Investigation of the impacts of the deployment of autonomous vehicles on first responders

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Abstract
Purpose – The purpose of this study is to address the significant impact AVs will have on public services and the ability of first responders to conduct their jobs safely and effectively. Autonomous vehicles (AVs) are expected to drastically change the transportation industry, and it is vital that first responders be equipped to integrate them into their occupational responsibilities.

Design/methodology/approach – A systematic literature review was conducted, and following a multistep exclusion process, 161 articles were selected for detailed review. The impacts of AVs on first responders were identified, classified and categorized into lists of challenges and opportunities. Based on the findings of the literature review, a SWOT (strengths, weaknesses, opportunities and threats) analysis was conducted, and stakeholder management strategies were designed.

Findings – Through the examination of the impacts of AVs on first responders, 17 identified challenges and opportunities were classified into the following categories: AV-related emergency response and training, perceptions and acceptance of AVs, technology development and laws and regulations. The study revealed that the optimal benefits of AVs would require stakeholders to focus more on how they interact with first responders; thus, 14 stakeholder management strategies were identified. First responders, AV manufacturers, legislators and future research paths will all benefit from this study, as it can facilitate smooth interactions between AVs and first responders.

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Originality/value – A range of studies have been published on the safety of AVs and the public’s perceptions of this new technology; however, the integration of AVs and their interactions with first responders has been neglected. The goal of this study was to fill that research gap by providing a thorough synthesis of autonomous driving systems in the context of their interactions with first responders.

Keywords First responders, Autonomous vehicles, Emergency personnel

Paper type Literature review

1. Introduction

The transportation industry is expected to be transformed by the extensive use of autonomous vehicles (AVs), which present both new opportunities and new challenges. They are able to safely navigate driving tasks without human interaction (Almaskati et al., 2023a), and they have the potential to enhance traffic safety, decrease congestion and lower transportation emissions by using a number of technologies, such as light detection and ranging (LiDAR), radio detection and ranging (RADAR) and cameras (Fagnant and Kockelman, 2015; Kopelias et al., 2020). The benefits of this technology are anticipated to be realized at full automation, or Level 5, when AVs operate in all environments without any human contact (Silva et al., 2022). Six levels of automation are defined by the Society of Automotive Engineers’ current standard: Level 0 denotes no driving automation, while Level 5 denotes complete driving automation (Almaskati et al., 2024).

The challenges primarily involve safety issues, and the interaction between first responders and autonomous driving technologies is one particular issue that requires further analysis. A first responder is a person (firefighter, emergency medical technician, paramedic or law enforcement officer) who is tasked with responding immediately to an accident or emergency situation to offer aid (Lasky et al., 2023). First responders regularly sustain injuries when delivering medical, fire and law enforcement services because they are frequently the first on the scene of an incident (Reichard et al., 2017). They are also more likely to be hit by approaching cars or be involved in an accident while responding to a traffic emergency (Tofighi et al., 2021). Police, firefighters and paramedics are victims of traffic-related fatalities 2.5–4.8 times more often than the USA’s national average (Seböck et al., 2023). It is unclear how autonomous driving technology will affect these concerning numbers because it is still in its early stages of development; it is also not apparent how first responders and AVs will communicate with one another. There have been numerous documented instances of AVs impeding rescue efforts and preventing first responders from carrying out their duties in a safe and efficient manner in San Francisco, CA (Eskenazi and Jarrett, 2023).

Research on the interaction between autonomous driving technology and first responders is notably lacking, despite the fact that many aspects of AVs have been thoroughly examined in published literature (Smith, 2020; Hansson et al., 2021; Stilgoe and O’Donovan, 2023). Liu et al. (2023a) conducted a study in which they polled first responders to determine their feelings about connected and AVs, and other researchers have also contemplated the amalgamation of automation with emergency response services. Winter et al. (2018) and Zarkeshev and Csiszár (2019) are among the authors who have carried out investigations to ascertain the inclination of patients toward the use of autonomous ambulances, and the ability of AVs to maneuver in the presence of emergency vehicles has been the subject of several studies (Buckman et al., 2021; Humayun et al., 2022; Parada et al., 2023). Gregg (2019) conducted a study that considered the integration of autonomous driving systems with law enforcement services; however, the study fails to comprehensively evaluate AVs’ implications for all first responders, not just law enforcement officers.
The following objectives were developed to overcome the shortcomings found in the existing literature and to address the significant impact AVs will have on public services and the ability of first responders to conduct their jobs safely and effectively:

