Autonomous Vehicles and Their Implications to Society

Olga Petrik
International Transport Forum (ITF) at the OECD, Paris, France

Synonyms

Autonomous; Automated; Driverless; Self-driving; Robotic vehicles

Definition

An autonomous vehicle is one that can drive itself without human conduction. The automation can be partial, when the automated system of the vehicle can conduct some parts of the driving tasks, or full, when the vehicle can perform all driving tasks under all conditions (geographic area, roadway type, traffic, weather, events/ Incidents) that a human driver could perform them.

Autonomous, automated, driverless, self-driving, robotic vehicles are the terms which are usually used interchangeably. However, there is a slight difference between “automated” and “autonomous” terms. As Wood et al. 2012 suggested, “‘Automated’ connotes control or operation by a machine, while ‘autonomous’ connotes acting alone or independently”. While the term “automated” is more precise for the most of the existing today projects, the term “autonomous” is more widespread and is usually used to refer to both autonomous and automated vehicles.

History and Levels of Vehicle Automation

The history of autonomous vehicles begins in the 1920s when a first radio-controlled vehicle travelled along New York City streets. Until the 1980s the experiments to create a driverless vehicle mostly involved guiding a vehicle using radio control or cables embedded in the road. The digital revolution in the 1960s boosted research and projects in robotics with efforts to create vehicles which would be able to sense, process the received information, and drive accordingly. First truly autonomous vehicles which were able to guide themselves based on sensors and autonomous robotic control were created in the 1980s, in the United States by Carnegie Mellon University’s Navlab and ALV in 1984 and in Germany by Mercedes-Benz and Bundeswehr University Munich in 1987. Since then the “intelligence” of the autonomous vehicles was gradually improving boosted by increase of computational power and by development of artificial intelligence. More driving tasks were becoming automated. In the 1990s first prototypes with parallel parking were created, and in the early
2000s, several car manufacturers adopted this technology in their vehicles. In the late 1990s, an Adaptive Cruise Control (ACC) system was installed on production vehicles by Toyota. In 2009 Google started its autonomous vehicle program. In a few years, this gave huge publicities to the automated vehicles and attracted a researcher to this field from other disciplines (Bagloee et al. 2016). Induct Technology’s Navia 8-seat shuttle with the max speed of around 20 km/h, which appeared on the market in the beginning of 2014, could be considered as the first self-driving vehicle to be available for commercial sale (Weber 2014).

The development of the autonomous vehicles led to the authorities in different countries to start designing related standards, policies, and regulations. In 2013 the National Highway Traffic Safety Administration (NHTSA) in the United States released a classification system based on four levels of automation. In 2016 NHTSA adopted the 6-level system developed by SAE International. The six levels (Table 1) include:

- At level 0, “no automation,” the human driver does everything without receiving any assistance from the vehicle. Most of the modern cars include one or more driver assistance features, and, therefore, they are level 1 vehicles.
- At level 1, “driver assistance,” the vehicle can assist the human driver in some parts of the driving task, but it does not perform the driving itself. An example of level 1 is parking assistance with automated steering and manual speed.
- At level 2, “partial automation,” the vehicle can perform some parts of the driving task taking full control (accelerating, braking, and steering), while the driver must monitor the environment and conduct the rest of the driving tasks.
- At level 3, “conditional automation,” the vehicle is able to conduct some of the driving tasks and to monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.
- At level 4, “high automation,” the vehicle can drive itself and monitor the driving environment, while the human may have the option to control the vehicle but does not need to take control. At this level the vehicle can operate only under certain conditions.
- At level 5, “full automation,” the vehicle can perform all driving tasks, under all conditions. No human intervention is required but the driver may have the option to control the vehicle.

### Technologies and Infrastructures

Autonomous vehicle operation consists of three consecutive steps: “sense,” “plan,” and “act” which include monitoring the environment for collecting information, making decision based

---

**Autonomous Vehicles and Their Implications to Society, Table 1** Levels of driving automation according to the Society of Automotive Engineers

<table>
<thead>
<tr>
<th>SAE level</th>
<th>Name</th>
<th>Execution of steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Fallback performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No automation</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver assistance</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial automation</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional automation</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

Source: Adapted from SAE International, Standard J3016 (SAE 2014)
on the information, and acting accordingly (Bagloee et al. 2016). The technologies needed for performing the three steps in order to reach level 5 of automation must allow the vehicle monitor the environment in real time (e.g., recognizing lanes, pedestrians, obstacles, traffic signs, weather conditions), to control vehicle’s route, to park the vehicle, to avoid collisions, and to optimize the speed depending on traffic and various conditions. Many of the required technologies for successful performance of the three steps are already developed while there are still some remaining challenges.

At the “sensing” step, sensing devices obtain information from the surrounding environment. Such devices include radars of different ranges, light radars (LIDAR), cameras, ultrasonic and infrared sensors, and Geographic Positioning Systems (GPS). This information is used as input for the decision-making software. The challenges related to the sensors include avoiding blind spots and keeping the sensors functioning despite possible adverse environmental conditions. To achieve more efficient collection of information, a system of “connected vehicles” can be used whereby the vehicles communicate with each other, with infrastructures, pedestrians, and clouds. Connectivity requires use of wireless communications with low latency to ensure real-time data exchange.

