TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Colorado Department of Transportation (CDOT)

INSTRUCTIONS:

Lead Agency contacts should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* *TPF-5(380)*	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☒Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

TPF Study Number and Title: **TPF 5(380) – Autonomous Maintenance Technology**		
Lead Agency Contact: **David Reeves**	**Lead Agency Phone Number:** **303-757-9518**	**Lead Agency E-Mail** David.reeves@state.co.us
Lead Agency Project ID: **5(380)**	**Other Project ID (i.e., contract #):** **n/a**	**Project Start Date:** 3/20/2018
Original Project Start Date: **3/20/2018**	**Original Project End Date:** **3/20/2023**	**If Extension has been requested, updated project End Date:** 3/20/2025

Project schedule status:

☐On schedule	☒On revised schedule	☐Ahead of schedule	☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Funds Expended This Quarter	Percentage of Work Completed to Date
684,268	n/a	60%

Project Description:

The mission of this study is to support and promote collaborative research efforts in the field of autonomous technologies in work zone applications, with the goal of improving the safety, efficiency and quality of work efforts, along with providing better solutions and valuable lessons learned for the integration of new technologies to further these goals. The participation of many transportation related agencies in this study furthers the cooperation in this industry, leading to improved future development of beneficial technologies and improved sharing of information and lessons learned. This is intended to further safety, efficiency, and quality of work done in this field for all relevant agencies. The following projects have been conducted.

- Project 1 – Project Management and Annual In-Person Peer Exchanges. Erika Miller (PI) from Colorado State University (CSU) (Status: Active)
- Project 2 - Evaluating the Human-Automated Maintenance Vehicle for Improved Safety and Facilitating Long Term Trust. Erika Miller (PI) CSU (Status: Completed - Final Report CDOT-2021-05)
- Project 3 - Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts. Xianbiao (XB) Hu - PennState (PI) – (Status: Active – Detailed CDOT QPR at end of this file)
- Project 4 - ATMA Tabletop. Will Moorhead - All Clear (PI). (Status: Completed – Final Report CDOT-2021-09)
- Project 5 - ATMA Cybersecurity Complement. Jeremy Daily – CSU (PI). (Status: Completed – Final Report CDOT-2022-04)
- Project 6 - ATMA Documentation. Xianbiao (XB) Hu - PennState (PI) – (Status: Active – Detailed CDOT QPR at end of this file)
- Project 7 - ATMA Incident Form Workshop - All Clear (PI). (Status: Completed)
- Project 8 - ATMA Cost-Benefits - Planning and Investing with informed Cost Benefit under Various Environments. Husain Aziz, Kansas State University (PI). (Status: Active – Detailed CDOT QPR at end of this file)
- Project 9 - Literature Review Synthesizing the current and Potential ATMA Applications Erika Miller (PI) CSU (Status: Completed - Final Report CDOT-2023-14 – Not on website yet due to accessibility requirements – but spreadsheet is available upon request)

Progress this Quarter
(includes meetings, work plan status, contract status, significant progress, etc.):

Project 1 – Project Management and Annual In-Person Peer Exchanges: Monthly meetings and working on transferring to Indiana DOT as Lead State for a new TPF solicitation https://pooledfund.org/Details/Solicitation/1622 - Autonomous Maintenance Technologies - Phase 2. Also have a purchase order to add funds to this task to manage this TPF through the end of this TPF project.

Project 3 – Development of ATMA/AIPV Deployment Guidelines (PennState): Task 5: Reporting being worked on. Penn State has worked with
CDOT to request a 6-month no cost extension. The new end date will be 5/22/2025.

Project 6 – ATMA Documentation (PennState): Completed Task 1 – Policy Review and making progress on Task 2 which is system description documentation with the hope of completing next quarter.

Project 8 – ATMA Cost-Benefits (Kansas State): The project has been kicked-off. The team is formed with graduate student researchers and we have started working on task-2: Synthesize the effect of weather, traffic and connectivity.

Anticipated work next quarter:

Project 1 – Project Management and Annual In-Person Peer Exchanges::

- Continued monthly meetings, Quarterly reporting and tracking project statuses for all projects under this TPF.
- Maintaining and updating outward facing Pooled Fund website.
- Continued work on all projects under contract projects.
- Organizing the annual AMT Peer Exchange for 2025.
- Transfer to Indiana DOT as lead state.

- Purchase Requisition to add funds was begun by CDOT in May 2024. Still waiting for a contract amendment though. Last checked, still in CDOT controllers queue to approve and sign.

