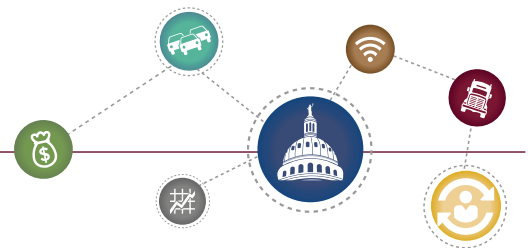




Revolutionizing Our Roadways

Implications of Automated Vehicle Crash Scenarios



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Vehicle Crash Scenarios**

by

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Published: May 2016

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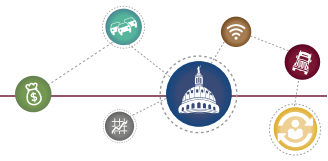
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Executive Summary

Since the introduction of automobiles, crashes have been an unfortunate reality on our transportation system. During 2014, in Texas alone:

- One reportable vehicle crash occurred every 66 seconds.
- One person was injured every 2 minutes 13 seconds.
- One person was killed every 2 hours 29 minutes (1).

These numbers are based only on Texas Peace Officer's Crash Reports (Form CR-3). However, many more unreported crashes occur every day, mostly involving insignificant property damage.

These numbers not only display the scale and magnitude of crashes taking place every day, but they also demonstrate that more than a century after the invention of the automobile, and in spite of all the advances (safety or otherwise) related to infrastructure and vehicles, we are still experiencing a high number of daily vehicle crashes on our transportation system.

The media often touts automated vehicle (AV) technology as the solution to eliminating crashes, more than 90 percent of which are due to human errors (2). These claims are not supported by any empirical data or scientific evidence. Yet, experts do believe that overall frequency and severity of crashes could be reduced by implementing more AV technologies, while acknowledging the intricacies and nuances that are involved in this process.

Despite its potential to reduce the occurrence of certain types of crashes or mitigate the severity of others, evidence shows that AV technology is not a panacea for decreasing crash rates. There is much for policy makers to consider and address in the area of AV technology and crashes as the car industry accelerates implementation into the average citizen's daily life.

Safety Issues of Automated Vehicle Technology

AV technology is not a futuristic vision. Depending on how automation is defined, many people already own or use vehicles that benefit from automated technology such as electronic stability control (ESC), anti-lock braking systems (ABS), and adaptive cruise control. More advanced automation features are scheduled for introduction to the market at an accelerated rate. For instance, GM has announced that its super-cruise (hands-off, feet-off, highway-only pilot system) will be available on select 2016 model year Cadillacs, and many other car manufacturers have also made announcements to introduce similar features in the near future.



Inherently, automated systems—composed of sensors, processors, actuators, and algorithms—are not prone to events and conditions such as inattention, distraction, drowsiness, or others that can lead to a crash. Nevertheless, these systems will be facing a new set of challenges that are largely different from what human drivers are faced with today. These systems may introduce new types of crashes due to new failure modes. Currently, the most practical assumption is that crashes will continue to be an inevitable part of a vehicle-centric transportation system, with or without automation.

To date, several crashes involving AV technologies have been reported, all of which happened at low speeds and involved minor property damages (3). In nearly all reported instances, the crashes were caused primarily by human operator errors and not the AV system. This signifies the robustness and reliability of these systems after operating for more than 1 million miles on public roads with mixed traffic. Nevertheless, statistically, 1 million miles of autonomous operation without any crash due to AV system failure or mistake is not of significance, and it should not be considered proof that the technology is immune to errors, mistakes, or failures. As the technologies advance into more complicated

systems and more of the vehicle operation becomes integrated with AV technology, careful consideration should be given to the possibility of crashes involving AVs and to potential needed changes to existing policies and regulations.

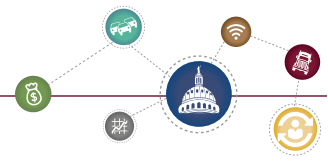
These systems may introduce new types of crashes due to new failure modes.

Key Finding: Texas Transportation Code Revisions

The most prominent finding in the study is the definition of *operator* in the Texas Transportation Code. Consideration should be paid to proper definition of *operator* within the Texas Transportation Code to address the nuances pertinent to AVs. A new definition of *operator* can eliminate many future disputes and also clearly define the roles and responsibilities to be met by the owner, operator, driver, occupant, and vehicle. This is particularly relevant in light of trends in offering transportation as a service where the occupant may simply be riding in the AV without having any control over the operation of the vehicle.

Google recently submitted an inquiry concerning the driver to the National Highway Traffic Safety Administration (NHTSA). In its interpretation, NHTSA concluded that the self-driving system—or AV in this report—is considered the driver for certification and compliance with Federal Motor Vehicle Safety Standards. This further signifies the need for appropriate definition of the driver or operator in the Texas Transportation Code.

Based on who is deemed the operator (i.e., the vehicle or the human driver), the quickest means of reporting a crash could vary. Therefore, thought should be given to further defining the quickest means as stated in the Texas Transportation Code. Several other examples from the Texas Transportation Code illustrate how the definition of operator can impact the existing interpretation and/or requirements for AVs.



Other Findings

Crash Reporting Considerations

Several current practices concerned with capturing and reporting information about a crash can be revisited to better address situations involving an AV. Examples of such considerations include provision of additional fields in the current crash report form and the citation form to capture data and information related to AVs, and establishment of a transparent crash-reporting mechanism to help inform the public about safety-related concerns for this specific technology.

Crash Data Considerations

AV technology is enabled by the ability to capture, process, and act upon vast amount of data that are captured from the driving environment. This poses new challenges and opportunities to revisit the transportation code and other state policies. This study found several instances that state policy can consider as it relates to AV crash data.

