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Evaluating the Human-Automated Maintenance Vehicle Interaction for Improved Safety and Facilitating Long-Term Trust

APPLIED RESEARCH & INNOVATION BRANCH

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16. Abstract

Automated Truck-Mounted Attenuators (ATMAs) utilize technology to remove a human driver from a vehicle with a high potential for collision. This report evaluates DOT workers' perceptions of working with this automated technology, in order to identify any disconnect between operators and the ATMA system. The study objective was to *1)* understand workers' acceptance and understanding of the ATMA technology; *2)* Identify ATMA-worker interactions that are successful and interactions that could be improved; and *3)* evaluate how various training impacts their perceptions, acceptance, and use. A survey was conducted with 13 DOT workers with experience using ATMAs. Overall, workers had a positive opinion regarding the ATMA; such as its improvement on safety, the automation's reliability, the reasonable workload associated with operating it, and design of the interfaces. However, workers were not confident in operating the ATMA in more complex environments. Workers that had received training in more diverse settings (e.g., classroom and hands-on practice) were more confident in the ATMA and in their own abilities.

These results show that: *1)* investments into ATMAs will likely be accepted and adopted by workers; *2)* the current design and structured operating practices are acceptable for use in non-complex driving environments; and *3)* initial and continued training in both classroom and test-track settings improves worker-ATMA operations.

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EXECUTIVE SUMMARY

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. However, the integration of automated technology into TMAs is expensive and does not necessarily guarantee safety improvements; implementing automation can undermine safety and project success if operated incorrectly (e.g., operating limitations and procedures not followed). Therefore, it is important to understand users' perceptions of ATMAs and how training can improve appropriate adoption of this technology. The objective of this study was to evaluate how work zone workers at the Department of Transportation (DOT) perceive the usefulness of and the capabilities of automation in TMAs, and how this differs based on training received.

A survey study was conducted with 13 workers who had experience with ATMAs from the Department of Transportation for Colorado and California, CDOT and Caltrans, respectively. Current deployment of ATMAs is limited, hence only a small sample size of workers with experience with ATMAs exists for data collection at this time.

Based on responses from the survey, there were seven study participants considered as "High Experience" users and six as "Low Experience" in relation to their experience with the AMTA. High Experience workers had received training in the classroom, test track, and parking areas for ATMAs; had an average of 2 years of experience working with ATMAs; and self-reported as having some to a lot of experience with ATMAs. Low Experience workers had received less training for ATMAs; had an average of less than 1 year of experience working with ATMAs; and self-reported as having only observed to some experience with ATMAs. Responses to survey questions were compared both as general trends across all participants, as well as differences between High Experience and Low Experience Groups.

Overall, workers reported a positive acceptance of the ATMA technology. This was supported by their perceptions of various vehicle design elements, such as the location of emergency stop buttons, the information provided on the display in the lead vehicle, and the workload for starting and running the automation. Workers also had a general positive regard towards safety and reliability of the ATMA technology, as supported by their expectation that it

would reduce crash severity; that it was an overall improvement compared to having a human driving the TMA; that they were confident the automation would reliably stop if someone walked in front of it; that it would respond appropriately to obstacles on its own; and that it would reliably detect obstacles. All respondents agreed that it was highly important to have a checklist and structured vocabulary used during start-up; have at least one operator always maintaining visual line of sight; and having an autonomous safety operator. Despite the many positive opinions, workers did not think the automation would reduce crash frequency, nor would it reduce project duration. Workers were also less confident in the automation's ability to safely change lanes and drive without assistance from a human operator. They also noted concerns regarding their trust in the automation under various contexts, such as in conditions of poor visibility, adverse weather, horizontal and vertical road curvatures, and denser traffic volumes.

Individuals in the High Experience Group reported greater trust in the technology and confidence in their own skills operating and understanding of the technology. They also reported a higher level of overall effectiveness of the training they received; most noticeably on how to start the automation, how to override the automation, and the operating limits of automation (i.e., features learned through hands-on experience); as opposed to how the overall automation works, location of components, and purpose of various components (i.e., knowledge that can be learned in a classroom). This is consistent with the fact that High Experience workers received more diverse training across all training environments.

Implementation Statement

Overall, the AMTA technology was positively regarded by the workers. However, better calibrated trust and confidence in the automation appeared to increase with more experience and training. These findings suggest that investments into ATMAs will likely be accepted and adopted by workers, and that diverse training for these systems offers improved utility. The framework for data collection and analysis can easily be reproduced as utilization of AMTAs becomes more widespread. The survey questions are provided as Appendix A, and, as such, can be repeated in future work. The findings presented in this study can help jurisdictions achieve the safety improvements that investment and deployment of automation in work zones offers, by identifying the disconnect between operators and the technology.

