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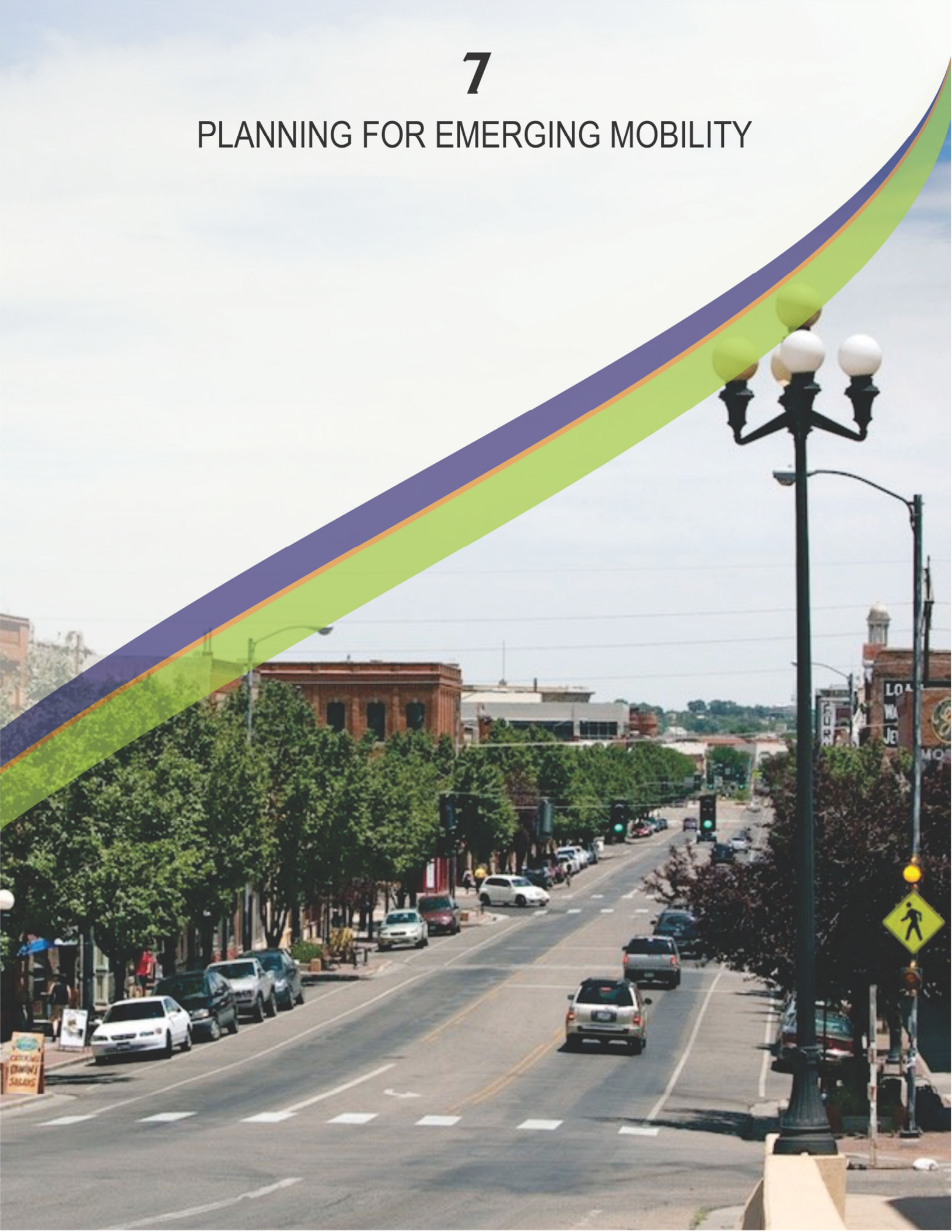
PLANNING FOR EMERGING MOBILITY



7.0 Planning for Emerging Technologies

7.1 Introduction

Throughout history, humans have innovated and developed new means of improving the way they move people and goods throughout their societies. One of the first major technological innovations that dramatically changed the world was the creation of the wheel. This primitive invention was a major technological improvement that completely changed the world. Many millennia later, it was the advent of the automobile that once again dramatically changed the way people and goods move. Today, we are once again experiencing a technological revolution.

A number of emerging technologies are changing the way that vehicles operate and how they interact with the public. This chapter discusses these emerging technologies and how their implementation will affect our transportation system. Although there are many emerging technologies, this chapter specifically discusses connected and autonomous vehicles (CAVs), transportation network companies (TNCs), and electric vehicles (EVs) in the context of the Pueblo Area Council of Governments (PACOG) Long Range Transportation Plan (LRTP).