For example, current state law does not specify the duration and type of data that need to be stored in case of a crash, which can in fact be used for post-crash investigation and other similar purposes. While other states (California and Nevada) have required 30 seconds of AV data to be stored prior to the crash, they remain silent about what data need to be stored. The availability

and accessibility of crash data to the authorities for crash investigation and reporting purposes also need to be considered in order to provide a uniform platform for the authorities to access, retrieve, and interpret the data.

AV technology is enabled by the ability to capture, process, and act upon vast amount of data that are captured from the driving environment.

Crash Response Considerations

When first responders are informed and dispatched to a crash scene, the assumption has been that a human driver is involved. However, this may not necessarily be true when AVs near market introduction. To ensure proper and effective response by first responders, this report discusses several policy considerations.

For example, the first responder at the crash scene will need some means to ensure the AV is disabled and the automated technology is disengaged. For the peace officers or others present at the scene of a crash, it may not be easily identifiable whether one or more vehicles are AVs. If specific procedures and protocols need to be followed in a crash involving an AV, clear markings or symbols to provide such distinction could assist the personnel present at the scene.



Purpose of This Report

In light of the existing and forthcoming AV systems, states will need to be prepared to make necessary adjustments to policies and laws, especially if they pertain to public safety. The discussions presented in this report aim at providing an overview of some of the major issues, technologies, and local regulations surrounding vehicle crashes, particularly those that could be related to AVs.

Before, during, and after a crash occurs, the human driver/operator assumes many responsibilities. Such responsibilities lead to taking certain actions by the human driver/operator, such as pulling over to the road shoulder or a safe location after a crash occurs, or safely returning to the crash scene.

In addition to the human driver, vehicles are also required to perform and fulfill certain requirements that are proposed or mandated through guidelines and regulations. These could range from logging data through an event data recorder (EDR) in case of a crash or providing technologies such as ESC.

Currently, the driver, vehicle, policies, and procedures are all at equilibrium. Roles, responsibilities, and requirements are fairly well

defined, and each party is educated and informed about them. However, this equilibrium is being disrupted by the introduction of AVs and can be further exacerbated in the event of the first AV crash. This disturbance to the current existing balance in the system is mostly due to two main reasons:

- As AV technology increasingly and progressively takes over the task of driving (actions that include perception, navigation, and actuation), the definition of the operator/driver becomes a topic for further discussion. The system may not be able to fulfill all responsibilities and actions that are currently performed by the driver in certain situations that can potentially lead to a crash.
- The AV technology produces a significant amount of data that could be used in case a crash occurs. These data, or information, could be used to not only mitigate the consequences of a crash but also help further investigate the crash itself.

The goal in this effort is to:

- Consider the impact and possible changes that may need to be introduced to the existing laws in Texas.
- Better define and frame the unknowns and questions that may arise in the event of an AV crash.
- Investigate the opportunities that could be potentially leveraged in improving the current state of traffic incident management (TIM).

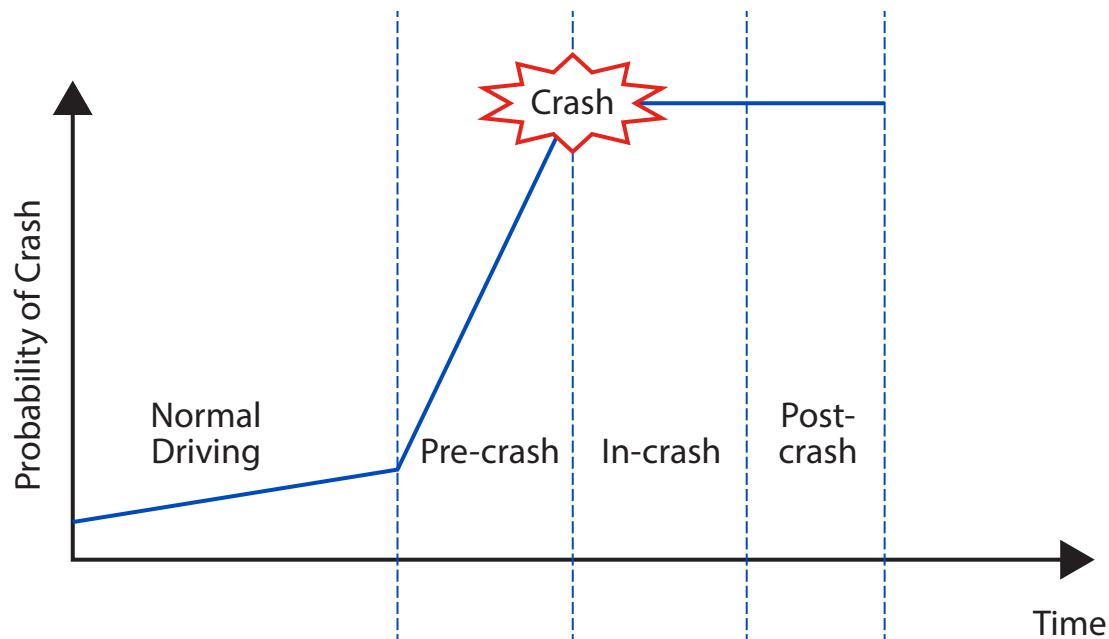
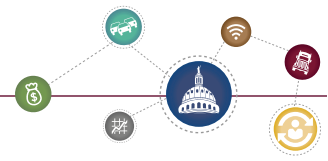


Figure 1. Three Stages of a Crash.

Understanding the Basics: Crashes, Safety Technology, and Levels of Automation

Three Crash Stages

Any crash involving vehicles can be broken into three stages, as illustrated in Figure 1:

1. Pre-crash—several seconds prior to the crash event taking place.
2. In-crash—the crash event itself, which lasts a few seconds.
3. Post-crash—the time span after the crash occurs and vehicle movement stabilizes.