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1 INTRODUCTION

Roadway work zones are a complex environment, with potential conflict points arising between traveling vehicles, vulnerable work zone workers, and slow[er]-moving heavy construction equipment. According to the Federal Highway Administration (FHWA), an injury associated with a work zone crash occurs every 16 minutes and a fatality every 15 hours in the United States (Eseonu et al., 2018; FHWA, 2019). In 2017, there were a total of 710 fatal crashes in work zones, with 40% occurring on interstates (FHWA, 2019). Statistics indicate that one out of every five fatalities in a work zone is a construction worker (OSHA, 2020). In 2017, there were 132 work zone worker fatalities (ARTBA, 2019).

1.1 Project Background

Impact attenuators, in various forms (e.g., “fixed” barriers, truck mounted, etc.), have been used as crash cushions in work zones for decades. Truck-Mounted Attenuators (TMAs) are vehicles deployed as shadow vehicles in work zones, with the intent to absorb energy from errant vehicle strikes (Cottrell, 2015). TMAs have been shown to decrease crash severity. These vehicles are typically used when there is a large speed differential between the general traffic and the work zone area. Historically, these vehicles are driven by a human operator, which puts the driver at a high risk for experiencing impact. Hence, the opportunity to remove the human from inside the ATMA offers an immediate reduction for injury potential. Crash data pertaining to collisions with TMAs is inadequately recorded and thus hard to quantify specifically how frequent these vehicles are struck. However, Cottrell (2015) used simulation and exposure rates to estimate yearly TMA crash counts for the state of Virginia and estimated 17, 26, 33, and 45 crashes with TMAs from 2011 to 2014, respectively. In Missouri, the DOT reported 19 crashes into truck- and trailer-mounted attenuators in work zones in 2019, and 39 in the first eight months of 2020, despite reduced traffic volumes related to COVID-19 (AASHTO, 2020). In an effort to remove the human from the TMA, Automated Truck-Mounted Attenuators have gained attention.

The ATMA vehicle is a typical TMA vehicle manufactured by Royal Truck & Equipment, with autonomous technology retrofitted, which is developed and implemented by Kratos Defense & Security Solutions. The ATMA is entirely unmanned once the automation is turned on and operates by following a lead vehicle that transmits high-accuracy positioning, speed and heading to the ATMA follow vehicle, see Figure 1.

Figure 1. CDOT's lead vehicle *(left)* and ATMA follow vehicle *(right).*

The ATMA is equipped with emergency stop (“e-stop”) buttons along the outside of the ATMA vehicle, as well as inside the lead vehicle, see Figure 2. When one of these emergency stop buttons is pressed, the engine in the ATMA completely turns off, bringing the vehicle to a stop.

Figure 2. E-stop button outside of ATMA *(left)* and inside lead vehicle *(right)*

At the time of this study, the Colorado Department of Transportation (CDOT) had one ATMA vehicle operational in their fleet, which they used as the follow vehicle for lane striping operations in predominately rural highway contexts. Additionally, at the time the study was conducted, the California and Missouri Departments of Transportation were testing an ATMA vehicle each for use in their fleets, but had not yet begun regular operations with their vehicles.

1.2 Study Objectives

It is essential to research the effectiveness of new technologies and safety techniques in work zones in order to validate their improvements on safety and operations. Moreover, it is critical to understand the effectiveness of new technologies from the perspective of the users who interact with this equipment, in order to overcome any barriers for safe adoption of technology. With an increasing emphasis on implementing automated technology in maintenance vehicles, this study specifically evaluates user perceptions of ATMAs. It is important that user perceptions are understood in order to capture the improved safety benefits that investments in ATMA technology offers. The overall objective of this research is to evaluate how workers perceive the usefulness and how well they understand the capabilities of automation in Truck-Mounted Attenuators. The goals of this study are to:

1. Understand workers' acceptance and understanding of ATMA technology;
2. Identify ATMA-worker interactions that are successful and interactions that could be improved; and
3. Evaluate how various training impacts their perceptions, acceptance, and use.

2 METHODS

A survey was developed, conducted, and analyzed as part of this research. The study had approval from the Colorado State University Institutional Review Board (IRB), protocol ID 20-9898H.

