATMA to their program to five states (other than CDOT) that have acquired or brought an ATMA to their DOT for consideration or operation. At least five other state DOTs have acquired an ATMA for operation in their program. The group has approved several research studies that have gone on to publish their findings, as well as creating a draft toolkit and other resources to further support deployment of the technology for many transportation organizations.

More information can be found at the below resources. The Autonomous Maintenance Technology Pooled Fund's website is linked here and has access to several resources supported and created by the pooled fund.

CDOT has provided access to several videos, pictures and decks that may be used for various content purposes. Approval for content use should be approved prior to use and include reference to the Colorado Department Transportation.

CDOT ATMA Video 2021
CDOT ATMA Pictures 2021
CDOT ATMA Pictures 2019
CDOT ATMA Validation and Test Plan 2021

Attach photographs, diagrams, or other images here. If images are of larger resolution size, please provide as separate files.

High resolution image file names are attached as separate files

- ATMA Updated Logo 2021
- ATMA Demonstration Video
- AutoAtten_20191016_1
- AutoAtten_20191016_4
- AutoAtten_20191016_7
- AutoAtten_20191016_11
- AutoAtten_20191016_13
- AutoAtten_10.22.2019_002
- AutoAtten_10.22.2019_013
- AutoAtten_10.22.2019_026

State of Development (40 points)

Innovations must be successfully deployed in at least one State DOT. The AII selection process will favor innovations that have advanced beyond the research stage, at least to the pilot deployment stage, and preferably into routine use.

9. How ready is this innovation for implementation in an operational environment? Please select from the following options. Please describe.

☐ Prototype is fully functional and yet to be piloted
☐ Prototype has been piloted successfully in an operational environment
☒ Technology has been deployed multiple times in an operational environment
☐ Technology is ready for full-scale implementation

CDOT has successfully not only piloted and brought the ATMA program to the State of Colorado but has had an ATMA in daily operation in two maintenance sections since 2018. As noted earlier as the program continues to succeed, CDOT continues to expand the type and volume of roadways the ATMA is approved for operation on. The ATMA program at CDOT is entering its fourth year and program staff continue to identify future program expansion (additional ATMAs to new maintenance sections, additional possible use cases for an ATMA (sweeping, mower, etc), greater volume roadway deployment, etc. While CDOT was the first state to successfully bring and deploy an ATMA to daily operation, several other states are working on planning activities to formally bring an ATMA program to their state, are in the process of acquiring an ATMA, or have acquired an ATMA for their DOT and are conducting various activities to deploy that vehicle on the roadside.

10. What additional development is necessary to enable implementation of the innovation for routine use?

The technology is available for implementation and integration into work zone operations by a state DOT or transportation organization. However, there will be variation from state to state or operation to

operation to fit the needs of that particular entity or local/state jurisdictional requirements, maintenance operations or use case of the ATMA.

The Autonomous Maintenance Technology Pooled Fund members have identified several common themes to deployment and have made this information available on the website above for future deployers. These steps or activities typically include business case development and project ideation, stakeholder engagement, determining organizational champion and impacted business units, funding and resource allocation, procurement, program setup, regulatory framework considerations, acquisition and installation of the technology on the vehicle, testing and validation and operational deployment.

11. Are other organizations using, currently developing, or have they shown interest in this innovation or of similar technology?? ☒ Yes ☐ No

If so, please list organization names and contacts. Please identify the source of this information.

*Please note – those with an asterisk are state DOTs or transportation organizations that have acquired an ATMA and are in some stage of deployment (planning, testing, validation or preparation for deployment approval).

It is worth noting that CDOT and the AMT Pooled Fund members have taken calls from several other state DOTs and transportation organizations not listed below that have inquired about their respective ATMA programs.

Organization	Name	Phone	Email
*California Department of Transportation	Theresa Drum	916-643-8852	theresa.drum@dot.ca.gov
Florida Department of Transportation	Raj Ponnaluri		Raj.Ponnaluri@dot.state.fl.us
Indiana Department of Transportation	Jeremy McGuffey	317-296-2504	JMcguffey@indot.in.gov
*Minnesota Department of Transportation (MNDOT)	Cathy Huebsch, Project Management Engineer	651-346-8695	cathy.huebsch@state.mn.us
*Missouri Department of Transportation	Chris Redline		christopher.redline@modot.mo.gov
*North Dakota Department of Transportation (NDDOT)	Travis Lutman, NDDOT	701-328-4274	tlutman@nd.gov
Pennsylvania Department of Transportation	Kevin Tobias, Office of Transformational Technology		kevtobias@pa.gov
Tennessee Department of	Airton Kohls, Research	865-974-0298	akohls@utk.edu

Transportation (TDOT)	Associate at the University of Tennessee Center for Transportation Research		
*Virginia Department of Transportation	David Rush, Work Zone Safety Program Manager	804-305-8938	david.rush@vDOT.Virginia.gov

Potential Payoff (30 points)

Payoff is defined as the combination of broad applicability and significant benefit or advantage over baseline practice.

12. How does the innovation meet customer or stakeholder needs in your State DOT or other organizations that have used it?

The ATMA's greatest benefit is drastically improving safety to CDOT staff by decreasing the overall exposure risk of driving the vehicle. One crash or incident has significant impact to the department, with impacts to the employees, and impacts to the driving public. From the operator perspective, the operator faces great potential harm from an injurious or fatal crash, post-traumatic stress following the crash, workplace job anxiety from having to operate and be in the vehicle following the crash. By removing the human operator, this exposure risk and potential harm is significantly lowered to the human if a crash does occur.

