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Do first responders trust connected and automated vehicles (CAVs)? A national survey

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ABSTRACT

Connected and automated vehicles (CAVs) leverage emerging vehicle connectivity and automation technologies to enhance traffic safety. Extensive research has been done to examine the safety impacts of CAVs on road users (including vehicle occupants and vulnerable road users). Still, the impacts on first responders, who respond to traffic incidents and assist road users, are under-discussed. Road users show growing interest in CAVs, but it is uncertain whether first responders would feel the same way. First responders face the risk of being struck by passing vehicles when they perform their duties on road or roadside. In addition, it is unknown whether CAVs can or will do a better job than human drivers in conventional vehicles when passing an incident scene. This study conducted a national survey among first responders in the US to understand their knowledge and incident management experiences related to CAVs, as well as their attributes and concerns towards CAV technologies, including advanced driver assistance system (ADAS), connected vehicle (CV) and self-driving or autonomous vehicle (AV) technologies. Over 1000 first responders participated in the survey, and the survey had representation from all 50 states, Washington DC, and US Territories. The survey results showed that 82% of first responders have not received any CAV-related safety training, and 41% of first responders self-reported having little knowledge about CAVs. Regarding the roles of AVs in emergency responses, only a tiny portion (3%) of first responders would trust AVs more than human drivers passing an incident scene, and the majority (86%) of first responders do not think AVs will outperform human drivers. Only 1% of first responders said they trust AVs, and 44% stated that they do not trust AVs at all. A statistical model was developed to identify the correlates of first responders' trust in AVs. Modeling results showed that education positively correlates to the likelihood of trusting AVs. This study found significant differences in perceptions towards CAVs across emergency response agencies and geographic regions. Law enforcement officers exhibit higher trust in AVs compared to firefighters; responders from DOT or public works are associated with the lowest levels of trust among all emergency response agencies. FEMA Region 3, which includes Maryland, Pennsylvania, and Virginia, shows the lowest levels of trust in AVs compared to human drivers among all regions in the country. This study provides valuable information for stakeholders to prepare responders for next-generation transportation emergency responses.

1. Introduction

Connected and automated vehicles (CAVs) encompass a range of emerging vehicle connectivity and automation technologies to enhance transportation safety. Given the technological and conceptual overlaps of emerging vehicle technologies, the acronym "CAV" in this study, except where otherwise specified, refers to any technologies related to connected vehicles (CVs), advanced driver assistance systems (ADAS), and/or self-driving or autonomous vehicles (AVs). These technologies are continually evolving, with considerable efforts from manufacturers and governments focused on their improvement (USDOT, 2021; NHSTA, n.d; Holt, 2021; Ford Media Center, 2021; LaReau, 2021). Existing research on CAVs has primarily focused on their impacts on road users, including vehicle occupants and vulnerable road users (Li and

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Kockelman, 2016; Papadoulis et al., 2019; Sinha et al., 2020; Wang et al., 2021; Fu et al., 2022; Wang et al., 2021; Fu et al., 2022; Liu et al., 2017; Liu and Khattak, 2016, 2020; Wang et al., 2021). However, little attention has been given to understanding the impacts of CAVs on the individuals responsible for managing roads—first responders who play a crucial role in traffic incident management (TIM) and roadside assistance. These responders include law enforcement officers, highway safety service patrol (SSP) operators, firefighters, emergency medical technicians, tow truck operators, and mobile mechanics.

Transitioning to CAVs presents both opportunities and challenges for traffic incident responders. Geofencing emergency response scenes using CAV technologies can enhance scene safety, while motorist alert systems can increase driver attentiveness and responsiveness, improving conditions for responders and road users (FHWA, 2022). A recent survey by the National Safety Council and the Emergency Responder Safety Institute (2019) found that 19% of drivers admit to inattentive driving that may put first responders at risk, while 24% are unaware of legal requirements when encountering emergency vehicles. Compared to human drivers who make errors leading to crashes, autonomous vehicles (AVs) are believed to be more reliable (RBR, 2019). However, it remains unclear how CAVs will interact with first responders at traffic incidents and emergency scenes compared to human drivers (Transportation Safety Advancement Group, 2020). Moreover, as AVs become more prevalent, understanding the risks and challenges associated with CAVs for first responders is crucial, given the rapidly evolving nature of the technology.

While numerous survey-based studies have explored public perceptions and interests regarding the deployment of connected and automated vehicles (CAVs) (Becker and Axhausen, 2017; Fu et al., 2022; Gkartzonikas and Gkritza, 2019), there is a notable lack of research on the perspectives of first responders. Although a few studies have touched on this topic, such as focus groups and interviews with emergency response officials (Terry et al., 2018; Transportation Safety Advancement Group, 2020), there remains a significant gap in scholarly research specifically investigating first responders' perceptions towards CAVs. To address this research gap, the present study conducted a national survey among first responders in the United States. The survey aimed to understand their knowledge, experiences, and perceptions related to CAVs, as well as their concerns and attributes concerning CAV technologies. Importantly, to the best of the authors' knowledge, no prior scholarly research has explored first responders' perceptions towards CAVs. They survey results can shed light on several key questions.

- How much knowledge do first responders have about CAVs?
- How many first responders have received safety training related to CAVs?
- Do first responders think CAVs have any bearing on how they manage a scene with these technologies?
- Do first responders trust CAVs more than human drivers while they pass an incident scene?
- Are there any organizational and geographic disparities among first responders in terms of their perceptions towards CAVs?

The survey, distributed through the network of the Emergency Responder Safety Institute (ERSI), garnered responses from over 1000 first responders across all 50 states, Washington DC, and U.S. territories. Through descriptive analyses and statistical modeling, this study identified key patterns in survey responses and explored correlates of first responders' perceptions towards CAVs. The outcomes of this study have the potential to provide valuable insights into first responders' perceptions and attitudes towards CAVs. This information can contribute to an improved understanding of the specific needs and concerns of first responders regarding CAV adoptions. Ultimately, it can help inform the development of appropriate training programs, policies, and strategies that ensure the effective and safe integration of CAVs into emergency response operations.

2. Literature review

Connected and automated vehicles (CAVs) have been a topic of extensive research in the transportation community over the past decade. While there is a significant body of research on the benefits of CAVs and public perceptions, there is a lack of studies specifically investigating the perspectives of first responders who are responsible for managing traffic incidents and ensuring road safety. This literature review provides an overview of the existing research on CAV impacts, public interest and acceptance, and the limited research on CAV-related emergency response.

2.1. CAV impacts

There has been extensive research on the impacts of CAVs on transportation systems, particularly in terms of safety (Li and Kockelman, 2016; Papadoulis et al., 2019; Sinha et al., 2020; Wang et al., 2021). For example, Li and Kockelman (2016) evaluated the safety benefits of CAV technologies by anticipating the reductions in various types of traffic crashes, including vehicle-to-vehicle crashes, and vehicle-to-pedestrian, and vehicle-to-cyclist crashes. Papadoulis et al. (2019) and Sinha et al. (2020) provided safety evaluation of mixing CAVs in traffic flows with traditional vehicles. Their assessment was based on the changes in crash events or conflicts involving motorists before and after CAV deployment of CAVs with different penetration rates. These studies provided valuable insights into the reductions in traffic crashes that can be achieved through the implementation of CAV technologies.

2.2. CAV interest and acceptance

As CAVs emerge as significant transportation technologies, understanding public interest and acceptance is crucial for effective deployment (Fu et al., 2022). Researchers, such as Bansal and Kockelman (2017), have conducted national surveys to gauge public interest in specific CAV applications, such as adaptive cruise control and blind-spot monitoring. The level of interest varies across different applications, with a significant proportion of survey participants expressing high interest in blind-spot monitoring. Xiao and Goulias (2021) examined the attributes and concerns of individuals regarding autonomous vehicles (AVs) in the Puget Sound Region of the United States. They found a mixture of positive attitudes and safety concerns toward AVs, which have increased over time. Comprehensive reviews by Becker and Axhausen (2017) and Gkartzonikas and Gkritza (2019) have explored people's interest in CAVs based on relevant studies. Additionally, Kasper et al. (2021) extended this topic to investigate the potential impact of the COVID-19 pandemic on public acceptance of self-driving delivery vehicles. In short, findings regarding public interest and perceptions of CAV technologies vary across studies. However, it is evident that people have mixed feelings about CAVs, especially when exposed to news reports of traffic crashes involving CAVs (Gladden, 2021). Recent reports have highlighted incidents where automation technologies, particularly in partially automated driver-assist systems like those used by Tesla, have been involved in crashes (NPR, 2022). Despite these incidents, there is still a growing interest in CAVs due to their overall promising safety impacts on transportation systems (Gladden, 2021; Teague, 2021; Yang and Fisher, 2021).