- Connected and Autonomous Vehicle – A connected vehicle can be defined as one communicating with other vehicles and with the world around them. An autonomous vehicle can be defined as one that propels itself without need of a human operator.
- Transportation Network Company – A transportation network company (TNC) refers to a rideshare business, such as Uber and Lyft. A ridesharing company matches passengers with vehicles via websites and mobile apps.
- Electric Vehicle – An electric vehicle (EV) is an automobile or truck that is propelled by one or more electric motors, using energy stored in rechargeable batteries.

The emerging technologies mentioned above are already in our communities. Although the pros and cons of these technologies can be debated at length, these technologies are here and are projected to increase, therefore it is vital that PACOG plan for them. Proper planning will ensure that the Pueblo Area reaps the full benefit of these technologies while mitigating the negative consequences that accompany them.

7.2 Connected & Autonomous Vehicles

CAVs will dramatically change the way people and goods are moved throughout U.S. communities. Though seemingly a new concept, they have been in production and even implemented in certain industries for decades. In the 1980s, Caterpillar Inc. began researching CAV technologies to cut costs, increase efficiency, and enhance safety in mining operations. By the mid-1990s, the CAV mining technology had been implemented.[26] Although outfitting CAV technology in a controlled environment, such as a mine, was not an easy task, it was easier than implementing the same technology in the uncontrolled environment of public roads. Additionally, this technology was extremely expensive, making it impractical for the general public. However, in the decades that followed, technological advancements allowed for CAV technology to be integrated cost effectively into vehicles. Many CAV technologies, such as cruise control, blind spot detection, forward collision warning, lane departure warning, automatic emergency braking, adaptive cruise control, and self-parking features, are already in vehicles on the road today.

At the federal level, since the 1990s the United States Department of Transportation (USDOT) has been looking at ways CAV technology will affect the nation's transportation network. Although there haven't been any federal laws or regulations passed pertaining to CAV, USDOT

[26] *Mining Technology Magazine*, "Haulage Goes Autonomous," July 27, 2011, https://www.mining-technology.com/features/feature125450/.

has issued several voluntary guidance documents to support the autonomous vehicle industry, states, and other stakeholders as they move forward in the testing and deployment of CAVs. Additionally, the State of Colorado has passed a law that sets common definitions and lays the groundwork to support the advancement and deployment of CAVs in Colorado.

When fully implemented, CAV technologies will fundamentally alter the way individuals interact with vehicles. CAV technology will increase safety on roadways, reducing the number of fatalities due to vehicle crashes. Chapter 5 of this plan documents that there were more than 600 fatalities on Colorado roadways in 2018, 36 of which were in Pueblo County; autonomous vehicles will have the potential to reduce vehicle crashes and fatalities. A negative consequence associated with CAV technology, however, is the loss of jobs that rely on human operators. This and other consequences, both positive and negative, will require government at all levels to plan for CAV technologies and put in place policies promoting the positive benefits while mitigating the negative consequences.

7.2.2 Connected & Autonomous Vehicles Defined

Connected vehicles and autonomous vehicles are often seen as synonymous. Though there are similarities between the two, there are also differences. The greatest difference is that a connected vehicle requires a human driver to operate it, whereas an autonomous vehicle does not. Additionally, the components that make a connected vehicle connected also are necessarily present in autonomous vehicles; however, the advanced components that make an autonomous vehicle self-driving are not necessarily present in connected vehicles. It is important to note that connected vehicles are available today for public purchase, whereas autonomous vehicles are still in the testing phase, as the industry continues to conduct research, development, and testing.

Connected vehicles, as previously mentioned, are already on the road today. What differentiates these vehicles from non-connected vehicles is that they utilize technology to communicate with other devices to share important transportation information. Connected vehicles can communicate with other vehicles, roadways, other infrastructure, and mobile devices. The vehicles and other devices utilize dedicated short-range communication (DSRC) to transmit data. The data transmitted to the vehicle provides information to the human operator on upcoming roadway conditions, vehicle hazards, alternative routes, and travel times. Additionally, connected vehicles also may utilize cellular technology such as 5G to communicate roadway conditions to cloud-based platforms. The information allows the driver to make better-informed decisions while operating the vehicle. If the connected vehicle is equipped with advanced driver assistance technology (as defined in **Table 7.1**), then the vehicle, in the place of the driver, can take emergency action.

Autonomous Vehicles

Autonomous vehicles are vehicles that can operate on the roadway without the need for a human operator to intervene in the driving task. The vehicles utilize many of the components that connected vehicles use; however, they also utilize other technologies to perform the dynamic driving task. Autonomous vehicles utilize technologies such as radar, Global Positioning System (GPS), cameras, and light detection and ranging devices; data from these components is fed into a centralized computer, which processes the data and performs the driving task. Autonomous vehicles are still in development today; many automotive, technology, and data companies are investing billions of dollars into their research and development. Companies in the United States and around the world have logged millions of miles on autonomous test vehicles on public roads to refine the technology and ensure safety. Although these vehicles are not available for purchase today, the automotive and technology industries estimate that in the near future, perhaps as early as 2030, they will become available.