In each of the three stages, the human driver is the sole decision maker and, as a result, the subject of a regulatory framework for taking necessary actions. This means that the human driver is held responsible and accountable for the crash and what may ensue. For instance, human drivers are responsible for not engaging in tasks other than driving, maintaining a safe following distance from the vehicle in front, and reporting a crash. Nevertheless, in spite of numerous trainings, warnings, and enforcement actions currently in

the driver education and legal system, crashes still occur because drivers oftentimes fall short in fulfilling their responsibilities. Hence, new technologies (i.e., active safety technology) are introduced to complement and assist the performance of the human drivers in meeting their responsibilities.

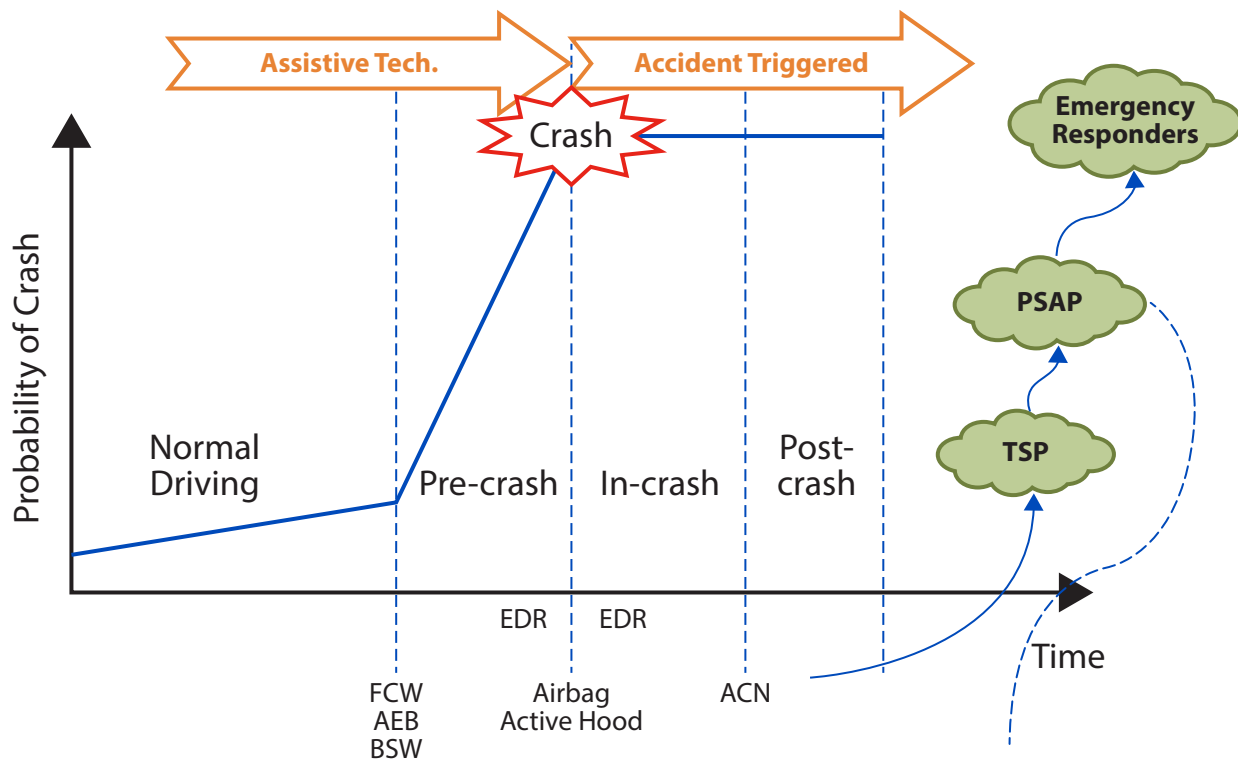
The Role of Current Active Safety Technology

During each of the three stages, certain automated technologies or applications (referred to collectively as active safety technology) can be engaged to:

- Eliminate the risk or avoid the crash.
- Mitigate the consequences of the crash.
- Provide critical information about the crash to a third party.

Reviewing technologies and practices that take place in each stage of a crash helps to better understand and further analyze topics and issues that could emerge in case of an AV crash.

These technologies fall mostly into two categories. The first category deals with situations prior to the event of



ACN = automatic crash notification; PSAP = public safety answering point; TSP = telematics service provider. FCW=forward collision warning; AEB=automated emergency braking; BSW=blind spot warning

Figure 2. Example of Active Safety Technology in Relation to the Three Stages of a Crash.

a crash. These technologies (or features) are designed to assist the driver to avoid or mitigate the severity of a crash. Examples of such features are ABS, ESC, automated emergency braking, active seatbelts, forward collision warning, and blind spot warning. Figure 2 shows an example of which of the three crash stages the active safety technologies impact.

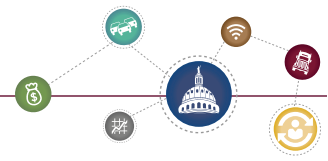
The second category of technologies includes features that are triggered by the crash and take place during or after the crash. Examples of these technologies include airbags, active hood, EDR, and automatic crash notification (ACN).

Automated Crash Notification

Most of these technologies are on board the vehicle and self-contained for the most part. However, ACN is currently the only integrated system in the vehicle that establishes a connection with the outside world when

a crash occurs. The most notable example of ACN is GM OnStar’s Automatic Crash Response functionality (for subscribed users). The technology uses sensors on board the vehicle to detect a crash and notifies the OnStar team so that it can provide crash information to a public safety answering point, which in turn dispatches emergency responders.

While ACN can play a major role in reporting the occurrence of a crash, not all vehicles are equipped with this technology, and not all equipped vehicles are subscribed users that can benefit from the service in case of an emergency. Hence, a larger practice is in place that deals with detecting, responding, and managing a crash—broadly referred to as traffic incident management.



