Introduction

This memorandum assesses the potential impacts of emerging technologies to Oregon’s transportation system in the next 20 to 30 years and their implications to ODOT planning and investment decisions.

Summary of transportation technologies

New transportation technologies, are advancing rapidly and could revolutionize how vehicles are operated in the coming decades. Advancements can be grouped into three categories: vehicle technology, mobility options, and freight and local delivery applications.

Vehicle technology

**Connected vehicles (CVs)**

CV technology enables vehicles to communicate with each other, roadside infrastructure, and smartphones and other devices to communicate with one another. CV applications are organized into three general categories that describe different types of connectivity: vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X).

Connected vehicles principally rely on two communication technologies: cellular technology and Dedicated Short Range Communications (DSRC). The FCC allocated a range of wireless spectrum, referred to as the 5.9 GHz band, for Intelligent Transportation System (ITS) services. DSRC utilizes the 5.9 GHz band and is a Wi-Fi derivative technology developed to support secure, low-latency communications. Cellular technology is now the most widely used form of communication technology inside vehicles and has enabled navigation systems to alert drivers of real-time traffic, incident and weather conditions. The newest generation of cellular technology, 5G or C-V2X, could potentially compete with DSRC as a communication platform for CVs because it could transmit low latency as well as enable peer-to-peer communication. NHTSA and U.S. DOT initiated the federal rulemaking process to mandate use of V2V radios in all new light vehicles by 2023, but the current administration has delayed this process and taken a technology-neutral approach to regulation. Furthermore, automotive manufactures diverge in their commitment to one primary communication platform with some manufactures emphasizing DSRC while others focus on 5G cellular.
CV deployments have resulted in documented safety, mobility, and operational benefits. Results from CV pilots conducted by U.S. DOT indicate that short-range communication technology could prevent 80 to 90 percent of incidents in which the driver is not impaired. However, the ongoing debate between 5G and DSRC advocates and the lack of federal rulemaking complicates investment decisions for state, regional, and local agencies.

**Automated vehicles (AVs)**
Technologies enabling AVs, including those that improve sensing, mapping, and control, have advanced rapidly over the past five years. The Society of Automotive Engineers (SAE) has established levels of automation that are used to describe different levels of vehicle autonomy and driver responsibility. The six levels are organized along a spectrum from no automation (level 0) to full automation (level 5). The AV system is capable of monitoring the driving environment at levels 3 and above.

AVs will impact the transportation system, but we do not yet know how, in large part because the deployment model for AVs remains uncertain. While AVs have the potential to create public benefits, such as reducing the occurrence and severity of collisions and improving mobility, AVs could also have societal and environmental costs. Potential advantages and disadvantages of three potential operating models are outlined below:

- **Personal automated vehicles**: includes motorists that own or lease their own self-driving vehicles. This operational model is highly convenient allowing for immediate and on-demand usage. Disadvantages include high costs and inflexibility to choose different modes for different trips.
- **Shared automated vehicles**: includes self-driving taxis to transport individuals or groups to destinations. This operational model allows users to choose the vehicles that best meet their needs, including door-to-door service. However, users must wait for vehicles and service could be limited at times.
- **Shared automated rides**: includes self-driving vans that take passengers to or near destinations. This operational model is associated with lower costs and is typically operated on a fixed route and schedule. This model is least comfortable, convenient, and expedient.

AV and CV technology could be combined to maximize the safety and efficiency benefits of AVs. According to U.S. DOT, “communication both between vehicles (V2V) and with the surrounding environment (V2X) is an important complementary technology that is expected to enhance the benefits of automation at all levels.” However, in the near term connected vehicle technology “should not be and realistically cannot be a precondition to the deployment of automated vehicles.”

Adoption of AVs will continue to occur incrementally over the next several decades. AVs could have major impacts on transportation demand by making travel more convenient and accessible for many and providing transportation options for people that previously could not drive, including the elderly, disabled, and those without a driver’s license. However, the introduction of AVs will likely affect urban, suburban and rural communities differently because of differing demographics, population density, and travel patterns.

**Electric vehicles (EVs)**
Electric vehicles (EVs) have the potential to significantly reduce transportation-related emissions. EVs have become more prevalent due to advances in battery technology resulting in batteries with longer operating ranges, faster recharging periods, and lower costs. These advancements make EVs more practical for more households and enable greater adoption of EVs.