The crash cushion on the vehicle is designed to absorb an impact in a way that attempts to preserve those striking the vehicle as well.

13. Identify the top three benefit types your DOT has realized from using this innovation. Describe the type and scale of benefits of using this innovation over baseline practice. Provide additional information, if available, using quantitative metrics, to describe the benefits.

Benefit Types	Please describe:
Improved Safety	Automated Truck-Mounted Attenuators (ATMAs) have the potential to improve work zone safety by removing the human driver from a location with a high potential for impact. This reduces the likelihood of human injury or death.
Improved Operation Performance	Because the ATMA operates via advanced autonomous systems including safety (ADS computer, lidar, radar and ultrasonic sensors and cameras) and communications (GPS and V2V) components, it more closely tracks the pathway of and distance to the lead operations vehicle, making it more effective at protecting against impacts.
Other (please describe)	Considering CDOT's ATMA is the nation's first autonomous impact protection vehicle, this technology affords the opportunity to contribute to continued research and development on cutting-edge technology.

	Additionally, the AMT Pooled Fund offers a collective group of IOOs that seek to continue to advance and accelerate the research and deployment of autonomous maintenance vehicles to improve worker safety. The AMT Pooled Fund funds research that provides vital data and information on autonomous maintenance vehicle research gaps and other topics that can support the advancement of the technology. Additionally, the pooled fund group serves as a community of practice for deployers and those interested in bringing deployment to their operations. The collaborative discusses issues faced in their deployment, shares lessons learned and other hot topics so that each deployer and interested IOO may learn from one another to advance deployments.

Click or tap here to enter text.

14 How broadly might this innovation be deployed for other applications. in the transportation industry (including other disciplines of a DOT, other transportation modes, and private industry)?

The ATMA sets the foundation and groundwork for automation to be more broadly introduced to DOT work zone and maintenance operations. There are many uses by a state DOT or IOO of a truck mounted attenuator or follow vehicle. Other similar leader-follower use cases that typically require a human operator in the attenuator include operations like roadside sweeping operations, roadside vegetation mower, work zone setup and cleanup, work zone mobile operation protection, multiple vehicle follow up (two+ follow vehicles) and many others. Several DOTs in the pooled fund are exploring these additional use cases to their operations leveraging the initial ATMA technology.

Additionally, this program allows a state DOT or IOO to understand the role of technology and how to safely and sustainable bring innovative and advanced technology into their operations.

Market Readiness (20 points)

The AII selection process will favor innovations that can be adopted with a reasonable amount of effort and cost, commensurate with the payoff potential.

15. What specific actions would another organization need to take along each of the following dimensions to adopt this innovation?

Check boxes that apply	Dimensions	Please describe:
☒	Gaining executive leadership support	Identifying the lead champion division within a state DOT or IOO is a critical first step identified by many deployers and those interested in deployment. It is critical to have a lead champion in the division that is socializing the dire need and significant benefit the ATMA brings to improving worker safety.
☒	Communicating benefits	Particularly to the general public, the organization would need to describe how and why automation of the follow vehicle offers safety benefits, as autonomous technology is new to most people and they are similarly unfamiliar with highway operations.
☒	Overcoming funding constraints	At face value, an ATMA is a significant initial capital cost, especially when compared to the traditional truck mounted attenuator. Additionally, establishing the program within the department, supporting pilot, testing and validation and deployment will require a dedicated funding and human resources. It is important for state DOTs and IOOs to balance these funding and resource requirements with the potential grave danger posed to their employees, and the tremendous safety benefit offered to the workers.
☒	Acquiring in-house capabilities	Program and organization staff may not inherently how to

		operate the ATMA's systems. However, with training and working closely with the vendor while building the internal program, this challenge can be overcome, all the while building staff capacity on an advanced technology.
☒	Addressing legal issues (if applicable) (e.g., liability and intellectual property)	Given the vehicle's level of automation, some state DOTs or IOOs may have a regulatory framework in their jurisdiction that needs to be considered as part of the deployment process to ensure the vehicle is approved for operation on the roadway. Additionally, as these vehicles operate in an unmanned fashion, incident related protocols and standard process procedures may need to be created by the department to ensure incident preparedness.
☒	Resolving conflicts with existing national/state regulations and standards	Autonomous vehicles are themselves an emerging technology, and much of national/state regulations and standards do not currently or adequately address them. For example, Colorado established the statewide Autonomous Mobility Task Force to fill the gap in the state's regulation and monitoring of autonomous vehicle projects.
☒	Other challenges	Given the emerging nature of this technology, there will be variation in planning, operational, procurement, legal, and programmatic requirements by a state DOT or transportation organization. It is critical that champions and sponsors identify all deployment requirements that must be addressed for on-road operation.

16. Please provide details of cost, effort, and length of time expended to deploy the innovation in your organization.

Cost: $293,392
Level of Effort: Varies based on program structure. In Colorado, there are two lead headquarters program staff that contribute approximately 10 – 15 percent of their time to the program, with several maintenance division staff that contribute anywhere between 10 – 50 percent of their time to the program.
Time: See response above.

17. To what extent might implementation of this innovation require the involvement of third parties, including vendors, contractors, and consultants? If so, please describe. List the type of expertise required for implementation.

ATMAs are a cutting-edge technology; as such, they require the involvement of vendors and academia that specialize in the development of autonomous vehicle systems. For instance, CDOT's ATMA was made possible by a partnership with Kratos Defense, a pioneer in the ATMA field.