- determine the impacts of AVs on first responders;
- identify and categorize the implications of AV–first responder interactions;
- identify the advantages and disadvantages associated with first responders and AVs in the context of a SWOT (strengths, weaknesses, opportunities and threats) framework; and
- discuss strategies that stakeholders can use to manage the challenges and opportunities identified.

The results of this study will help AV manufacturers, legislators and first responders and will provide stakeholders with vital information that can assist in properly preparing first responders for the broad implementation of AVs.

2. Methodology
A systematic literature review of journal articles, theses, technical reports and conference papers was conducted to compile a database of relevant literature. A keyword search using the phrases “autonomous vehicles” and “first responders” was performed in online search engines such as Google Scholar, Science Direct, IEEE and MDPI. Variations of these phrases or more detailed descriptions were also considered, e.g. “driverless vehicles” or “self-driving vehicles” for AVs, and “paramedics,” “law enforcement,” “emergency medical services” and “firefighters” for first responders. These terms were entered in various different combinations to ensure that all pertinent literature was reviewed. Figure 1 shows the research methodology developed to fulfill the objectives of this study.

The keyword search produced multiple scholarly articles, thus necessitating the formulation of a multi-step screening and exclusion methodology. The literature search yielded 323 articles, and after the screening and exclusion procedure shown in Figure 2, 161 papers were deemed relevant for this research. In addition, examining the citations of the selected papers led to the discovery of other research publications beyond the initial search.

2.1 Publication year
The distribution and frequency of articles based on their year of publication are depicted in Figure 3. The 161 articles considered included articles published from 2011 to April 2024. The figure depicts the yearly distribution in two-year increments and indicates an increase
in published articles in 2019–2020. This notable jump remained consistent until 2024. The chart also demonstrates that the greatest number of articles (41) were published from 2021 to 2022, followed by 2019–2020 and 2023–2024, with 40 papers each.

2.2 Publication country and geographical distribution

The distribution of the 161 articles in the database was published in 29 countries, indicating a global interest in the impacts of autonomous driving systems on first responders. As demonstrated in Figure 4, more than half (56%) of the articles reviewed were published in the USA; The Netherlands had the second highest publication rate with 4%, followed by Canada, Greece and the UK with 3% each. Bangladesh, Qatar and Zimbabwe published 1% or less of the articles reviewed and cumulatively represent 13% of all the articles studied.

Figure 5 illustrates the continental distribution of the articles analyzed. North America had the greatest number of articles published (59%), followed by Europe with the second highest number of publications (25%). Asia represented 11% of the publications, whereas Australia and New Zealand represented 4%. Africa and South America had the lowest number of publications, with less than 1% each. This variation in geographical distribution indicates that developed countries in North America and the European continent have published a greater number of studies relating to first responders and AVs, which may be reflective of their greater interest in the advancement of AV technology.

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3. Challenges and opportunities for the deployment of autonomous vehicles

AVs are expected to wield a considerable impact on the future of transportation and mobility, and while these impacts are generally expected to be positive, particularly in the lens of traffic safety (Wang et al., 2020), the impacts they will have on first responders merit further study. The following categories are explored in the section below within the context of AV-first responder interactions:
3.1 Autonomous vehicle-related emergency response and training

3.1.1 Autonomous vehicle traffic stops and accident response. When a traffic accident occurs, first responders are the first to arrive, offer help (Tofighi et al., 2021) and gather the information needed to determine the cause of the accident (Rayno et al., 2023). Conventional vehicle-focused accident response training and data collection standards may not be applicable in AV-related situations; consequently, when their use becomes more prevalent, first responders will need to be prepared to use engagement methods tailored specifically to them (Lee et al., 2023; Rayno et al., 2023). The widespread deployment of AVs will lead to a significant reduction in law enforcement engagements with citizens (Palodichuk, 2015), and first responders will need to be trained on how to interact with an AV without a driver or human passenger to mitigate emergencies (Balcombe and Morag, 2023).

