THE DRIVE TOWARD CHANGE

USE CASES FOR AUTOMATED VEHICLES

Oregon Department of Transportation

Version 1.0
May 2018

TABLE OF CONTENTS

Introduction to Automated Vehicle Use Cases 1

Terminology: Automated or Autonomous? 2

Use Case 1: Vehicles with Conditional Automation 3

Use Case 2: Vehicles with Full Automation 5

Use Case 3: On-Demand Fleets of Automated Vehicles 8

Use Case 4: Automated Regional Public Transit 11

Early Deployment Opportunity: Automated Low-Speed Passenger Shuttles 13

Use Case 5: Automated Interregional Transit 15

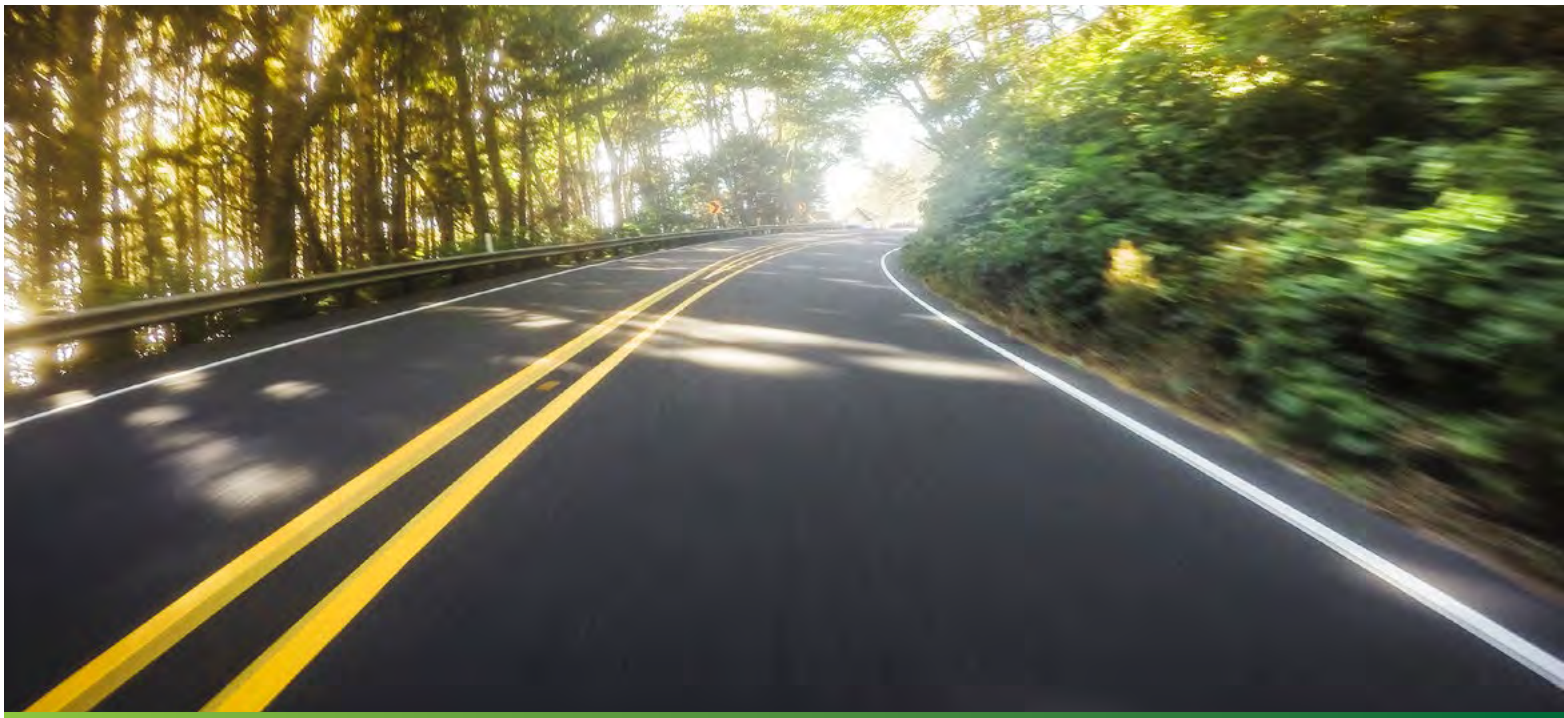
Use Case 6: Automated Local Delivery Vehicles 17

Use Case 7: Automated Medium- and Long-Haul Freight Trucks 19

Use Case 8: Automated Heavy Equipment Vehicles 22

Early Deployment Opportunity: Automated Truck Mounted Attenuator Vehicles 24

References 26



INTRODUCTION TO
AUTOMATED VEHICLE USE CASES

Automated vehicles are here.

Automated vehicles (AVs) are already being tested and could soon be deployed on public roads in Oregon. In November 2017, Waymo began a pilot project for a driverless taxi service in Phoenix, Arizona, and GM recently announced plans to deploy fleets of fully automated cars without steering wheels or pedals in 2019. The AV industry is rapidly transitioning from the testing phase to the deployment phase.

This guide is intended to prepare the Oregon government and other stakeholders for the deployment of automated vehicles. It provides an overview of how automated vehicles could be used, when they will be available to the public, how they could change our transportation system, and what policy questions they raise.

There are many applications for automated vehicle technology.

Self-driving cars and on-demand fleets frequently make headlines, but there are many kinds of automated vehicles in development. For example, in the next 10 years, automated tractors could become a common sight, as well as automated buses, trains, and trucks. This handbook discusses how automated vehicle technology could transform personal travel, public transit, freight, and even heavy equipment on farms or at construction sites. As policymakers craft laws and regulations for automated vehicles, it is important that they keep the full range of applications in mind.

Within a few years, Oregon could see the limited deployment of some early automated vehicles.

Included with the use cases are two early deployment opportunities for automated vehicles in Oregon. These vehicles, an automated low-speed passenger shuttle and an automated truck-mounted attenuator, are almost ready for deployment and could easily be part of pilot testing in Oregon in the next couple of years. Other applications may also be deployed within a few years.

The deployment of automated vehicles has wide-ranging policy implications.

This guide also reviews the potential impacts automated vehicles could have on a wide range of policy issues. Experts agree that over the next 50 years, automated vehicles could profoundly change where we live, where we shop, what kind of jobs we have, and what our cities look like. This guide focuses on the near-term impacts: changes we could see in the next five, 10, or 15 years. None of the impacts discussed in this guide are certain, but they are based on the most current information available and on predictions by experts in the field.

This guide also explores some of the questions policymakers may want to answer as they begin crafting laws and regulations for automated vehicles.

The lists of policy implications for each use case are not exhaustive. They are intended to help conceptualize the scope of issues raised by the deployment of automated vehicles.

TERMINOLOGY
AUTOMATED OR AUTONOMOUS?

What is the difference between an automated vehicle and an autonomous vehicle?

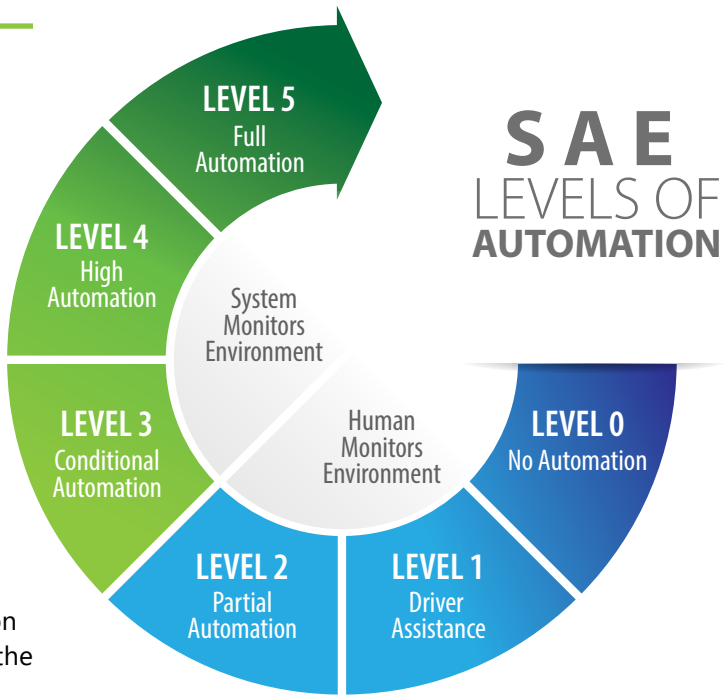
You will often see the two terms for AVs used interchangeably, but there are some nuances. Automated vehicles have some degree of automation, up to and including full autonomy. Even lane-assist technology and adaptive cruise control are included in the definitions of automation.