Traffic Incident Management

The overall TIM practice is a means to reduce the number of secondary crashes, fatalities, and incident-related congestion. Parties involved in TIM practice may or may not receive near real-time data from the vehicle about the crash, but in either case, the parties (e.g., fire department, towing companies, hospitals, and traffic management centers) are all required to respond to the crash and fulfill a given set of responsibilities.

Five Levels of Vehicle Automation: Background and Significance

In addition to the human responsibilities during normal driving conditions and throughout the three stages of a crash, vehicles are required to perform certain tasks when encountering specific situations or certain triggers (e.g., ABS engaging when hard-braking on loose gravel). All these requirements are spelled out in state and/or federal regulations and guidelines. In this context, state regulations and guidelines deal mostly with the responsibilities of the human driver (maintaining safe driving distance, proper maintenance of vehicle safety systems such as rear brake lights, driver training, and more) and also the roles and responsibilities of those who respond to a crash. On the other hand, federal regulations and guidelines are concerned mostly with vehicle requirements and standards, especially if they are

safety related. For instance, the National Highway Traffic Safety Administration (NHTSA) introduced regulations that led to mandatory installation of seat belts, ABS, and other similar technologies.

In addition to the human responsibilities during normal driving conditions and throughout the three stages of a crash, vehicles are required to perform certain tasks when encountering specific situations or certain triggers.

In this context, there is currently a reasonable balance between vehicle technologies, federal regulations, and state policies governing the operation of vehicles. However, introduction of AVs could potentially disrupt this balance and introduce new elements that will possibly prompt a need to reevaluate policies and regulations. This imbalance is due to the nature of AV technology and the fact that many of the existing assumptions governing policies will no longer be applicable. To better clarify why some assumptions will be challenged, it is important to understand AV technology terminology and how it is described and categorized.

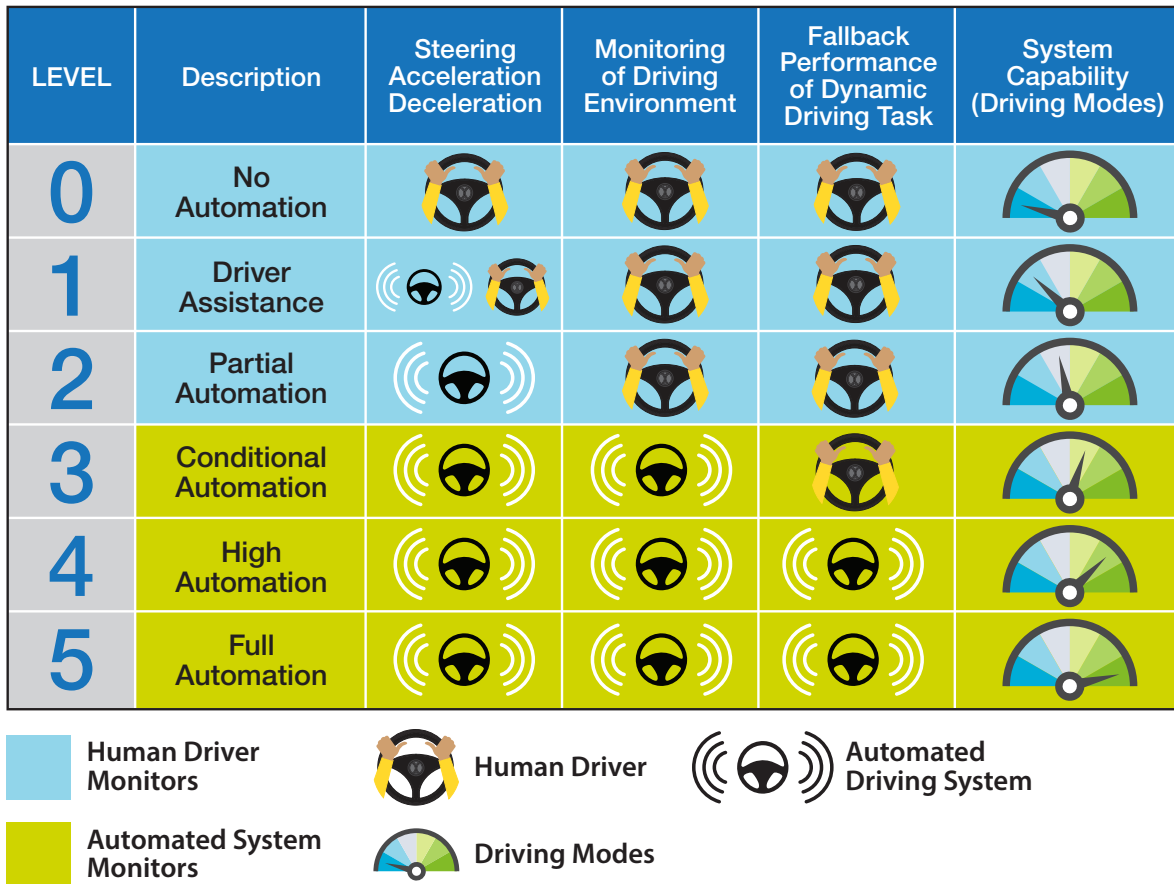


Figure 3. SAE Levels of Automation.

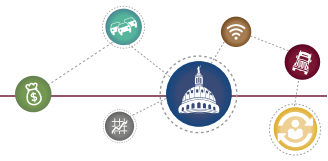
Why Five Levels of Vehicle Automation?