2.3. CAV-related emergency response research

Scholarly research examining the influence of connected and automated vehicles (CAVs) on emergency responses is relatively scarce. A study conducted by Terry et al. (2018) involved focus groups and one-on-one interviews with 79 public safety officials from emergency response agencies in the United States and Canada. Participants were asked to consider six hypothetical emergency response scenarios, including traffic stops, traffic direction, securing a scene, and responding to an incident, in the context of CAVs operating in a driverless mode. The study provided valuable insights for improving first responders' interactions with CAVs at incident scenes. Notably, the study highlighted the importance of consistent behavior in Level 4 and Level 5 automated driving systems (ADS) to enhance the safety of public safety officials during incident response and traffic control. Furthermore, the availability of advance information about the involved vehicles was identified as a means to improve response efficiency by enabling better resource management. Enhanced connected-communications between public safety officials and surrounding CAVs were found to enhance safety during response operations and traffic control. In addition, data obtained from ADS-equipped vehicles, such as speed records and diagnostics, were deemed valuable for aiding investigations at incident scenes and traffic stops. The Transportation Safety Advancement Group (2020) conducted a survey to assess respondents' familiarity with and confidence in CAV technology. It is important to note that this survey was not conducted using scientific methods and collected a total of 32 responses, with only 7 respondents identified as being from emergency response agencies. Of these, there was only one respondent from the fire department and one from law enforcement. The survey provided some insights regarding the impact of CAVs on emergency responses. One notable concern raised by survey participants was whether CAVs, when operating autonomously, would respond safely and appropriately to temporal traffic controls and first responders at an incident scene. Additionally, there was little confidence among the survey participants that autonomous vehicles (AVs) would respond properly by pulling over and yielding the right of way to emergency vehicles. Furthermore, it remains unclear how or whether CAVs can comply with Move Over Laws. Additionally, ongoing research sponsored by the National Cooperative Highway Research Program (NCHRP, 2022), specifically project 20–102 (16) titled "Impacts of Connected, Automated Vehicle Technologies on Traffic Incident Management Response," aims to develop guidance for preparing emergency responders for CAV deployment. It is worth noting that this research project does not propose specific scientific research tasks, such as surveys or experiments, to directly investigate responders' perceptions towards CAVs.

3. Methodology

Fig. 1 illustrates the methodology employed in this study, which involved conducting a national survey among first responders. The primary objectives of the survey were twofold: 1) to gather information regarding the perceptions of first responders towards CAV technologies, and 2) to identify the contributing factors that influence their perceptions through data analysis and modeling of the survey data.

3.1. Survey design

This study designed a national survey to collect information on first responders' knowledge and incident management experiences related to CAVs, as well as their attributes and concerns towards CAV technologies. The survey consisted of three sections. The first section included questions about socio-demographics, such as gender, age, race, education, state of residence, and agency/organization type (fire, police, emergency medical service, towing, etc.). The second section focused on responders' working experience and general responder safety training background, which was not specifically related to CAVs. The third section formed the core of the survey and included questions about first responders' CAV-related training (if any), their knowledge and perceptions towards CAVs, and their concerns, challenges, and perceived risks as a first responder in an environment with large-scale CAV deployment. Respondents were also asked to provide recommendations for improving responder safety in the context of CAVs. Additionally, the survey included questions about respondents' incident experiences, as it was hypothesized that a first responder's perception, such as their trust in CAVs, may be influenced by their involvement in near-miss or struck-by events. Respondents were asked to rate and compare their trust in human drivers and CAV technology, particularly full automation, considering their impacts on the safety of first responders at emergency response scenes. Prior to the CAV-related questions, the survey provided a brief introduction to CAV technologies, encompassing connected vehicles (CVs), advanced driver assistance systems (ADAS), and self-driving or autonomous vehicles (AVs). Table 1 presents the survey design, outlining the specific questions asked in the survey.

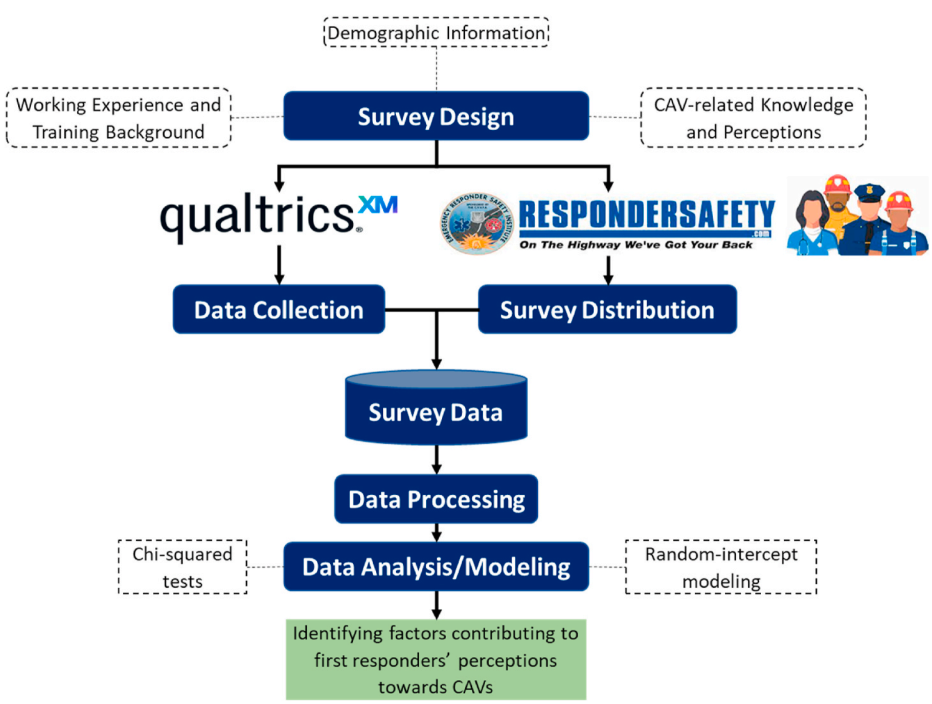


Fig. 1. Overview of methodology.

Table 1
Survey sections and key questions.

Section	Questions	Type of Response
Section I: Demographic information	1. What is your gender?	Categorical, single choice (3 choices)
	2. What is your age?	Continuous
	3. What is your ethnicity?	Categorical, single choice (5 choices)
	4. What is the state of your primary residence?	Categorical, single choice (52 choices)
	5. What is the highest degree or level of education you have completed?	Categorical, single choice (7 choices)
	6. What is the type of your organization?	Categorical, single choice (7 choices)
Section II: Working experience and training background	7. How many years of experience do you have as an incident responder?	Categorical, single choice (7 choices)
	8. Have you ever completed any responder safety training?	Categorical, single choice (3 choices)
	8.a. How often do you participate in TIM responder safety training?	Categorical, single choice (6 choices)
	9. Have you ever experienced a near-miss or struck-by incident?	Categorical, single choice (3 choices)
	9.a. When was the last time you experienced a struck-by incident?	Categorical, single choice (6 choices)
	9.b. How often do you typically experience near-miss incidents?	Categorical, single choice (6 choices)
	10. What are the most probable reasons for near-miss or struck-by incidents?	Categorical, multiple choices (10 choices)
	11. As a responder, how much do you trust human drivers passing an incident scene?	Ordinal, single choice (6 choices)
	12. Which factors make you trust/distrust human drivers?	Categorical, multiple choices (9 choices)
Section III: CAV-related knowledge and perceptions	13. Before participating in this survey, are you familiar with CAV technologies?	Categorical, single choice (5 choices)
	14. Do you own a vehicle with CAV technologies or applications?	Categorical, single choice (7 choices)
	15. As a vehicle user or rider, how much do you trust AVs or self-driving cars?	Ordinal, single choice (6 choices)
	9.c. Have you received any safety training related to CV, ADAS, and/or AV technologies?	Categorical, single choice (4 choices)
	9.d. What programs have you received CAV-related safety training?	Categorical, multiple choices (5 choices)
	16. As a responder, do you trust self-driving cars more than human drivers?	Categorical, single choice (3 choices)
	17. Which factors make you trust/distrust self-driving cars?	Categorical, multiple choices (10 choices)
	18. Do you think any bearing CAVs have on how you manage traffic incidents? If yes, please specify.	Open-ended
	19. Which of the provided recommendations would improve responder safety on roadways with self-driving cars?	Categorical, multiple choices (8 choices)

Notes: Respondents were allowed to skip some questions if not applicable to them. For example, if a person answered that they never completed any responder safety training, this person would not be shown the question about CAV responder safety training. In Table 1, the primary questions were labeled using numbers, while subset questions (which may be skipped) were labeled using the same numbers but with an additional letter.

3.2. Survey distribution and data collection

This was an online survey created using Qualtrics. The survey was administered after obtaining Institutional Review Board (IRB) approval from the University of Alabama. Prior to entering the survey, all participants were required to provide consent to be included in the study. The study received support from the Emergency Responder Safety Institute (ERSI), which facilitated the distribution of the survey through their responder safety learning network (Liu et al., 2023). A pilot test was conducted to assess the survey's effectiveness prior to its full rollout among the ERSI network. The survey was sent to a random sample of 500 contacts from ERSI's contact list, which consists of over 10,000 first responders in the US. Within three days, 10 responses were collected, and close attention was paid to participants' completion times. The average completion time exceeded 20 min, leading to adjustments aimed at ensuring the survey could be finished within 15 min for most participants. The adjustments included removing certain questions and improving others, such as converting open-ended questions to multiple-choice format. The full survey rollout began on July 19, 2022 (Tuesday) and recorded over 1196 unique responses within a week. The average time taken to complete the survey was 20.72 min, with a standard deviation of 74.73. It is important to note that some participants had extremely long completion times, contributing to the higher standard deviation. The median completion time was 10.13 min, and the 75th percentile value was 14.25 min. The survey had representation from all 50 states, Washington DC, and U.S. Territories. As an incentive for survey participation, a raffle was conducted among the first 250 respondents, which included the 10 participants from the pilot test. $25 gift cards were offered as prizes to encourage their involvement.