"Autonomous vehicles" generally refers to vehicles at the higher levels of automation, where they can function without a human driver. AVs will have impacts on our transportation system long before they reach full autonomy. Thus, the Oregon Department of Transportation (ODOT) prefers the more inclusive term "automated vehicles."

Another related term is "Automated Driving Systems." The National Highway Traffic Safety Administration (NHTSA) released new guidance on these technologies in September 2017. The term, and its acronym ADS, are used throughout the report.

The SAE Levels of Automation

The Society of Automotive Engineers (SAE) has identified a spectrum of six levels of automation, from Level 0, in which there is no automation whatsoever, through Level 5, or full automation under all conditions. These levels describe who is monitoring the driving and to what degree: a human or the system.



At SAE Levels 3 and above, the system is responsible for monitoring the driving environment, at least under some circumstances. At lower levels of automation, the vehicle's acceleration, braking, and steering may all be handled by the system, but the human driver remains responsible for monitoring the driving environment and taking over if the system cannot navigate the current situation or if conditions become unsafe.

At the beginning of each use case, you will find an icon in the upper right-hand corner. It indicates the SAE levels discussed in the use case:

SAE LEVELS 1-5

SAE LEVEL 3

USE CASE 1: VEHICLES WITH CONDITIONAL AUTOMATION

What is conditional automation?

Today, there are cars on the road that can control their speed and following distance on the freeway using adaptive cruise control technology. Some cars also have systems to help human drivers stay in their lanes or come to emergency stops, often called "lane keeping assist" technology. However, even with these systems in place, human drivers still need to pay complete attention to their surroundings at all times.

Vehicles with conditional automation will allow the human driver to take their eyes off the road, but only under certain conditions. One example is a vehicle that operates autonomously on freeways but requires a human driver to take control in busy city centers or in adverse weather conditions. A common example here in Oregon—for a commute from Portland to Salem, the human driver could merge onto Interstate-5, switch on the automated mode, and be hands-free until they approach their exit in Salem. However, the driver would need to be ready to take control at a moment's notice if the vehicle encountered conditions where it could not drive itself, such as ice or heavy precipitation.

When will conditional automation be ready for deployment?

Some manufacturers claim this technology will be available on the market within the next two years. The earliest versions may only operate at low speeds; for example, Audi's "Traffic Jam Assist" will allow drivers to give the vehicle control at speeds under 40 mph on a freeway. Other manufacturers, such as Waymo, Nissan, and Volvo, have tested technology that would allow the vehicle to drive itself on the freeway at regular speeds. Tesla's Autopilot feature currently requires that the human driver monitor the surroundings, but the company has stated that many of its vehicles could be upgraded to this level or higher with a wireless software update.

However, switching between human and automated modes creates several challenges that manufacturers will need to address before this technology is ready for sale. How will the vehicle recognize that it has encountered conditions where it cannot safely drive itself? How will it alert the human driver to take over, especially if the driver is distracted or asleep? How long does it take a human driver who has not been paying attention to their surroundings to regain awareness and safely take control of the vehicle?

How could conditional automation change our transportation system?

Initially, partially automated vehicles will bring only incremental changes to our transportation system. Though these vehicles will sometimes operate autonomously, human drivers will still need to be alert at all times, ready to take control. Therefore, people will probably use them in much the same way we currently use conventional vehicles. Possible impacts could include:

- Saving lives and improving safety by reducing the number of crashes on freeways. Today, 94 percent of crashes are caused primarily by human error.
- Contributing to crashes by allowing human drivers to disengage, get distracted, or rely on the automated mode under conditions for which it was wasn't designed.
- Encouraging people to travel or commute longer distances by reducing the stress of driving.

What are the policy implications of conditional automation?

Distracted driving laws may need to be adjusted.

- What activities will be acceptable while a vehicle is in automated mode? For example, should human drivers be allowed greater use of handheld electronic devices while their vehicles are in automated mode?
- How can we encourage human drivers to be prepared to take control even when the vehicle is in automated mode?

Insurance requirements and liability laws may need to be adjusted.

- How will fault be determined in incidents involving a vehicle in automated mode? Or a vehicle switching between modes?
- What is the liability of the manufacturer vs. the liability of the owner/operator?

Automated Vehicles in Rural Areas

News coverage of AVs often focuses on fleets of automated vehicles in city centers and suburbs, but the early benefits of automated vehicles may be most apparent in rural areas. Because the first automated vehicles will only be able to operate in automated mode on highways and mostly empty stretches of road, they have great potential to improve the experience and safety of driving in rural areas.

SAE LEVEL 4-5

USE CASE 2:
VEHICLES WITH FULL AUTOMATION

What is full automation?

Vehicles with full automation will be able to operate without human control from the beginning to the end of a trip, with equivalent or better performance than a human driver. These vehicles may not even have steering wheels or pedals. Passengers will not need to be ready to take over at a moment's notice; instead, they will be able to spend their travel time as they wish—working, reading, watching TV, or relaxing. These vehicles could improve the safety of the transportation system and increase mobility for those who do not or cannot drive. However, they could also create new challenges as they increase demand for travel, require new infrastructure investments, or increase congestion by frequently driving unoccupied or longer distances than human drivers may tolerate.

When will full automation be ready for deployment?

Vehicle manufacturers and technology companies are aggressively investing in research and development, all vying to produce the first fully self-driving vehicle. Several companies assert that the first such vehicles could hit the road in the next three to five years, and GM recently announced it intends to deploy fully automated vehicles in 2019. The earliest versions of fully automated vehicles may only be designed to operate in certain areas; for example, they may be able to drive themselves in a metropolitan area for which they have detailed maps and navigation information, but either cannot drive or require a human driver to take control outside that area. Later models will be able to operate anywhere and under all conditions.

How could full automation change our transportation system?

These vehicles could increase mobility for:

- People who cannot or chose not to drive, including seniors, children, people with suspended licenses, and some people with disabilities.
- Everyone, by making travel more convenient and letting people use their commute time for other activities.

Possible changes to traffic and vehicle behavior could include:

- Saving lives and increasing safety by reducing the number of crashes. Today, 94 percent of crashes are caused primarily by human error.
- Increasing congestion. People may be willing to travel more if they don't have to drive themselves, and vehicles may also make trips without any passengers.
- Decreasing congestion. These vehicles may be able to follow each other more closely than human drivers can safely do, and they may even be able to coordinate their movements to ease the flow of traffic.
- Increasing safety by reducing the number of traffic violations, if these vehicles are programmed to obey traffic laws.

Possible impacts to infrastructure could include:

- Allowing people to choose to live farther from city centers, if commuting is less onerous.
- Increasing the wear and tear on roads, if vehicles drive more miles.
- Decreasing the demand for parking. It may be cheaper for vehicles to drop their passengers off and drive home or circulate rather than pay for a parking spot.
- Reducing traditional revenue streams for local governments, which often depend on parking fees and traffic fines.

Charging Automated Vehicles for Road Use

Some automated vehicles may travel more miles on average in a year than conventional vehicles. They will potentially make traveling less stressful and will be able to make trips with no one in the vehicle, i.e., zero-occupancy trips. This means an automated vehicle could do more to deteriorate the roads and worsen congestion than a conventional vehicle does now. Experts also expect most automated vehicles to be electric, meaning they will not pay a gas tax.

One way to ensure automated vehicles pay their fair share for the wear and tear they inflict on the road would be charge them for each mile driven. In Oregon, this could be a requirement to enroll AVs in a road usage charging program, such as the OReGO program. Each automated vehicle would be charged a small fee based on the number of miles it drove (OReGO).

What are the policy implications of full automation?

Current licensing and liability laws may not be applicable to automated vehicles.

- Who must take out insurance for an automated vehicle?
- How will fault be determined in incidents involving an automated vehicle?
- For vehicles that can be operated by a human or operated in autonomous mode, will owners be required to have valid driver licenses?

Law enforcement procedures may need to be adapted.

- How will the police know whether a person or the automated driving system is in control of the vehicle?
- If an unoccupied automated vehicle was involved in a crash, how would the vehicle fulfill the requirements for a driver, including notifying emergency services and exchanging insurance information?

Road use and congestion management policies may need to be adjusted.

- How can we respond to increased congestion if people are willing to drive farther and more often?
- How can we manage road use by vehicles with no passengers?
- Should automated vehicles and conventional vehicles be allowed to operate in mixed traffic?

Land use and urban design policies may also need to change.

- If people are willing to live farther from city centers, how will we address sprawl or shifting demand for housing?
- If demand for parking declines, how will cities repurpose spaces now used for parking lots and parking garages?