In 2010, the automotive industry found itself in a disadvantaged position when an outsider company, Google, began experimenting with the advanced concept of self-driving cars—something that had been around for decades but without much progress. This generated a new energy and created a wave of activities across the automotive industry, adjacent industries (e.g., insurance), local and federal government agencies, and academia. However, the industry collectively struggled to use common terms and references when talking about this technology. Some used the term autonomous, while some used automated. Some called it self-driving, robocars, etc. To provide a common language for discussions within the broader automated/autonomous vehicle community, in January 2014, the Society of Automotive Engineers (SAE) published the J3016 report (4) offering a taxonomy describing the full range of levels

of automation in on-road motor vehicles (see Figure 3). SAE categorized automation into five levels (discounting Level 0, which describes vehicles with no automation).

Levels 1 and 2

As shown in Figure 3, for Level 1 and 2 vehicles, the human driver is responsible for “monitoring of driving environment” and must also be immediately available to perform certain tasks if prompted or in case of a system failure. However, a Level 2 AV, unlike a Level 1 AV, is capable of performing lateral and longitudinal maneuvers (i.e., steering and braking/accelerating). For example, a Level 2 system could be traffic jam assist, which can keep the vehicle within a lane and a driver-specified distance from the vehicle in front of it, while the driver monitors the environment and is readily available to take over the driving task if required to do so.



Levels 3–5

Similar to Level 2 systems, Level 3–5 systems also perform the lateral and longitudinal maneuvers. However, unlike Level 2, Level 3–5 systems are given the task of monitoring the driving environment. Level 4 and 5 systems not only monitor the environment but are also responsible for performing all aspects of the driving task, whether the human is available to intervene upon request or not. This means that should conditions be met, Level 4 and 5 vehicles can operate without a human even inside the vehicle.

The Policy Challenge

These two differences between the Level 2 and Level 3–5 systems (i.e., monitoring of the driving environment and the systems' requirement to perform in the absence of a human driver to intervene) are two main elements challenging some of the assumptions that form the foundation of policies and regulations. To date, human drivers have been deemed responsible for not only monitoring their driving environment for events and potential hazards to ensure a safe operation, but also for performing all driving tasks. Yet, the first assumption is now challenged by the introduction of Level 3–5 systems, and the second assumption is challenged by Level 4–5 systems.

Given the discussions presented in this section regarding the phases of a crash, technologies that are currently available on vehicles (i.e., active safety technology) and forthcoming levels of automation, the rest of this report investigates possible policy questions that may arise should a Level 3–5 vehicle be involved in a crash.



AV Crash Issues That May Affect Texas Law

Analysis of Current Law

In spite of optimistic views of automation, it is prudent to assume that while vehicle automation can perhaps change the severity and/or frequency of crashes, it will not likely eliminate crashes involving vehicles.

Based on this assumption and discussions presented in the previous section of this report, researchers reviewed the Texas Transportation Code (Title 7. Vehicles and Traffic—Subtitle C. Rules of the Road—Chapter 550. Crashes and Crash Reports) to identify existing policies and regulations that could be affected by the introduction of Level 3–5 AVs. This section presents the analysis of the sections of the Texas Transportation Code that could possibly be affected by an AV crash.

Use and Definition of the Term Operator

Of significance in dealing with an AV crash is how the term *operator* is defined. The current definition is stated as:

Sec. 541.001. (1) "Operator" means, as used in reference to a vehicle, a person who drives or has physical control of a vehicle.

Sec. 541.001. (3) "Person" means an individual, firm, partnership, association, or corporation.

In the Texas Transportation Code, there are many instances that can fall short or be ambiguous if the term *operator* is not properly defined



to address the differences that are introduced by AVs. These differences are mostly in the context of who is in control or who should be in control. For instance, the “failure to stop and render aid” provision of the Texas Transportation Code Sec. 550.021(a)(3) states:

The operator of a vehicle involved in an accident that results or is reasonably likely to result in injury to or death of a person shall immediately determine whether a person is involved in the accident, and if a person is involved in the accident, whether that person requires aid.

As evident from this statement, if *operator* is not defined in light of nuances and subtleties of the AV technology, one can interpret the operator as the person behind the steering wheel (driver) or the person inside the vehicle (occupant), the AV system, or the firm/partnership/association/corporation that has control of the vehicle. If the latter two entities are deemed to be the operator, determining whether another person was involved in the crash or whether the person requires aid becomes a challenging, if not impossible, task.

A proper and all-encompassing definition of the *operator* is critical in assigning roles, responsibilities,

and obligations to different entities in the context of AV operation. This definition will also influence how ensuing prosecutions might take place. Google recently submitted an inquiry concerning the driver to NHTSA. In its interpretation, NHTSA concluded that the self-driving system—or AV in this report—is considered as the driver for certification and compliance with Federal Motor Vehicle Safety Standards (5). This further signifies the need for an appropriate definition of *driver* or *operator* in the Texas Transportation Code.

Citation and Reporting by Law Enforcement

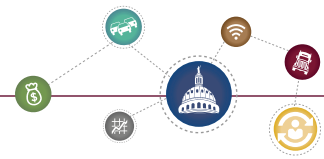
The current citation form and crash reporting form do not provide the option to indicate a crash involving an AV. Though a narrative section is available on the crash reporting form where the officer can provide an explanation of the nature of the crash, the same is not applicable on the citation form. In addition, the traffic citation form assumes the operator to be the driver behind the wheel who has committed a traffic offense. However, this may not necessarily be an accurate assumption in the context of an AV.

The current citation form and crash reporting form do not provide the option to indicate a crash involving an AV.

Data Availability

While laws regarding downloading and accessing the EDR information vary slightly in each state,¹ they are not necessarily concerned with storage or data elements gathered because these are mostly regulated at the federal level with privacy concerns in mind. However, in absence of any regulatory framework at the federal level for storage and retrieval of data from AV systems in case of a crash, this responsibility can be assumed by

¹ While it has been ensured that an EDR’s data are accessible and do not record any personally identifiable information, 15 states, including Texas, have enacted statutes relating to EDRs and privacy. Texas Transportation Code Title 7. Vehicles and Traffic—Subtitle C. Rules of the Road—Chapter 547. Vehicle Equipment—Sec. 547.615 prohibits download of data, except under the following circumstances: (1) with the owner’s consent, (2) with a court order, (3) for the purpose of improving motor vehicle safety, and (4) for the purpose of determining the need for or facilitating emergency medical response.



the states to ensure accessibility of data for beneficial reasons, while protecting the privacy of the operator and the general public.