Many believe that CAVs will be electric due to the advancements in battery technology. However, adequate charging infrastructure for these vehicles continues to be a concern and a limiting factor. National and state efforts are expanding access to public charging stations with the most substantial efforts occurring at the state and regional level. Oregon supports the West Coast Electric Highway, a network of EV DC fast charging stations.
located along I-5, Hwy 99, and other major roads that span British Columbia, Washington, Oregon, and California. Oregon is also a member of the Multi-State Zero Emission Vehicle (ZEV) Task Force, a group of nine states that have committed to putting a combined 3.3 million ZEVs on their roads by 2025.

As EV adoption increases, fewer drivers will pay their fair share for use of Oregon roads resulting in declining gas tax revenue. Oregon has taken the lead in addressing how EVs will impact transportation funding and was the first state to pilot a road usage charge (RUC) program. Oregon is working with RUC West, a consortium of fourteen western states, to expand RUC research and pilots.

**Mobility options**

Mobility options are also advancing rapidly and include: transportation network companies (TNCs), car share, bike share, microtransit, and Mobility as a Service (MaaS) as shown in Figure 1 below. In addition to these services, companies are beginning to offer dockless or electric shared mobility options including scooter share and electric bike share services and programs.

![Figure 1. Shared Mobility Service Models](image)

Without public sector intervention, benefits from mobility options are likely to be disproportionately concentrated in wealthier, urban communities. Because most shared mobility providers are private, for-profit entities, they do not have an incentive to provide services in less profitable rural markets without specific subsidies or mandates. Access to shared mobility services can also be more difficult in unbanked communities, or for people who lack a smartphone with a data plan. As the new, shared mobility ecosystem expands and requires greater connected and real-time data, however, ODOT will need to think strategically about how it invests in and accommodates technology infrastructure that can support emerging mobility options. ODOT is also positioned to help facilitate conversations with partner DOTs around data standardization to encourage inter-operability between federal, state, regional, and municipal partners.

**Freight and local delivery applications**

The freight industry is undergoing significant changes and advancements in logistic management enabled by automated technologies affecting both long-distance freight movements as well as distribution networks. In addition, consumer expectations and new e-commerce services have influenced the local delivery providers to develop more demand responsive delivery services. This includes individual delivery services (i.e. UberEATS), an increased emphasis on car and bike deliveries, and fleets of smaller trucks.
The trucking industry could gain safety, environmental, and operational benefits from connected, automated, and electric vehicles. For example, CAV technology is being utilized in pilots that enable trucks to engage in cooperative adaptive cruise control, or “platooning” and advancements in propulsion technologies have enabled battery-electric and fuel-cell options for long-haul freight vehicles. The currently shortage of truck drivers across the country has increased interest in these technologies.

Impacts of trends on system performance

Emerging technologies will undoubtedly impact the transportation system in the next 20 to 30 years, however, it is impossible to predict exactly how. This memorandum identifies eight of ODOT’s foundational goals, drawn from the Oregon Transportation Plan and recent modal and topic plans, and assess how they could be impacted by emerging technologies. The eight foundational goals are:

- Safety
- Efficient freight movement
- Equity
- Mobility
- Transportation options
- Fuel efficiency/reducing CO₂ emissions
- Transportation funding sufficiency,
- Land use management

Figure 2 illustrates the potential impacts emerging technologies could have on performance metrics related to these eight foundational goals. The horizontal axis shows whether impacts are anticipated to be positive or negative, while the vertical axis displays the certainty or uncertainty of the predicted outcome. Figure 2 depicts a range of potential outcomes—including best case, worst case, and most likely scenarios—we could see by 2040 if no new policy interventions are introduced.
The following section provides a more detailed description of the range of potential impacts for the performance measures under each foundational goal and is intended to supplement Figure 2 and Table 1. Table 1 includes each foundational goal, its respective performance measure, and likely impacts by 2040. This assessment will be used to identify policy implications and inform updates to ODOT’s modal and topic plans and investment decisions.

Table 1. Likely Impacts to ODOT Foundational Goals and Performance Measures

<table>
<thead>
<tr>
<th>Goal Area</th>
<th>Measure</th>
<th>Likely Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Safety</td>
<td>Safety is expected to improve significantly even with a limited adoption of connected and automated vehicles.</td>
</tr>
<tr>
<td>Efficient freight movement</td>
<td>Efficient freight movement</td>
<td>Truck platooning, automated freight vehicles, and advanced logistics are likely to improve the safety and reliability of freight movement.</td>
</tr>
<tr>
<td>Equity</td>
<td>Mobility for transportation disadvantaged</td>
<td>More transportation choices are likely to be available to many people who are unable to drive today. However, the benefits may not extend to all transportation disadvantaged populations.</td>
</tr>
<tr>
<td></td>
<td>Transportation costs/mile</td>
<td>Shared automated trips, including public transit vehicles and TNC trips, are likely to cost less per mile than trips taken by private auto or public transit today.</td>
</tr>
</tbody>
</table>
## ASSESSMENT OF KEY TRENDS