Terminology – It is important to note that the term "connected and autonomous vehicle (CAV)" is used to refer to autonomous vehicles in the remainder of this document because autonomous vehicles utilize both autonomous and connected technologies.

Society of Automotive Engineers Levels of Automation

In order to set a standard with common definitions for CAVs, the Society of Automotive Engineers (SAE) has developed the "Levels of Automation," as detailed below and in **Table 7.1**. The levels of automation are a ranking system to define at what level of automation a vehicle is classified. This system has become the industry standard widely used by the federal government, states, technology companies, and automotive companies.

Level 0 – A vehicle in this level does not have any kind of automation or driver assistance. A majority of vehicles on the road today are classified higher than level zero.

Levels 1–3 – Vehicles in these levels provide driving assistance or limited automation; these vehicles still need a human driver to operate or take control of the vehicle depending on the level of automation. Examples of technology that can be present in these vehicles are cruise control, automatic emergency breaking, adaptive cruise control, forward collision warning, lane departure warning, and lane-keeping assistance.

- **Level 1** – In a vehicle at level one, the vehicle is controlled by the driver, but some driving assistance features may be included in the vehicle design.
- **Level 2** – A vehicle at level two has combined automated functions, such as acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
- **Level 3** – In a vehicle at level three, the driver is a necessity but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

Level 4–5 – Vehicles in these levels provide autonomous driving, that is, the vehicle performs the driving task and a human driver is not needed to operate the vehicle.

- **Level 4** – In vehicles at level four, human drivers can take control of the vehicle if they choose to do so. Level four vehicles can only operate autonomously in certain conditions, for example, in a specific geographical area such as a specific city or county.
- **Level 5** – A vehicle at level five is fully autonomous; the vehicle performs all of the driving tasks under all conditions. Vehicles in this level may still allow a human driver to take control; however, human control is not necessary and takes place only if the human chooses to do so. It is important to note that vehicles that are level five eventually may not have steering wheels or pedals.

Table 7.1:. SAE Levels of Automation

Level of Automation	Name	Definition
0	No Automation	Zero autonomy; the driver performs all driving tasks.
1	Driver Assistance	Vehicle is controlled by the driver, but some driving assistance features may be included in the vehicle design.
2	Partial Automation	Vehicle has combined automated functions, such as acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
3	Conditional Automation	Driver is a necessity but is not required to monitor the environment. The driver must be ready to take control of the vehicle with notice.
4	High Automation	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
5	Full Automation	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Source: Data from: Society of Automotive Engineers, accessed 2020, https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic.

7.3 Federal & State Roles

When fully implemented, CAVs will change transportation fundamentally; however, as with all new technologies, there will be unforeseen consequences. Both federal and state governments have recognized that regulations will be required to safely implement CAVs. They also recognize that regulations may stifle innovation, especially at a time when the technology is still evolving.

One example is the CAV classification as a "vehicle"; even as an emerging technology, CAVs are still considered vehicles. Both the federal and state governments will regulate them as standard vehicles. The first federal CAV guidance document, discussed in detail in Section 7.3.1, highlights each government's role in regulation.

Federal Role

The federal role is to:

- Set federal motor vehicle safety standards (FMVSS) for new motor vehicles and motor vehicle equipment (to which manufacturers must certify compliance before they sell their vehicles).
- Enforce compliance with the FMVSS.
- Investigate and manage the recall and remedy of noncompliance and safety-related motor vehicle defects and recalls on a nationwide basis.
- Communicate with and educate the public about motor vehicle safety issues.
- Issue guidance for vehicle and equipment manufacturers to follow, such as vehicle performance guidance for CAVs.

State Role

The state role is to:

- License (human) drivers and register motor vehicles in their jurisdictions.
- Enact and enforce traffic laws and regulations.
- Conduct safety inspections, where states choose to do so.
- Regulate motor vehicle insurance and liability.[27]

7.3.1 Federal Action

The federal government has been involved with CAVs for many years, working with industry, academia, state/local governments, and transportation stakeholders to support the safe development, testing, and integration of automated vehicle technologies. Although Congress has not enacted any laws regulating CAVs, USDOT has been actively involved in guiding the conversation. Since 2016, USDOT has published a series of voluntary guidance documents, which provide stakeholders direction and have been released by the National Highway Transportation Safety Administration (NHTSA), an administration under USDOT.