SAE LEVEL 4-5

USE CASE 3: ON-DEMAND FLEETS OF AUTOMATED VEHICLES

What is an automated on-demand fleet?

Today, on-demand fleets include taxi companies and ride-hailing services like Uber and Lyft. Automated vehicle technology has the potential to expand the reach of on-demand fleets, while also lowering the cost. Rather than owning a car of their own, many people are already finding it cheaper and more convenient to request an on-demand vehicle to take them from home to work, the store, or a transit center. This could increase with an even more efficient automated fleet. These fleets would rely on the same technology as personal automated vehicles, but would likely circulate while waiting for new passengers rather than parking or driving themselves home. Initially, companies will likely deploy fleets in city centers and then expand to more suburban and rural areas.

Renting Out Your Personal Car

Today, the average car is parked 95 percent of the time (Shoup, 2017). What if instead, your car could be out earning money whenever you're not using it? Some experts believe that rather than taxi-like fleets of automated vehicles, people may choose to rent out their personal vehicles while they're at work or otherwise occupied. In fact, there are already apps that allow you to do this with your conventional vehicle—but it would likely be easier and more efficient with an automated vehicle.

When will automated fleets be ready for deployment?

Pilot programs have already been established in several cities around the world, where passengers can ride in prototype automated vehicles as long as a testing driver and engineer are present and prepared to take over in an emergency. In November 2017, Waymo revealed that their back-up drivers would now sit in the back of the vehicle, rather than behind the wheel, and that drivers would soon be phased out entirely. In January 2018, GM announced plans to deploy a fleet of fully automated vehicles without steering wheels or pedals by 2019.

How will automated fleets change our transportation system?

These vehicles could impact other modes of transportation by:

- Reducing personal ownership of vehicles. It may be cheaper and more convenient to order a car as needed rather than owning your own car.
- Providing new transportation options to areas underserved by public transit, especially in suburban neighborhoods.
- Making public transit more accessible by providing convenient transportation to and from transit centers. For example, you could order a fleet vehicle to get to the train station.
- Competing with public transit. Automated private fleets are expected to be relatively inexpensive, offer the same privacy as a personally owned car, and not require traveling to or making transfers at public transit stations.

These vehicles could impact traffic by:

- Decreasing congestion, if passengers share rides. This may result in fewer vehicles on the road.
- Increasing congestion, especially if fleets replace or compete with transit. Automated fleets could also increase congestion if the fleet vehicles circulate or make trips without any passengers.

These vehicles could impact infrastructure by:

- Increasing the wear and tear on roads, if vehicles drive unoccupied while circulating for passengers.
- Decreasing the demand for parking spaces. If it is cheaper to drive than it is to park, vehicles may constantly circulate while waiting for passengers.

These vehicles could impact the workforce by:

- Eliminating some jobs, creating new jobs, and/or changing the kind of jobs available in transportation and related industries.
- Reducing the overall cost of transportation, giving people more discretionary spending and increasing demand for other goods and services.

What are the policy implications of automated fleets?

Road use and congestion management policies may need to be adjusted.

- How can we discourage fleet vehicles from circulating unoccupied while waiting for new passengers?
- How can we incentivize ride-sharing, especially in congested areas and during peak traffic times?
- How can cities reprioritize curb space to accommodate vehicles that frequently pull over to pick up or drop off passengers?

Public transit may need to adapt to the presence of on-demand fleets of automated vehicles.

- How can transit agencies partner with fleets to provide end-to-end transportation services?
- How could public transit respond to competition from fleet services?

Policymakers may also need to address workforce and equity concerns.

- How can we ensure that displaced workers find new jobs?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?
- How can we ensure that fleet services are able to provide adequate transportation for people with disabilities?

First- and Last-Mile Problem

One reason people choose not to use public transit is that they struggle to get to and from transit stations. In other words, they struggle with the first and last mile of any trip.

Automated private fleets or even public shuttles have the potential to solve this problem by providing convenient, frequent, and relatively low-cost transportation to and from transit stations.

SAE LEVEL 3-5

USE CASE 4: AUTOMATED REGIONAL PUBLIC TRANSIT

What is automated regional public transit?

Today, many people rely on regional public transit for their daily transportation, making use of light rail, subways, trams, buses, and shuttles. Automated vehicle technology has the potential to expand the reach of public transit and to make those services cheaper, more dependable, and more convenient. For example, it may allow buses to run more frequently, so you may not have to wait as long at the bus station. While transit employees will likely monitor the bus remotely and ride the bus with you as hosts, the automated driving system will control where you go and what stops you make. The bus may even be able to adjust its route to bring you closer to your destination.

When will automated regional transit vehicles be ready for deployment?

Some subways, light rail, and elevated rail systems have been equipped with automated technology for decades. For example, the SkyTrain in Vancouver, B.C., has been operating autonomously since 1985 by using signaling technology and electromagnetic propulsion. The SkyTrain and other automated rail systems are made possible because they operate on closed tracks, where humans and animals can't cross in the path of the train. They also don't intersect with other rail networks or other forms of traffic, and they tend to be restricted to metro regions. Cities, airports, and amusement parks continue to invest in such rail systems; in 2017, the Honolulu Authority for Rapid Transit began construction on a fully-automated, 20-mile elevated rail network.

Advances in technology may eventually allow buses, shuttles, and trams to operate autonomously even in downtowns. Some of the first automated buses and shuttles may require designated lanes and navigate by following magnets embedded in the roadway, but several companies have tested buses that navigate using a system of sensors similar to those found in automated car prototypes. Some of these buses can also recognize traffic lights, respond to obstacles in the roadway, brake, approach bus stops, and open and close their doors without any intervention by a human driver. In the long term, we could see automated buses and shuttles that can operate in mixed traffic, and even adjust routes mid-trip in response to passengers' preferred pickup and drop-off points.

How could automated regional transit change our transportation system?

Possible changes to traffic patterns could include:

- Improving safety by reducing the number of crashes.
- Decreasing congestion, if expanded hours of operation and flexible routes increase ridership. Public transit tends to be the most efficient use of road space per person. Studies have shown that when public transit routes parallel heavy transit corridors, it relieves traffic.

Automated technology could improve public transit by:

- Reducing the cost of fares.
- Enabling more frequent service. This could make public transit a more viable transportation option for some passengers, increasing ridership.
- Expanding service areas.
- Coordinating or merging with automated vehicle fleets, providing door-to-door service.

Automated public transit could increase mobility for:

- People who cannot or chose not to drive, including seniors, children, people with suspended licenses, and some people with disabilities.
- Areas currently underserved by public transit, if automated technology reduces the cost of transit.

Automated public transit could impact the economy by:

- Eliminating some jobs, creating new jobs, and/or changing the kinds of jobs available in transportation and related industries.
- Reducing the cost of transportation, giving people more discretionary spending and increasing demand for other goods and services.

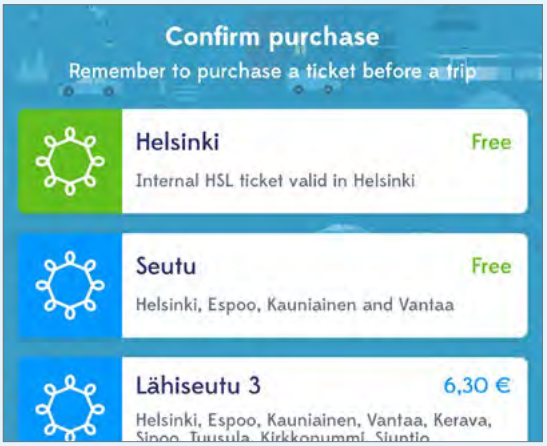
What are the policy implications of automated regional transit?

Road use and transportation infrastructure policies may need to be adjusted.

- How can public transit agencies partner with private fleets to provide comprehensive and convenient transportation service to customers?
- How can cities reprioritize curb space to accommodate public transit vehicles that have more flexible service routes?
- Should we create designated lanes for certain types of automated public transit vehicles?

Policymakers may also need to address workforce and equity concerns.

- How can we ensure that displaced workers find new jobs?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?
- How can we ensure that new kinds of public transit are able to provide adequate transportation for people with disabilities?



The Whim app, used in Helsinki. (Courtesy of MaaS Global's communications department.)

Transportation as a Service

With the advent of automated vehicle technology, we could see convenient door-to-door transportation provided by a combination of public and private services. Some cities, such as Helsinki, have already created a single digital platform where passengers can not only check routes and see times, but also pay for different modes of transportation, public and private.

EARLY DEPLOYMENT OPPORTUNITY: AUTOMATED LOW-SPEED PASSENGER SHUTTLES

What is an automated low-speed passenger shuttle?