2.1 Survey Development

The survey was administered online using the Qualtrics Survey Software. The survey questions were developed by the research team at CSU, after they observed the ATMA being operated for two full days and attended a full day training session held at CDOT on ATMA operations. The survey was then sent to two of the ATMA program managers at CDOT for their input and review.

2.2 Survey Content

A copy of the survey is provided in the Appendix of this report. The survey was designed to capture respondent’s DOT work experience, ATMA training, ATMA experience, trust in the ATMA, operating limitations of the ATMA, and design of automation HMIs (e.g., displays, buttons). The majority of the questions used a 7-point (i.e., on a scale of 1 to 7, how would you rate…) or 10-point Likert scale responses.

2.3 Survey Administration

A link to the survey was provided only to DOT crews that had an ATMA vehicle in their fleet. As a result, the survey was sent to one crew in Colorado and one in California; 20 people were provided the survey, of which 13 responded. The Colorado ATMA has been operational on roads for approximately three years, while the California ATMA has only been used in testing and training operations, at the time of data collection. It was important to only capture perceptions of workers who have actual experience (on-road or training) with these ATMAs, hence the pool of possible participants was small, yet well versed in real-world ATMA procedures. Participants were asked to complete the survey between February through April 2020. The link to the survey was emailed to the DOT workers by their supervisors and they were given time to complete it during their shift. The ATMA program managers for CDOT and Caltrans were the contact points between the CSU research team and the DOT ATMA crews. These program managers provided the survey link and information to their respective units. The survey took approximately 15 minutes to complete.

2.4 Data Analysis

Survey responses were compiled and analysed using Excel and R (version 3.5.1). Overall user perceptions of the ATMA were evaluated, as well as a comparison of perceptions between workers that received a high amount and a low amount of ATMA training (see next chapter for definitions).

3 RESULTS

There was a total of 13 responses for the survey; 12 of the respondents worked at CDOT and one worked for Caltrans.

3.1 Training Group Definitions: High and Low Experience

Participants were grouped into one of two groups based on the type of training they reported having received, see Table A. Participants in the High Experience Group (N = 7) received ATMA training in all three settings: classroom, test track, and parking areas. Participants in the Low Experience Group (N = 6) only received training in two or fewer of these training settings; two reported classroom and test track training, three only classroom training, and one only test track training. None of the participants in the Low Experience Group had ATMA training in a parking area.

Table A. ATMA Training Received

Training Type	**All** *N*	**High Exp.** *N*	**Low Exp.** *N*
Classroom and test track and parking areas	7	7	0
Classroom and test track	2	0	2
Classroom only	3	0	3
Test track only	1	0	1

The average number of years having worked at the DOT was slightly higher for the Low Experience Group (mean = 13.7, SD = 8.6) as compared to the High Experience Group (mean = 12.2, SD = 8.4). However, this likely has little to no impact on their experience with the ATMA, as the ATMA has only been around for less than three years at the time of data collection.

High Experience participants had an average of 2.05 years working with the ATMA, ranging from 7 months to 3 years. Low Experience participants had an average of 0.92 years of experience with the ATMA, ranging from 1 month to 2 years. Participants were asked to selfevaluate their exposure to the ATMA, where participants in the High Experience Group self-reported more experience and the Low Experience Group self-reported less, see Table B.

Table B. Self-Reported Experience with ATMA

Self-Reported Experience Level	All	High Exp.	Low Exp.
	N	*N*	*N*
A lot of experience	3	3	0
Some experience	7	4	3
Observed the ATMA but never operated	3	0	3

3.2 Effectiveness of Training

Participants were asked to rate the overall effectiveness of the ATMA training they received on a 10-point Likert scale, from 1 (not effective at all) to 10 (extremely effective), see Table C. On every category, participants in the High Experience Group (i.e., those that received training in more diverse environments) rated their training experience more effective than the Low Experience Group.