3.3. Data analysis and modeling

Prior to conducting the analysis, data pre-processing was conducted in this study. This involved the removal of responses completed within 3 min and the exclusion of respondents who reported being too young, such as those aged 18–20 years, considering their self-reported working experience of over 10 years. The final dataset used for analysis consisted of 1049 complete responses. Descriptive analysis methods were employed to analyze the survey data, including the use of tables and charts, as well as modeling the correlates of responses to key survey questions, such as the level of trust in CAVs. Chi-squared tests were performed in the descriptive analysis to examine the significance of associations between variables of interest. The dependent variable in the analysis was binary, indicating whether a responder trusts an AV or self-driving car more than human drivers passing an incident scene. A binary logistic regression model was estimated to determine the relationships between the dependent and independent variables. Equations (1)–(3) were used to formulate the model estimation process.

$$P_i = Pr\ (Y = 1|X = x_i) \tag{1}$$

$$Log\frac{P_i}{1 - P_i} = logit(P_i) = \beta_0 + \beta_1 x_i \tag{2}$$

$$P_i = \frac{exp\ (\beta_0 + \beta_1 x_i)}{1 + exp\ (\beta_0 + \beta_1 x_i)} \tag{3}$$

where P_i is the probability that the corresponding $Y = 1$ will be satisfied, meaning a participant trusts AVs more than human drivers; β_0 is the model intercept and β_1 represents the coefficients of independent variables x_i, such as sociodemographic factors and response agency dummy variables. Considering the multi-level structure embedded in the survey data (i.e., responses nested in states which are further nested in geographic regions), this study considered a hierarchical modeling technique to capture the potential observed factors at different hierarchies. Specifically, this study adopted the random-intercept modeling to allow model intercept estimates β_0 to vary across states:

$$\beta_0 \sim N\ (\mu, \sigma^2) \tag{4}$$

where, β_0 are the random parameters that follow a normal distribution with a mean μ and variance σ^2. The odds ratios were calculated based on model estimates to quantify the effect of independent variables on the dependent variable:

$$OR = \frac{\frac{Pr\ (Y_i=1|X=x_i+1)}{1-Pr\ (Y_i=1|X=x_i+1)}}{\frac{Pr\ (Y_i=1|X=x_i)}{1-Pr\ (Y_i=1|X=x_i)}} = \frac{exp\ (\beta_0 + \beta_1(x_i+1))}{exp\ (\beta_0 + \beta_1 x_i)} = \exp(\beta_1) \tag{5}$$

It is defined as the ratio of the probability of happening of an event to the probability of not happening of an event, e.g., the probability of a first responder trusting AVs more than human driver's vs the probability of a first responder not trusting AVs more than human drivers. A paper by Dai et al. (2006) provides more technical details about logistic regression with random intercepts.

4. Descriptive analysis results

4.1. Socio-demographics of survey participants

Fig. 2 illustrates the gender and age distributions of the first responders who participated in the survey. The majority of survey participants (83%) were male, and over 50% of them were 45 years or older. Fig. 3 presents the socio-demographic distributions of race and education levels among the survey participants. The survey had a significant representation of Caucasian or White individuals (84%). Latino or Hispanic individuals accounted for only 3% of the sample, African Americans accounted for 2.5%, and there were also participants from Native American, Asian, Native Hawaiian or Pacific Islander, and multiracial backgrounds. In terms of education, 34% of the respondents held a bachelor's degree or higher, while 41% had an associate degree or attended a technical or trade college.

Fig. 4 provides a breakdown of the agency types represented by the survey participants. It should be noted that respondents were allowed to select multiple agencies if they had experience working with various organizations. Among the participants, 32% reported having worked for multiple emergency response agencies. Among those representing a single agency, 43% were from fire departments, 9.2% were from paramedics or private emergency medical services (EMS), 5.9% were from law enforcement, 3.2% were from the towing and recovery industry, and 3% were from the Department of Transportation (DOT) or public works.

Fig. 5 displays the geographic distributions of the survey participants, categorized by state and the 10 FEMA regions in the United States. The survey included participants from all 50 states, Washington DC, and US Territories. However, it is important to note that the obtained samples may not fully represent the overall population of first responders in the United States in terms of the stated regions or FEMA regions. The survey's sampling methodology may have led to certain regions being over- or under-represented.

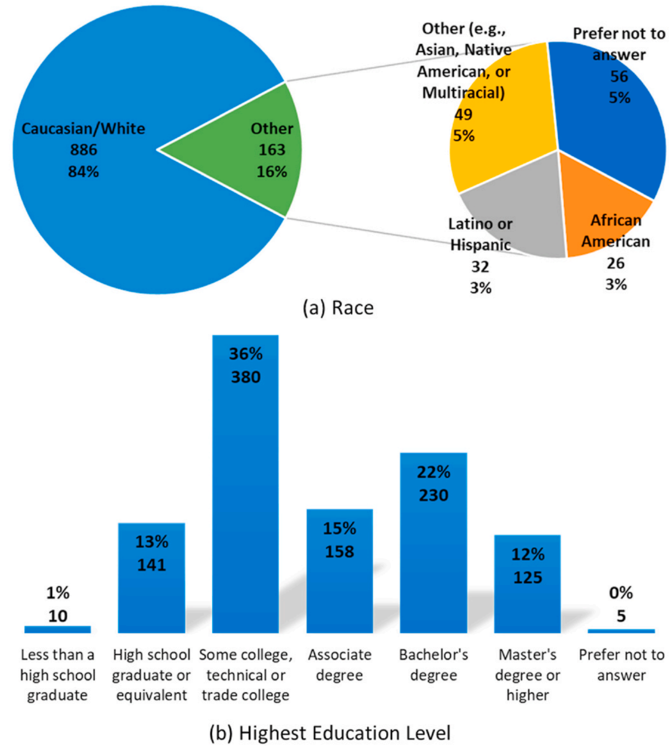


Fig. 3. Sample distributions by race and education level (N = 1049).

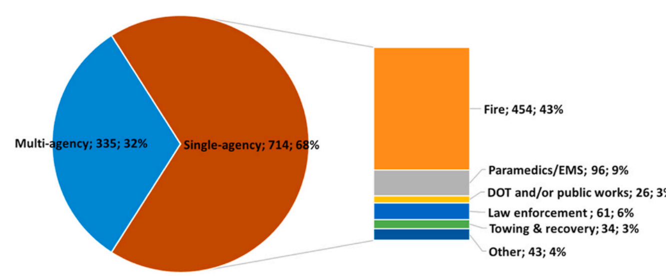


Fig. 4. Sample distribution by agency type (N = 1049).

4.2. Current emergency response practices

Fig. 6 presents the distributions of survey participants' working experience and training background. Specifically, 46% of the participants indicated having over 20 years of working experience as first

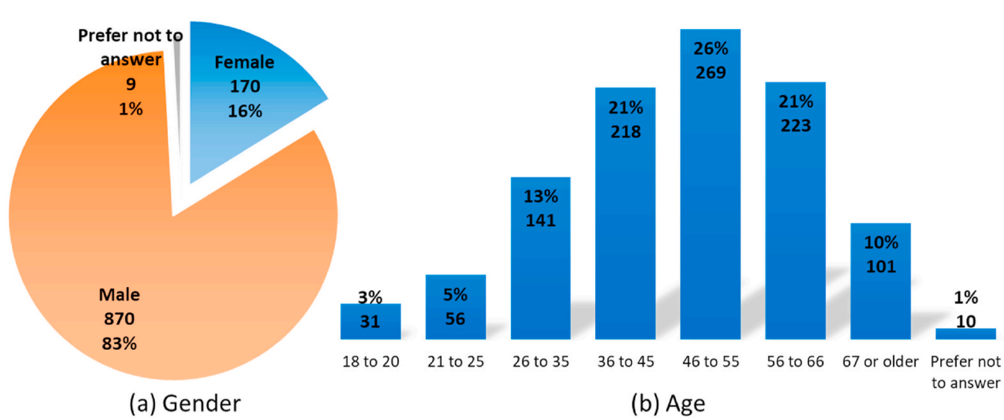


Fig. 2. Gender and age distributions of survey participants (N = 1049).