Federal Automated Vehicle Policy: Accelerating the Next Revolution in Roadway Safety

The report titled *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety,* issued in 2016, was USDOT's first comprehensive policy document.[28] It set in motion a series of policy updates that are discussed in this chapter. The document's goal was to accelerate the development of CAVs while ensuring that the technology is implemented in a manner that provides safety benefits from the time of its release and into the future.

[27] USDOT, NHTSA, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety,* September 2016, https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf.

[28] USDOT, NHTSA, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety,* September 2016, https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf.

The document was divided into four sections:

1. "Vehicle Performance Guidance for Automated Vehicles" – Outlined best practices for the safe pre-deployment design, development and testing of CAVs prior to commercial sale or operation on public roads.
2. "Model State Policy" – Reiterated a state's responsibilities as it pertains to motor vehicles and set a model framework for states to utilize, thus discouraging a patchwork of laws and regulations across the nation.
3. "NHTSA's Current Regulatory Tools" – Defined how CAVs fit into the existing NHTSA regulatory powers, including letters of interpretations, exemptions from existing standards, rulemaking to amend existing standards or create new standards, and enforcement authority to address defects that pose an unreasonable risk to safety.
4. "Modern Regulatory Tools" – Due to the speed with which CAV technology advances, this section highlighted potential new tools, authorities, and regulations. Some of these potential powers included safety assurances, cease-and-desist authority, enhanced data collection, and expanded exemption authority for CAVs.

Automated Driving Systems: A Vision for Safety 2.0

A year following the release of *Federal Automated Vehicle Policy*, NHTSA released *Automated Driving Systems: A Vision for Safety 2.0*, which updated and replaced the previous guidance document.[29] The new guidance document focused on safety and best practices for legislatures and state DOT officials.

The document released voluntary guidance on the topics in **Table 7.2**.

Table 7.2: Topics in Automated Driving Systems: A Vision for Safety 2.0	
• System safety	• Crashworthiness
• Operational design domain	• Post-crash automated driving system behavior
• Object and event detection and response	• Data recording
• Fallback	• Consumer education and training
• Validation methods	• Federal, state, and local laws
• Human-machine interface	• Safety self-assessment
• Vehicle cybersecurity	

Additionally, prior to and during this time, multiple states began introducing legislation pertaining to CAVs. Since 2012, at least 41 states and the District of Columbia have considered legislation related to autonomous vehicles.[30] Due to increased interest from state legislators regarding CAVs, NHTSA released a best practices document for legislatures to guide states in a common direction.[31] The following were recommendations made by NHTSA for legislatures:

- Provide a "technology-neutral" environment.
- Provide licensing and registration procedures.

[29] USDOT, NHTSA, *Automated Driving Systems: A Vision for Safety 2.0*, September 2017. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[30] National Conference of State Legislators, *Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation*, February 18, 2020, https://www.ncsl.org/research/transportation/autonomous-vehicles-self-drivin.g-vehicles-enacted-legislatispx

[31] National Science & Technology Council and the USDOT, *Ensuring American Leadership in Automated Vehicle Technologies*, January 2020, https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/360956/ensuringamericanleadershipav4.pdf.

- Provide reporting and communications methods for public safety officials.
- Review traffic laws and regulations that may serve as barriers to operations of CAVs.

The last major portion of the guidance regarded best practices for state highway safety officials. It recognized that states generally have the responsibility to reduce traffic crashes within their jurisdictions. The document put forth best practices guidelines on the ways state officials should approach CAVs. The areas covered by these practices include:

- Administrative
- Application for entities to test CAVs on public roadways
- Permissions for entities to test CAVs on public roadways
- Specific considerations for CAV test drivers and operators
- Considerations for registration and titling
- Working with public safety officials
- Liability and insurance

Preparing for the Future of Transportation: Automated Vehicles 3.0

In 2018, USDOT published *Preparing for the Future of Transportation: Automated Vehicles 3.0*.[32] The document built upon but did not replace the previous Automated Driving Systems: A Vision for Safety 2.0 document. The updated document continued to expand guidance for CAVs and, for the first time, brought together many surface transportation operating administrations to publish a multimodal approach to CAVs. The policies put forth in the document were established based on following six new principles:

1. Prioritize safety
2. Remain technology neutral
3. Modernize regulations
4. Encourage a consistent regulatory and operational environment
5. Prepare proactively for automation
6. Protect and enhance the freedoms enjoyed by Americans

These principles guided USDOT in developing a multimodal approach to CAVs. Whereas previous guidance documents were developed with heavy input from NHTSA, USDOT approached *Automated Vehicles 3.0* with input from many surface transportation administrations. This step was included to provide a comprehensive multimodal look at CAVs. The document included key policy issues for the following surface transportation authorities:

- National Highway Transportation Safety Administration
- Federal Motor Carrier Safety Administration
- Federal Highway Administration
- Federal Transit Administration

Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0

In January 2020, USDOT in collaboration with the White House released *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0*. This document continues to build on the previous guidance documents. However, unlike previous reports, which were driven mainly by USDOT, this guidance document was created with the input from more than 38 federal departments, independent agencies, commissions, and entities within the Executive Office of the President. The document guidance puts forth polices and recommendations to set the United States as the leading nation in the world for CAV technology development and integration. The following three core areas of interest with supporting sub-areas are identified:

1. Protect Users and Communities
   a. Prioritize safety
   b. Emphasize security and cybersecurity
   c. Ensure privacy and data security
   d. Enhance mobility and accessibility

[32] USDOT, NHTSA, *Preparing for the Future of Transportation: Automated Vehicles 3.0*, September 2018, https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf.

2. Promote Efficient Markets
    a. Remain technology neutral
    b. Protect American innovation and creativity
    c. Modernize regulations
3. Facilitate Coordinated Efforts
    a. Promote consistent standards and polices
    b. Ensure a consistent federal approach
    c. Improve transportation system-level approach[33]

7.3.2 State of Colorado Action

The State of Colorado has recognized that CAVs are an emerging technology that will change the way the citizens of the state interact with the state's transportation system. For that reason, the State has taken measures to ensure that Colorado does not lag behind this rapid evolving technology. In the past four years, Colorado has passed laws regarding autonomous vehicles and has integrated CAV activities within CDOT. These actions aim to prepare Colorado for the time when CAVs are deployed on public roads.

Colorado CAV Law

In 2017, the Colorado Legislature passed Senate Bill 17-213 and then-Governor John Hickenlooper signed the bill into law. As Colorado's first legislative action regarding CAVs, the law set in place a framework to support the CAV industry within the state. Included in the law are provisions that set definitions of CAVs as well as guidelines for CDOT and the Colorado State Patrol to follow for CAV deployment in the state. Major provisions of the law require or allow the following for CAVs:

1. Confirms that levels of automation 0–3, as defined by SAE International, are legal under Colorado law with a human driver.
2. Defines "Automated Driving System" (i.e., CAVs) as vehicles in levels 4–5 as defined by SAE International. These vehicles are authorized to operate within Colorado without a human driver, if they can meet all applicable state and federal laws.
3. Allows CAVs to operate in Colorado even if they do not meet all state and federal laws; however, approval of operation is required by CDOT and the Colorado State Patrol.
4. Prohibits any state agency or local jurisdiction to set policies or regulations for CAVs that are different from the standard set for human drivers. [34]

CDOT's Actions

CDOT developed the Connected and Autonomous Technology (CAT) Program to oversee CAV activities throughout the state. The purpose of the CAT program is "to accelerate the responsible use of connected and autonomous technologies in Colorado." The program will assist in meeting CDOT's overall CAV program mission to "improve the movement of goods and services throughout Colorado by leveraging the benefits of connected and autonomous mobility technologies while mitigating potential risks." CDOT will meet this purpose and achieve the mission by following these objectives:

1. Integrate CAT into CDOT planning and operations through consultation and education.
2. Provide strategy and direction for CAT planning, policy, and investment.
3. Facilitate development of statewide and inter-state CAT infrastructure network.
4. Partner with industry to accelerate CAT investment and deployment in Colorado.
5. Advocate for policy and regulation that aligns with program framework.
6. Build public support and enthusiasm for CAT technology through education and engagement.

[33] National Science and Technology Council and United States Department of Transportation, *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0*, January 2020, https://www.transportation.gov/sites/dot.gov/files/2020-02/EnsuringAmericanLeadershipAVTech4.pdf.

[34] "Programs: Autonomous Vehicles," Colorado Department of Transportation, accessed July 27, 2020, https://www.codot.gov/programs/operations/intelligent-transportation-systems/innovation/autonomous-vehicles.

7. Partner with local, regional, and national stakeholders to align efforts.[35]

The CAT program is designed in a manner to assist in developing partnerships with local, regional, and national stakeholders so that Colorado can realize the benefits of CAVs as they are deployed in the state. The program will do so by acting on the listed objectives above; however, the state will also leverage the following existing transportation assets:

- 23,000 miles of highway across many unique environments including rural, suburban, urban, mountains, and plains.
- 1,400 miles of fiber optic cable throughout the state.
- A large Internet of Roads (IoR) network, which provides connected vehicle infrastructure throughout Colorado. IoR is the country's first commercial-scale connected vehicle environment. It uses V2X (Vehicle to Everything) technology to communicate with connected vehicles to improve the safety and mobility of the transportation system. In Pueblo County, I-25 is slated to be a component of the IoR system.