3.1.2 First responder interaction protocols. It is well acknowledged that first responders should be thoroughly trained in AV-related emergency responses, which encompass traffic stops, traffic direction, securing a scene and responding to an accident (Liu et al., 2023a); however, no universal protocols for communication between AVs and first responders have been established. The National Highway Traffic Safety Administration (NHTSA) has advised state transportation authorities to collaborate with public officials to gather and disseminate information on autonomous driving systems (Brugeman et al., 2018) and has stressed the importance of states developing regulations that require manufacturers to notify law enforcement and first responders of collisions involving AVs (U.S. Department of Transportation, 2018).

3.1.3 Manufacturer-established training programs. Waymo, an AV manufacturer, created training materials to educate first responders on how to safely respond to emergencies, even when the AV is damaged (Waymo, 2023). They have also trained first responders at more than 75 agencies and given them access to a hotline that links them with experts who can handle any issues that may come up during an accident response (Brugeman et al., 2018; Waymo, 2023). Training sessions cover a wide range of topics, such as the fundamentals of AV technology, driving lessons and the vehicle’s response to emergency vehicles (Brugeman et al., 2018).

3.1.4 Autonomous vehicle security implications. AVs have profound implications for law enforcement guidelines and traffic stops. Pearl (2022) considered the legal and law enforcement issues relative to widespread AV adoption and identified the use of AVs for illegal activities and the regulation of surveillance data collected by AVs as possible negative implications. AVs are vulnerable to autonomous crimes that involve the vehicle being operated remotely to commit an illegal act such as drug trafficking (Douma and Palodichuk, 2012). Unlike conventional vehicles, AVs can also be hacked to force a collision and may be used as a weapon, necessitating the need for advanced safety and security standards (Lyons, 2015). They are more susceptible to cyberattacks, including cyber ransom, accident provocation and privacy invasion, as well as to car and data theft (Malik and Sun, 2020). Their vulnerability necessitates effective law enforcement training on the
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*Source:* Table created by the authors
management of cyber investigations to reduce the negative implications of these threats before they become a national security problem (Lyons, 2015).

3.2 Autonomous vehicle perceptions and acceptance

3.2.1 Perceptions of first responders. Lee et al. (2023) interviewed police officers, firefighters and emergency medical services members across the USA to determine how first responders would interact with problematic vehicles. Those interviewed expressed concerns about disabling AVs to prevent additional accidents without having to physically step into the vehicle. The law enforcement officers also conveyed their uncertainty about how to approach AVs, which led to the authors identifying the need to illuminate the vehicles’ interiors to reveal the occupants (Lee et al., 2023). Similarly, Goodison et al. (2020) held a workshop that focused on a range of topics, such as traffic stops and crashes, that are related to interactions between law enforcement officers and AVs. Their findings highlighted the importance of enhancing communication and cooperation among pertinent parties, such as AV manufacturers, law enforcement and the public. The absence of generalized protocols was noted as a problem, and the authors recommended that standard operating procedures be developed for law enforcement personnel and that they receive extensive training on implementing them (Goodison et al., 2020).

Liu et al. (2023a) surveyed first responders in the USA to gain a deeper understanding of their experiences with, attitudes toward and concerns about AVs. The results showed that 82% of first responders had never taken an official course on autonomous driving systems (Liu et al., 2023a) and lacked confidence in the technology. They didn’t think that AVs performed any better than conventional vehicles and expressed that they would be more inclined to trust a human driver (Liu et al., 2023a). Law enforcement personnel and firefighters showed the highest level of faith in AVs, although 44% said they did not trust them (Liu et al., 2023a). These percentages could improve, however, if governmental organizations begin offering training. To guarantee that their employees are ready to deal with AVs, first responder agencies should offer time and support in addition to instructional materials and training (Liu et al., 2023b).