Project 6 – ATMA Documentation (PennState):

- Complete task 1 Policy Review, and send the draft to Heather Pickering-Hilgers and David Reeves at CDOT for initial review, then to the pooled fund TAC member for comments.
- Start to work on task 2.1 System Description Document

Project 8 – ATMA Cost-Benefits (Kansas State):

- Compile a literature review on ATMA existing studies
- Identify the factors to be considered in the ATMA cost-benefit tool

Significant Results:

Research projects on track.
Annual in-person meeting planning for April 2025 has significant momentum/progress.
Monthly meeting attendance is good.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Contracting between universities-pooled funds and CDOT is slow, delaying start times of many of our projects. This will lead to refunding unspent funds before the TPF end date is 3/20/2025 so can no longer start any new projects. FHWA end date for all the projects is 12/31/2025 which means all projects need to be completed and fully paid out by this date and the TPF closed out. Project 8 end date is 12/04/2025 so CDOT may request an FHWA end date to provide some time for administrative needs if needed.

Potential Implementation:

Progress reports at monthly meetings continue to show increased use of ATMA technology. So far, the following states have an ATMA with Colorado and Missouri having two each.

States with ATMA:

- California 1
- Colorado 2
- Indiana 1 (leased)
- Minnesota 1
- Missouri 2
- North Dakota 1
- Ohio 1
- Oklahoma 1
- Total 10

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Study No: 5380-19-03

Description:	**Reporting Period:** 2024 Quarter 3 **Type:** SP&R **PO:** 471001861 **PO Amount:** $ 92,579.37 **Start:** 5/23/2023 **End:** 6/22/2025 **Principal Investigator(s):** Xianbiao (XB) Hu Penn State University xbhu@psu.edu 814-863-0523 **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** Heather
While Autonomous Truck Mounted Attenuator/Impact Protection Vehicles (ATMA/AIPV) are being developed and show promising benefits in roadway maintenance, what's not well studied is the impacts of such autonomous system to traffic operation and roadway safety, and subsequently how should DOT develop deployment strategies with those aspects taken into consideration. To bridge this important gap, this project aims to develop a practical software tool that takes in DOT inputs such as roadway network GIS shapefile, traffic counts and ATMA/AIPV system characteristics, and outputs a set of recommended deployment strategies, including the roadway maintenance sequence, staffing plan and needed resource, potential impacts to the traffic network and any suggested traffic management plan to ensure a smooth and safe traffic flow while effectively maintaining the roadway facilities.	

MILESTONES, TASKS, AND DELIVERABLES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
	100	5/23/2023	PO Issued/Notice to Proceed
6/22/2023	100	6/5/2023	Kick-Off Meeting
7/5/2023	100	7/1/2023	Project Brochure development
9/22/2023	100	9/22/2023	Task 2 - Capacity Drop Derivation and Validation
1/22/2024	100	1/22/2024	Task 3: Optimal Deployment Strategy Development
5/22/2024	100	5/22/2024	Task 4: Excel-Based Lookup Table Development
11/22/2024	75		Task 5: Reporting

SIGNIFICANT EVENTS

(latest date first)

- 2024Q3– Details
    1. Penn State team is working on Task 5: Reporting
    2. Penn State has worked with CDOT to request a 6-month no cost extension. The new end date will be 5/22/2025.
- 2024Q2– Details
    1. Penn State team completed Task 4 - Excel-Based Lookup Table Development
    2. Penn State is drafting the final report, and will send it out to CDOT PM for review in Q3.
- 2024Q1– Details
    1. Penn State team completed Task 3 - Optimal Deployment Strategy Development.
- 2023Q4– Details
    1. Penn State team completed Task 2 - Capacity Drop Derivation and Validation
- 2023Q3– Details
    1. Project kickoff meeting was scheduled and happened on 6/5/2023
    2. Project brochure was generated and accepted on 7/1/2023
- 2023Q2– Details
    1. IGA was signed between CDOT and PennState on 5/23/2023.
- 2021Q4 – Details
    1. Grant transfer: the contract has arrived at PennState. OSP is reviewing the languages and terms in the contract.
    2. Attended the pool fund annual meeting in Denver, CO, in person.
    3. Continued to work on Tasks 4 optimal deployment strategy development, and task 5 open-source sofrware tools development.
- 2021Q3 – Details
    1. The grant transfer process has been initated. The proposal has been submitted to CDOT. MST has terminated this project
    2. The tasks 2&3 on modeling and validaiton have been completed. Due to COVID-19 restrictions, we took a different modeling approach to work with the new dataset.
    3. PI plans to present the results at the October AMT annual workshop in Denver in person.
- 2021Q2– Details
    1. PI Hu is leaving Missouri S&T and joining Penn State University. The pool fund members voted to allow PI to carry this grant to his new University. No changes to budget, timeline, SOP are expected.
    2. Missouri S&T will send out a relinquishment letter to release the unused fund, hopefully next week (week of 7/19)
    3. Continued to work on task 2, 3 and 4. The modeling approached has been revised to work with new dataset under COVID-19 restrictions. Validation is being performed and showing promising results.
- 2021Q1– Details
    1. Continued to work on task 3: Data collection and model calibration. In this task, we originally proposed to use video recordings, or other types of data inputs such as LiDAR on the ATMA vehicles to collect data and calibrate our model. Due to COVID-19, this ATMA operations are being affected. As a result, we looked into the other datasets that share some similarities with ATMA operation, and are using NGSIM dataset to validate the model.
    2. Due to the data changes, we're revisitng task 2 – traffic flow modeling. Specially, we're developing two different models, including one model for 2-lane highway (i.e. one lane each