Table C. Perceived (Average) Effectiveness of Training Received (10-point Likert)

Note: higher values represent more effective perception of training, with 5.5 as neutral point

Effectiveness of Training on…	All	High Exp.	Low Exp.
How overall vehicle automation works	6.6	6.9	6.3
Location of automation system components	6.0	6.4	5.6
Purpose of various automation system components	7.0	7.3	6.8
How to start automation	6.8	7.9	5.6
How to override automation	7.3	8.0	6.7
Operating limits of automation	5.7	6.4	4.8

3.3 Tasks with ATMA

Participants were asked if they have ever performed various tasks with the ATMA, their responses by Experience Group are shown in Table D. The values in the table represent the proportion of participants in each group that reported having performed each task at least a few times. Note, the autonomous safety operator job is the person that monitors the automation display from the lead vehicle and is responsible for supervisory control of the ATMA. The emergency-stop ("e-stop") button is the emergency stop button that immediately brings the ATMA vehicle to a sudden stop by turning off the engine. Having to intervene and clear an automated-stop ("a-stop") means the ATMA falsely detected an obstacle and the human operator must override it in order to avoid an unnecessary stop by the ATMA; if the operator does not intervene and clear the a-stop within the given time, then the ATMA comes to an automated stop. For all of the tasks, a larger percentage of the High Experience Group reported having performed the task as compared to the Low Experience Group; with the only exception being that every participant reported having seen the ATMA operate in automated driving mode.

Table D. Experience Performing Tasks with the ATMA

Have you ever...	**All** *% yes*	**High Exp.** *% yes*	**Low Exp.** *% yes*
Manually driven ATMA (not automated)	76.9	100	50
Seen ATMA driving in automated mode	100	100	100
Used automation for daily operations in real-world	46.2	71.4	16.7
Turned on automation from lead vehicle	61.5	85.7	33.3
Turned on automation from follow vehicle	61.5	85.7	33.3
Worked as autonomous safety operator	53.8	57.1	50
Worked outside/near ATMA while automated	61.5	85.7	33.3
Used e-stop while ATMA was automated	61.5	85.7	33.3
Had to intervene and clear an a-stop	38.5	57.1	16.7

3.4 Vehicle Design

Opinions about the vehicle design were asked based on a scale of 1 "strongly disagree" to 7 "strongly agree", where answers below 4.0 represent an opinion of disagreement and responses above 4.0 represent an opinion of agreement; see Table E for general vehicle design and Table F for HMI design. Based on the Mann-Whitney U Test, there were no statistically significant differences ($p > 0.05$) between High and Low Experience Groups regarding any of the vehicle design questions.

Overall, participants agreed that the e-stop buttons inside the lead vehicle and outside the follow vehicle were in a good location for pressing during an emergency. The workers surveyed tended to be neutral about whether the automation system was frustrating to use.

Table E. Perceived (Average) Agreement of Vehicle Design Elements (7-point Likert)

Note: values less than 4 equals disagree, 4 equals neutral, greater than 4 equals agree

How strongly do you agree that…	All	High Exp.	Low Exp.
Automation is frustrating to use	4.2	4.3	4.0
e-stop button(s) *inside* lead vehicle are in a good location for pressuring during an emergency	5.6	5.6	5.7
e-stop button(s) *outside* follow vehicle are in a good location for pressing during an emergency	5.6	5.6	5.7
a-stop button(s) inside lead vehicle are in a good location for pressing when an obstacle has been detected	5.5	5.5	5.6

Participants seemed to agree that the information on the automation's HMI display in the lead vehicle pertaining to the ATMA was clear and understandable. Participants seemed to be satisfied with the workload associated with starting and running the ATMA; as represented by Likert scale ratings in the disagree direction relating to the display requiring too much input during automation start-up; and to the display requiring too much input while automation was running. They were neutral on whether the display warned about too many obstacles. In the High Experience Group, participants somewhat agreed that warnings on the HMI display were provided with enough time to appropriately respond, while participants in the Low Experience Group were more neutral about these warnings providing enough time to respond appropriately.

Table F. Perceived (Average) Agreement of [HMI] Display Design (7-point Likert)

Note: values less than 4 equals disagree, 4 equals neutral, greater than 4 equals agree

How strongly do you agree that…	All	High Exp.	Low Exp.
Information is clear and understandable	5.1	5.0	5.3
Warns about too many obstacles	4.2	4.1	4.3
Requires too much input during automation start-up	3.9	3.7	4.2
Requires too much input while automation is running	3.7	3.6	3.8
Warnings provided with enough time to appropriately respond	4.4	4.7	4.0

3.5 Safety and Trust

Participants were asked questions comparing their perceptions of automation versus manual TMA operations on a 7-point Likert scale, see Table G. The 7-point Likert scale was based on how much they agreed with the statements, where greater than 4 trended towards agree and less than 4 trended towards disagree.