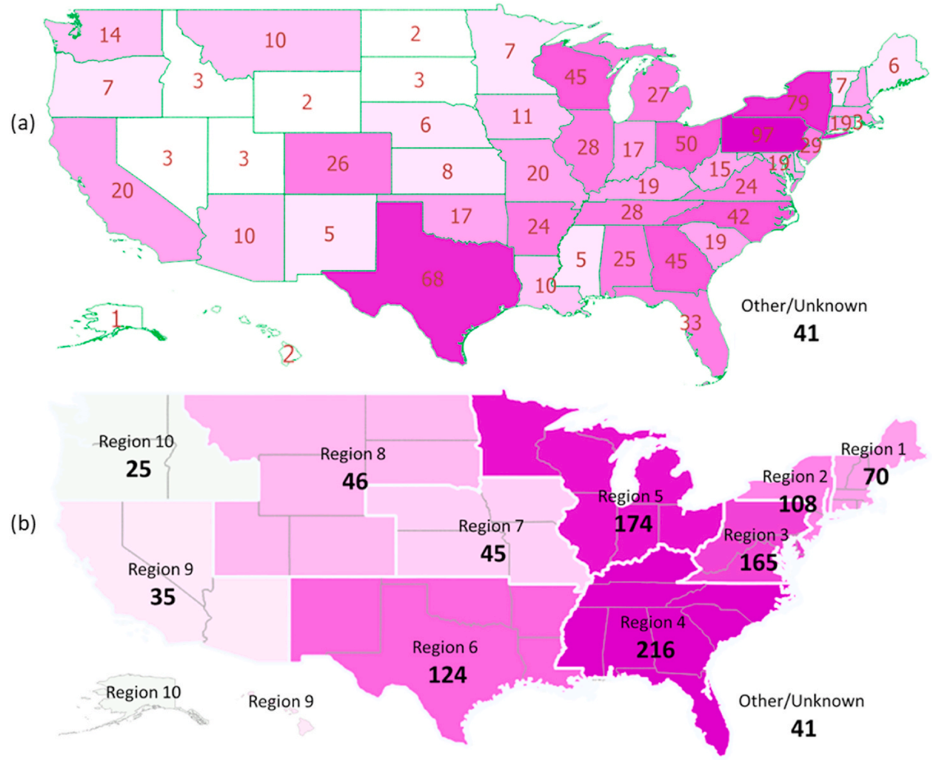


Fig. 5. Geographic distributions of survey participants (N = 1049): (a) by state and (b) by FEMA region.

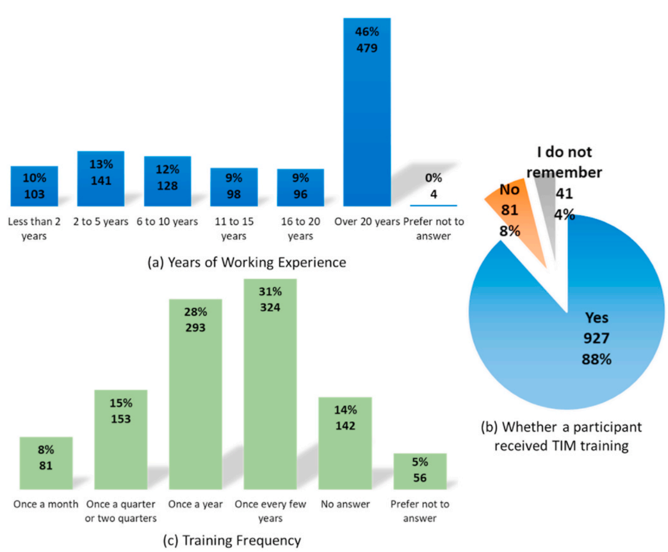


Fig. 6. Working experience and training background: (a) Years of working experience; (b) whether a participant received TIM training; (c) Frequency of TIM training.

responders, while 10% reported having less than 2 years of emergency response experience. Regarding Traffic Incident Management (TIM) training, most respondents (88%) said they had received relevant responder safety training, particularly focusing on responder safety. Less than 8% said they never received any training. Participants were also asked how often they receive responder safety training; over 60% said they attended the safety training once a year or more frequently.

In addition, participants were asked to share their experiences of being involved in incidents such as near-miss or struck-by events and their perspectives regarding the roles of human driver behaviors in the safety of first responders. As shown in Fig. 7, a significant majority (59%) reported having experience being involved in near-miss or struck-by incidents. Thankfully, the frequency of these incidents among responders is low. Various reasons contribute to these incidents, as identified by the participants. The highest percentage (93%) believed that driver distraction is the most probable cause for such incidents. This was followed by inattentive driving behavior, with 77% of participants acknowledging it as a contributing factor, and driving under the influence (DUI), which was identified by 63% of participants. When rating the level of trust in human drivers passing an incident scene, 43% of the participants said they did not trust human drivers at all, implying the need to develop strategies to increase the responders' trust in passing drivers or vehicles.

4.3. *CAV-related knowledge and training background*

Fig. 8 shows the distributions of survey participants' knowledge and perceptions relevant to CAV technologies. Regarding familiarity with CAV technology, around 35% of the participants reported that they are familiar with CVs, ADAS, and AVs; there is no significant difference among these three concepts. It is possible that both the technological and conceptual overlaps exist in CVs, ADAS, and AVs. Furthermore, 41% of the participants indicated that they were not familiar with any of these CAV concepts. Though some CAV applications are built into recent vehicle models (Sinclair, 2021), most participants (54.2%) said that they own a vehicle with CAV features, not excluding participants (14%) who do not have a vehicle. About 17% of the participants said their vehicle has ADAS features, 7% said their vehicle has CV features, and only 2% reported that their vehicle has Level 3+ automation. Respondents were asked to rate their trust in AVs or self-driving cars as vehicle users or riders. The results showed that only 1% of the participants said that they trust AVs, and 44% said that they do not trust AVs at all.

Speaking of emergency response training (Fig. 9), 82% of the participants reported that they never received any CAV-related safety training, and 11% said they had received some CAV training. There may

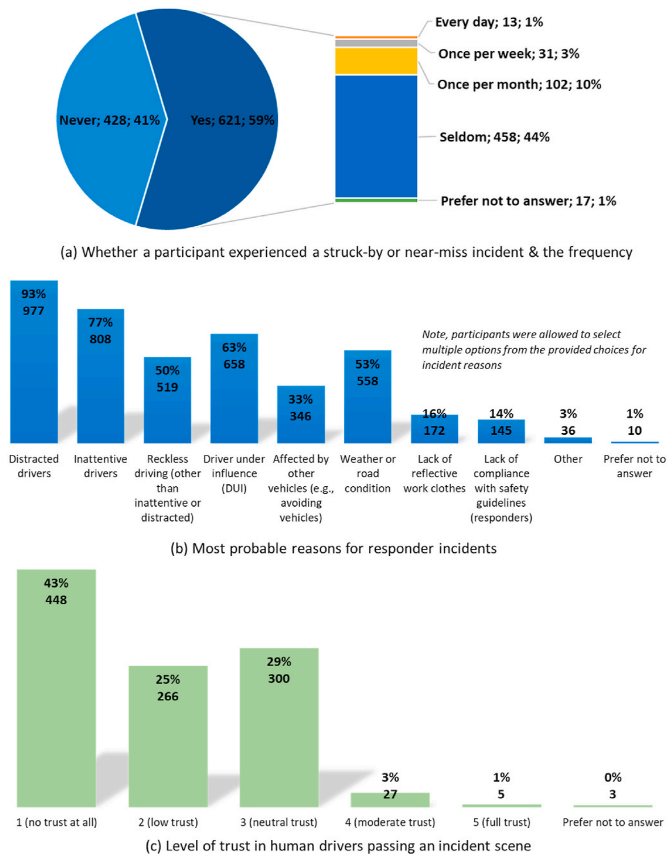


Fig. 7. Incident experiences and trust in human drivers (N = 1049): (a) Whether a participant experienced a struck-by or near-miss event; (b) Most probability reasons for responder incidents (Note, Participants to select multiple options from the provided choices for incident reasons); (c) Level of trust in human drivers.

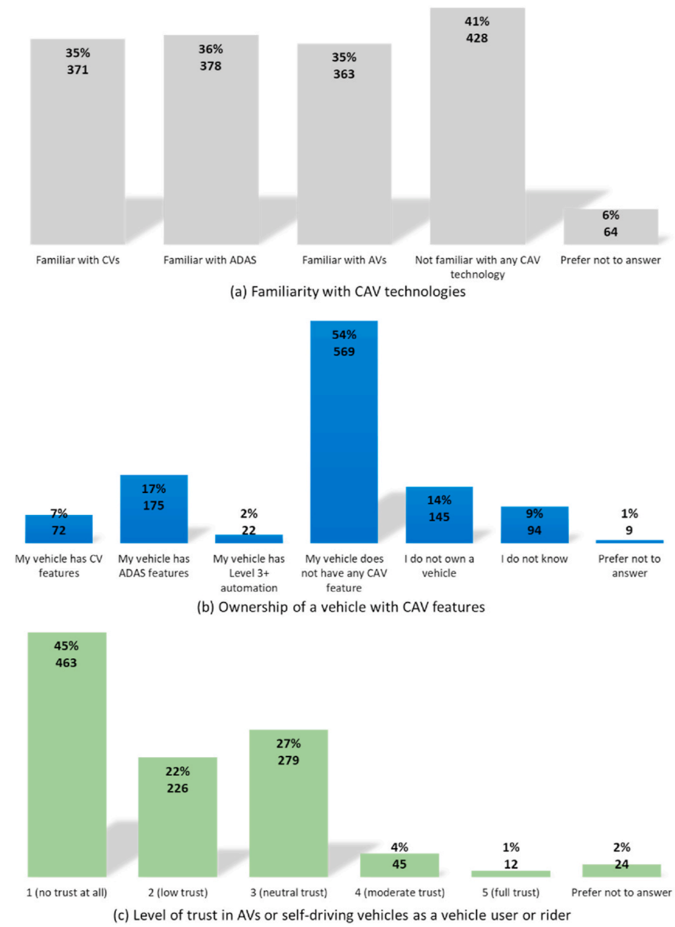


Fig. 8. Knowledge and perceptions relevant to CAV technologies (N = 1049): (a) Familiarity with CAV technologies; (b) Ownership of a vehicle with CAV features; (c) Level of trust in AVs or self-driving vehicles as a user or rider.

be a limited number of CAV-related training programs available for emergency responders. According to the survey, the most attended training program is offered by the Emergency Responder Safety Institute (ERSI), but only 76 participants out of 1049 attended the ERSI program. Most first responders in the U.S. remain under-educated about how to deal with CAVs in traffic incident management, and the efforts to provide CAV-related safety training to first responders are needed.