Many people may encounter their first automated vehicle on a school campus or in a business park, where the vehicles can operate at low speeds and within a well-mapped fixed route on private property. Within these controlled environments, automated vehicles can act as passenger shuttles that carry eight to 15 people.

Many current models of automated shuttles come without steering wheels or pedals, are powered by electricity, and operate at speeds less than 25 mph. They include emergency stop buttons, and some early demonstration deployments have included an attendant who has a controller to guide the shuttle if needed. As automated vehicle technology improves, these vehicles could serve broader geographic areas within cities and operate on the same roadways as other vehicles, pedestrians, and cyclists.

Where have automated shuttles been tested?

Automated low-speed shuttles have been ferrying passengers in pilot projects and demonstrations across Europe and Asia for the past few years. More recently, automated shuttles have featured in demonstrations in the United States. For example, the University of Michigan has tested automated shuttles and plans to launch a pilot program operating automated shuttles on campus in the near future. Automated shuttles have also made test runs at a business park in San Ramon, Calif., and in downtown Las Vegas.

When will automated shuttles be available?

While there have been many promising tests and demonstrations, the technology still requires fine-tuning, particularly for shuttles that may have to operate in mixed traffic. In Oregon, an automated shuttle could be deployed on a closed campus within a few years.

What are the benefits of automated shuttles?

- Automated shuttles could make traveling across a campus or business park faster and more convenient. Current deployments operate on fixed routes, but as technology improves, these vehicles could provide on-demand services.
- In particular, automated shuttles could help improve the mobility of seniors or people with disabilities.

What are the obstacles to deployment of automated shuttles?

The technology for automated shuttles is still in development.

- Current models cannot read and respond to traffic signals.
- They can only operate in controlled, well-mapped environments.
- They have a limited ability to communicate with drivers, cyclists, and pedestrians around them.

Automated shuttles also face regulatory questions.

- It can be difficult to determine where a private campus ends and a public road begins. In some locations, automated shuttles may have to wait for legislation or special permission before beginning operation.
- What are the licensing and registration requirements for an automated shuttle with no human driver?
- Who is responsible for insuring the automated shuttle, and how will liability be determined in the event of a crash?

SAE LEVEL 3-5

USE CASE 5: AUTOMATED INTERREGIONAL TRANSIT

What is automated interregional transit?

In the United States, there are few examples of medium- or long-distance public transit. However, some private transit companies, such as Amtrak trains, receive public funding and are integrated into the public transit system in many cities. Private companies like Greyhound Lines, Peter Pan Bus Lines, and Megabus also provide interregional bus services. Automated vehicle technology has the potential to make these services safer, cheaper, more frequent, and more reliable.

Initially, driver assistance technology could help improve the safety of buses and trains. As the technology advances, bus drivers may only need to control the vehicle in towns and cities, where driving decisions are more complex. When the bus is on the highway, it could operate in automated mode. Fully automated transit could even come to compete with airlines for medium-distance trips: Rather than flying to Seattle, it may be cheaper and more convenient to take an automated bus. Bus and rail designs may also change. For example, rather than sending one large bus along a route, transit providers may instead deploy a platoon of smaller buses that peel off to make drop-offs or pick-ups, reducing the number of stops each bus has to make.

When will automated interregional transit vehicles be ready?

Currently, there are no proposals to develop medium- or long-distance automated buses, in part because conventional bus services are not in high demand. When Americans have to travel more than 50 miles, they opt to use buses just 2 percent of the time, whereas personal vehicles account for more than 90 percent of long-distance travel. However, automated long-distance buses will likely be technologically feasible around the same time as automated cars.

Technical and financial challenges have also delayed the automation of long-distance rail systems, such as commuter trains or intercity rail networks. Automated trains face technical challenges because most long-distance rail systems have exposed tracks, leaving them accessible to people, animals, or falling debris. Because these trains operate at high speeds and take a long time to slow down, they need to identify obstacles well in advance. Automated rail installations or upgrades can also be prohibitively expensive, and automated technology can't reduce operational costs for long-distance train systems as much it can for other forms of transportation. Nevertheless, France's national railway operator plans to operate automated high-speed trains by 2023.

How could automated interregional transit change our transportation system?

Without further study, it's impossible to say how automated vehicle technology will impact interregional transit. For example, if fewer people own their own cars in the future, more people may need to use interregional transit. However, on-demand fleets of automated cars could also make it more convenient for people to travel to and from airports, so people may choose to fly rather than use buses or trains. Automated vehicle technology could also impact traffic, cost of fares, and travel times, all of which factor into people's decisions about whether to use interregional transit.

If the automated interregional rail and bus services are widely used, they could:

- Improve safety by reducing the number of crashes.
- Offer more frequent services.
- Spur travel between cities and facilitate longer commutes.
- Alleviate congestion. High-occupancy transit buses are a much more efficient use of road space than personal vehicles.

Automated public transit could impact the economy by:

- Eliminating some jobs, creating new jobs, and/or changing the kinds of jobs available in transportation and related industries.
- Reducing the cost of transportation, giving people more discretionary spending and increasing demand for other goods and services.

What are the policy implications of automated interregional transit?

Policymakers may need to consider how public roads and resources are allocated.

- Should we create designated lanes for automated interregional transit?
- What role should public agencies have in funding and operating interregional transit systems?

Policymakers may also need to address workforce and equity concerns.

- How can we ensure that displaced workers find new jobs?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?
- How can we ensure that new kinds of public transit are able to provide adequate transportation for people with disabilities?

SAE LEVEL 4-5

USE CASE 6: AUTOMATED LOCAL DELIVERY VEHICLES

What is an automated local delivery vehicle?

Mail services and restaurants have offered local delivery options for decades. In the past few years, online retail and delivery services like UberEATS have increased on-demand delivery options. Many grocery stores now allow customers to shop online and then convey groceries directly to their homes. Automated vehicles could make these services cheaper and more convenient, encouraging more stores to offer delivery options and encouraging more customers to take advantage of them.

Rather than driving to the hardware store and back, you could order a drill bit online and have an automated vehicle drop it off at your house in a matter of hours. Companies have developed different models for how this might work. An employee, a robot, or a drone might transport the drill bit from the vehicle to your front door, or you could receive an alert on your phone and go to the vehicle to retrieve the drill bit yourself.

When will automated local delivery vehicles be ready for deployment?

Automated delivery vehicles could become available around the same time that the first fully automated personal vehicles hit the market. A number of vehicle manufacturing, online retail, and food delivery companies have indicated interest in automated vehicles, and some have shared prototype examples in the past few years. For example, Domino's recently teamed up with Ford to experiment with automated pizza delivery. However, this pilot program is limited in scope and designed to better understand how people might interact with automated delivery vehicles, not to enhance the technology.

How could automated local delivery vehicles change our transportation system?

Many experts anticipate that automated vehicle technology will reduce shipping costs. If these vehicles reduce the cost of delivery, they could:

- Allow customers to access more on-demand delivery services.
- Increase demand for online retail.

These vehicles could impact traffic patterns by:

- Decreasing congestion, if customers make fewer trips to stores.
- Increasing congestion, if stores use more delivery vehicles and those vehicles make more trips.

What are the policy implications of automated local delivery vehicles?

Road use and congestion management policies may need to be adjusted.

- How can we ensure that delivery vehicles don't worsen congestion? Should automated delivery vehicles be priced higher or restricted during peak traffic?
- These vehicles will need to make frequent stops. How will pick-up and drop-off zones need to change to mitigate the impact on traffic?

Land use and urban design policies may also need to change.

- More people may move to suburbs and rural areas as it becomes more convenient to live farther from city centers. How might land use laws change to accommodate changing demand for housing?
- In the short term, how might parking requirements in urban areas change to allow for loading of automated delivery vehicles?
- In the long term, stores may become more specialized or offer different types of services. How could urban design requirements adapt to the changing retail environment?

Policymakers may also need to address workforce concerns.

- Automated delivery services could change the kind of jobs available in delivery and retail services. How can we ensure that displaced workers find new jobs?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?