In general, all participants tended to agree that the automation was an overall improvement compared to having a human driving the TMA. However, participants did not trust the driving skills of the automation more than their own driving skills. Participants also strongly disagreed that the automation would reduce crash frequency and strongly disagreed that it would reduce project duration. Although they did tend to somewhat agree that the automation would reduce crash severity. Response were not significantly different ($p > 0.05$) between the two training groups.

Table G. Perceived (Average) Agreement of ATMA on Safety and Trust (7-point Likert)

Note: values less than 4 equals disagree, 4 equals neutral, greater than 4 equals agree

How strongly do you agree that…	All	High Exp.	Low Exp.
Automation is an overall improvement compared to a human driving the TMA	4.9	4.7	5.0
Automation will reduce crash frequency	3.0	2.6	3.5
Automation will reduce crash severity	4.5	4.1	4.8
Automation will reduce project duration	2.3	2.4	2.1
You trust the automation more than your own driving skills	2.5	2.0	3.0

Participants were asked how important they considered various operating procedures in terms of balancing safety and productivity while using the ATMA's automation, see Table H. Overall, participants tended to value more structure and established procedures while starting and running the automation. These questions were based on a 10-point bipolar Likert scale, from 1 (not important at all) to 10 (extremely important). As such, with a 10-point bipolar scale, responses from 1 to 5 represent less perceived importance and responses from 6 to 10 represent high perceived importance (i.e., 5.5 was the central point between the bipolar end points).

Table H. Perceived (Average) Importance of Operating Procedures (10-point Likert)

Note: higher values represent more important, with 5.5 as neutral point

There should be...	All	High Exp.	Low Exp.
An automation checklist used during start-up	8.8	9.0	8.6
At least one operator always maintaining visual line of sight	8.3	8.0	8.7
Structured vocabulary/phrases used during start-up	8.3	8.7	7.8
Someone who's only job is autonomous safety operator	7.0	6.4	7.7

Participants were also asked questions relating to their perceived trust in the automation under various situations, see Table I. These were also based on a bipolar 10-point Likert scale from

1 (not confident at all) to 10 (extremely confident), with responses above 5.5 as confident and below 5.5 as not confident.

It is noteworthy that participants in the High Experience Group were significantly more confident in their ability to override the automation if needed in a critical situation (High: mean = 8.3, SD = 2.1; Low: mean = 5.8, SD = 2.6), U = 35, p = 0.045.

Table I. Perceived (Average) Confidence in Automation (10-point Likert)

Note: values less than 5.5 equals not confident, 5.5 equals neutral, greater than 5.5 equals confident

The ATMA can...	All	High Exp.	Low Exp.
Reliably stop if you walk in front of it	7.1	7.1	7.0
Respond appropriately to obstacles on its own	6.7	7.1	6.2
Reliably detect obstacles	6.5	6.6	6.3
Safely change lanes [while automated]	5.4	5.1	5.7
Drive without assistance from human operator	5.1	5.3	4.8

3.6 Operating Limitations

Participants were asked various questions regarding their understanding of the automation's safe operating limits, see Table J.

Participants in the High Experience Group appeared more confident in their overall understanding of the ATMA's operating limits. In a question asking how confident, on a 10-point Likert scale, they were that they understood the operating limits of the automation, the mean for the High Experience Group was 7.0 (SD = 3.1), while the mean for the Low Experience Group was 5.7 (SD = 2.4).

A Mann–Whitney U test was used to compare the maximum speed participants thought the automation could be safely operated at. Participants in the High Experience Group significantly (p = 0.032) reported higher maximum ATMA operating speeds (High Experience: mean = 19.1 mph, range = [9, 40 mph]; Low Experience: mean = 9.2 mph, range = [7, 10 mph]).

Table J. Perceived Safe Operating Limits of Automation

Concept	High Exp.	Low Exp.
Overall confidence in understanding operating limits of automation: 1(not at all confident) to 10 (extremely)	7.0 (confident)	5.7 (neutral)
Max speed automation can be safely operated at	19.1 mph	9.2 mph

Participants were also asked if they thought the gap distance between the lead vehicle (e.g., paint striping truck) and the follow vehicle (e.g., TMA) should be different when in automated mode compared to with a human driver, see Table K. Four participants in each group thought the gap distance should be the same, but two people in the Low Experience Group thought the gap should be longer and three people in the High Experience Group thought the gap should be shorter while automated compared to if a human was driving.