4.4. Perceptions towards CAVs

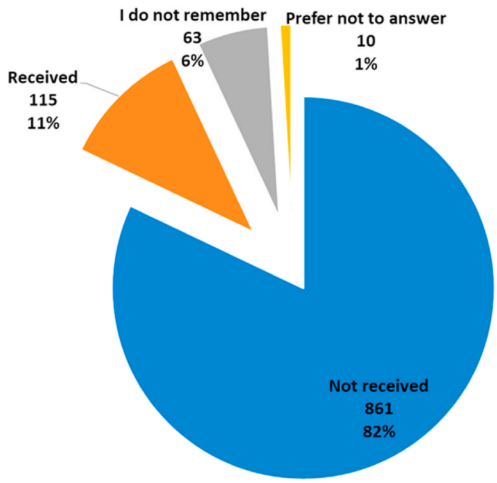
As stated above, human drivers are one of the leading issues associated with responder safety. CAVs are expected to help improve responder safety, but it was unclear whether first responders would believe so. In the survey, participants were asked whether they would trust AVs or self-driving vehicles more than human drivers passing an incident scene. As shown in Fig. 10, only 3% believed that AVs are more trustworthy than human drivers, and 86% said “No".

Table 2 shows the breakdown of responders’ trust in AVs compared to human drivers by agency. The results showed that participants from law enforcement have the highest odds of trusting AVs more than human drivers. Chi-squared tests were performed to examine whether there are significant disparities across agencies. When including participants representing multi-agency and other unidentified agencies, the chi-squared test result showed no significant inequality, possibly because many participants with multi-agency experience are from fire departments. The chi-squared test result showed marginally significant disparities across agencies (p-value = 0.06) if excluding responses from multi-agency and other agencies.

A chi-squared test showed the regional differences are statistically significant (Chi-squared = 20.62, df = 10, p-value = 0.02). Fig. 11 shows the percentages of the participants not trusting AVs more than human drivers in ten regions delineated by the FEMA (2020). Overall, states in the east and south are less likely to trust AVs over human drivers than states in the north and west. Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming) and Region 9 (California, Nevada, and Arizona) are associated with lower percentages of responders not trusting AVs more than human drivers. Region 3 (Delaware, Maryland, Pennsylvania, Virginia, District of Columbia, and West Virginia) has the highest percentage (93.9%) of responders not trusting AVs more than human drivers.

When asked about the reasons (Fig. 12) for not trusting AVs, 45% of the participants stated that AVs are unpredictable, 36% did not provide specific reasons, 34% mentioned not having experience managing AV crashes, and 30% said they were not trained to protect themselves from AVs passing an incident scene. Given these perceptions towards CAVs, participants were asked to suggest recommendations for improving the safety of first responders in the context of large-scale CAV deployment. As shown in Fig. 13, among the listed recommendations, the most suggested recommendation (68%) is safety training for first responders on CAV technology, followed by a crash warning system that would alert the traveling public (including self-driving cars) approaching the event scene (67%). More than half of the participants recommended standard protocols across manufacturers for disabling and towing AVs and standard behavioral responses of AVs to first responder commands.

In addition, participants were asked to provide feedback in response to an open-ended question regarding whether they believe CAVs have



(a) Whether a participant received CAV-related safety training (N = 1,049)

(b) What CAV-related programs a participant participated (N = 179)

Fig. 9. CAV-related safety training: (a) whether a participant received CAV-related training; (b) what CAV-related programs a participant participated.

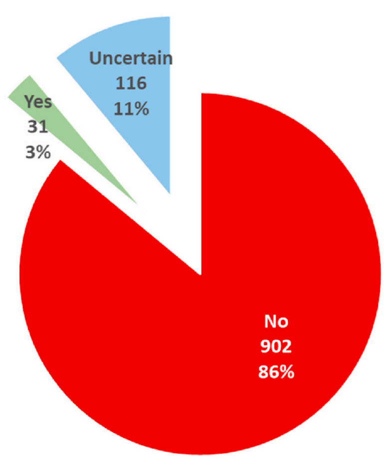


Fig. 10. Distribution of responses for the question - whether they would trust AVs or self-driving vehicles more than human drivers passing an incident scene (N = 1049).

any impact on how they manage traffic incidents. Out of over 350 participants, more than 30% expressed uncertainty about the potential impacts of CAVs on their safety and incident management practices. Approximately 20 participants specifically expressed concerns about the ability of AVs to accurately recognize incident scenes and respond appropriately to first responders on the road. Another concern raised by a few participants was related to the process of disabling CAVs. These concerns can be attributed to the limited knowledge that first responders (and the general public) have regarding CAV technology. The survey participants highlighted the need for training to adequately prepare them for the widespread adoption of CAVs. Appendix A provides selected comments shared by participants.

5. Modeling results

As shown in the previous section, the perceptions of first responders towards CAVs exhibit variability across emergency response agencies and geographic regions. Furthermore, additional factors, such as responder age, education, and CAV knowledge, may also contribute to their perceptions. To systematically identify the correlates of first responders' perceptions, this study developed a model to quantitatively estimate the relationships between their perceptions and the available factors in the survey data.

5.1. Model overview

Initially, a model was constructed by including all available variables from the survey data. These variables encompassed factors such as the age, gender, education, race, agency type, years of working experience, experience of near-miss and struck-by incidents, safety training, familiarity with CAV technology, level of trust in CAVs, level of trust in human drivers when passing an incident scene, and FEMA region (represented by dummy variables). Some of these variables displayed high correlation with others, such as age and years of working experience, as well as ownership of CAVs and familiarity with CAVs. Consequently, the variables for working years and ownership of CAVs were omitted from the final model. Similarly, certain variables, including CAV-related safety training and incident experience, demonstrated no significant relationship with first responders' perceptions towards CAVs and were excluded from the final model. It is worth noting that these insignificant relationships may be attributed to the limited sample size of the survey data. Revisiting these relationships with a larger dataset and employing advanced modeling techniques (e.g., machine learning) would be worthwhile. Table 3 presents the descriptive statistics of variables included in the final models. The dependent variable in this model is binary, representing whether a responder trusts an AV or self-driving car more than human drivers passing an incident scene (1 = Yes or Uncertain; 0 = No). It is worth noting that, for modeling purposes, the categories of "Yes" and "Uncertain" have been merged into a single category to prevent excessively small percentages in one category. Note, Observations with the response "Prefer not to answer" were removed, resulting in a final sample size of 1010 observations for modeling. Table 4 presents the final modeling results for both the fixed-intercept model and the random-intercept model, which incorporates a hierarchical modeling approach to account for the nested structure of the data. The random-intercept model considers the multi-level nature of the observations, where individual responses are nested within states. Based on model summary statistics, such as the Akaike Information Criterion (AIC) and R-squared, the random-intercept model slightly outperformed the fixed-intercept model. This indicates that the inclusion of the random intercepts at the state level improves the model's fit and captures some of the variability in the data due to state-level factors. All variables in the final models exhibit at least one significant estimate at a confidence level of 90% or higher (i.e., p-value <0.1), with these variables encompassing age, education, agency, familiarity with CAV technology, level of trust in CAVs, trust in human drivers, and FEMA region represented by dummy variables. The final modeling results show the quantified associations between responders' trust in AVs relative to human drivers when passing an incident scene.

5.2. Model interpretation

A positive coefficient indicates an increased likelihood or odds of trusting AVs more than human drivers when passing an incident scene. The modeling results reveal that older responders are less likely to trust AVs compared to human drivers. This may be related to the acceptance

Table 2
By-agency breakdown of responders' trust in AVs compared to in human drivers (N = 1049).

Agency	Trusting AVs more than human drivers				Odds of trusting AVs more than human drivers ("yes or uncertain" over "no")	Odds Ratio
	No		Yes or Uncertain			
	Freq	Percent	Freq	Percent		
Fire	395	90.0%	44	10.0%	0.11	0.37
Paramedics/Private EMS	82	88.2%	11	11.8%	0.13	0.44
Law enforcement	46	76.7%	14	23.3%	0.30	1 (reference)
Towing & Recovery	29	87.9%	4	12.1%	0.14	0.45
DOT and/or Public works	22	88.0%	3	12.0%	0.14	0.45
Multiagency	292	88.8%	37	11.2%	0.13	0.42
Other	36	92.3%	3	7.7%	0.08	0.27

Notes.
All responses: Chi-squared = 9.87, df = 6, p-value = 0.13.
Excluding multiagency and other: Chi-squared = 9.07, df = 4, p-value = 0.06.