3.2.2 Autonomous emergency medical transport. It may soon be commonplace to use AV technology for emergency medical transport (Gowda et al., 2018). Emergency medical professionals use ambulances, specifically designed cars equipped with medical equipment, to move patients from the scene of an accident to a hospital so they can get the care they need (Das and Ghosh, 2021). Conventional emergency medical service arrangements require the involvement of a single paramedic, who is responsible for patient care and a human driver. By eliminating the driver, self-driving ambulances could mitigate the shortage of emergency medical services personnel (Winter et al., 2018).

The number of motor vehicle fatalities and delayed response times are directly correlated (Byrne et al., 2019), and research has shown that connected vehicles and AVs can significantly reduce the average emergency response time (Obenauf, 2019). The USA’s current response times are delayed because of several issues but could be decreased by self-driving ambulances. Driving is an essential component of the medical care provided by emergency medical personnel and has a significant impact on patient health and safety (Becker and Hugelius, 2021). With the use of advanced computer vision and IoT technologies, Das and Ghosh (2021) presented a concept for an automated ambulance that would guarantee patient comfort; provide access to data about traffic congestion, hospital locations and quickest routes; and virtually link to a doctor (Das and Ghosh, 2021). Unfortunately, this may also lead to a reduction in the employment of emergency medical personnel in an attempt to reduce operational costs.
3.2.3 **Patient perceptions of autonomous ambulances.** Notwithstanding the benefits of autonomous ambulances, patients’ unwillingness to ride in them presents a significant challenge. Zarkeshev and Csiszár (2019) conducted a consumer readiness survey in Kazakhstan and Hungary with the goal of determining patients’ willingness to ride in an autonomous ambulance and discovered that patients in both nations lacked confidence in them and were not ready to use them. Similar findings were made by Winter et al. (2018), who discovered that patients prefer riding in a traditional ambulance. Gender was found to be a noteworthy contributing factor, as female patients expressed less willingness to ride in self-driving ambulances than males (Winter et al., 2018).

3.3 **Autonomous vehicle technology development**

3.3.1 **Interactions between autonomous vehicles and emergency vehicles.** All first responder vehicles (police cars, fire trucks and medical vehicles) are considered emergency vehicles (Nayak et al., 2020) and have to interact seamlessly with autonomous cars to speed up emergency response times. According to Lu and Kim (2017), first responders have the unusual responsibility of getting emergency vehicles to the scene of an accident as quickly as possible, as the amount of time it takes for help to arrive is a major factor in mortality. The interactions between the emergency vehicle and other road users are frequently the main source of difficulty for first responders (Chen and Habibovic, 2019).

The NHTSA has stressed that AVs need to be outfitted with object recognition and reaction systems that can handle a variety of scenarios, such as emergency vehicles and police officers manually rerouting traffic (U.S. Department of Transportation, 2018). As demonstrated by a number of recorded crashes involving Tesla vehicles and on-road or roadside first responders, as well as an instance in which an AV obstructed a fire truck responding to an emergency, AVs still struggle with maneuvering in the presence of emergency vehicles (Bartneck, 2022; Parada et al., 2023). As of August 2023, there were 55 documented incidents in San Francisco in which AVs impeded rescue operations. These incidents included instances where the vehicles ran over yellow emergency tape, blocked driveways to firehouses and failed to move to allow first responders to pass (Eskenazi and Jarrett, 2023).

3.3.2 **Algorithms for improved emergency vehicle detection.** Several studies have suggested methods for enhancing the AVs’ movement in such situations, thereby facilitating more seamless interactions between emergency vehicles and autonomous cars.