Table K. Gap Distance for ATMA and TMA Operations

The gap distance between lead and follow (TMA) should be…	**All** *N*	**High Exp.** *N*	**Low Exp.** *N*
Shorter for automated control	3	3	0
Same for automated and manual control	8	4	4
Longer for automated control	2	0	2

Lastly, participants were asked how confident they were that the automation could operate under various conditions, see Figure 3. Once again these were based on a 10-point Likert scale from 1 (not confident at all) to 10 (extremely confident), with 5.5 being the bipolar neutral point. Participants were more confident in the capabilities of the automated truck under “No traffic" and “Light traffic" and least confident in its capabilities in “long tunnels", “heavy rain", and “snow".

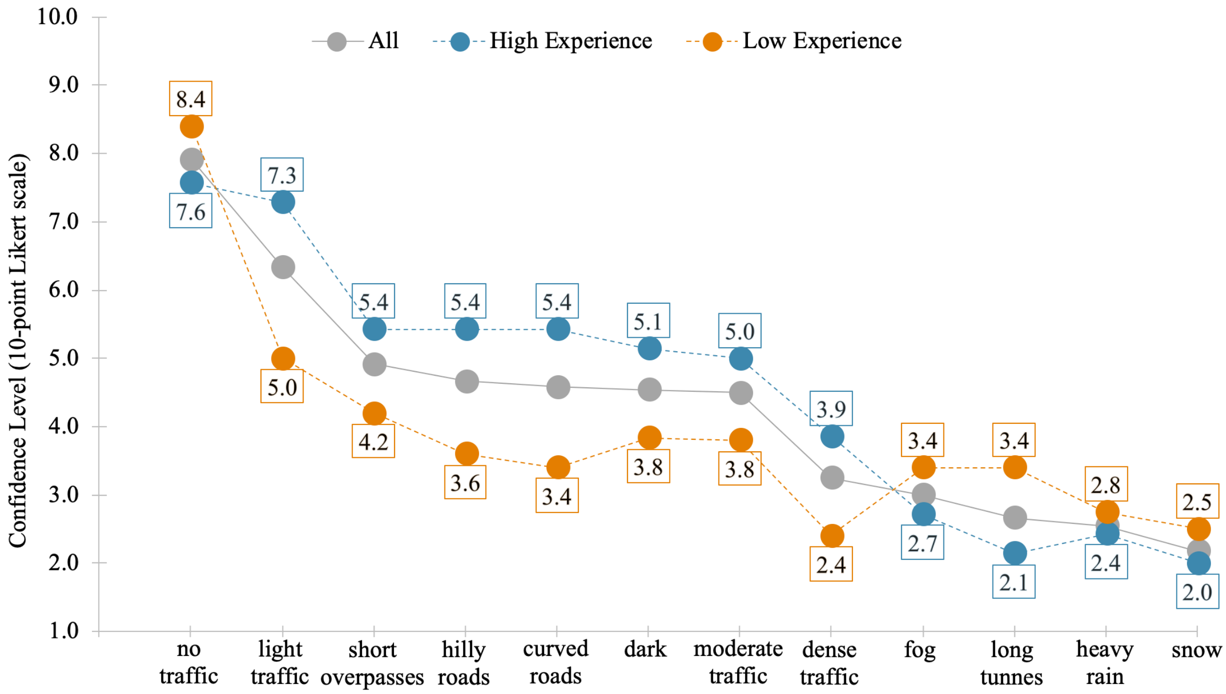

Figure 3. Average confidence in automation reliability for various conditions.

4 CONCLUSION AND RECOMMENDATIONS

4.1 Key Findings Summarized

Across all categories surveyed, workers in the High Experience Group reported higher levels of effectiveness of the training they had received; particularly relating to how to start the automation, how to override the automation, and operating limits of the automation. Whereas the differences in reported training effectiveness between the two groups was smaller between how the overall automation works, the location of automation components, and the purpose of the various automation components. It is likely the High Experience Group benefited from the more diverse, hands-on training sessions they received (i.e., classroom, test track, and parking areas), as opposed to the predominately classroom training session that the Low Experience Group received.

In both groups, workers were most confident in the capabilities of the automation under “no traffic" and “light traffic" conditions, respectively. Low volume traffic conditions offer fewer challenging conditions (i.e., less potential for conflict) and, as a result, workers considered the automation more reliable. Workers agreed that the autonomous truck would operate well in rural areas, but showed less confidence about using it in populated areas or in adverse weather, where visibility is poor. Under many of the conditions, the Low Experience Group reported lower levels of confidence in the automation’s ability to operate safely. This group also reported lower maximum speed capabilities and the need for longer gap distances under automation.

