AUTOMATED VEHICLES

Overview of Automated Vehicle Technology

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Research has repeatedly demonstrated driver error plays a role in more than 90% of road crashes.[1] In the past two decades, vehicle manufacturers have designed new and increasingly sophisticated features providing drivers more assistance to help prevent or mitigate crashes. These advanced driver assistance systems (ADAS) are an important precursor to the development of higher levels of automation (i.e., Levels 3, 4, and 5). Currently, there are great expectations that higher levels of automation will dramatically reduce road crashes.

In the meantime, vehicles equipped with ADAS hold promise to improve safety for all road users. Specifically, this technology may be able to compensate for age-related declines among older drivers' skills. This is an important application of the technology because older drivers (65 years and up) are often over-represented in crash statistics.[2] In fact, this demographic of drivers may be well-positioned to reap the benefits of ADAS-equipped vehicles to mitigate decrements in driving ability. However, for safety benefits to be realized by all drivers, effective education and training that acknowledges strengths and limitations of these vehicles are crucial. Otherwise, reductions in crashes may not be achieved as drivers adapt their driving behaviour in response to new technologies in ways that are unsafe and increase risk.

This factsheet shares some common principles of automated vehicle (AV) technology to help provide context for drivers. Answers to common questions often asked about AV technology and core principles of this technology are below.

Questions & Answers

Different Levels of Automation

What levels of automation exist for passenger cars?

The National Highway Traffic Safety Administration (NHTSA) and Society of Automotive Engineers (SAE) International have identified several levels of vehicle automation. For more detailed definitions of the levels of automation, see the **Introduction to the Use of Automation in Vehicles** fact sheet:

- **Level 0 - No automation:** Vehicle has no automated functions.

Your brain is your vehicle's most important safety feature.

- **Level 1 - Driver assistance:** Vehicle has some limited automation (e.g. steering or acceleration/braking support, but not both simultaneously) in certain conditions.
- **Level 2 - Partial automation:** Vehicle can automate certain combinations of functions (e.g., steering and acceleration/braking support) under certain conditions.
- **Level 3 - Conditional automation:** Vehicle can assume the complete driving task under limited conditions, and the driver must be ready to resume driving at any point.
- **Level 4 - High automation**: Vehicle can perform all the driving tasks under specific driving conditions and environments.
- **Level 5 - Full automation:** Vehicle can handle all driving tasks without human input, under all types of driving conditions and environments.[3]

At what level of automation does a driver no longer have to be engaged in the driving task?

All levels, except Levels 4 and 5, require driver input. Compared to Level 3 vehicles that require a driver to resume control when it cannot reliably function, level 4 vehicles must be able to respond safely even when its operational limits are reached. It is hypothesized that the system may bring the vehicle to a controlled stop in a safe area or, should it require assistance, potentially relinquish control to a remote human driver if no driver were present or if the driver were unable or unwilling to take control.[4] Level 5 automated vehicles do not require any driver intervention and can handle all driving tasks under all types of driving conditions and environments. However, Level 4 or 5 personal vehicles are likely a decade or more into the future. Level 3 vehicles have launched in limited quantities and in specific markets for real world evaluation, but mass market deployment of Level 3 vehicles is still several years away.

Automated Air Travel vs. Automated Driving

Why can't the same technology used to automate planes be integrated into road-based vehicles?

Key factors such as the functionality and capability of vehicles, road conditions, potential obstructions, and the proximity of other vehicles directly impact the level of vehicle automation possible. In fact, there is evidence to suggest, in some respects, navigating a roadway with a Level 5 vehicle is ten billion times more difficult than flying an automated aircraft due to the varying conditions drivers may encounter driving in such a limited and confined road space.[5]

What are some issues drivers would encounter that would be different from pilots?

Some issues that may be encountered by drivers and not experienced by pilots include:

- Proper spacing of road-based vehicles around other road users is a constant issue whereas in aircraft it is a limited concern.
- Poor road conditions caused by weather or lack of maintenance can affect vehicles for the duration of a trip. In an aircraft, similar automated functions are rarely used if the weather is poor.
- Wildlife interacting with roadways is a significant concern for vehicle drivers. Although wildlife is still an issue for aircraft, it is not as prominent.
- Pedestrians and other users of active transportation (e.g., bicyclists, skateboarders, rollerbladers) share the road with vehicles and must be given a safe distance. This is not a concern for aircraft.