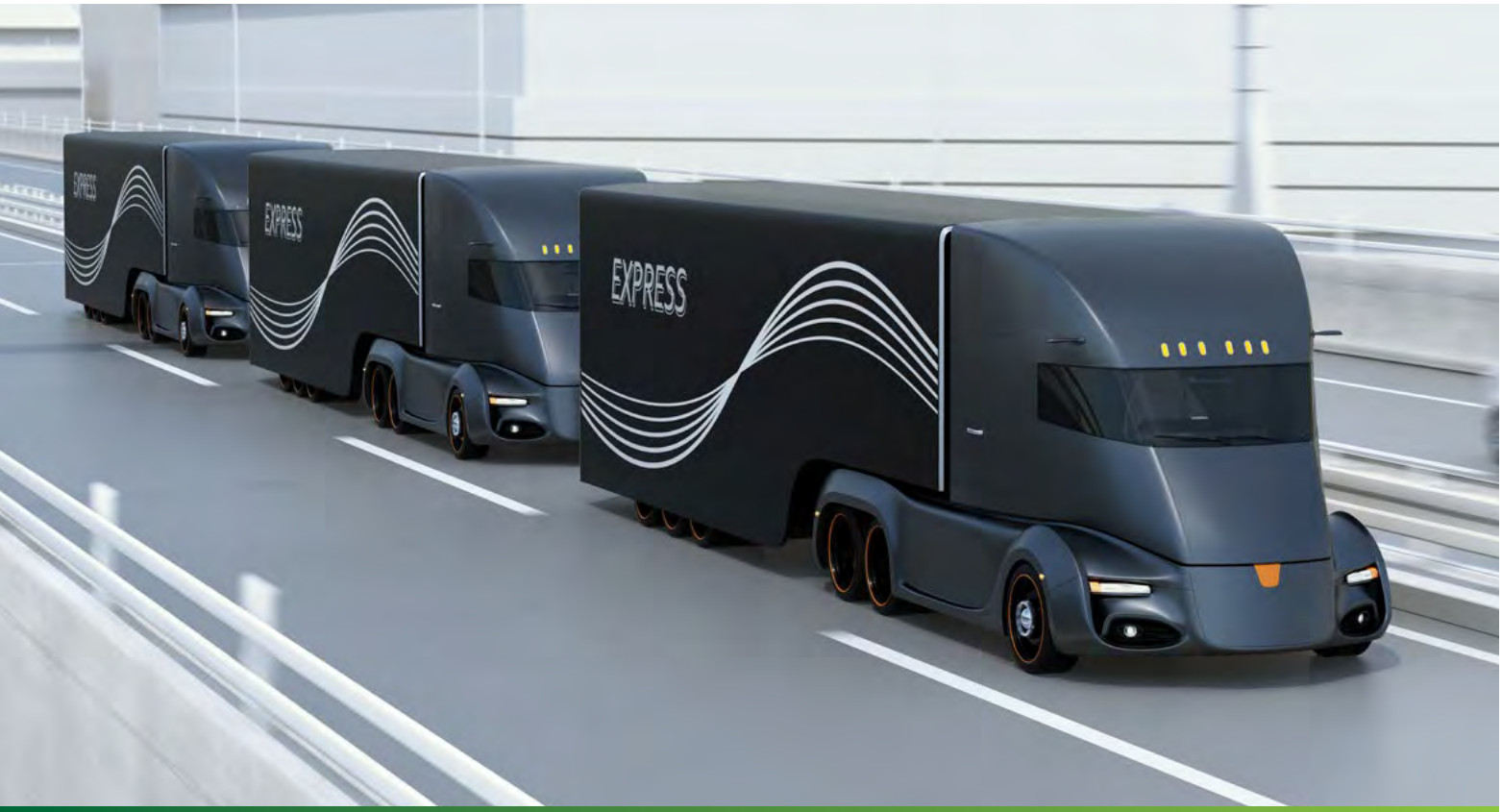
SAE LEVEL 2-5

USE CASE 7: AUTOMATED MEDIUM- AND LONG-HAUL FREIGHT TRUCKS

What is an automated freight truck?

Many companies are interested in developing automated technology for large commercial trucks, from medium-duty vehicles at as little as 10,000 pounds to heavy duty vehicles weighing 80,000 pounds or more. Every year, large commercial trucks move about $700 billion worth of goods, or roughly 70 percent of all freight in the United States. Many other industries depend on trucking services to ship products and raw materials, making trucking essential to the U.S. economy. However, truck driving can also be dangerous; the Federal Motor Carrier Safety Administration (FMCSA) reports that in 2015, large trucks were involved in 6.6 percent of collisions overall and in 11 percent of fatal collisions.

Over the next 10 years, automated technology could make trucking safer and more efficient, either by assisting human drivers who continue to operate trucks, or by taking over driving responsibilities for part or all of each trip. In more advanced models further in the future, a truck driver might be able to rest while the truck is in automated mode. This could make truck driving more efficient and safer by reducing the number of crashes caused by driver fatigue or human error.



When will automated freight trucks be deployed?

Several companies are testing trucks equipped with driver assistance technology, including automatic braking, lane-keeping assistance, and platooning technology. Platooning technology allows two or more trucks to closely follow each other and coordinate speed, acceleration, and braking. These trucks would not be able to operate autonomously, and would always be under the supervision of a human operator, but platooning technology helps save fuel, lower emissions, and improve safety.

Some companies also aim to develop trucks that are capable of driving without human supervision, at least on highways. For example, two companies, Otto and Embark, have made successful deliveries using trucks with conditional automation. In both cases, the truck was able to drive itself on the highway but required a human driver to take control in towns and cities, where the driving environment is more complex.

However, widespread deployment of fully automated trucks will likely take longer than deployment of personal automated vehicles. Industry experts do not expect to see fully automated trucks for at least 10 years. Even in the most advanced of today's automated trucks, human drivers are still needed to maintain equipment, manage routes, handle cargo, and take over driving once the truck leaves the highway.

How could automated freight trucks change our transportation system?

Automated trucks could possibly impact traffic patterns and road use by:

- Improving safety through driver assistance technology.
- Posing safety challenges, if long platoons of trucks block traffic entering and exiting freeways.

Automated trucks could impact the trucking industry by:

- Increasing the productivity and efficiency of truck drivers by allowing them to rest when the automated system is in control of the vehicle.
- Increasing the retention of qualified drivers, if automated technology improves safety and reduces the stress of driving.
- Reducing the cost of shipping and potentially increasing the demand.

In the long term, automated trucks could possibly impact the economy by:

- Eliminating some jobs, creating new jobs, and/or changing the kinds of jobs available in trucking and related industries.
- Reducing the overall cost of shipped goods, giving people more discretionary spending and increasing demand for other goods and services.

What are the policy implications of automated freight trucks?

Infrastructure investments may need to be considered.

- What infrastructure investments, such as smart traffic lights or redesigned on- and off-ramps, may be needed to facilitate the deployment of automated commercial trucks?
- Who should bear responsibility for installing and maintaining this equipment?
- Should transportation system operators consider new bridge weight restrictions, if heavy platoons of freight vehicles traveling close together impose much greater loads on bridges?

Insurance requirements and liability laws may need to be changed.

- How will fault be determined in incidents involving a large commercial truck in automated mode? Or switching between modes?
- Who will need to insure the trucks, the manufacturer or the trucking company?

Policymakers may also need to address workforce concerns.

- How can we provide opportunities for displaced workers?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?

SAE LEVEL 2-5

USE CASE 8: AUTOMATED HEAVY EQUIPMENT VEHICLES

What are automated heavy equipment vehicles?

Heavy equipment vehicles are used in construction, maintenance, mining, agriculture, and port operations. They range from farm tractors to street sweepers to cranes. Companies are looking to enhance many of these vehicles with automated technology, both to increase productivity and to improve the safety of human workers.

Automated heavy equipment vehicles face different technical challenges than automated cars or buses. Many heavy equipment vehicles never have to operate in mixed traffic, so they don't need to achieve high speeds, read traffic signals, or respond to the unpredictable behavior of human drivers. However, they often operate near human workers, which presents its own set of safety considerations. They also require robotic technology that allows them to manipulate their environment, for example by excavating holes or lifting crates.

When will automated heavy equipment vehicles be deployed?

You may have already seen automated vehicles being used in mines, on farms, or at construction sites. Automated haulage system trucks began assisting with mining operations in Australia and Sweden in 2016. As part of a 2017 pilot project in the San Francisco area, an autonomous track loader participated in an excavation job by cutting, transporting, and dumping dirt. Some companies are also in the process of developing construction and maintenance vehicles designed for use on public roads. *(See the Early Deployment Opportunities: Automated Truck Mounted Attenuator.)*

Automated Guided Vehicles at Ports

For decades, ports across the world have been making use of a special kind of automated vehicle, called an automated guided vehicle (AGV). Like older automated trains and subways, AGVs follow tracks or magnetic strips embedded in the concrete. They are also separated from human workers as much as possible, operating only within designated areas of a port facility.

Today, companies are working to create automated heavy equipment vehicles that use more advanced technology, such as 3D mapping systems or sensors like those found in automated car models.

How will automated heavy equipment vehicles impact our transportation system?