direction), and another model for multi-lane highway. The reason is according to Highway Capacity Manual, the level of service of 2-lane highway is determined by the percent time spent following (PTSF), and the level of service of multi-lane highway is determined by traffic density. As such, we need to differentiate them, and develop different models.
3. We are working on a paper titled "Identification of Operational Design Domain for Autonomous Truck Mounted Attenuator System on Multilane Highways", and are planning to submit to the journal of transportation research record for publication.

- 2020Q4 – Details
  1. Continued to work on task 3: Data collection and model calibration. In this task, we originally proposed to use video recordings, or other types of data inputs such as LiDAR on the ATMA vehicles to collect data and calibrate our model. Due to COVID-19, this ATMA operations are being affected. As a result, we're looking into the other datasets that share some similarities with ATMA operation. We're evaluating the dataset of openACC and NGSIM dataset.
  2. Once the dataset evaluation is finished, we may need to revisit task 2 – traffic flow modeling, so as to Once the dataset evaluation is finished, we may need to revisit task 2 - traffic flow modeling, so as to accodomate the data availability.
  3. We're slightly behind the schedule, again, due to covid-19 which affected the data collection efforts. However, we should be able to catch up rather quickly, once we identify the dataset to use. We have about two years left before PO expires, so timeline-wise, this should be not an issue.
  4. We are working on a paper titled "Modeling and Development of Operation Guidelines for Leader-Follower Autonomous Truck-Mounted Attenuator Vehicles", and are planning to submit to the journal of transportation research record for publication.
  5. Had regular conference call with PM Ashley Nylen.
- 2020Q3 – Details
  1. On 7/9/2020, presented on an invited webinar titled "Work Zone Safety and How to Use New Technologies to Mitigate Work Zone Intrusion", which was by TRB Standing Committee on Maintenance and Operations Management AKR10. Attracted 600+ registrants with $95 paid tickets. Satisfactory rate 93%. 7/9/2020. http://www.trb.org/Main/Blurbs/180727.aspx. Presenters included X. Hu, J. Lorme, A. Nylen, T. Weldon.
  2. Summarized research progress into a paper titled "Usage of Microscopic Traffic Simulation to Quantify Traffic Impact of Autonomous Maintenance Technology" to the TRB Workshop on Traffic Simulation and CAV Modeling. The paper has been accepted. The team will make a presentation on Nov. 16-18, 2020. https://trb.secure-platform.com/a/page/cavmodeling. Authors include Q. Tang, X. Hu, A. Nylen, T. Weldon.
  3. Continued to work on task 3: Data collection and model calibration. In this task, we proposed to use video recordings, or other types of data inputs such as LiDAR to collect data and calibrate our model. Due to COVID-19, this ATMA operations are being affected. About 30% done.
  4. Had regular conference call with PM Ashley Nylen.
- 2020Q2 – Details
  1. Submitted a paper titled "Evaluation Methodology of Leader-Follower Autonomous Truck Mounted Attenuator Vehicle System for Work Zone Maintenance" back to the journal of transportation record for consideration of publication.
  2. Continued to work on task 2: Traffic flow modeling. We implemented Newell car-following model and lane-changing model.
  3. Continued to work on task 3: Data collection and model calibration.
  4. Had regular conference call with PM Ashley Nylen.
- 2020Q1 – Details

1. Attended the TRB 2020 Annual Meeting. Presented two ATMA research papers, titled “Field Testing and Evaluation of Leader-Follower Autonomous Truck Mounted Attenuator Vehicle System for Work Zone Maintenance” and “Quantification of Traffic Impact by Leader-Follower Autonomous Truck Mounted Attenuator Vehicle System for Work Zone Maintenance”
2. Finished task 1: literature review. We focused on the car following model and lane changing model.
3. Started to work on task 2: Traffic flow modeling. About 50% done.
4. Started to work on task 3: Data collection and model calibration. About 10% done.
5. Invited by TRB AHD10 Committee on Maintenance and Operations Management for a public webinar on Autonomous Maintenance Technology in summer 2020, exact date and time TBD
6. Had regular conference call with PM Ashley Nylen.