While both groups agreed about the importance of structured operating procedures while using the ATMA, the Less Experience Group attached more importance than the High Experience Group to human supervision for tasks such as maintaining visual line of sight and having an autonomous safety operator. This group was also less satisfied by the timing of the warnings on the HMI, reporting that the warnings did not provide adequate time to respond. Overall, this suggests that the higher experienced workers are more comfortable with the ATMA having minimal supervision as long as proper protocols are in place.

Although participants strongly disagreed that the automation would reduce project duration, the High Experience Group showed less disagreement towards this opinion. One possible explanation for this, is that the High Experience Group, due to their experience, are able to complete a project in less time. Despite this reporting of expected increased project duration, participants in both groups agreed that the ATMA would reduce crash severity. It is likely that this improvement in safety would strongly outweigh the modest increase in project duration that could come from ATMA operations.

4.2 Recommendations

Overall, the work zone workers surveyed in this study agreed that automated technology in TMAs was an overall improvement to safety and did not negatively impact their workload. These findings suggest that investments into ATMAs will likely be accepted and adopted by workers. However, improvements to technology or increased worker exposure is needed in order to increase worker comfort in more complex roadway conditions.

Additionally, workers' trust, confidence, and an accurate understanding of the automation appeared to increase with more experience and training. These findings suggest that training for ATMAs offers worthwhile improved utility. Workers benefited from an increased amount and variety of training received. Classroom training was beneficial to general system components, while test-track and similar hands on experience increased understanding and confidence in operating procedures. However, regular training exercises is likely beneficial to adhere to ATMA operating limitations.

5 DISSEMINATING RESULTS

The results of this study were presented at the Transportation Research Board (TRB) 100th Annual Meeting in January 2021, at Poster Session 1223 – "Advancements in Highway Maintenance Management." A manuscript based on these results was also published in the Traffic Injury Prevention Journal.

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APPENDIX A: SURVEY QUESTIONS

Automated Truck-Mounted Attenuator User Perceptions Survey

1. How would you describe your exposure of operating the autonomous truck mounted attenuator?
    - o A lot of experience
    - o Some experience
    - o Used a few times
    - o Observed the vehicle, but never operated
    - o Some knowledge, but never seen it operated
    - o None

2. Have you ever...	Never	A few times	Many times
a) Seen the vehicle driving in automated mode	○	○	○
b) Been on a crew that used the automation for daily maintenance and operation activities in the real-world	○	○	○
c) Turned on automation from lead vehicle during start-up procedures	○	○	○
d) Turned on automation from follow vehicle during start-up procedures	○	○	○
e) Worked outside and near to the vehicle while it was automated	○	○	○
f) Monitored automation display monitor/tablet from the lead vehicle for automated vehicle (i.e., autonomous safety operator)	○	○	○
g) Used e-stop button for vehicle while it was automated	○	○	○
h) Had to intervene and clear an A-stop	○	○	○
i) Driven attenuator vehicle (not while automated)	○	○	○

3. How many months/years ago did you first have exposure to the automated truck mounted attenuator? ____

4. What best describes the training you received for the automated truck mounted attenuator (check all that apply)?
    - o Had at least one "classroom" training session
    - o Had training on a test track (isolated away from other vehicles)
    - o Had training on roads/parking areas (not closed to other vehicles)
    - o No formal training, but had on-job training in the field
    - o No training at all
    - o Other (describe) ____

5. If you attended a training class for the automated truck mounted attenuator, how would you rate its overall effectiveness (1 not effective to 10 extremely effective) in explaining...

a) How the overall vehicle automation works	1 2 3 4 5 6 7 8 9 10
b) The location of the various automation system components	1 2 3 4 5 6 7 8 9 10
c) The purpose of the various automation system components	1 2 3 4 5 6 7 8 9 10
d) How to start the automation	1 2 3 4 5 6 7 8 9 10
e) How to override the automation	1 2 3 4 5 6 7 8 9 10
f) The operating limits of the automation	1 2 3 4 5 6 7 8 9 10

6. What is your typical role as it relates to the automated truck mounted attenuator? (example: supervisor, lead vehicle driver, autonomous safety operator, paint striper, etc.)