While most of these vehicles are not primarily designed for road use, many may also occasionally be operated on public roads. For example, farmers sometimes drive tractors on public roads to transport them between fields. Cranes are occasionally driven in mixed traffic to travel to and from downtown construction sites. When these off-road vehicles are automated, they will still have occasional on-road applications.

What are the policy implications of automated heavy equipment vehicles?

Policymakers will need to keep automated heavy equipment vehicles in mind when crafting laws for other vehicles that use public roads. A law designed with an automated car or bus in mind could have unintended consequences or automated tractors or cranes.

- If an automated heavy equipment vehicle might occasionally be used on public roads, should they have to meet all the same requirements for operation of automated cars? Should an automated tractor have to have a person behind the wheel while operating on public roads?

Should we regulate how these vehicles interact with humans on job sites?

- Should these vehicles be allowed to operate in the same space as human workers?
- How should companies train their workers to interact with automated heavy equipment vehicles?

Policymakers may also need to address workforce concerns.

- How can we ensure that displaced workers find new jobs?
- How can we ensure that workers have the training and skills for the new kinds of jobs created?

EARLY DEPLOYMENT OPPORTUNITY: AUTOMATED TRUCK MOUNTED ATTENUATOR VEHICLES

What is an automated truck mounted attenuator?

One example of an automated maintenance vehicle intended for use on public roads is the automated truck mounted attenuator. Truck mounted attenuators (TMAs) are designed to provide a rolling crash barrier between work zones and any vehicle that fails to slow down or change lanes. TMAs save lives and prevent injuries for both motorists and maintenance workers, but they put the TMA driver at risk of injury when the attenuator is hit. Automating these TMAs removes the driver from a hazardous position while still protecting the roadway workers and the traveling public.

ATMAs follow a lead vehicle, such as a striping or mowing vehicle. The lead vehicle wirelessly transmits high-accuracy data on its position, speed, and heading. The ATMA receives this transmission and copies the lead vehicle's movements using steering, throttle, and brake actuators.

Where have automated truck mounted attenuators been tested?

Automated TMAs (ATMAs) have been tested and are already in use in a couple of states. The Florida Department of Transportation tested an ATMA in 2015. In August 2017, the Colorado Department of Transportation (CDOT) became the first transportation department in the United States to purchase and demonstrate an ATMA. A CDOT road striping crew first used the ATMA near Fort Collins.

When will automated truck mounted attenuators be available?

This technology is currently used in a handful of states, but only in a limited capacity as part of pilot programs. For example, Colorado uses its ATMA in rural areas away from heavy or mixed traffic. Oregon could conduct a pilot program for ATMAs in the near future.

What are the benefits of automated truck mounted attenuators?

- ATMAs could save lives and prevent injuries by removing TMA drivers from this hazardous position.
- ATMAs present an ideal early deployment opportunity because they are typically used in low speed operations.
- This technology can be used to retrofit existing TMAs.

What are the obstacles to deployment of automated truck mounted attenuators?

The technology used for ATMAs has not yet been proven or certified.

- The manufacturers have not certified that the ATMA meets vehicle safety standards.
- The following vehicle copies the movements of the lead vehicle exactly; if the lead vehicle encounters an obstacle and has to change lanes, the ATMA won't change lanes until it also encounters the obstacle. This leaves the lead vehicle without protection until the ATMA also changes lanes.
- The sensor systems of current versions of ATMAs still have "blind spots" that will need to be eliminated to ensure they can operate safely in mixed traffic, particularly in cases where they need to change lanes or make other maneuvers to avoid obstacles.
- The lead and following vehicles sometimes lose communication when passing under overpasses or through tunnels.
- The technology is still in the late stages of development and is not commercially available. For example, when CDOT conducted performance verification tests, they identified changes that the manufacturers needed to make to the programming code.

REFERENCES

Introduction to Automated Vehicle Use Cases

Boudette, N.E. (2018, January 12). G.M. says its driverless cars could be in fleets by next year. *New York Times*. Retrieved from https://www.nytimes.com/2018/01/12/business/gm-driverless-car.html?_r=0

Lee, T.B. (2017, October 3). Fully driverless cars could be months away. *Ars Technica*. Retrieved from https://arstechnica.com/cars/2017/10/report-waymo-aiming-to-launch-commercial-driverless-service-this-year/

Terminology: Automated or Autonomous?

National Highway Traffic Safety Administration. (2017). *Automated driving systems 2.0: A vision for safety*. Retrieved from https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

Society of Automotive Engineers International. (2016). *Taxonomy and definitions for terms related to driving automated systems for on-road motor vehicles* (Surface Vehicle Recommended Practice No. J3016_201609). Retrieved from https://www.sae.org/standards/content/j3016_201609/

Use Case 1: Vehicles with Conditional Automation

Audi 2018 S4. (n.d.). *Audi*. Retrieved from https://www.audiusa.com/models/audi-s4

Auld, J., Sokolov, V., & Stephens, T. S. (2017). *Analysis of the effects of connected–automated vehicle technologies on travel demand. Transportation Research Record: Journal of the Transportation Research Board, 2625,* 1–8. https://doi.org/10.3141/2625-01

Tesla Motors. (n.d.). *Autopilot: Fully self-driving hardware on all cars*. Retrieved from https://www.tesla.com/autopilot

Ayre, J. (2017, November 1). Google/Waymo stopped testing Level 3 self-driving tech after testers literally fell asleep while using it, switched to full autonomy. *Clean Technica*. Retrieved from https://cleantechnica.com/2017/11/01/googlewaymo-stopped-testing-level-3-self-driving-tech-testers-literally-fell-asleep-using-switched-full-autonomy/

Fagella, D. (2017, June 4). Self-driving car timeline for 11 top automakers. *Venture Beat*. Retrieved from https://venturebeat.com/2017/06/04/self-driving-car-timeline-for-11-top-automakers/

Floyd, M. (2017, August 26). Audi's traffic jam assist is another step toward dulling the pain of nightmare commutes. *Automobile Magazine*. Retrieved from http://www.automobilemag.com/news/audi-traffic-jam-assist/

Hawkins, A. J. (2018, January 23). Tesla Model S plows into a fire truck while using autopilot. *The Verge*. Retrieved from https://www.theverge.com/2018/1/23/16923800/tesla-firetruck-crash-autopilot-investigation

Hoogendoorn, R., van Arem, B., & Hoogendoorn, S. (2014). Automated driving, traffic flow efficiency, and human factors: Literature review. *Transportation Research Record: Journal of the Transportation Research Board, 2422,* 113–120. https://doi.org/10.3141/2422-13

Llaneras, R. E., Cannon, B. R., & Green, C. A. (2017). Strategies to assist drivers in remaining attentive while under partially automated driving: Verification of human–machine interface concepts. *Transportation Research Record: Journal of the Transportation Research Board, 2663,* 20–26. https://doi.org/10.3141/2663-03

National Highway Traffic Safety Administration. (2015). *Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey: A brief statistical survey* (Traffic Safety Facts: Crash Stats No. DOT HS 812 115). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115

Use Case 2: Vehicles with Full Automation

Bhavsar, P., Das, P., Paugh, M., Dey, K., & Chowdhury, M. (2017). Risk analysis of autonomous vehicles in mixed traffic streams. *Transportation Research Record: Journal of the Transportation Research Board, 2625,* 51–61. https://doi.org/10.3141/2625-06

Bierstadt, J., Aaron Gooze, Chris Gray, Josh Peterman, Leon Raykin, & Jerry Walters. (2014). Effects of next-generation vehicles on travel demand and highway capacity. *Fehr and Peers Think*. Retrieved from http://orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf

Chen, F., Balieu, R., & Kringos, N. (2016). Potential influences on long-term service performance of road infrastructure by automated vehicles. *Transportation Research Record: Journal of the Transportation Research Board, 2550,* 72–79. https://doi.org/10.3141/2550-10

Csepinszky, A., Giustiniani, G., Holguin, C., Parent, M., Flament, M., & Alessandrini, A. (2015). Safe integration of fully automated road transport systems in urban environments: Basis for missing legal framework. *Transportation Research Record: Journal of the Transportation Research Board, 2489,* 115–122. https://doi.org/10.3141/2489-13

Litman, T. (2018). Autonomous vehicle implementation predictions: Implications for transport planning. *Victoria Transport Policy Institute*. Retrieved from https://www.vtpi.org/avip.pdf

OReGO. (n.d.). *Oregon Department of Transportation*. Retrieved from www.myorego.org

Shaheen, S., Hannah Totte, & Adam Stocker. (2018). Future of mobility white paper (California Transportation Plan 2050). *California Department of Transportation*. Retrieved from http://www.dot.ca.gov/hq/tpp/offices/osp/future-of-mobility.pdf