Some detail on the IoR effort is of value in this LRTP report. According to a CDOT web announcement, "The IoR will bring nearly $44 million in public and private investment to Colorado to provide a 537-mile network in primarily rural environments that will provide real-time communication with connected vehicles. Supported by automotive and tech partners like Ford Motor Company, Qualcomm, and Panasonic that are already working with CDOT, the IoR will send safety and mobility-critical messages directly to drivers through infrastructure-to-vehicle (I2V) communication. It will also allow CDOT to 'listen' to the roadways through vehicle-to-infrastructure (V2I) communication, immediately notifying CDOT of crashes or hazards on the road to expedite emergency services and hasten the clearance of a crash scene."[36]

7.3.3 Consequences of CAVs

As is apparent from research, guidance, and laws that are being put forth at both the federal and state levels, CAVs will begin to be deployed on roadways in the near future. Although this emerging technology is still in its infancy, and predictions vary on when these vehicles will be fully deployed, it is apparent that CAVs will be the vehicles of the future.

CAVs are ushering in a transportation revolution that will make U.S. roads safer, provide mobility options to those who otherwise haven't had them, reduce or increase congestion, make certain jobs obsolete and create new ones, alter government revenue streams, and change the way communities are built.

While it is impossible to predict exactly how these vehicles will impact society, change is inevitable. In order to ensure that citizens of the PACOG area reap the full benefits of CAVs and simultaneously mitigate the negative consequences associated with their deployment, PACOG must plan now. The decisions made today will shape the future. A review of some of the positive and negative consequences of the future deployment of CAVS follows.

Safety

Roadway safety is an area in which CAVs will dramatically bring about a positive change. As mentioned in Chapter 5 there were a total of 3,942 crashes in Pueblo County in 2018, of which 34 were fatal. Additionally, 44 percent of those 34 fatal crashes involved drugs or alcohol. Whether these crashes result in fatalities, injuries, or property damage, they put an enormous human and economic burden on our society. According to a NHTSA study, "motor vehicle crashes [nationally] in 2010 cost $242

[35] Colorado Department of Transportation, *Division of Mobility Operations, Connected and Autonomous Technology (CAT) Program*, accessed July 27, 2020, https://transportationops.org/sites/transops/files/CDOT%20cat-program-framework_2018.pdf.

[36] Connect2DOT, "CDOT 'Internet of Roads' Presents the Future of Colorado's Transportation System," August 15–September 6, 2018, http://www.connect2dot.org/announcements/cdot-internet-of-roads-presents-the-–future-of-colorados-transportation-system.

billion in economic activity, including $57.6 billion in lost workplace productivity, and $594 billion due to loss of life and decreased quality of life due to injuries."[37] CAVs will make our roadways safer by removing the human driver from the driving task.

It is no secret that humans make mistakes, especially when operating vehicles. USDOT's *Automated Driving Systems: A Vision for Safety 2.0* guidance document highlights that the major factor in 94 percent of all fatal crashes is human error.[38]

Mobility

CAVs will provide people with a new form of mobility that otherwise would not have been available to them. Mobility is a key factor in life choices; it can impact whether or not a person is employed, can access useful and pleasant activities, and can receive essential services. This is especially true for people with disabilities who are unable to drive. According to the findings of a study that looked at the impacts CAVs will have on people with disabilities, CAVs could provide 2 million employment opportunities for people with disabilities.[39] Additionally, CAVs could dramatically benefit low-income individuals by providing additional transportation options in areas where mass transit is not a practical or a viable option.

Congestion

CAVs have the potential to either reduce or increase congestion on roadways. If the shared ownership model is deployed, CAVs can alter congestion levels by reducing the number of vehicles on the roadways. Currently, vehicles are parked for 95 percent of the time; if these vehicles were CAVs they could provide rides to other individuals when not in use by their owners.[40] If the shared ownership model were implemented, there would not be the need for as many vehicles on our roadways. Additionally, TNCs are investing heavily in CAV technology to replace drivers with technology, reduce or remove personal vehicle ownership altogether, and move toward a subscription model to auto travel. Background on TNCs is presented in Section 7.4.

CAVs also have the potential to increase congestion on roadways. With a single ownership model in place, work commutes could change dramatically. For example, if an individual were to commute to work and then have their vehicle return home to park and return to pick them up for the return journey, daily person miles traveled would double. In a shared CAV ownership model, CAVs may be circling areas until they are needed, in a manner similar to TNCs today. Both CAV scenarios could dramatically increase vehicle mile traveled. While the jury is still out on which ownership model will become reality, the policies and planning that takes place today will influence how CAVs affect traffic congestion in the future.