In light of the significance of AVs’ capacity to identify emergency vehicles, Nayak (2019) created vision-based algorithms that examine visual input, identify emergency vehicles and set them apart from other users of the road and then track the locations of the vehicles using pixel coordinates. After the emergency vehicle has been correctly identified, the AV can determine the best course of action to avoid any obstacles and permit the emergency vehicle to pass through. This may include lane-keeping or emergency lane changes (Nayak, 2019). Garg et al. (2019) proposed an ambulance detection system that uses both visual and auditory recognition. In this system, a microphone picks up ambient noise and sends it to a sound detection module that uses a support vector machine, while a rear-mounted camera provides frames to deep learning modules that use convolutional neural networks (Garg et al., 2019). The AV uses both aural and visual sensors to determine whether the emergency vehicle is in a situation that requires nearby vehicles to move out of the way. Funke et al. (2016) and Obenauf et al. (2019) suggested implementing virtual emergency lanes to shorten response times.

Researchers have also proposed maneuvering techniques to shorten emergency response times by concentrating on vehicle-passing sequences. This technique uses an intersection
control algorithm or a cloud-based traffic control platform but can only be used when every nearby vehicle is connected and autonomous (Lu and Kim, 2017; Chen and Habibovic, 2019). Humayun et al. (2022) also suggested creating algorithms that work with advanced technology. In this scenario, all emergency vehicles would be outfitted with Global Positioning Systems (GPS) and Internet of Things (IoT) sensors that would enable them to gather data, import it to the cloud over a 5G network and decide which controls are most appropriate. Buckman et al. (2021) proposed a game-theoretic method for controlling an autonomous emergency vehicle that interacts with other cars. Parada et al. (2023) presented a risk index that shows the possible dangers of a collision, as well as a method based on multi-agent proximal policy optimization that is designed to guarantee that AVs can maneuver safely in the presence of an emergency vehicle.

3.3.3 Driving assistance for first responders. First responders frequently have to drive under adverse conditions while performing a secondary activity because of the nature of their work and the necessity of a prompt response. For example, ambulance workers must not only ensure that hospital staff are ready to receive injured patients but must also treat them en route (Kun et al., 2015). Despite efforts by agencies to teach first responders how to multitask safely, there is a dearth of data demonstrating the efficacy of dual-task training. Motor vehicle accidents account for the majority of law enforcement fatalities (Zahabi et al., 2022), and in the USA, law enforcement personnel, firefighters and paramedics are victims of traffic fatalities 2.5–4.8 times more often than the national average (Sebök et al., 2023). According to Shahini et al. (2020), these collisions are often caused by drivers speeding and paying attention to in-vehicle technologies while reacting to emergencies. In addition to the high rates of fatalities, a study by Duncliffe et al. (2019) found that paramedics observed in simulated emergency ambulance-driving scenarios demonstrated increased stress levels and mental demands that contributed to a lack of awareness and a greater risk of driving errors.

3.3.4 Programming first-responder autonomous vehicles. Autonomous driving systems offer first responders the benefit of being able to detach from getting to and from the scene of an accident and focus on the secondary task at hand to reduce the frequency of their involvement in motor accidents (Kun et al., 2015). However, in an emergency, first responders often resort to breaking traffic laws that civilians are behooved to keep. Examples of such behaviors include failing to stop at red lights and driving in the wrong direction of traffic (Kun et al., 2015). Before AVs can be used by first responders, manufacturers will need to configure them to accommodate first responders’ driving habits and ensure that they are tamper-resistant (Shay et al., 2016).

3.3.5 Mitigation of occupational safety hazards. First responders often risk their own lives to protect their communities, and the utilization of an autonomous system would mean that they could go about their jobs with greater safety and efficiency. For example, firefighters are commonly exposed to high temperatures, airborne particles and low visibility conditions (Cuenca-Lozano and Ramírez-García, 2023). A prototype for a vehicle with an autonomous embedded system such as that suggested by Pineles and Valles (2018), however, would reduce their exposure to these risks by gathering topographical and environmental real-time data from the burning site. This would allow the firemen to organize their approach more effectively and locate those who may be trapped at the scene.