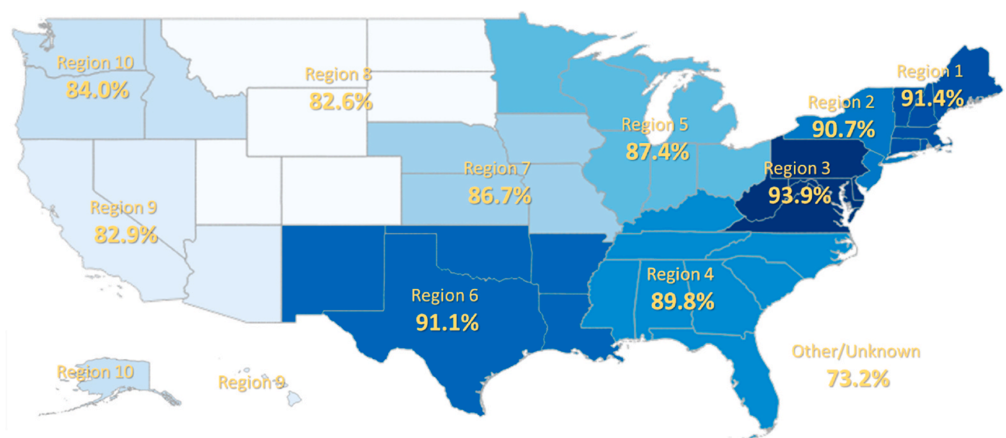


Fig. 11. By-FEMA region percentages of responders not trusting AVs more than human drivers (N = 1049).

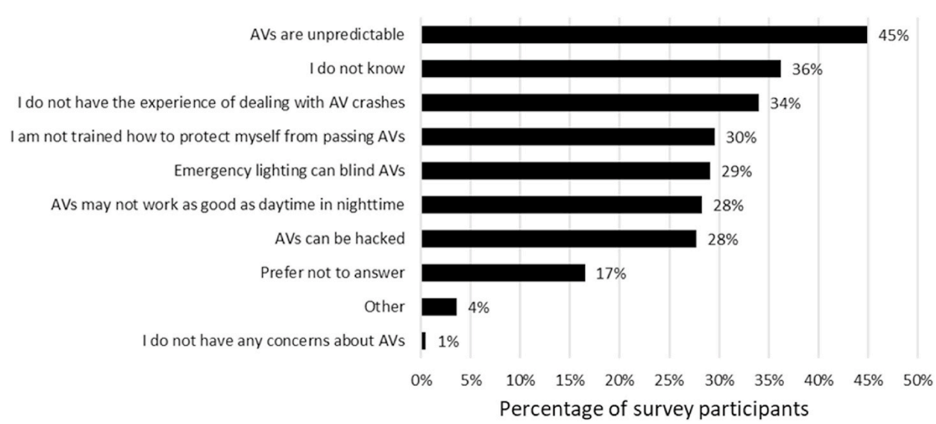


Fig. 12. Reasons for distrusting AVs (N = 1049) (Note: Participants were allowed to select multiple options from the provided choices).

of innovative technologies. Research has shown that younger people are more inclined towards new vehicle technologies, including connected vehicles and self-driving vehicles (Bansal and Kockelman, 2017; Xiao and Goulias, 2021). Education is another factor that its relationship with the odds of trusting AVs more than the knowledge about the technological acceptance can explain human drivers. A linear relationship between education level and the odds is found; a responder with a higher level of education is more likely to trust AVs than human drivers. Given an estimated odds ratio of exp (1.248) = 3.483, the odds of trusting AVs over human drivers can be 248.3% (or 2.483 times) higher among responders with a master's degree or higher education level compared to those with the highest education level equivalent to high school or lower. When comparing different emergency response agencies, law enforcement responders exhibit odds that are 215.8% (or 2.158 times) higher of trusting AVs over human drivers compared to responders from fire departments. In contrast, responders from DOT or public works agencies are associated with the lowest odds of trusting AVs. The reasons may be related to their working environments. Law enforcement responders are often more concerned about human behaviors (e.g., violations and crimes) in a traffic incident, while other agencies focus on the traffic and vehicles.

In the survey, the participants were asked to claim their familiarity with CAV technologies, and 41% of them stated that they were unfamiliar with any CAV-related technologies, including CV, ADAS, and AV.

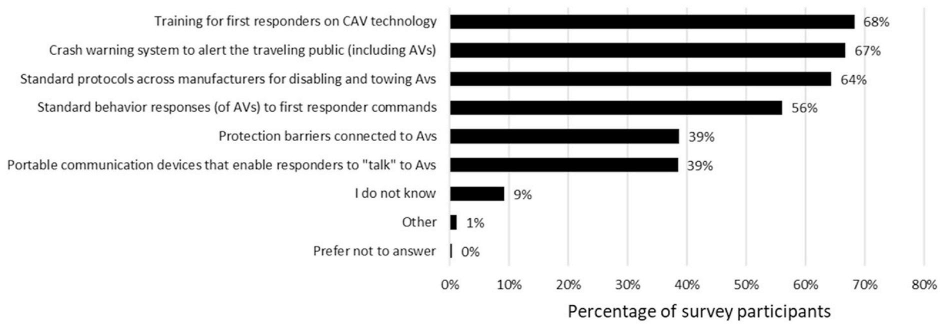


Fig. 13. Recommendations for improving responder safety (N = 1049) (Note: Participants were allowed to select multiple options from the provided choices).

The model in Table 4 reveals that among these participants, the odds of trusting AVs over human drivers can be 53.3% (=1–0.467) lower if first responders are familiar with ADAS and/or AV technologies. Two possible reasons could lead to this finding. A large amount of information and news available to first responders and the general public may be negative about AV technologies (Gutta, 2021; Hutson, 2017; VEST, n.d.). Another reason is that the emergency responses and the safety of responders have not been seriously thought of by manufacturers whose focus remains on their customers who will buy and use their vehicles (Responder Safety Learning Network, 2022).

A strong, positive, and linear relationship is found between the level of trust in AVs (as a vehicle user) and their trust in AVs compared to human drivers (as a responder), which is not surprising. Regarding the relationship with the level of trust in human drivers, most responders are concerned about motorist behaviors while passing an incident scene, stating that human drivers are most likely responsible for near-miss or struck-by incidents, according to the survey results shown in Fig. 7. The model estimates for other two levels of trust in human drivers (Level 2 and 3) show that responders who are more likely to trust drivers are less likely to trust AVs, indicating that they do not believe AVs will improve the safety of first responders. More specifically, the odds of trusting AVs over human drivers are 46.7% lower for respondents with Level 2 trust in human drivers and 51.4% lower for respondents with Level 3 trust in human drivers, in comparison to those with Level 1 trust in human drivers.

The estimates for FEMA region dummy variables confirmed the geographical differences in first responders' perceptions towards AVs, as shown in Fig. 11. By comparing the coefficient magnitudes, Regions 1 to 3 are associated with the least trust in AVs, followed by Regions 4 to 6. Regions 7 to 10 are associated with greater trust in AVs. Region 3 (Delaware, Maryland, Pennsylvania, Virginia, District of Columbia, and West Virginia) has the lowest odds of trusting AVs more than human drivers (80% lower than the base group).

6. Discussion

This study conducted a national survey aiming to provide insights into the current state of knowledge, training, and perceptions among first responders regarding the adoption of CAVs. The survey results are instrumental in identifying existing knowledge gaps and training needs, assessing the impact of CAVs on incident scene management, understanding the level of trust in CAVs compared to human drivers, and determining potential variations in perceptions based on organizational or geographic factors. The information obtained from the survey is expected to be highly valuable in informing the development of targeted interventions, training programs, and policies aimed at ensuring the effective and safe integration of CAVs into emergency response operations nationwide.

One of the key questions the survey aimed to address is: Do first responders trust connected and autonomous vehicles (CAVs), especially fully autonomous vehicles (AVs) or self-driving cars? It is important to understand their level of trust in CAVs as they will need to effectively interact with these vehicles under already-challenging circumstances such as managing traffic incidents or providing roadside assistance. Although CAVs are anticipated to enhance overall traffic safety, there is a lack of comprehensive discussion regarding their specific impact on first responders, who already encounter substantial risks in their line of work. To answer this question, the survey included three specific inquiries. First, it sought to determine whether first responders trust human drivers, considering that human behavior is responsible for the majority of traffic crashes (Shinar, 2017). Second, it assessed whether they trust AVs or self-driving vehicles as vehicle users or riders. Finally, it aimed to ascertain whether they trust CAVs more than human drivers, providing implications for the potential improvement of safety when working on the road or roadside, at least based on their perceptions.

Unsurprisingly, the survey results indicate a significant lack of trust in human drivers when passing an incident scene. A majority of surveyed first responders demonstrated either low trust (25%) or no trust at all (43%) in human drivers. Survey participants also shared their perspectives regarding the role of human driver behaviors in ensuring first responders' safety. An overwhelming 93% of participants identified driver distraction as the primary cause of struck-by incidents or near-miss events involving first responders on the road or roadside. Inattentive driving behavior (77%) and driving under the influence (DUI) (63%) were also identified as noteworthy concerns. These findings underscore the critical impact of the behaviors of passing drivers on the safety of first responders. Therefore, the adoption of CAVs that either assist drivers or take over driving tasks is expected to significantly improve responder safety. However, the survey results revealed a lack of trust in CAVs among first responders at the time of the survey. When asked to rate their trust in autonomous vehicles (AVs) or self-driving cars as vehicle users or riders, merely 1% of participants expressed trust in AVs, while 44% stated that they do not trust AVs at all. These survey findings align with a previous study conducted in 2021 which reported that nearly half of drivers feel less safe sharing the roads with AVs, and 63% expressed fear of riding in an AV (Edmonds, 2021). These results suggest that, at least at the time of the survey, first responders had not fully embraced the potential benefits of CAVs. Another key question directly asked participants to compare their trust in human drivers with their trust in AVs or self-driving vehicles passing an incident scene. The survey revealed that a mere 3% of respondents believed AVs to be more trustworthy than human drivers, whereas a substantial majority of 86% held the opposite view.