Talebpour, A., Mahmassani, H. S., & Elfar, A. (2017). Investigating the effects of reserved lanes for autonomous vehicles on congestion and travel time reliability. *Transportation Research Record: Journal of the Transportation Research Board, 2622,* 1–12. https://doi.org/10.3141/2622-01

United Kingdom Department for Transport. (2016). *Research on the impacts of connected and autonomous vehicles (CAVs) on traffic flow, version 1.1* (No. SO13994/3). Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/530091/impacts-of-connected-and-autonomous-vehicles-on-traffic-flow-summary-report.pdf

Zmud, J., Goodin, G., Moran, M., Kalra, N., Thorn, E., National Cooperative Highway Research Program, National Academies of Sciences, Engineering, and Medicine. (2017). *Strategies to advance automated and connected vehicles*. Washington, D.C.: Transportation Research Board. https://doi.org/10.17226/24873

Use Case 3: On-Demand Fleets of Automated Vehicles

Boesch, P. M., Ciari, F., & Axhausen, K. W. (2016). Autonomous vehicle fleet sizes required to serve different levels of demand. *Transportation Research Record: Journal of the Transportation Research Board, 2542,* 111–119. https://doi.org/10.3141/2542-13

Brownell, C., & Kornhauser, A. (2014). A driverless alternative: Fleet size and cost requirements for a statewide autonomous taxi network in New Jersey. *Journal of the Transportation Research Board, No. 2416,* 73–81. https://doi.org/10.3141/2416-09

Chen, T. D., & Kockelman, K. M. (2016). Management of a shared autonomous electric vehicle fleet: Implications of pricing schemes. *Transportation Research Record: Journal of the Transportation Research Board, 2572,* 37–46. https://doi.org/10.3141/2572-05

Clements, L. M., & Kockelman, K. M. (2017). Economic effects of automated vehicles. *Transportation Research Record: Journal of the Transportation Research Board, 2606,* 106–114. https://doi.org/10.3141/2606-14

Fagnant, D. J., Kockelman, K. M., & Bansal, P. (2015). Operations of shared autonomous vehicle fleet for Austin, Texas market. *Transportation Research Record: Journal of the Transportation Research Board, 2536,* 98–106. https://doi.org/10.3141/2536-12

Hawkins, Andrew J. (2017, November 7.) Waymo is first to put fully self-driving cars on US roads without a safety driver. *The Verge*. Retrieved from https://www.theverge.com/2017/11/7/16615290/waymo-self-driving-safety-driver-chandler-autonomous

Henderson, P. (2017, May 25). Some Uber and Lyft riders are giving up their own cars: Reuters/Ipsos Poll. Reuters. Retrieved from https://www.reuters.com/article/us-autos-rideservices-poll/some-uber-and-lyft-riders-are-giving-up-their-own-cars-reuters-ipsos-poll-idUSKBN18L1DA

Kane, J., Adie Tomer, & Robert Puentes. (2017). *How Lyft and Uber can improve transit agency budgets*. Brookings Institution. Retrieved from https://www.brookings.edu/research/how-lyft-and-uber-can-improve-transit-agency-budgets/

Lavieri, P. S., Garikapati, V. M., Bhat, C. R., Pendyala, R. M., Astroza, S., & Dias, F. F. (2017). Modeling individual preferences for ownership and sharing of autonomous vehicle technologies. *Transportation Research Record: Journal of the Transportation Research Board, 2665,* 1–10. https://doi.org/10.3141/2665-01

Lineart, P. (2017, February 17). GM plans to build, test thousands of self-driving bolts in 2018. *Reuters*. Retrieved from https://www.reuters.com/article/us-gm-autonomous-exclusive/exclusive-gm-plans-to-build-test-thousands-of-self-driving-bolts-in-2018-sources-idUSKBN15W283

Martin, E., Shaheen, S., & Lidicker, J. (2010). Impact of carsharing on household vehicle holdings: Results from North American shared-use vehicle survey. *Transportation Research Record: Journal of the Transportation Research Board, 2143,* 150–158. https://doi.org/10.3141/2143-19

Masunaga, S., & Mitchell, R. (2017, November 20). Volvo to supply Uber with up to 24,000 self-driving SUVs for taxi fleet. *Los Angeles Times*. Retrieved from http://www.latimes.com/business/autos/la-fi-hy-volvo-uber-20171120-story.html

Mendes, L. M., Bennàssar, M. R., & Chow, J. Y. J. (2017). Comparison of light rail streetcar against shared autonomous vehicle fleet for Brooklyn–Queens Connector in New York City. *Transportation Research Record: Journal of the Transportation Research Board, 2650,* 142–151. https://doi.org/10.3141/2650-17

Shoup, Donald. (2017). *The high cost of free parking*. New York: Routledge.

Stocker, A., & Susan Shaheen. (2017). Shared automated vehicles: Review of business models. In *Roundtable on Cooperative Mobility Systems and Automated Driving* (Vol. Discussion Paper No. 2017-09). Transportation Sustainability Research Center, University of California at Berkeley. Retrieved from https://www.itf-oecd.org/sites/default/files/docs/shared-automated-vehicles-business-models.pdf

Zhang, W., & Guhathakurta, S. (2017). Parking spaces in the age of shared autonomous vehicles: How much parking will we need and where? Transportation Research Record: *Journal of the Transportation Research Board, 2651,* 80–91. https://doi.org/10.3141/2651-09

Use Case 4: Automated Regional Public Transit

Anderson, M. L. (2014). Subways, strikes, and slowdowns: The impacts of public transit on traffic congestion. *American Economic Review, 104(9),* 2763–2796. https://doi.org/10.1257

Crawford, A. (n.d.). Honolulu Is building America's first fully driverless transit system. *CityLab*. Retrieved from https://www.citylab.com/life/2014/09/honolulu-is-building-americas-first-fully-driverless-transit-system/380292/

Fulton, Lew, Jacob Mason, & Dominique Meroux. (2017). *Three revolutions in urban transportation: How to achieve the full potential of vehicle electrification, automation and shared mobility in urban transportation systems around the world by 2050*. The Institute of Transportation Studies at the University of California at Davis and the Insistitute for Transportation and Development Policy. Retrieved from https://www.itdp.org/publication/3rs-in-urban-transport/

Hazan, Joël, Nikolaus Lang, Peter Ulrich, Jeffrey Chua, Xanthi Doubara, & Thomas Steffens. (2016). *Will autonomous vehicles derail trains?* Boston Consulting Group. Retrieved from https://www.bcg.com/publications/2016/transportation-travel-tourism-automotive-will-autonomous-vehicles-derail-trains.aspx

Krauth, O. (2018, February 12). New autonomous pods move in swarms to improve public transportation. *TechRepublic*. Retrieved from https://www.techrepublic.com/article/new-autonomous-pods-move-in-swarms-to-improve-public-transportation/

Larsen, R. (1997). Feasibility of advanced vehicle control systems for transit buses. *Transportation Research Record: Journal of the Transportation Research Board, 1604,* 155–162. https://doi.org/10.3141/1604-18

Levin, M. W., & Boyles, S. D. (2015). Effects of autonomous vehicle ownership on trip, mode, and route choice. *Transportation Research Record: Journal of the Transportation Research Board, 2493,* 29–38. https://doi.org/10.3141/2493-04

The Mercedes-Benz Future bus: The future of mobility. (n.d.). Daimler. Retrieved from https://www.daimler.com/innovation/autonomous-driving/future-bus.html

Miller, Jennifer M. (2015). Autonomous vehicles: Implications for employment demand. *National Academy of Engineering's The Bridge: Linking Engineering and Society, 45(3),* 5–11. Retrieved from https://www.nae.edu/File.aspx?id=142835.