Current EDRs may record:

- Pre-crash vehicle dynamics and system status.
- Driver inputs.
- The vehicle crash signature.
- Restraint usage/deployment status.
- Post-crash data, such as the activation of an ACN system (6).

While EDRs are currently not mandatory in vehicles, many automakers choose to install them. However, the type, amount, and duration of the data captured by EDRs are very limited and not comparable to what can be captured and stored by an AV system.

Current state regulation does not require a specific list of vehicle data or information to be available for crash investigation purposes

Data Accessibility

Current state regulation does not require a specific list of vehicle data or information to be available for crash investigation purposes. As a result, state regulation is also silent on how such information or data must be accessed or retrieved from the vehicle. Current practices by the law enforcement community require use of multiple devices and technologies to access and retrieve such data from the vehicle EDR. The type of information, format, quality, duration, etc. of these data elements can vary not only from vehicle to vehicle, but also from one model year to another. This lack of standardization creates challenges for the law enforcement community investigating a crash. The amount and complexity of data gathered and collected by AVs only increase, and should availability and accessibility of such data from AVs be required by the state, agencies responsible for accessing, analyzing, and storing such data (e.g., the Department of Public Safety) will need adequate training and education about the details of the technology.

Post-crash Actions

Reviewing the Texas Transportation Code revealed that once a crash occurs, a number of actions are required from the driver (i.e., operator). Some examples of such actions are as follows:

Sec. 550.023. (1) DUTY TO GIVE INFORMATION AND RENDER AID. The operator of a vehicle involved in an accident resulting in the injury or death of a person or damage to a vehicle that is driven or attended by a person shall:

(1) give the operator's name and address, the registration number of the vehicle the operator was driving, and the name of the operator's motor vehicle liability insurer to any person injured or the operator or occupant of or person attending a vehicle involved in the collision;

Sec. 550.024. (1) DUTY ON STRIKING UNATTENDED VEHICLE. (a) The operator of a vehicle that collides with and damages an unattended vehicle shall immediately stop and:

(1) locate the operator or owner of the unattended vehicle and give that person the name and address of the operator and the owner of the vehicle that struck the unattended vehicle;

Given the discussion of the definition of the operator, the listed tasks can prove challenging if not impossible. For instance, Sec. 550.023(1) requires the driver of the vehicle to provide certain information to the other person or operator involved in the collision. Sec. 550.024(1) requires the operator of the vehicle to locate the owner of the unattended vehicle that was struck. Such requirements become increasingly complex tasks if the crash involves a Level 5 AV (full automation) that may or may not have a person inside the vehicle, especially if the operator is required to perform these actions immediately following the crash.

Crash Notification and Reporting

The current law, as indicated by Texas Transportation Code Sec. 550.026(a), states that the operator of the vehicle involved in a crash resulting in death, injury, or damage to a vehicle to the extent that it cannot be



normally and safely driven shall immediately by the quickest means of communication give notice of the crash to the authorities, which are defined as:

- The local police department if the crash occurred in a municipality.
- The local police department or the sheriff's office if the crash occurred not more than 100 feet outside the limits of a municipality.
- The sheriff's office or the nearest office of the department if the crash is not required to be reported.

Considering this in the context of the AV, it can be safely assumed that the vehicle is capable of reporting such events, especially in the case of a Level 5 AV, even if it is not currently required by state or federal law. However, depending on how the operator is defined and who is deemed to be the operator at the time of the crash, the type of information that needs to be communicated will need to be defined. Moreover, most crashes are reported through 911. Depending on which 911 center receives the call, the center may or may not be able to receive ACN data originating from the AV. Current ACN systems found in new vehicles (e.g., GM OnStar) offer crash-related services only with active (paid) subscription.

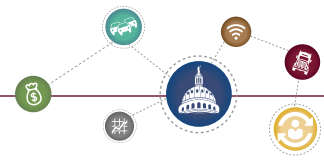
Investigation

According to Sec. 550.041(1)(a), a peace officer who is notified of a motor vehicle crash resulting in injury to or death of a person or property damage to an apparent extent of at least \$1,000 may investigate the crash and file justifiable charges relating to the crash. To date, officers are trained to investigate such crashes by evaluating and analyzing the dynamics and evidence at the scene (e.g., physical evidence, environmental factors, and occupant kinematics and seating location). Investigating a crash involving an AV, however, requires a new skillset and expertise. If a crash involves an AV (Level 2 and above), the peace officer needs to determine:

- At the time of the crash, was the driver or the system in charge of monitoring the environment?
- At the time of the crash, did the driver or the system fail to detect and recognized a threat in the environment that led to a crash?
- At the time of the crash, was the driver or the system responsible for taking over in case of a failure?
- At the time of the crash, did the driver or the system fail to take over control of the vehicle and that led to a crash?

Finding answers to these overarching questions is the primary way for the peace officer or the investigation team to determine who the operator was at the time of the crash and whether he or she (or it) was at fault.

Finding answers to these overarching questions is the primary way for the peace officer or the investigation team to determine who the operator was at the time of the crash and whether he or she (or it) was at fault. To answer these questions, the investigator needs access to vehicle data and the ability to analyze and interpret the retrieved data, assuming the relevant data were properly stored. These data are beyond what is currently stored by the EDR and require new training, expertise, tools, and equipment that are currently not available to those who may be investigating crash scenes involving an AV.