Level 5 automated vehicles are still under development and are decades away from being available to the public.

Many issues encountered by road-based vehicles are entirely different than the type of challenges encountered in other forms of transportation such as aircraft.

Many of these issues encountered by road-based vehicles are entirely different than the challenges encountered in other forms of transportation such as aircraft. Although there are some similarities behind principles governing automated transport, the context in which these issues are resolved for road-based vehicles versus air transportation makes it impossible for AV technology to be used interchangeably. Technology for automated vehicles will have to be developed and exclusively used for that type of transportation.

Are standards of training applied to pilots and drivers a factor in the ability to implement AV technology?

Yes. The training standards for aircraft pilots are more rigorous than those of land-based vehicles. For instance, to qualify as a First Officer on a commercial airline in the US, pilots must undergo a minimum of 1500 hours of training, and continually re-certify to maintain their qualification.[6] Further, to qualify as a pilot-in-command (Captain) they must have completed an additional 1000 hours of flight training. Even for non-commercial airlines, pilots are expected to have a minimum of 50 hours of training, including at least 20 hours with an instructor.[7] This is in addition to the dozens of hours required in a flight simulator. As a result, behaviour differences or disruptions are less pronounced among pilots.

This is in sharp contrast to driver training skills. To illustrate, in order to obtain a full driving licence in most North American jurisdictions, limited training is required. For example, driver education programs are not mandatory in several jurisdictions, and there is substantial variation between programs. Many driver education programs offer less than 30 hours of in-vehicle training.[8] There is also no minimum of logged hours required on the roadway in the majority of programs to obtain a driver's licence. The result is driver training, and subsequent skills, is much more varied than pilot behaviour. This creates unpredictability, which makes it more difficult for AV technology to imitate driver behaviour and respond to complex situations.

Therefore, even though automated air travel has been achieved to a limited extent in air transportation, automated personal vehicles (i.e., Level 3, 4, and 5) are not publicly available and remain in development.

Technological Limitations & Failure Rates

Are there other barriers to widespread implementation of AV technology in vehicles beyond the varied nature of road environments?

Level 3, 4 or 5 vehicle vehicles are equipped with an automated driving system (ADS), which is an integrated set of automated systems operating simultaneously to perform the driving task. ADS-equipped vehicles are able to perform all aspects of the driving task, but only under defined conditions and specified road environments based on the level of automation and cannot operate if these specifications are not met. As such, the ADS must meet certain standards and regulations. Although no technology is perfect, given the stakes of road safety are high in terms of personal and public safety, rigorous vehicle safety standards are continually being developped and modernized to ensure automated vehicles do not cause systematic road hazards or increase risk to road users.

For this reason, companies developing AV technology are required to report incidents where human drivers had to resume control of the vehicle to prevent a crash, as well as actual crash data. Currently, the frequency of these instances and collisions is varied across several vehicle manufacturers, but all report incidents consistently challenging human drivers such as rear-end collisions. One study from California estimated the

average automated vehicle had one collision for every 42,000 miles travelled.[9] In light of these failure rates, it is unlikely AVs will be available to consumers anytime soon.

What is the acceptable failure rate of AV technology for road-based vehicles?

Although there are no US federal government standards for the failure rate of AV technology in many jurisdictions, discussions for implementation include possibly requiring a six sigma level which means three defects per million uses.[10]

In other words, these vehicles must be able to perform advanced maneuvering, navigate bad weather, adjust responses to driving conditions, safely avoid hazards, and make ethical decisions about potential hazards.[11] In essence, the technology must be capable of performing all the tasks human drivers perform. This level of automation has not yet been achieved.

Automated Vehicles in Canada

Are automated vehicles available for purchase in Canada?

No. Currently, vehicles with Level 3 conditional automation and higher are not available for public purchase in Canada. When these vehicles become available for consumer purchase, drivers must still monitor the driving task, including steering and accelerating/braking, and must be prepared at all times to intervene at a moment's notice.[12] While these vehicles will monitor roadways and prompt drivers when they need to resume control of the vehicle, they will continue to rely upon input from drivers.