Silver, Nate & Reuben Fischer-Baum. (2015, August 28). Public transit should be Uber's new best friend. *FiveThirtyEight.* Retrieved from https://fivethirtyeight.com/features/public-transit-should-be-ubers-new-best-friend/

Taylor, Andy. (2018, February 2). Mobility-as-service: Coming to a city near you soon... *Eno Transportation Weekly.* Retrieved from https://www.enotrans.org/article/mobility-service-coming-city-near-soon/

Thomson, A. (2017, June). China built a self-driving... something. *Popular Mechanics.* Retrieved from http://www.popularmechanics.com/technology/infrastructure/a26782/china-built-a-self-driving-something/

Trommer, S., Viktoriya Kolarova, Eva Fraedrich, Lars Kröger, Benjamin Kickhöfer, Tobias Kuhnimhof, ... Peter Phleps. (2016). *Autonomous driving: The impact of vehicle automation on mobility behavior.* Institute for Mobility Research. Retrieved from https://www.ifmo.de/publications.html?t=45

Vancouver SkyTrain. (n.d.). *Railway Technology.* Retrieved from https://www.railway-technology.com/projects/vancouver/

Van Dijke, J., & van Schijndel, M. (2012). CityMobil, advanced transport for the urban environment: Update. *Transportation Research Record: Journal of the Transportation Research Board, 2324,* 29–36. https://doi.org/10.3141/2324-04

Early Deployment Opportunity: Automated Low-Speed Passenger Shuttles

Davis, Katherine. (2017, November 22). The 32-acre park in Ann Arbor that's leading driverless car innovation. *Chicago Inno.* Retrieved from https://www.americaninno.com/chicago/inno-on-the-road-ann-arbor/the-32-acre-park-in-ann-arbor-thats-leading-driverless-car-innovation/

Kröger, Lars, Tobias Kuhnimhof, & Stefan Trommer. (2016). *Modelling the impact of automated driving: Private AV scenarios for Germany and the U.S.* Institute for Mobility Research. Retrieved from https://www.researchgate.net/publication/312374303_Modelling_the_Impact_of_Automated_Driving_Private_AV_Scenarios_for_Germany_and_the_US

NAVYA and Keolis partner with City of Las Vegas to launch first driverless public transit vehicle to operate in U.S. (2017, January 10). *Business Wire.* Retrieved from https://www.businesswire.com/news/home/20170110006423/en/NAVYA-Keolis-Partner-City-Las-Vegas-Launch

Ruggiero, Angela. (2017, March 7). San Ramon: Driverless shuttles make their debut. *East Bay Times.* Retrieved from https://www.eastbaytimes.com/2017/03/06/san-ramon-driverless-shuttles-make-their-debut/

Said, Carolyn. (2016, December 31). Self-driving shuttle loops around Santa Clara University Campus. *San Francisco Chronicle.* Retrieved from http://www.sfchronicle.com/business/article/Self-driving-shuttle-loops-around-Santa-Clara-10827588.php

Use Case 5: Automated Interregional Transit

LaMondia, J. J., Fagnant, D. J., Qu, H., Barrett, J., & Kockelman, K. (2016). Shifts in long-distance travel mode due to automated vehicles: Statewide mode-shift simulation experiment and travel survey analysis. *Transportation Research Record: Journal of the Transportation Research Board, 2566,* 1–11. https://doi.org/10.3141/2566-01

Lavrinc, D. (2013, April 26). It's not a lack of technology that's keeping trains from going driverless. *Wired.* Retrieved from https://www.wired.com/2013/04/why-arent-trains-autonomous/

Toor, Amar. (2017, June 16). France aims to have 'driverless' high-speed TGV trains by 2023. *The Verge.* Retrieved from https://www.theverge.com/2017/6/16/15815666/driverless-tgv-high-speed-trains-france-sncf

Use Case 6: Automated Local Delivery Vehicles

Carlson, Galen, & Nico Larco. (n.d.). *Urbanism Next: Re-imagining retail.* Sustainable Cities Initiative at the University of Oregon. Retrieved from https://urbanismnext.uoregon.edu/files/2017/06/Re-Imagining-Retail-Urb-Next-SCI-Carlson-Larco-2017-yz1xdh.pdf

McKinsey Global Institute. (2017). *A future that works: Automation, employment, and productivity, an executive summary.* Retrieved from http://guides.libraryconnectivity.org/ld.php?content_id=40360679

Stewart, Jack. (2017, August 29). Ford's robocar delivers pizza in the name of science. *Wired.* Retrieved from https://www.wired.com/story/ford-self-driving-pizza-delivery-dominos/

Use Case 7: Automated Medium- and Long-Haul Freight Trucks

Costello, Bob. (n.d.). *Related to: Industry data.* American Trucking Associations. Retrieved from http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

Davies, Alex. (2017, November 13). Self-driving trucks are now delivering refrigerators. *Wired.* Retrieved from https://www.wired.com/story/embark-self-driving-truck-deliveries/

Davies, Alex. (2016, October 25). Uber's self-driving truck makes its first delivery: 50,000 beers. *Wired.* Retrieved from https://www.wired.com/2016/10/ubers-self-driving-truck-makes-first-delivery-50000-beers/

Dougherty, Conor. (2017, November 13). Self-driving trucks may be closer than they appear. *The New York Times.* Retrieved from https://www.nytimes.com/2017/11/13/business/self-driving-trucks.html

Federal Motor Carrier Safety Administration. (2017). *Large truck and bus crash facts 2015* (Large Truck and Bus Crash Facts). Retrieved from https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2015

Federal Motor Carrier Safety Administration. (2017). *The large truck crash causation study: Analysis brief* (No. FMCSA-RRA-07-17). Retrieved from https://www.fmcsa.dot.gov/safety/research-and-analysis/large-truck-crash-causation-study-analysis-brief

Following too closely, Pub. L. No. 2014 ORS 811.485, 2015 Oregon Revised Statute. Retrieved from https://www.oregonlaws.org/ors/811.485

Freedman, David H. (n.d.). Self-driving trucks: Tractor trailers without a human at the wheel will soon barrel to highways near you - What will this mean for the nation's 1.7 million truck drivers? *MIT Technology Review,* (March/April 2017). Retrieved from https://www.technologyreview.com/s/603493/10-breakthrough-technologies-2017-self-driving-trucks/

National Highway Traffic Safety Administration. (2016, August.) *2015 motor vehicle crashes: Overview* (Traffic Safety Facts: Research Note No. DOT HS 812 318). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812318

Noorvand, H., Karnati, G., & Underwood, B. S. (2017). Autonomous vehicles: Assessment of the implications of truck positioning on flexible pavement performance and design. *Transportation Research Record: Journal of the Transportation Research Board, 2640,* 21–28. https://doi.org/10.3141/2640-03

Nowakowski, C., Thompson, D., Shladover, S. E., Kailas, A., & Lu, X.-Y. (2016). Operational concepts for truck maneuvers with cooperative adaptive cruise control. *Transportation Research Record: Journal of the Transportation Research Board, 2559,* 57–64. https://doi.org/10.3141/2559-07

Surakitbanharn, Caitlin A., Ph.D., Mikaela Meyer, Baylee Bunce, Jackson Ball, Christina Dantam, & Roshini Mudunuru. (n.d.). *Preliminary ethical, legal and social implications of connected and autonomous transportation vehicles (CATV).* Purdue Policy Research Institute. Retrieved from http://guides.libraryconnectivity.org/ld.php?content_id=40361526

Tsugawa, S. (2013). An overview on an automated truck platoon within the energy ITS project. *IFAC Proceedings Volumes, 46*(21), 41–46. https://doi.org/10.3182/20130904-4-JP-2042.00110

Use Case 8: Automated Heavy Equipment Vehicles

Beede, David, Regina Powers, & Cassandra Ingram. (2017). *The employment impacts of autonomous vehicles* (No. ESA Issue Brief # 05-17). Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce. Retrieved from http://guides.libraryconnectivity.org/ld.php?content_id=40360321

Gershgorn, Dave. (2017, October 19). Construction is as far from a Silicon Valley darling as you can get - and that's why it's ready for automation. *Quartz.* Retrieved from https://qz.com/1106909/construction-is-the-next-industry-hit-by-automation-and-thats-good/

Robarts, Stu. (2016, September 7). Watch Volvo's autonomous truck navigate itself through a dark mine. *New Atlas.* Retrieved from https://newatlas.com/volvo-fmx-autonomous-truck-testing-boliden-mine-kristineberg-sweden/45305/

Saurí, S., Morales-Fusco, P., Martín, E., & Benítez, P. (2014). Comparing manned and automated horizontal handling equipment at container terminals: Productivity and economic analysis. *Transportation Research Record: Journal of the Transportation Research Board, 2409,* 40–48. https://doi.org/10.3141/2409-06

Simon, Matt. (2017, October 19). This robot tractor is ready to disrupt construction. *Wired.* Retrieved from https://www.wired.com/story/this-robot-tractor-is-ready-to-disrupt-construction/

Early Deployment Opportunity: Automated Truck Mounted Attenuator Vehicles

Colorado Department of Transportation. (2017). *CDOT and partners drive safety with world's first self-driving work zone vehicle.* Retrieved from https://www.codot.gov/news/2017-news/august/cdot-and-partners-drive-safety-with-world2019s-first-self-driving-work-zone-vehicle

Hill, Chris. (n.d.). First truck mounted attenuators to be tested in Florida DOT closed work zones. *Equipment World.* Retrieved from https://www.equipmentworld.com/highways-2-0-first-truck-mounted-attenuators-to-be-tested-in-florida-dot-closed-work-zones/