In short, the answer to the question "Do first responders trust CAVs?" is that the majority of first responders do not trust CAVs. There is prevalent skepticism among first responders regarding the trustworthiness of CAVs. These results indicate the necessity for efforts to address their concerns and build confidence in the safety and reliability of CAVs, particularly in relation to their operations when passing incident scenes. To inform the efforts, participants in the survey were asked to provide recommendations for improving the safety of first responders in the context of large-scale CAV deployment. The most suggested

Table 3
Descriptive statistics of model variables (N = 1010).

Variable	Category	Frequency	Percentage
Trusting AVs over human drivers[1]	No	896	88.7%
	Yes or Uncertain	114	11.3%
Age[2]	18 to 35	225	22.3%
	36 to 45	214	21.2%
	46 to 55	259	25.6%
	56 and above	312	30.9%
Education[3]	High school or lower	148	14.7%
	Some college or associate degree	523	51.8%
	Bachelor's degree	220	21.8%
	Master's degree or higher	119	11.8%
Agency	DOT and/or Public works	25	2.5%
	Fire	438	43.4%
	Law enforcement (police, sheriff, etc.)	59	5.8%
	Paramedics/Private EMS	95	9.4%
	Towing & Recovery	31	3.1%
	Multi-agency	324	32.1%
	Other	38	3.8%
Familiarity with CAV[4]	Familiar with CV	359	35.5%
	Familiar with ADAS or AV	441	43.7%
	Not familiar with any CAV technologies	428	42.4%
Level of trust in CAVs as a vehicle user or rider[5]	1 (no trust at all)	454	45.0%
	2 (low trust)	224	22.2%
	3 (neutral trust)	276	27.3%
	4 (moderate trust)	56	5.6%
Level of trust in human drivers passing an incident scene[5]	1 (no trust at all)	428	42.4%
	2 (low trust)	261	25.8%
	3 (neutral trust)	290	28.7%
	4 (moderate trust)	31	3.1%
FEMA Region	Region 1	66	6.5%
	Region 2	105	10.4%
	Region 3	161	15.9%
	Region 4	210	20.8%
	Region 5	169	16.7%
	Region 6	119	11.8%
	Region 7	42	4.2%
	Region 8	44	4.4%
	Region 9	33	3.3%
	Region 10	24	2.4%
	Other (e.g., U.S. Territories)	37	3.7%

Notes.
1. To prevent excessively small percentages in one category for the dependent variable, the categories of "Yes" and "Uncertain" have been merged into a single category for modeling purposes.
2. Age, initially collected as a continuous variable from survey responses, was later grouped into categories for analysis. Therefore, all variables in this table are categorical.
3. Education categories were regrouped for modeling purposes.
4. This variable contains responses from a question that allows participants to select multiple options from the provided choices. All other questions require participants to select a single response.
5. These variables are ordered, whereas all other variables in this table are categorical. In order to avoid extremely small percentages for the highest level of trust, the highest level of trust was merged with the level of moderate trust.
6. Observations with the response "Prefer not to answer" were removed, resulting in a final sample size of 1010 observations for modeling.

recommendation (68%) was safety training specifically focused on CAV technologies. However, the availability of CAV-related safety training programs for emergency responders is currently limited. By utilizing statistical modeling, this study revealed significant relationships between first responders' trust in AVs and factors such as age, education, agency type, knowledge of CAVs, and FEMA region. The modeling insights can help target specific groups for training initiatives and contribute to the development of effective CAV-related safety training programs for first responders.

The modeling results demonstrate significant disparities in trust in AVs among different agencies, emphasizing the importance of tailoring training programs to meet the specific requirements of each agency. Agencies have distinct roles in traffic incident management, and their concerns may arise from their particular working environments. Law enforcement responders prioritize human behaviors such as violations and crimes, while other agencies focus on traffic and vehicles. Besides, agencies have varying training resources, considering factors like the towing and recovery services, where tow truck operators are typically compensated based on hourly rates or service fees. Consequently, training methods or approaches must accommodate these unique circumstances and limitations. By customizing training programs to address the specific duties, concerns, and resource constraints of each agency, the effectiveness and applicability of the training can be maximized. In addition, the study identified variations in trust in AVs among FEMA regions. The regional differences in the phases of CAV adoption, road user behaviors, and responder training resource availability highlight the need for tailored approaches to CAV preparedness among first responders. It is also crucial to acknowledge the importance of coordinated efforts in preparing first responders for the adoption of CAVs, as CAVs will operate across jurisdictions rather than being confined to a single state. Furthermore, the modeling results showed a significant correlation between the level of trust in AVs and their knowledge of CAVs. This finding has important implications for the development of training programs, as it highlights the need to consider the influence of individuals' knowledge about CAVs on their perceptions. It is important to note that not only first responders but also the general public have access to information about CAV technologies from various sources, which shapes people's perceptions towards CAVs (Lee and Hess, 2022). Hence, training programs should strive to provide accurate and comprehensive information about CAVs, including both their capabilities and limitations. This approach is essential to prevent under-trust or over-trust in emerging vehicle technologies.

In addition to training programs, the survey findings have significant implications for the development of policies regarding the interaction between first responders and CAVs. Participants overwhelmingly recommended the implementation of standardized protocols for disabling and towing AVs, as well as establishing standard behavior responses of AVs to first responder commands. Standard protocols for disabling and towing AVs are crucial to ensure the safety and efficiency of emergency response operations involving CAVs. These protocols would provide consistent procedures and guidelines for responders when dealing with disabled or malfunctioning AVs at incident scenes, minimizing disruptions and ensuring safety. Similarly, establishing standard behavior responses of AVs to first responder commands is essential for seamless coordination and communication during emergencies. AVs must be programmed to appropriately recognize and respond to signals and commands from first responders, such as yielding the right of way and following instructions. Consistency in behavior responses will enhance the ability of first responders to manage traffic incidents and provide effective assistance.

7. Limitations

This study is subject to limitations related to the quality of survey data. Similar to other surveys, responses may contain dishonest or incorrect answers due to variations in respondents' understanding of the question statements. Additionally, while the survey aimed to include participants from all states, the sample data may not fully represent the entire population of first responders in the US. Notably, certain states, such as Pennsylvania, are over-represented, possibly due to the strong local network of the distributing organization, ERSI. Moreover, firefighters are over-represented as ERSI initially focused on fire services before expanding to cover all emergency response services. Normalizing

Table 4
Final modeling results for the correlates of trust in CAVs compared to in human drivers.

Variable		Fixed-intercept		Random-intercept		
		β	P-value	β	P-value	Odds Ratio
Intercept	Mean	−2.585 ***	0.000	−2.730 ***	0.000	
	Standard deviation (across states)	–	–	<0.001		
Age	18 to 35	−0.255	0.427	−0.232	0.472	0.793
	36 to 45	−0.142	0.638	−0.107	0.725	0.898
	46 to 55	Base		Base		
	56 and above	−0.895 **	0.009	−0.859 **	0.013	0.424
Education	High school or lower	Base		Base		
	Some college or associate degree	0.404	0.372	0.388	0.392	1.474
	Bachelor's degree	0.747	0.120	0.726	0.131	2.067
	Master's degree or higher	1.286 **	0.012	1.248 **	0.015	3.483
Agency	DOT and/or Public works	−0.157	0.827	−0.360	0.624	0.698
	Fire	Base		Base		
	Law enforcement (police, sheriff, etc.)	1.202 ***	0.004	1.150 ***	0.006	3.158
	Paramedics/Private EMS	0.364	0.373	0.321	0.434	1.378
	Towing & Recovery	0.629	0.355	0.452	0.513	1.572
	Multi-agency	0.568 **	0.040	0.544 **	0.050	1.723
	Other	−0.204	0.783	−0.241	0.746	0.786
Familiarity with CAV	Familiar with CV	0.395	0.135	0.442 *	0.087	1.556
	Familiar with ADAS or AV	−0.598 **	0.013	−0.761 ***	0.003	0.467
	Otherwise	Base		Base		
Level of trust in CAVs as a vehicle user or rider	1 (no trust at all)	Base		Base		
	2 (low trust)	1.250 ***	0.001	1.236 ***	0.001	3.440
	3 (neutral trust)	2.315 ***	0.000	2.279 ***	0.000	9.763
	4 (moderate trust)	3.446 ***	0.000	3.382 ***	0.000	29.429
Level of trust in human drivers passing an incident scene	1 (no trust at all)			Base		
	2 (low trust)	−0.665 **	0.022	−0.628 **	0.031	0.533
	3 (neutral trust)	−0.733 **	0.014	−0.722 **	0.016	0.486
	4 (moderate trust)	0.626	0.243	0.647	0.229	1.909
FEMA Region	Region 1	−1.526 **	0.048	−1.223 **	0.068	0.294
	Region 2	−1.121 **	0.027	−1.227 **	0.037	0.293
	Region 3	−1.535 ***	0.003	−1.612 ***	0.004	0.200
	Region 4	−1.044 **	0.023	−1.057 **	0.035	0.348
	Region 5	−1.029 **	0.025	−1.042 **	0.042	0.353
	Region 6	−1.094 **	0.024	−1.124 **	0.043	0.325
	Region 7	−0.450	0.393	−0.524	0.420	0.592
	Region 8	−0.368	0.400	−0.389	0.535	0.678
	Region 9	−0.837	0.331	−0.618	0.378	0.539
	Region 10	−0.323	0.614	−0.313	0.681	0.731
	Other (e.g., U.S. Territories)	Base		Base		
Summary Statistics						
Number of observations		1010		1010		
Number of groups (states)		–		54		
Log Likelihood		−272.76		−271.30		
AIC		605.5		606.6		
R^2		0.393		0.397		

Notes: * = significance at 90% confidence level; ** = significance at 95% confidence level; *** = significance at 99% confidence level.

survey samples based on state-level first responder population data and socio-demographic distributions can improve the accuracy of the results, and this should be a major focus for future research efforts. Furthermore, it is important to note that the modeling results are specific to the included factors and the employed random-intercept binary logistic model. Different variables and modeling methods may yield different results.