3.3.6 Public health support. Following an earthquake, damage to transportation systems often makes it impossible to transport injured individuals to medical facilities. Zhao et al. (2022) examined the advantages of using connected and autonomous cars for this purpose, as they are capable of efficiently planning a route using real-time traffic data. Not only can these cars help medical professionals move injured patients, but they can also assist in
evacuation efforts. Khalid et al. (2021) also considered using AVs as emergency transportation services and proposed developing an IoT-enabled autonomous driving system that gets patients prompt medical attention and assists in preparing the health-care industry for international crises such as the COVID-19 pandemic. Autonomous emergency vehicles also have the potential to alleviate stress on the public health system in cases of national crises, when emergency medical services experience significantly higher demands (Hannoun and Menendez, 2022).

Research has also been conducted on the installation of robotic first aid systems in AVs, which has the potential to reduce the need for an ambulance in situations involving non-trauma crises like heart attacks or strokes (Kurebwa and Mushiri, 2019). This would minimize the strain on the public health system, as the self-service ambulances could collect information such as a patient’s vital signs and subsequently proceed with transporting the patient to the nearest hospital (Grudnik et al., 2023). A similar strategy was proposed by Elayan et al. (2021), who installed technology in AVs to produce an intelligent cooperative emergency response system that could shorten hospital wait times, emergency treatment times and travel times. The introduction of self-service ambulances is also expected to assist in assessing the severity of patients’ problems to prioritize their care; however, it is essential to consider the implications of this technology prior to introducing it into medical services (Grudnik et al., 2023).

3.3.7 Frameworks for cyber attacks. AVs use a combination of sensors to effectively perceive their surroundings. Their safety is dependent on the use of multiple integrated sensors, often involving visual cameras, LiDAR and RADAR sensors (Yeong et al., 2021). The dependency on these different technologies increases the vulnerability of the AVs and makes them more vulnerable to cyberattacks and hacking, which includes any type of virtual interference with the operation of the AV (Gurney, 2015; Khadka et al., 2021). AVs also depend on GPS for navigation, which makes them vulnerable to hacking techniques such as GPS spoofing and jamming, where interference causes the AV to behave in an unexpected manner through third-party routing control (Parakkal and Vairayar, 2017). To protect them from the risk of being hacked, Khadka et al. (2021) proposed a benchmarking framework for detecting and responding to cyberattacks.

3.4 Laws and regulations
3.4.1 The role of the driver. Autonomous driving systems are a disruptive technology that is expected to significantly alter the transportation sector and will directly impact first responders and other sectors and groups. Facilitating their smooth introduction into the transportation system will require policymakers to introduce legislative actions that consider every aspect of the vehicles, including safety, security, liability and data privacy, and encourage intelligent planning for a clear path into the future (Fagnant and Kockelman, 2015). In the USA, the federal government regulates the manufacturing safety standards of all vehicles through NHTSA, while state government agencies regulate their operation (Browne, 2017). It is thus necessary that laws and standard regulations introduced at the state and federal levels are cohesive rather than conflicting and contradictory.

The literature makes it clear that one of the primary benefits of AVs is their ability to improve traffic safety through the elimination of human error in the driving environment (Lari et al., 2015). Eliminating the role of the driver introduces new issues encompassing liability and adaptation of traffic codes, however, that must be addressed by legislation. The development of such policies is essential for first responders, specifically law enforcement officers, to enable them to continue to safely and effectively do their jobs. Traffic codes will likely have to be revised to redefine the role of the driver by designating responsibility for
their operation (Palodichuk, 2015), specifically at higher levels of automation. Questions regarding who should assume responsibility in the event of an inevitable accident are frequently at the center of discussions about AVs and liability concerns (Pearah, 2017). While centering the blame on the manufacturer seems like the obvious course of action, doing so could deter innovation in AVs (Gurney, 2015). Because of the potential conflict of interest between the manufacturer’s liability concerns and the consumer’s desire for safety (Robinson et al., 2022), legislation should be developed to structure tort liability for AV manufacturers that incentivizes the development and enhancement of AVs (Gurney, 2015).