    ____

7. What state DOT do you work for? ____

8. How long have you worked for the DOT? ____

9. Consider the automation display monitor/tablet in the lead vehicle for the follow vehicle automation. How strongly do you agree (1 strongly disagree to 7 strongly agree) with the following statements...

a) The information is clear and understandable	1 2 3 4 5 6 7
b) The display warns about too many obstacles	1 2 3 4 5 6 7
c) The display requires too much input during automation start up	1 2 3 4 5 6 7
d) The display requires too much input while automation is running	1 2 3 4 5 6 7
e) Warnings are provided with enough time to appropriately respond	1 2 3 4 5 6 7

10. How strongly do you agree (1 strongly disagree to 7 strongly agree) with the following statements about the automated truck mounted attenuator...

a) The automation is an overall improvement compared to having a human drive the truck mounted attenuator vehicle	1 2 3 4 5 6 7
b) The automation is frustrating to use	1 2 3 4 5 6 7
c) I trust the driving skills of the automation more than my own driving skills	1 2 3 4 5 6 7
d) The automation will reduce the number of crashes	1 2 3 4 5 6 7
e) The automation will reduce the severity of crashes	1 2 3 4 5 6 7
f) The automation will reduce the length of time it takes to finish a project	1 2 3 4 5 6 7
g) The e-stop button(s) inside the lead vehicle are in a good location for pressing during an emergency	1 2 3 4 5 6 7
h) The e-stop button(s) outside the follow vehicle are in a good location for pressing during an emergency	1 2 3 4 5 6 7
i) The a-stop button(s) inside the lead vehicle are in a good location for pressing when an obstacle has been detected	1 2 3 4 5 6 7

11. On a scale of 1 (not confident at all) to 10 (extremely confident), how confident are you that the vehicle can safely and reliably operate in automated mode in the following conditions...

a) fog	1 2 3 4 5 6 7 8 9 10
b) snow	1 2 3 4 5 6 7 8 9 10
c) heavy rain	1 2 3 4 5 6 7 8 9 10
d) dark	1 2 3 4 5 6 7 8 9 10
e) no traffic	1 2 3 4 5 6 7 8 9 10
f) light traffic	1 2 3 4 5 6 7 8 9 10
g) moderate traffic	1 2 3 4 5 6 7 8 9 10
h) dense traffic	1 2 3 4 5 6 7 8 9 10
i) hilly roads	1 2 3 4 5 6 7 8 9 10
j) curved roads	1 2 3 4 5 6 7 8 9 10
k) short overpasses	1 2 3 4 5 6 7 8 9 10
l) long tunnels	1 2 3 4 5 6 7 8 9 10

12. Consider the vehicle operating in automated driving. On a scale of 1 (not confident at all) to 10 (extremely confident), how confident are you that...

a) You understand the operating limits of the automation	1 2 3 4 5 6 7 8 9 10
b) The vehicle can drive without assistance from an operator	1 2 3 4 5 6 7 8 9 10
c) The vehicle reliably detects obstacles	1 2 3 4 5 6 7 8 9 10
d) The vehicle responds appropriately to obstacles without user interference	1 2 3 4 5 6 7 8 9 10
e) The vehicle would stop if you walked in front of it	1 2 3 4 5 6 7 8 9 10
f) You could stop the automation if needed in a critical situation	1 2 3 4 5 6 7 8 9 10
g) It is safe to change lanes with the automation on	1 2 3 4 5 6 7 8 9 10
h) You can tell when one of the sensors are not working properly	1 2 3 4 5 6 7 8 9 10

13. How important (1 not important to 10 extremely important) in terms of balancing safety and productivity do you think the following are while operating the vehicle in automated mode...

a) There should be an operator who's only task is to monitor the follow vehicle	1 2 3 4 5 6 7 8 9 10
b) There should be specific phrases/terms used between the drivers of the lead and follow vehicles during start-up	1 2 3 4 5 6 7 8 9 10
c) At least one operator should have visual line of sight of the follow vehicle	1 2 3 4 5 6 7 8 9 10
d) Using the automation checklist during start-up	1 2 3 4 5 6 7 8 9 10

14. While in automated mode, the gap distance between the lead vehicle and follow vehicle should be...
    - o Much longer than if a human was driving
    - o Somewhat longer than if a human was driving
    - o About the same
    - o Somewhat shorter than if a human was driving
    - o Much shorter than if a human was driving

15. What do you think is the max speed the automation can safely operate? __________________

16. Because this is an autonomous vehicle, do you change the way you operate the attenuator truck? If so, how? ____

17. Do you have any further opinions about the automated truck mounted attenuator? (Such as: Why it is or is not a good addition to the fleet? When you think it should or should not be used? etc.) ____