Texas Stakeholder Workshop: Policy Questions to Explore

In addition to review of literature and existing policies that currently govern how crashes are dealt with, a workshop with local Texas stakeholders was organized to further examine the topics and evaluate the alternatives. The workshop was attended by individuals from the following organizations:

- Texas Department of Transportation.
- Texas Department of Public Safety.
- Texas EMS Trauma and Acute Care Foundation.
- Texas Department of Motor Vehicles.
- Texas Municipal League.
- Texas District and County Attorneys Association.²

Some questions that were raised during the course of this effort need to be further explored and investigated:

- Given the fact that AVs capture vivid images of their surroundings through cameras and other sensors, and these imagery and data can potentially be stored in the vehicle, under what terms and conditions should the responsible public agency release crash report information that may include such visual information, yet ensure the protection of personally identifiable information?
- Currently, most car manufacturers view the data that are generated by the AV as proprietary and competitive because they can reveal how the system operates, where it may have deficiencies, and how it handles critical situations. Should the reporting of crash data and information that includes storage and retrieval of vehicle data take into account the competitive nature of this information?
- Given that currently the law enforcement community is not equipped with the necessary tools and training required to investigate a crash involving an AV, and also the level of technical complexities involved with this technology, should the law enforcement agency that has jurisdiction be the primary source of investigation? Or should there be a dedicated team of experts at the state level who can take over as the primary source of investigation?

²Views expressed during the workshop are the views of the individuals and not their respective employer.

- What period of time before and after the crash should the data from the AV be stored? (California and Nevada currently require 30 seconds prior to the crash.) For how long should the data be maintained after the crash? (California and Nevada currently require three years.) Given the possibly large amount of data that can be stored and consequently retrieved from the AVs, is the responsible state agency prepared and equipped to store and maintain the said data for the required period of time?
- AVs rely highly on a network of onboard sensors and other complex systems to operate. Based on the critical nature of these systems and their safety implications, should there be requirements to address maintenance of the safety-critical systems (e.g., cameras and radars) of an AV?

If a crash occurs and the AV is deemed to be at fault, should this particular vehicle be allowed to continue its operation on public roads?

- Given the subtleties and possibly disguised nature of AVs, as automakers strive to maintain the current styling principles of AVs to blend with existing vehicles, what may be needed to identify an AV? How can first responders identify the type of vehicle(s) involved in a crash if involvement of an AV is going to require an additional set of procedures?
- For the safety of the first responders and others at the accident scene, is there a need for first responders to ensure that the AV is disabled and incapable of driving itself after being involved in a crash, even if the vehicle appears to have been stationary for an extended period of time?
- If a crash occurs and the AV is deemed to be at fault, should this particular vehicle be allowed to continue its operation on public roads? Should this particular vehicle be required to undergo specific repair and maintenance to ensure its safe operation? Should this particular vehicle be subject to improvement of its software and control logic to avoid similar future crashes? If so, what criteria need to be met before

subjecting the vehicle to software improvement? Should this software improvement be installed on all similar makes and models of the same AV?

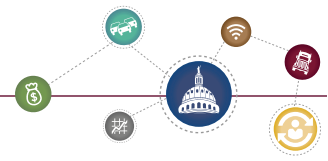
- Should disciplinary actions that result from a crash be revised based on introduction of the AV technology? Will revising the definition of *operator* introduce changes in the nature of such disciplinary actions?
- Based on the sensitivity of this topic and technology, in case of an AV crash in Texas, which entity should be in charge of matters related to public relations to address the safety concerns of the public?
- Under current state law, after a crash, a vehicle can be normally and safely driven if the vehicle can operate under its own power in its usual manner, without additional damage or hazard to the vehicle, other traffic, or the roadway. How can this be ensured? Should the vehicle be able to operate in a degraded state?
- How can any and/or all the discussions presented here differ if the vehicle was operated by a public agency (e.g., state government, university, or research institution)?



Summary of Considerations for Policy Makers

In this report, much has been discussed regarding AV technology, Texas' laws and regulations pertaining to crashes, and other adjacent technologies and practices that could potentially be impacted based on the introduction of AVs. Based on the literature review and the stakeholder workshop, the considerations presented in this section should be viewed as an early attempt at capturing situations that may arise in case of an AV crash in Texas. It is intended to provide state policy makers with an initial list of what may need to be considered.

Topics, discussions, and considerations presented here are by no means comprehensive and all-encompassing. What follows in this section is a series of thoughts and possible actions for state policy makers to consider to be better prepared for the first AV crash in Texas. Policies can affect actions that occur prior, during, or after a crash event.



Pre-crash

Any policy that is considered to address AV-related crashes should note the gap that exists between the current capability and expertise available in the agencies responsible for implementing and executing the said policies. Considerations should be paid to the proper definition of *operator* within the Texas Transportation Code to address the nuances pertinent to AVs. This new definition of *operator* can eliminate many future disputes and also clearly define the roles and responsibilities to be met by the owner, operator, driver, occupant, and vehicle. This is particularly relevant in light of trends in offering transportation as a service where the occupant may simply be riding in the AV without having any control over the operation of the vehicle.

Considerations should be paid to the proper definition of *operator* within the Texas Transportation Code to address the nuances pertinent to AVs.

The current crash report form and citation form in Texas can include additional fields to capture the data and information related to AVs.

While ACN can eliminate or improve upon many of the challenges and inconsistencies faced by TIM practices across the country and in Texas, further deployment of the infrastructure to support ACN can move forward independent of the AV technology. Nevertheless, it is safe to assume that newer vehicle models, as well as AVs offered by car manufacturers, will be equipped with ACN, providing the opportunity for further integration of the two.

Availability and use of ACN can improve TIM processes and practices. However, the effectiveness of ACN is a function of the following criteria:

- The availability and capabilities of the support infrastructure from the public agencies involved.
- The market penetration rate of vehicles equipped with ACN or advanced ACN.