Land Use

The way our cities and communities look could be dramatically different when CAVs are available to the public. For cities in particular, parking lots could become a thing of the past. Regardless of the ownership model that is put in place—shared, single owner, or subscription—there would not be the need for as many parking spaces as is the case currently. This shift will dramatically change the way cities look and feel. For example, due to the reduced need for parking spaces, a city could remove street parking and expand sidewalks or bike paths. Likewise, large parking lots could be developed or made into parks. For the emerging

[37] "Automated Vehicles for Safety," USDOT, NHTSA, accessed July 27, 2020, **https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.**

[38] USDOT, NHTSA, *Automated Driving Systems: A Vision for Safety 2.0,* September 2017. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[39] Henry Claypool, Amitai Bin-Nun, Ph.D., and Jeffrey Gerlach, "The Ruderman White Paper: Self-Driving Cars: The Impact on People with Disabilities" (Ruderman Family Foundation White Paper Series, January 2017), 16, https://rudermanfoundation.org/wp-content/uploads/2017/08/Self-Driving-Cars-The-Impact-on-People-with-Disabilities_FINAL.pdf.'

[40] David Z. Morris, "Today's Cars Are Parked 95% of the Time," Tech–Transportation, *Fortune*, March 13, 2016, https://fortune.com/2016/03/13/cars-parked-95-percent-of-time/.

"knowledge worker," whose product can be generated on a computer while working from home, work commute trips may trend down or disappear. Preparing for the many land use changes that are possible is a planning challenge for all communities.

CAVs could also exacerbate suburban sprawl since a major factor on where people decide to live is the distance they must travel to their place of employment. In 2018, the average commute time for Coloradans was 23.7 minutes with only 2.1 percent of the workforce commuting more than 90 minutes.[41] CAVs will dramatically change the way people commute. Without the need for a human driver, an individual could conduct a variety of productive/leisure tasks in their vehicle such as working, watching movies or shows, or even sleeping. This freedom will make longer commutes more tolerable. Potentially, more individuals could live farther away from their employment/urban centers in communities with lower costs of housing and living.

Employment

While CAVs will open up new job opportunities to individuals who lack transportation options, they also have the potential to change the way some jobs are conducted or even remove the need for them. As an example, transportation workers will be affected greatly by CAVs; in Colorado, 6.5 percent of the Pueblo metropolitan statistical area workforce is directly employed by the transportation and material moving industry.[42] Although it is too early to predict if these jobs will be completely eliminated, the need for human operators will likely be reduced. The tasks performed by the former operator will most likely be changed, or potentially removed completely. However, CAVs will bring about a rise to new industries and jobs, many of which are yet to be determined. It is important that the workforce be prepared for the employment changes that are to come.

Revenue

State and local government revenue streams will also be altered by CAVs. A majority of CAVs in the future will be electric vehicles. The electrification of vehicles will make the motor fuel tax system trend toward obsolete. Likewise, if the shared and subscription ownership model for CAVs is implemented, then there will be fewer registered vehicles, resulting in a decline in revenues. As previously mentioned in the land use section, there will be less need for parking, thus revenues from parking will decline as well. Furthermore, CAVs will operate according to the letter of the law, resulting in a loss of revenues from traffic enforcement.

The way state and local governments are funded will need to be reexamined to ensure that budgets are not adversely affected by the changes underway. Whereas large jurisdictions have more diverse means to bring in revenues and will not be affected as much by CAVs, small jurisdictions may be adversely affected due to their reliance on traffic enforcement revenues for their budgets.[43] CAVs will require governments to develop new and innovative means to collect revenues.

7.4 Transportation Network Companies

TNCs have been around for nearly a decade; they are also commonly referred to as rideshare companies and known by their company names such as Uber and Lyft. TNCs are a service that expand mobility options to many people and provide an alternative means of convenient transportation. In addition to providing mobility options, they also provide primary and supplemental employment to many individuals at a relatively easy barrier of entrance.

[41] DataUSA: Colorado, Commute Time," 2018 values, https://datausa.io/profile/geo/colorado#housing.

[42] US Bureau of Labor Statistics, "Occupational Employment Statistics: May 2018 Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates, Pueblo, Colorado," last modified March 29, 2019, https://www.bls.gov/oes/2018/may/oes_39380.htm#53-0000.

[43] Michael Maciag, "Special Report: How Autonomous Vehicles Could Constrain City Budgets," *Governing*, July 2017, https://www.governing.com/gov-data/gov-how-autonomous-vehicles-could-effect-city-budgets.html#data.

How a TNC Works

When TNCs first launched, they were available only in large urban centers due to the constraints of economy of scale. However, in the last decade, TNCs have expanded to smaller cities and rural communities. These companies are, for the most part, not actual vehicle owners or operators. They are technology companies that created a platform linking drivers with riders. An individual can sign up to be a driver (independent contractor) by going through a relatively simple process to register on a web-based application. The barriers to entrance are owning a safe vehicle, passing a background check, and owning vehicle insurance. Once this process is complete the driver is able to pick up and drop off passengers by using an application on their cellular device. Passengers can order rides using the same application on their cellular devices by creating a user account and linking a credit card or prepaid card to the application.