3.4.2 Redefining traffic violations and other laws. Existing traffic violations will need to be changed for autonomous driving systems; for example, AVs could be programmed to ensure that registration tags and insurance are current, which would eliminate those associated offences (Palodichuk, 2015). At high levels of automation in which the vehicle does not require human intervention, drinking and driving traffic laws will also need to be amended to account for the fact that the vehicles can safely drive themselves despite the rider’s level of inebriation (Gurney, 2015). Other traffic codes that might be impacted include reckless driving, vehicular manslaughter and laws that hold hackers responsible for interference with the operation of an AV (Douma and Palodichuk, 2012; Lari et al., 2015).

3.4.3 Personal privacy vulnerability. The integration of AVs into first-responder services magnifies the significance of privacy and data security. One example is the medical data that self-service ambulances will collect. Because automated systems are not bound by the same privacy laws as health-care professionals, new systems must be put in place to protect the information collected from data theft and prioritize patients’ rights to privacy and confidentiality (Grudnik et al., 2023).

The introduction of AVs into public roadways also creates new challenges for law enforcement officers. For instance, if an AV breaks the law or is being used for illegal activities, it is unclear what levels of action police are able to take to protect the community at large without intruding on an individual’s privacy (Ryan, 2020). It is also feared that AVs will compromise riders’ privacy through the collection of data, such as their current location, previous travel patterns and route planning, that can be relayed to a third party, including law enforcement (Boeglin, 2015). Such personally identifiable digital information that was previously unavailable to law enforcement officers may make the public feel as though their personal privacy is being infringed upon (Palodichuk, 2015).

4. Discussion

4.1 Strengths, weaknesses, opportunities and threats analysis of the impacts of the first responder–autonomous vehicle implications

The adoption of autonomous driving technology will have both positive and negative impacts on first responders and society. Although they are expected to provide many advantages, such as increased traffic safety (Kopelias et al., 2020), it remains unclear how AVs will affect first responders. Figure 6 displays a SWOT analysis of first responders and AVs and outlines the impacts of the technology. This framework is useful in identifying the various ways that AVs are expected to impact first responders and can also be used as a guideline for developing appropriate management strategies that can strategically maximize the benefits of the AV technology while simultaneously minimizing the negative implications that are introduced by associated threats and impediments.

4.2 Stakeholder management strategies

Prior to their widespread deployment, governmental entities and other relevant stakeholders will have to consider how AVs will impact first responders and enact policies and legislation
that will ensure that their safety is prioritized and that society reaps the benefits of the technology (Almaskati et al., 2023b). Table 2 proposes management strategies that stakeholders can implement to effectively address the challenges and opportunities associated with first responders and AVs.

First responders’ lack of trust in AVs is attributed in the literature to their lack of sufficient training on this emerging technology. Thus, educational programs, targeted training and generalized AV and protocols should be developed and disseminated to first responders so that they can be better prepared to respond to AVs’ presence on the roads and to accidents that involve them. AV manufacturers should also consider improving the autonomous driving system’s ability to detect and respond to emergency vehicles, as various incidents have been reported in which the vehicle is disruptive to first responders. Additionally, they should design them to reduce their vulnerability to cyberattacks and hacking.