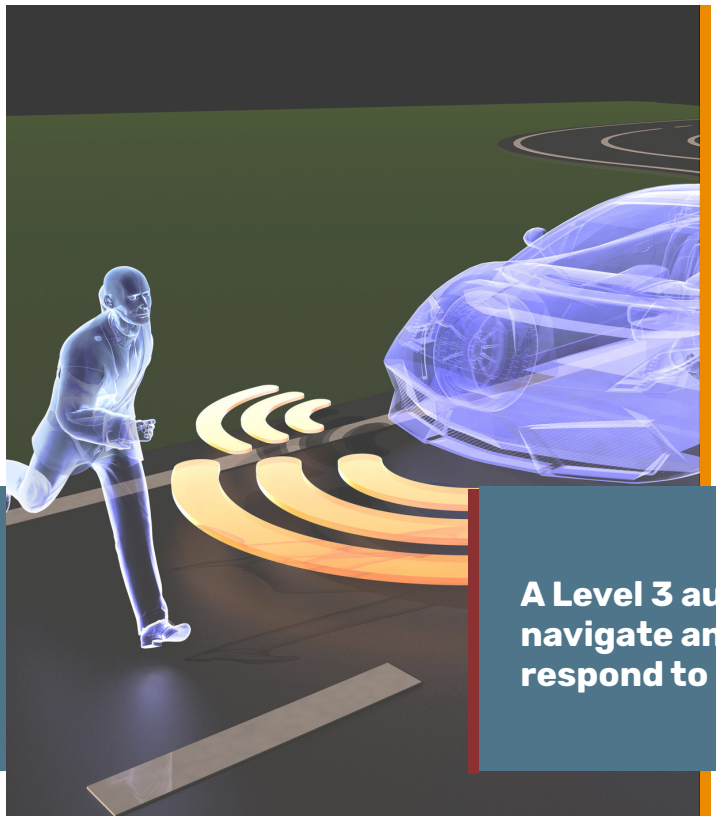
What are some limitations of automated vehicles?

Vehicles with conditional automation are not able to drive independently in more difficult or challenging road conditions or environments,[13] such as inclement weather, complex road environments, or navigate in situations involving vulnerable road users. Although certain vehicle technologies can assist drivers in challenging situations, drivers must take over control of the vehicle in extreme conditions. As such, drivers must remain attentive to the driving task and avoid fatigue, distraction or impairment.

Further, this technology is imperfect and limited by the scope of its design. Although it may successfully navigate an initial hazard, it may be unable to respond to secondary hazards.[14] This means in situations where the vehicle has avoided a collision with other drivers, the vehicle's automated features may create unsafe road conditions that a human driver would have to correct by taking control of the driving task. For example, if the vehicle's system made a lane change to successfully avoid an animal who suddenly ran out into the road, the human driver could be required to take over control if the vehicle ahead also stopped abruptly in response to the same hazard.

What type of research is being done in Canada?

In 2016, Ontario launched a pilot program to test automated vehicles. This pilot program is open to manufacturers, technology companies, and academic research institutions. The pilot program outlines clear rules of the road,[15] and has strict terms and conditions for testing. In all instances, the municipality in which testing is being conducted must be notified. The pilot program applies to vehicles capable of Level 3 automation and above.[16] Canada's capital, Ottawa, is one of the first major cities to engage in pilot testing in the city's West End area of Kanata.[17] Edmonton and Calgary also began testing driverless shuttles in Fall 2018.[18] Additionally, federal politicians and key decision-makers have continually expressed support for the advancement of AV technology in Canada.[19] Transport Canada also uses a Motor Vehicle Test Centre in Blainville, Quebec, to assess



A Level 3 automated vehicle may successfully navigate an initial hazard but may be unable to respond to secondary hazards that could arise.

the effectiveness of driver assistance technologies currently available on the market.[20]

Functional Limitations of Automated Vehicles

Can I rely upon an automated vehicle to navigate poor weather?

No. Currently, vehicles with conditional automation cannot function reliably in rain or snow as it may interfere with proper functioning of vehicle sensors or obscure road markings. As such, these vehicles still require capable drivers to take control.

Will the technology alert me to potential hazards?