<table>
<thead>
<tr>
<th><strong>Mobility</strong></th>
<th><strong>Access to jobs and educational opportunities</strong></th>
<th>Automated technology is likely to allow some people to commute farther and access new career and educational opportunities.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Travel time reliability (TTR)</strong></td>
<td><strong>Travel time reliability</strong></td>
<td>Travel time reliability is likely to improve even with moderate adoption of CAV technologies.</td>
</tr>
<tr>
<td><strong>Congestion</strong></td>
<td><strong>Impacts to congestion</strong></td>
<td>Impacts to congestion are uncertain and dependent upon the uses of AVs (see VMT). Non-recurrent congestion should decrease under any scenario.</td>
</tr>
<tr>
<td><strong>Vehicle miles traveled (VMT)</strong></td>
<td><strong>Vehicle miles traveled</strong></td>
<td>It is difficult to predict impacts to VMT and will depend upon on whether AVs will be used predominately in as private or shared vehicles.</td>
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</table>

### Transportation options

| **Urban transportation options** | **Residents of urban communities are likely to experience increased access to more transportation options, potentially resulting in improved access to jobs, education, and services.** |
| **Rural transportation options** | **Access to transportation options could moderately improve in rural areas with limited public transit services, but this is dependent on market support for expansion in rural areas.** |
| **Active transportation choices** | **Increased access to shared mobility options could enable greater use of active transportation options for short-trips, addressing first-and-last mile issues. However, if non-active trips become more affordable, active transportation trips could decrease.** |

### Fuel efficiency / reducing CO₂ emissions

| **Fuel efficiency / reducing CO₂ emissions** | **Some fleet electrification is likely and could generate some environmental benefits. The prevailing usage of EVs will obviate VMT as a factor in emissions.** |

### Transportation funding sufficiency

| **Transportation funding sufficiency** | **Integrated vehicle technology enables some degree of expansion for a “user-pays” funding system, and some mechanisms are identified to ensure that all vehicles are paying some share for their use of the roadway. However, funding continues to be constrained, and increases in revenue are not fully sufficient to cover existing and future infrastructure needs.** |

### Land use management

| **Land use** | **It is difficult to predict impacts to land use patterns. However, any impact will be somewhat tempered by Oregon’s Statewide Planning Goals.** |
Safety

Safety is expected to improve significantly with a relatively high level of certainty. CAV technology could reduce human error that leads to crashes. CAVs could communicate with each other, infrastructure, and other devices in real time about vehicle position, traffic and infrastructure condition, inclement weather, work zones, and other safety-related elements. CAVs could also improve information available to drivers and road operators about conditions enabling more active system management. AVs can reduce driver error and distraction and can leverage even more safety benefits.

CAV technology has the potential to improve safety outcomes on our roadways, with as little as 15-30 percent market penetration. Benefits from CAVs are likely to accrue to all system users, especially the most vulnerable road users. Although CAVs are expected to provide significant safety benefits to the transportation system, technological advancements could develop more slowly than predicted and fail to provide anticipated reductions in crashes. Level 3 automated vehicles could fail to adequately manage expectations regarding driving responsibilities, leading to distracted drivers unready to assume control of the vehicle when needed. Other concerns could include cybersecurity risks and failure of individual users or companies to update software.

Efficient freight movement

Advancements in vehicle technology, logistics and other freight technologies will likely enable more efficient freight movement. Connected freight vehicles provide information on travel time, road and weather conditions contributing to the safety and efficiency of freight movement. Platooning, automated freight vehicles, and advanced logistics result in reduced shipping costs and more reliable delivery times. Data sharing between system operators and freight vehicles can improve information about the system and guide investment and operational decisions. Even if CAV technologies mature more slowly than predicted, limited deployments could still improve the safety, reliability, and efficiency of freight movement.

Equity

Emerging technology trends are likely to provide benefits for many populations. However, the benefits are not likely to extend to all populations or with an even distribution as new mobility services could be concentrated in more affluent and urban areas.

- **Mobility for the transportation disadvantaged** is likely to improve with increased access to affordable and efficient transportation options for those who are unable to drive. Expanded public and private transportation services could increase access to jobs, education, social activities, and essential services. However, new mobility services may not be available to some people with physical disabilities and public transit services may decrease in some areas.