Autonomous driving systems can also be introduced to support first responders, who often must perform secondary tasks while operating their vehicles and are often involved in traffic accidents as a result. Because first responders have a different driving style that requires them to drive at high speeds and there is a lack of traditional laws, manufacturers will have to consider how to account for this type of behavior when programming their vehicles.
<table>
<thead>
<tr>
<th>ID</th>
<th>Management strategy</th>
<th>Relevant stakeholders</th>
<th>Identified variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Develop local law-enforcement guidelines to inform first responders how to interact with AVs</td>
<td>Public officials and state transportation agencies</td>
<td>ER.2, ER.3, PA.1</td>
</tr>
<tr>
<td>2</td>
<td>Design a disengagement mechanism that is accessible outside the vehicle</td>
<td>Manufacturers</td>
<td>ER.1</td>
</tr>
<tr>
<td>3</td>
<td>Familiarize first responders with AVs and implement training programs</td>
<td>Public officials and state transportation agencies</td>
<td>PA.1</td>
</tr>
<tr>
<td>4</td>
<td>Improve AVs’ object detection and response capabilities</td>
<td>Manufacturers</td>
<td>TD.1, TD.2</td>
</tr>
<tr>
<td>5</td>
<td>Introduce autonomous driving systems in first-responder vehicles to alleviate the dangers of multitasking while driving</td>
<td>Public officials and state transportation agencies</td>
<td>TD.3, TD.5</td>
</tr>
<tr>
<td>6</td>
<td>Account for emergency vehicles’ requirements and program them accordingly</td>
<td>Manufacturers</td>
<td>PA.2, TD.4</td>
</tr>
<tr>
<td>7</td>
<td>Educate the general public on AV technology to prepare potential patients for the deployment of self-driving ambulances</td>
<td>Policymakers</td>
<td>PA.2, PA.3, TD.5</td>
</tr>
<tr>
<td>8</td>
<td>Familiarize the public with self-driving ambulances so that they can gain trust in the technology</td>
<td>Policymakers, manufacturers</td>
<td>PA.2, PA.3</td>
</tr>
<tr>
<td>9</td>
<td>Implement cyber investigation training programs</td>
<td>Law enforcement agencies</td>
<td>ER.4</td>
</tr>
<tr>
<td>10</td>
<td>Design autonomous driving systems that are protected from cyberattacks</td>
<td>Manufacturers</td>
<td>TD.7</td>
</tr>
<tr>
<td>11</td>
<td>Develop guidelines that set forth the illegal use of AVs</td>
<td>Law enforcement agencies</td>
<td>ER.4, LR.3</td>
</tr>
<tr>
<td>12</td>
<td>Define the role of the driver in the operation of an AV</td>
<td>Policymakers</td>
<td>LR.1</td>
</tr>
<tr>
<td>13</td>
<td>Redefine traffic violations and other laws as needed</td>
<td>Policymakers</td>
<td>LR.2</td>
</tr>
<tr>
<td>14</td>
<td>Introduce privacy laws to protect AV users’ confidentiality</td>
<td>Policymakers</td>
<td>LR.3</td>
</tr>
</tbody>
</table>

**Source:** Table created by the authors
The deployment of AVs will have legal implications that may require the refinement of existing traffic laws. Unlike in a conventional vehicle, the role of a driver in an AV is ambiguous, and the responsible party in an accident involving an AV is not legally defined. Beyond liability, policies will also have to consider the adaptation of traffic violations in the context of this technology, the privacy vulnerability of AV users and law enforcement’s access to the information collected by AVs.

5. Conclusion
As autonomous driving technology advances, the number of AVs on roads will increase. If society is to fully enjoy the safety benefits of this innovative technology, first responders need to receive extensive training on how to interact with it. AVs and first responders and their integration and interaction have not been the focus of many published studies; hence, this review aimed to remedy that by evaluating autonomous driving systems in the context of their interactions with first responders by examining AV-related emergency response and training, AV perceptions and acceptance, AV technology development and laws and regulations. This study classified the challenges and opportunities associated with the implications of AVS’ impacts on first responders, developed stakeholder management strategies and performed a SWOT analysis to illuminate the impacts of the technology on first responders. The results showed that the optimal advantages of the technology for society at large would require stakeholders to focus more on how AVs interact with first responders. First responders, AV manufacturers, legislators and future research paths will all benefit from this study, as it can facilitate smooth interactions between AVs and first responders.

Successful and safe integration of AVs is dependent on first responders being prepared for the technology, and although their interactions with AVs are explored in the existing literature, there remain significant knowledge gaps that can be addressed by future research studies. One such area is how training affects first responders’ perceptions of AVs and whether it makes a difference in their level of trust in the technology. Research into this topic would provide a more in-depth understanding of first responders’ expectations, which could be useful for both the future development of AVs and the training methods implemented. Future studies may also evaluate whether autonomous first responder vehicles are able to effectively alleviate the occupational hazards first responders routinely face, especially when driving in response to emergency calls.

References


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