Once drivers and passengers create their accounts, passengers can order rides using the application. The driver receives a notification of the location of the passenger and, once accepted, the two are linked and the driver will pick up and drop off the passenger as requested. The application completes the transaction and the driver is paid a portion of the predetermined fare with the remaining portion of the fare going to the TNC.

In addition to picking up one passenger, many TNCs have implemented a shared ride service. This feature allows multiple people to take the same ride if their end destinations are in similar locations. To incentivize this behavior, the TNC offers reduced fares for individuals who partake in the shared ride offering. The shared ride service opens the transportation service to additional low-income individuals and those wishing to conserve spending.

Link to CAV

Many TNC companies such as Uber and Lyft are investing billions of dollars in research and development on CAV technology. These companies are motivated by reducing their costs, and currently the biggest cost for TNCs is paying the driver. As previously mentioned, the TNC only receives a relatively small portion of the fare. The financial strategy of TNCs is to remove the driver from the equation completely and create a fleet of exclusively CAV vehicles. By having a fleet of CAVs, TNCs simultaneously would be both more profitable and able provide passengers with less costly rides than currently available. The shift in cost would make rideshare better for consumers and expand the service to lower-income individuals. As indicated in Section 7.3.3, many TNCs are exploring a subscription model in which, instead of owning a vehicle, an individual pays a monthly subscription for unlimited service or a certain number of rides per month. While it is too early to predict which kind of business model TNCs will use when they deploy their CAV fleets, it is important to monitor their technical and business development because they can dramatically change vehicle ownership and travel patterns.

7.5 Electrification of Vehicles

The future of vehicles is moving not only toward CAVs but also toward the electrification of vehicles. EVs, although still a small portion of vehicle sales in the United States, are on the rise due to a number of factors. The leading factor is their low carbon footprint as compared with traditional gasoline-powered internal combustion engine vehicles. In 2018 there were 42 different models of EVs for sale in the United States, and sales of plug-in hybrids and battery electric vehicles sales rose 80 percent from the year prior.[44] Their popularity will continue to increase as their prices trend lower and their supporting infrastructure is developed.

What Is an EV?

EVs rely on electric power to propel them as opposed to traditional vehicles, which require combustion engines. EVs have a battery pack built into the chassis that powers four individual motors that power each wheel individually. This

[44] Congressional Research Service, *Vehicle Electrification: Federal and State Issues Affecting Deployment* (R45747), prepared by Bill Canis, Corrie E. Clark, and Molly F. Sherlock, June 2019, https://fas.org/sgp/crs/misc/R45747.pdf.

makes EVs more efficient than traditional combustion engine vehicles, which lose energy through the combustion of fuel. Whereas in the past EVs were criticized for their short range, today many EVs have ranges that exceed 300 miles on a single charge.

Benefits and Consequences of EVs

EVs will provide great benefits to society, although there are known consequences that will need to be addressed. Some of the benefits and consequences are listed below.

Benefits

Energy efficiency – EVs are more energy-efficient than traditional combustion engine vehicles. An EV converts over 77 percent of electrical energy to power at the wheels, whereas gasoline converts up to only 30 percent of stored energy in the gasoline to power at the wheels.

Environmentally friendly – EVs emit no pollution, and although the power plants that fuel them may do so, there are other environmentally friendly ways to generate electricity including by nuclear, hydro, solar, and wind powered plants.

Energy Independence – The electricity to power EVs is generated domestically, reducing the reliance on foreign oil.

Consequences

Revenue loss – Because EVs do not use gasoline to power them, EV owners do not pay motor fuel tax, which is the primary means to build and repair roads.

Infrastructure – Major infrastructure investments will be required to allow for greater saturation of EVs in the vehicle market. EVs requir charging, which is more time consuming than fueling up a traditional combustion engine. Charging station infrastructure and placement at residential, shopping, and work locations will require thoughtful planning and investment.[45]

7.6 Conclusion

Emerging technologies have shaped and will continue to shape our society. Alexander Graham Bell's telephone replaced the telegraph, and Henry Ford's assembly line made the horse and buggy obsolete. No one at that time could predict how the future would look for communication and transportation, but society changed and adapted. Today, the connected and autonomous vehicle, transportation network companies, and electric vehicles are the technologies that will shape our future. Though we cannot predict how this future will look, we can and will begin to plan for it.

[45] "All Electric Vehicles," US Department of Energy, Office of Energy Efficiency & Renewable Energy and US Environmental Protection Agency, accessed July 27, 2020, https://www.fueleconomy.gov/feg/evtech.shtml.