- **Transportation costs per mile** are likely to decrease for trips taken today by public transit as automated vehicle technology matures. This is due the decreased overhead from removing drivers. Reductions in travel costs could allow people to make more trips, including those at lower income levels. However, if public transportation services decrease and travel costs increase, people at lower income levels could experience constraints on the number of trips they can make.

- **Access to jobs and educational opportunities** are likely to increase as AVs are implemented. Commute times could be leveraged for other activities resulting in a willingness to commute longer distances. How AVs are used – shared vs. personal/private – will impact how benefits are distributed. For example, personally owned AVs would concentrate benefits for those that are more affluent.
Mobility

Impacts to mobility are difficult to predict with a high level of certainty. The predominant operational model and resultant changes in VMT, and the timeline under which CAVs are deployed, will significantly influence mobility.

- **Travel time reliability (TTR)** is likely to improve even with moderate deployment of CAV technology. Safety benefits related to CAVs will contribute to traffic “smoothing” through reductions in crashes and incidents. Travel time may increase but would become more reliable as access to real-time traveler information improves.

- **Vehicle miles traveled (VMT)** impacts are difficult to predict with a high degree of certainty and are dependent upon AV operational models. A shared-ownership model where the public opts for a shared mobility paradigm could decrease reliance on single-occupancy trips. If a private ownership model prevails, VMT per capita could increase.

- **Congestion** is difficult to predict and is dependent upon the AV operational model adopted. Either AV operational model, shared or personal/private, could contribute to increased congestion. If ridesharing and other forms of shared mobility are common, congestion could worsen as AVs make zero-occupancy trips. If personal/private AVs are common, congestion could increase as people make more trips. However, non-recurrent congestion should decrease under any scenario as safety benefits are realized.

Transportation options

Impacts to transportation options are uncertain and the distribution of benefits is likely to vary according to geography and income. Public transit services could erode as the public opts to take more trips via private shared mobility options or private vehicles. However, it is possible that an increased use of first-and-last-mile automated vehicle transit could increase the use of public transit.

- **Urban transportation options** are likely to improve as people experience increasing travel options, including TNCs, microtransit, car share, bike share, and e-scooters. These emerging options improve access to jobs, education, and essential services. However, these increased options are likely to be concentrated in affluent communities and could contribute to the erosion of fixed route transit service in some areas.

- **Rural transportation options** could expand from AV technology providing increased access for people in areas with limited public transit services. However, the market may not support expansion of new transportation choices in rural areas.

- **Active transportation choices** are expanding with many new active transportation services coming online today. Increased access to shared mobility options, including bike and e-scooter share, enables people to use active transportation options for short trips, increasing access to public transit and addressing first-and-last mile issues. However, as non-active shared mobility options become accessible and affordable active transportation trips could decrease.

Fuel efficiency/reducing CO₂ emissions

Impacts to emissions are uncertain and dependent upon the public’s adoption of EVs and development of the supporting infrastructure. Some fleet electrification is likely and EVs could be widely adopted generating some reductions in CO₂ emissions. The prevailing operational model of EVs, whether it is shared or private, could also influence emissions. It is likely that shared automated vehicles, which are expected to be mostly electric, will emerge as a transportation option in some urban environments. CAVs are likely to improve system reliability
and reduce nonrecurrent congestion which may provide a fuel efficiency benefit regardless of VMT. However, if AVs are not electric and if people use AVs to more frequent and longer trips, CO₂ emissions could increase.

**Transportation funding sufficiency**

Increased fuel economy and fleet electrification will continue to reduce gas tax revenue. The rate at which this decreases is uncertain and arresting this decrease is dependent on the expansion of a user-pays system. The technology that would allow for a user-pays system based on miles driven is present in newer vehicles and can be retrofitted into older vehicles as demonstrated by the road usage charge pilots. When – or if – this or another system is implemented is a political and policy question.

**Land use management**

It is difficult to predict impacts to land use patterns. The operational model that emerges for AVs will influence impacts to land use patterns and it is still uncertain which operational model is likely to emerge. It is possible that a combination of operational models could be deployed in conjunction with shared mobility options prevalent in urban areas and private ownership models prevalent in rural areas. Shared mobility operational models are anticipated to support denser development patterns and private ownership models are expected to contribute to longer commute distances and more diffuse land patterns. However, any impact will be somewhat tempered by Oregon’s Statewide Planning Goals.