8. Conclusions

A national survey was conducted among first responders in the US to assess their knowledge, experiences, and perceptions related to CAVs. The survey, conducted in collaboration with the Emergency Responder Safety Institute (ERSI), received over 1000 responses from all 50 states, Washington DC, and US Territories. The survey collected information on first responders' sociodemographic characteristics (age, gender, education, and race), emergency response agency type, working experience, near-missing and struck-by incident experience, safety training background (general and CAV-related), attributes towards current incident management practices (level of trust in human drivers, and reasons of responder injuries), and the perceptions towards CAVs (familiarity with technologies, level of trust, and concerns about CAVs). Survey data were analyzed utilizing statistical techniques, including Chi-square tests and advanced statistical modeling, to investigate the factors that are correlated with first responders' perceptions towards. Specifically, the statistical modeling was performed to uncover the relationships between first responders' trust in AVs and associated factors.

The descriptive analysis revealed that 40% of first responders reported having limited knowledge about CAV technologies, including CVs, ADAS, and AVs. In terms of trust in CAVs, only 1% of participants expressed trust in AVs, while 44% indicated no trust at all, aligning with previous findings. A survey conducted by AAA found that nearly half of drivers feel less safe sharing the road with AVs, and 63% expressed fear of riding in an AV (Edmonds, 2021). Regarding responder safety training, the majority (82%) of first responders in the country have not received any training related to CAVs, leaving them undereducated on how to manage incidents involving CAVs or when encountering them at emergency scenes. According to the survey, 93% of first responders identified driver distraction as the most likely cause of responder-involved incidents, such as near-miss and struck-by events. With advanced connectivity and automation features in CAVs, driver distraction may no longer pose a threat to responders if CAVs are widely adopted. However, the survey results indicated that only a small percentage (3%) of first responders believe AVs can be trusted more than human drivers passing incident scenes. The majority (86%) of first responders do not believe AVs will outperform human drivers. Additionally, the study found significant variation in the odds of trusting AVs across different agencies and geographic regions.

The modeling results demonstrated that older responders are less likely to trust AVs compared to human drivers, potentially due to lower acceptance of innovative technologies among seniors (Bansal and Kockelman, 2017; Xiao and Goulias, 2021). Education showed a positive association with the likelihood of trusting AVs over human drivers. Law enforcement officers exhibited higher levels of trust in AVs compared to firefighters, while responders from DOT or public works agencies had the lowest levels of trust in AVs. Familiarity with CAV technologies among responders was significantly related to their attitudes towards AVs. Unfortunately, those familiar with ADAS and/or AVs expressed less trust in AVs compared to human drivers. To promote widespread adoption of CAVs, additional efforts are needed to increase responders' confidence in emerging vehicle technologies alongside technological advancements (Hutson, 2017; Gutta, 2021; VEST, n.d.; Responder Safety Learning Network, 2022). The level of trust in AVs significantly influenced responders' perceptions. A strong, positive, and linear relationship was observed between the level of trust in AVs (as a vehicle user) and trust in AVs compared to human drivers (as a responder). Moreover, the model quantitatively highlighted regional differences in responders' perceptions, with responders from the northeast, east, or south being less likely to trust AVs compared to those from the northwest or west. FEMA Region 3 (Delaware, Maryland, Pennsylvania, Virginia, District of Columbia, and West Virginia) exhibited the lowest odds of trusting AVs over human drivers.

In summary, the majority of first responders exhibit a lack of trust in CAVs. This lack of trust can be attributed to limited exposure to CAV technologies, which is influenced by the low penetration rate of CAVs and the limited availability of safety training programs. Though it is still an early deployment or testing stage for CAVs, efforts to address first responders' concerns regarding CAVs affecting emergency responses are needed before wide adoption. One of key efforts identified in the survey is the need for safety training focused specifically on CAV technologies. This study provides valuable insights for targeting specific groups in training initiatives and developing effective CAV-related safety training programs for first responders. It is essential to tailor training programs to meet the unique requirements of each agency. Different agencies have distinct roles in traffic incident management, with law enforcement responders prioritizing human behaviors while other agencies focus on traffic and vehicles. Moreover, agencies have varying training resources; therefore, training methods must consider these specific circumstances and limitations to ensure maximum effectiveness and applicability. In addition, regional differences in CAV adoption phases and responder training resource availability highlight the importance of regional approaches to CAV preparedness among first responders, while coordinated efforts are necessary to ensure their readiness for CAV adoption across jurisdictions. Furthermore, training programs should consider the impact of individuals' knowledge on their perceptions and provide accurate and comprehensive information about CAVs, covering their capabilities and limitations. This approach is crucial to ensure that there is a balanced understanding of CAVs, preparing first responders for next-generation transportation emergency responses without falling into the trap of under-trust or over-trust.

Author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A. Selected comments about CAV impacts on traffic incident management

Identification of incident scenes and responders	*"How will they know to move around an incident scene when traffic patterns have changed due to the scene."*
	"I'm not sure how they will respond to warning signs and flaggers."
	"Unsure how such vehicles will respond to rapidly changing traffic patterns in the event of an emergency"
	"These vehicles do not obey traffic control devices such as cones or stopped vehicles blocking lanes. We find ourselves watching oncoming traffic with humans to prevent CV or AV encroachment of scene."
	"Vehicles especially if damaged They act in unexpected ways. Also vehicles with this technology encountering scenes may not act as expected as the vehicle may not be programmed to make adjustments regarding responders in unexpected places or equipment and apparatus not typically in the roadway."
	"Yes AV cannot anticipate the nonstandard environment in the real world."
	"Yes computers don't recognize incidents like people."
	"Yes danger to responders on roadway. Danger of being hit by these vehicles passing scene and not identifying a responder or incident."
	"Yes if these systems in the vehicles don't recognize other incident locations in time to avoid them there is a danger to on scene responders."
	"Yes, recent events have shown that these vehicles may not adapt to emergency traffic or Traffic Incident Management tactics in use by first responders. Drivers who use these technologies may be over reliant on them and may not be paying attention to avoid a collision with emergency traffic, stopped emergency vehicles or first responders operating in the roadway."
	"Yes. I feel AI may be unpredictable, especially if the computer or brain has been damaged."
Vehicle disabling	*"a vehicle that appears disabled can't simply be chocked to immobilize and would need to be addressed somehow"*
	"To ensure vehicle is stopped/turned off before attempting rescue for crew safety"

(*continued on next page*)

(*continued*)

	"Yes, disabling of vehicle."
	"Yes. They must be treated as a potential hazard and uncontrolled variable. Disabling the vehicle if it's possible, use trucks as physical barricades or drag them away from the action"
Other concerns	*"Automated vehicles are even worse than EVs."*
	"Don't trust them"
	"I feel they will make drivers even more complacent and distracted."
	"Once in an accident, what of any of these vehicles beginning to activate and 'park' with us around it. Can camera's be 'hacked' so others can view what's happening in or around the vehicle? How will these vehicles respond to emergency vehicles (responding) who behave differently than normal traffic patterns when responding to calls? Can a driver start their vehicle with a smart phone after a collision?"
	"Yes, I believe people will try and rely on these "auto" features and it will result in more MVA's and increase the auto-ped strikes."
	"Yes, in addition to scene safety and all the other concerns and hazards scene safety is a huge factor in mitigating additional unnecessary harm to person or property."
	"Yes. Self-driving autos are, in my opinion, a HUGE safety hazard to on-scene responders due to the fact that the sensors COULD fail and cause the auto to crash into either equipment or people on the scene. "
Training	*"Additional training in awareness and handling these new vehicles should be mandatory."*
	"Can't answer this without more training on the cv, adas, and av."
	"Training is needed so no one gets run over or injured."
	" We're going to need to modify our SOG's/SOP's, conduct mandated State Specific training courses with annual refresher courses to keep up with the changes in these technologies. Perhaps create a new type of TIM course specific to these vehicle types. Fire Companies are going to have to modify Operational and Tactical strategies."
	"Yes, but would like to have additional training "
	"Yes. Training is needed."

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