- The active subscription of the users to crash notification services offered by the car manufacturer.

AV technology can generate and make available a richer set of data pertaining to crashes (e.g., the distance from the lead vehicle or object, relative speed or acceleration compared to the lead vehicle or object, and video recordings of the crash scene). However, this poses challenges such as:

- Transmission of data to a telematics service provider or public safety answering point and availability of communication bandwidth.
- Increased cost to the car manufacturers to store the additional data.
- Integration of such data into ACN.
- Common data language, standards, and requirements that need to be transmitted or accessed by law enforcement or other public agencies.

Considerations should be made to define the boundaries of safe operation in case of a crash (e.g., moving to the shoulder or a designated area, and the manner in which the vehicle is expected to find such areas).



Any pertinent policy action that is deemed necessary by the policy makers should not only cover the testing and development of the AVs but also private or commercial operation of such vehicles on public roads. Establishing a transparent crash reporting mechanism can help inform the public of the safety-related concerns of the technology.

Crash

In establishing and enforcing any policies related to AVs, the capabilities and expertise available at public agencies and first responders to receive and interpret crash-related data need to be taken into account.

Based on who is deemed the operator (e.g., the vehicle or the human driver), the quickest means of reporting a crash could vary, so thought should be given to further define the quickest means.

Current state law does not specify the duration and type of data that need to be stored in case of a crash, which can in fact be used for post-crash investigation and other similar purposes. While other states (California and Nevada) have required 30 seconds of AV data to be stored prior to the crash, they remain silent about what data need to be stored.

Post-crash

The availability and accessibility of crash data to the authorities for crash investigation and reporting purposes need to be considered in order to provide a uniform platform for the authorities to access, retrieve, and interpret the data.

Protecting the privacy of the operator and others (e.g., pedestrians or other drivers) due to the increased data-capturing capabilities of AVs should be considered.

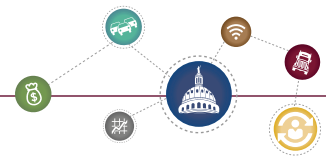
Protecting the privacy of the operator and others (e.g., pedestrians or other drivers) due to the increased data-capturing capabilities of AVs should be considered. Given that the fidelity and resolution of data can be captured from the AV's suite of sensors, crash data can be used for crash scene reconstruction. Hence, thought should be given to the legality and procedures that need to be in place to support it.

Assuming that AV crash data will be stored on board the vehicle, and later retrieved and maintained by the authorities, considerations should be made to only access and retrieve the data that are relevant, as opposed to accessing and storing all available data. This is mostly due to the proprietary or competitive nature of such data for the vehicle manufacturer.

Provision of timely public information and outreach following an AV crash can provide the public with the necessary information to ensure their safety and inform any necessary action that is required of them.

The first responder at the crash scene will need some means to ensure the AV is disabled and the automated technology is disengaged.

Given the complexities of the AV technology, provision of proper training and tools should be considered for the team investigating an AV crash.



For the peace officers or others present at the scene of a crash, it may not be easily identifiable whether one or more vehicles are AVs. If specific procedures and protocols need to be followed in a crash involving an AV, clear markings or symbols to provide such distinction could assist the personnel present at the scene.

If the AV system is deemed at fault, questions arise about whether this was a systematic problem common among all similar AVs or just one isolated fault or error that led to a crash. In the case of a systematic problem in all similar AVs, consideration should be paid to provide the means and policies to address such a problem and prevent future incidents from happening.

Opportunities for Improving Traffic Incident Management

This subsections look at existing challenges within the TIM domain that AV technology could potentially improve upon. What is presented here should be deemed potential for improvement and not implementable in the very near term. These TIM challenges are mentioned here solely to inform policy makers of what adjacent topics could be addressed if policies related to AV crashes are to be introduced.

Review of available literature revealed many challenges faced by the TIM practitioner. Presented here is a list of challenges that were mentioned most frequently in the literature and demonstrated characteristics that could potentially be addressed by AV technology.

Inconsistent Notification of Incident Responders

Typically, public safety agencies, including law enforcement, fire and rescue, and emergency medical service agencies, are the first to be notified of an incident through 911 dispatch. Notification of support responders, particularly transportation agencies, can be less consistent.

If transportation agencies do not support 24-hour operations or promote an active role in TIM, public safety personnel may overlook notification of support responders. In addition, if no formal guidelines are in place for notifying support responders or if recently

instituted guidelines are not being followed, notification of support personnel may vary depending on the particular public safety personnel managing the incident. Given the current potentially sensitive nature of AVs, it would be prudent to consider possible methods of informing all stakeholders that need to be involved with a crash involving an AV.

If the AV system is deemed at fault, questions arise about whether this was a systematic problem common among all similar AVs or just one isolated fault or error that led to a crash.

Inaccurate Incident Reports

Motorists who carry cellular telephones are commonly the first to detect an incident and provide notification. While the speed with which the incident is reported is beneficial, motorists may not provide accurate location information and may exaggerate incident severity. Motorists may use landmarks to describe the incident location rather than roadway identifiers and may confuse directional information. As a result, unnecessary, inadequate, or insufficient response resources may be dispatched to the incident scene. However, AVs are equipped with a variety of sensors that can provide accurate and detailed information. This further signifies the importance of using ACN systems for AVs to improve the accuracy and dependability of AV crash reports.

Slow Detection

In urban areas, higher traffic volumes and a prevalence of cell phone users in the traffic stream generally result in quick and reliable incident detection times. In nonurban or remote areas, where passing vehicles are less frequent, incidents may go undetected for some time. Similar to the argument about the accuracy of incident reporting, it is paramount to consider reporting mechanisms for AVs, especially if the AV is designed to operate on roads with higher speed limits (e.g., highway autopilot).

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