Possibly. Although vehicles with conditional automation will possess early warning systems to alert drivers of potential hazards based on input from sensors and travelling speed, the driving environment is full of unexpected events and as such drivers must remain alert and respond accordingly if the vehicle cannot formulate a safe response to avoid a hazard.

Can I engage in other activities while driving?

No. Vehicles with conditional automation require an attentive and engaged driver. Research shows some drivers have indicated they would negatively modify or adapt their driving behaviour while using automated vehicles. This would diminish any safety benefits offered by these vehicles.

Can these vehicles negotiate complex road situations that require ethical judgement?

No. Vehicles with conditional automation are not equipped to make ethical decisions and navigate complex road environments that require judgments by drivers, such as merging onto a busier roadway or interpreting gestures from other drivers to proceed when they are uncertain about the right of way.

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What are some of the logistical challenges with building this technology into the vehicle?

Vehicles are regulated by size, weight, and emissions to operate safely. Vehicles exceeding these standards pose a potential road safety risk. This technology can drastically affect the design of the vehicle, and one of the primary challenges for engineers is to incorporate AV technology into vehicles so as not to compromise road safety or other safety standards.

Will these vehicles be able to navigate unexpected road obstacles such as construction zones?

No. Currently, these types of unexpected road obstacles cannot be safely navigated by a vehicle with conditional automation and will require human drivers to intervene. This demonstrates some of the limitations of the technology and why higher levels of automation are difficult to achieve. However, as the technology continues to develop this could be improved.

Are these vehicles susceptible to hacking?

Likely. Cyber-vulnerability may exist in any vehicle, regardless of automation level. Automated vehicles that incorporate some degree of connectivity through a data network will be vulnerable to cyberattacks. Although there are safeguards to implement robust cybersecurity in these vehicles, there is a risk of deliberate interference from an outside operator.

How will these vehicles interact with conventional vehicles?

Early research indicates outcomes will vary depending on what types of roads the vehicle is being driven on, behaviour of drivers, and the state of technology at

Vehicles with conditional automation can perform the driving task under limited conditions and environments. It is crucial that drivers remain fully engaged and monitor the driving task.

the time of driving. If drivers fail to safely adopt this technology, and instead rely upon them to perform advanced driver functions, positive impacts upon road safety will not be achieved. However, if drivers are properly educated about their use, there is potential to improve road safety. At the same time, when these vehicles begin to interact with conventional vehicles, it is expected there will be some initial heightened risk due to drivers being unfamiliar with the technology.[21] This risk is expected to decrease over time.

Can these vehicles be used to drive anywhere?

No. Vehicles with conditional automation can only operate in areas that have been extensively mapped. This is to ensure vehicles can operate correctly in terms of environmental conditions (gravel road versus paved, areas with specific weather conditions) and rules of a particular road (stop signs, speed limits, unique intersections). In such instances, drivers are expected to navigate these unexpected obstacles directly.

How will the purchase price be affected?

Initially, it is believed Level 3 vehicles will have a higher purchase price. However, if this technology is successfully adopted and used safely on a wide scale, some financial gain through reduced insurance costs is anticipated. Of course, this is dependent upon actual reductions in crashes through the proper use of this technology.

Conclusion

While automated vehicle technology can potentially enhance driver safety, several limitations are important to understand. For instance, although vehicles with conditional automation can perform some automated functions under certain conditions, drivers must remain fully engaged in the driving task. If not, their safety and safety of those around them would be significantly compromised. Core driving skills are still needed to achieve safe roadways. Since older drivers are already well-established in these areas, they potentially could effectively use this technology to increase their mobility while maintaining a certain level of safety and also help set standards for all drivers.[22] However, a key to realizing safety benefits for older drivers specifically, but for all drivers generally, will be effective education about the capabilities and limits of their particular vehicle model and its accompanying technologies.

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Traffic Injury Research Foundation

The vision of the Traffic Injury Research Foundation (TIRF) is to ensure people using roads make it home safely every day by eliminating road deaths, serious injuries and their social costs. TIRF's mission is to be the knowledge source for safer road users and a world leader in research, program and policy development, evaluation, and knowledge transfer. TIRF is a registered charity and depends on grants, awards, and donations to provide services for the public. Visit **www.tirf.ca**.

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