- 2019Q4 – Details
    1. Attended the AMT peer exchange annual meeting at Fort Collins, CO.
    2. Presented ATMA research highlights at Missouri S&T, including MoDOT project, MATC project, 2 TRB papers and this pool fund project
    3. Official kickoff meeting with pool fund management team.
    4. Started to work on task 1: literature review. We focused on the car following model and lane changing model. About 90% done.
    5. Had regular conference call with PM Ashley Nylen.
- 2019Q3 – Details
    1. Finished the paperwork between CDOT and Missouri S&T. Contract is now signed

ANTICIPATED WORK NEXT PERIOD

- What are you planning on doing next quarter.
    1. Penn State is drafting the final report, and will send it out to CDOT PM for review in Q3.

ISSUES

- [2020Q1] Potential issue: Due to COVID-19, AMTA testing/operation in Missouri and Corolado has been slower than planned. Although task 3 is not scheduled to start until late this year, it will need to use the data from field data collection. So this is more like a potential issue down the road, but it’s not affecting the project right now.
- [2019Q3] The start date of this contract was delayed for about 2 months, due to contracting issue at Missouri S&T. The kickoff meeting happened on 10/22/2019. However, the project progress wasn’t delayed and we’re on schedule.
- [2019Q3] We’re in the process of hiring a postdoc/graduate student for this project. We will be billing a little bit slower than originally planned, hopefully this will be OK.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Systematic Documentation for Autonomous Maintenance Technology Promotion and Deployment

Study No: 5380-20-06

Description:	**Reporting Period:** 2024 Quarter 3 **Type:** SP&R **PO:** 471001862 **PO Amount:** $ 129,788.70 **Start:** 5/16/2024 **End:** 10/15/2026 **Principal Investigator(s):** Xianbiao (XB) Hu Penn State University xbhu@psu.edu 814-863-0523 **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** Heather Pickering-Hilgers (Leader, Tech)
Systematic documentation is an important part of software development and deployment. A successful documentation will make information easily accessible, provide a limited number of user entry points, help new users learn quickly, simplify the product and help cut support costs. This is especially the case when it comes to promoting and deploying new technologies that potential customers are interested in but may have many questions to ask. This project aims to produce a set of documents to provide systematic technical support for state DOT or other agencies that are interested in deploying ATMA. The scope of work of this project is to conduct literature review on federal and state regulation on autonomous vehicle testing and deployment, work with key stakeholders from public and private sectors that are working on autonomous maintenance technology, and summarize and document the knowledge for the purpose of autonomous maintenance technology promotion and deployment.	

MILESTONES, TASKS, AND DELIVERABLES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
	100	5/16/2024	PO Issued/Notice to Proceed
6/15/2024	100	6/13/2024	Kick-Off Meeting
9/15/2024	100	9/15/2025	Task 1 – Policy Review
12/15/2024	40		Task 2.1: System Description Documentation
4/15/2025	0		Task 2.2: System Test Manual
8/15/2025	0		Task 2.3: Concept of Operation
12/15/2025	0		Task 2.4: development Needs Document
12/15/2025	0		Task 2.5: User Manual Updates
4/15/2026	0		Final Presention
4/15/2026	0		Final Report

- 2024/5/16 Notice to Proceed
- 2024/6/13 Kickoff meeting

Task	Deliverable	Description	Estimated Delivery Date
1	1	Policy Review	Within 90 days of the Agreement Effective Date
1	2	Kick-off meeting	Within 30 days of the Agreement Effective Date
1	3	Prepare QPRs	Within 15 days after the end of each quarter
2	4	System Description Document	Within seven (7) months of the Agreement Effective Date
2	5	System Test Manual	Within 11 months of the Agreement Effective Date
2	6	Concept of Operation (ConOps)	Within 15 months of the Agreement Effective Date
2	7	Development Needs Document	Within 19 months of the Agreement Effective Date
2	8	ATMA User Manual Updates	Within 19 months of the Agreement Effective Date
3	9	Prepare final presentation slides	Within 30 days of Agreement Expiration Date
3	10	Prepare draft and final report (including QA/QC Process and Statement)	For the draft report, prior to 75 days before Agreement Expiration Date. For the final report, prior to 30 days before Agreement Expiration Date.

SIGNIFICANT EVENTS
(latest date first)

- 2024Q3– Details
    1. Penn State team has completed Task 1 – Policy Review
    2. Penn State team will work on Task 2 : System Description Documentation and should have it completed in the next quarter.
- 2024Q2– Details
    1. The Intergovernmental Agreement (IGA) between CDOT and Penn State was finally signed on 5/13/2024.
    2. The kickoff meeting was scheduled and held on 6/13/2024. XB, David, and Heather attended the meeting.
    3. The Penn State team is currently working on Task 1 - policy review. Previously, the team conducted a comprehensive literature review, including an analysis of federal policies and industry standards. Since three years have passed, the team will now conduct a market scan focusing specifically on the policy aspects at both the federal and state levels.
- 2021Q4– Details

    1. Grant transfer: the contract has arrived at PennState. OSP is reviewing the languages and terms in the contract.
    2. Attended the pool fund annual meeting in Denver, CO, in person.
- 2021Q3– Details
    1. The grant transfer process has been initated. The proposals have been submitted to CDOT.
- 2021Q2– Details
    1. PI Hu is leaving Missouri S&T and joining Penn State University. The pool fund members voted to allow PI to carry this grant to his new University. No changes to budget, timeline, SOP are expected.
    2. Missouri S&T will send out a relinquishment letter to release the unused fund, hopefully next week (week of 7/19)
    3. Finished Task 1 – Literature review. The draft report was sent to the pool fund member for feedback. We then addressed each comments and responded by email. The final report for task 1 has been uploaded to website and Google Drive.
- 2021Q1 – Details
    1. Finished the paperwork between CDOT and Missouri S&T. Contract was signed on 2021/1.
    2. Finished the paperwork between Missouri S&T and subcontractor Kratos. Contract was signed on 2021/2
    3. Kickoff meeting was held on 3/19/2021
    4. Started to work on task 1.1 Literature Review

ANTICIPATED WORK NEXT PERIOD

- What are you planning on doing next quarter.
    1. Finish task 1 Policy Review, send the draft to Heather and David for review, then to the pooled fund for comments
    2. Start to work on task 2.1 System Description Document

ISSUES

- [2020Q1] No issue so far

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

ATMA Cost-Benefits - Planning And Investing With Informed Cost Benefit Under Various Environments
Study No: 5380-21-08

Description: Autonomous Maintenance Technology (AMT), including the autonomous truck-mounted attenuator (ATMA), has gained traction due to its safety effectiveness in work zones. Data from field tests indicate the achievable functionality of ATMA systems within business-as-usual environments. Given that AMT services (including the ATMA) need to operate under varying conditions—weather, visibility, congestion states—and for different purposes (snow plowing vs. patching), there is a need to assess the change in functionality levels of AMT systems dictated by these external factors (that we cannot control). Also, the cost-effectiveness of the AMT technologies has not been explored, accounting for application type, technological adaptation, road network geometry, and overall context (urban vs. rural). The goals of this project are to: i. Explore and synthesize the effect of weather (light conditions, rain, snow), road geometry (urban vs. rural, terrain), and connectivity, ii. Assess the cost-benefits of the technologies—infrastructure, comparison to existing processes, iii. Build an MS-Excel-based decision support tool—which AMT system and where to deploy (minimal cost with the least technological barriers)	**Reporting Period:** 2024 - Quarter 3 **Type:** SP&R **PO: 471001960** **PO Amount: $101,541.75** **Start:** 06/05/24 **Original End:** 01/05/26 (18-months) **New End Date:** NA **Principal Investigator(s):** HM Abdul Aziz, Kansas State University, azizhusain@ksu.edu, (765)491-4787 **CDOT Research Project Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Oversight Team Members:** Sally Mayer, KDOT (Project Champion)

MILESTONES, TASKS, AND DELIVERABLES

Planned	% done	Achieved	Description, Discussion, and Related Issues
			RIC Approved
			Oversight Team Scoping Meeting
			RFP Sent
			PI Selected
06/05/24	100	NA	PO Issued/Notice to Proceed (E-mail from Project Manager)
08/01/24	100	08/12/24	Hire GRA for hthe project
09/30/24	0	11/20/24	Kick-Off Meeting/Project Updates

SIGNIFICANT EVENTS
(latest date first)

- 2024Q3 – The project has been kicked-off. The team is formed with graduate student researchers and we have started working on task-2: Synthesize the effect of weather, traffic and connectivity.

ANTICIPATED WORK NEXT PERIOD

- Compile a literature review on ATMA existing studies
- Identify the factors to be considered in the ATMA cost-benefit tool

ISSUES

- None