At the “planning” step, the automated system processes the received data and makes decisions based on that. The decisions could be regarding the vehicles’ actions such as acceleration, steering, and braking or regarding choosing the best route, changing the lane, etc. The system must be able to response to events and changing conditions in a dynamic way. For choosing the route and avoiding obstacles, very detailed maps can be uploaded into the system or received wirelessly from external sources. The maps used for the navigation must be always updated to avoid failures. For data analysis and decision-making, machine learning and artificial intelligence are applied. Their wide application became possible with a substantial growth of computational power in the last years. The “planning” step is the one at which most of the technological difficulties are faced since current capabilities of artificial intelligence in data analysis and decision-making are still far away from the ones which are necessary to ensure safe, efficient, and human-compatible autonomous driving, especially in a chaotic environment of a city. Interactions with humans in all aspects of operation of autonomous vehicles (with passengers, pedestrians, cyclists, other drivers) are one of the main challenges which require knowledge from social and behavioral sciences.

Connecting the vehicles with each other, as well as with physical and digital infrastructure, can help at the “planning” step to shift the decision-making from the vehicle to a more powerful control center, which processes the data, makes decisions, and communicates them to the vehicle remotely and wirelessly. The required physical infrastructures include charging stations, parking and loading zones tailored for autonomous vehicles, dedicated lanes, special landmarks helping the vehicle to detect bridges and tunnels, connected traffic signals that allow to optimize the vehicles’ movements, ground-based units for global navigation systems, communication equipment, specific pavement, etc. Digital infrastructure provides the virtual representation of the physical world with which the automated system will interact, and it includes navigation and coordinate systems (such as GPS and global navigation satellite system, GNSS), infrastructure for internet communications, and cellular coverage of a very high quality. Digital infrastructure should follow some common standards and protocols. In the United States, dedicated short-range communication (DSRC) is being developed for that purpose and tested on several case studies such as deployment of connected vehicles in the city of Ann Arbor (Maddox et al. 2015) and other projects in New York, Tampa, and Wyoming (Brugeman et al. 2018).

At the third step, “act,” the vehicle control system changes the motion of the vehicle in terms of its position and speed (i.e., accelerate, brake, steer). Since car’s sensing, navigation, and driving systems can be negatively affected by adverse environment conditions (imperfections of road, traffic conditions, weather conditions, etc.) or deliberate interference, another challenge
is maintaining those systems operating without failures and ensuring cybersecurity. The fully automated system at level 5 has to drive the vehicle taking into account dynamically changing environment, including obstacles, pedestrians, road infrastructure, signs, etc.

Some car manufactures have announced that vehicles with levels 4 and 5 automation will arrive shortly while others have advanced much later dates (such as 2030) (ITF 2015).

Implementation Pathways

The implementation pathways on the way to level 5 of automation can vary depending on the vehicle type. While trucks and light-duty vehicles are likely to start functioning first on freeways, in the case of passenger and delivery autonomous transport, urban areas are well-suited (ITF 2015).

Despite the high speeds, freeways tend to be more uniformly designed. The traffic flows are more organized and predictable; cyclists and pedestrians are usually absent. Vehicle platooning and separating the lanes for the autonomous vehicles can help to speed up the introduction of autonomous vehicles on freeways. A vehicle platoon consists of several vehicles with some level of automation and with a driver or without. The vehicles move closely to each other and are connected and coordinated through vehicle-to-vehicle communications.

In the case of urban environment, introduction of autonomous vehicles is likely to start with passenger vehicles operating at low speeds in restricted areas such as campuses, resorts, airports, sport clubs, etc. The vehicles also can be applied for first- and last-mile transit. Delivery vehicles might also operate on separated routes at low speeds.

The ITF (2015) suggested different pathways of autonomous vehicle deployment depending on their type and level of automation. The authors take as a departure point the established technologies of automation at levels 0–1, such as Anti-Lock System, emergency braking, Lane Change Assist and Lane Keeping Assist, Lane Departure Warning (alerting the driver if the vehicle is leaving the lane), Park Distance Control and Park Assist, Front Collision Warning, and Adaptive Cruise Control (measuring and controlling the distance and speed relative to vehicles driving ahead).

The pathway for the deployment of the urban mobility autonomous vehicles starts with the currently achieved level at which low-speed fully automated vehicles operate in limited areas and on dedicated infrastructure. The potential evolution will go along two dimensions: increase of speed and decrease of restrictions on area of deployment and infrastructure. At the intermediate steps of the pathway, the vehicles will be able to operate on dedicated lanes or on dedicated infrastructure and will provide door-to-door (or street corner to street corner) transit on demand. At the last step, the fully automated vehicles will be able to operate in mixed traffic.

In the case of autonomous private vehicles, the pathway leads from the currently available levels of automation to level 5 full automation. In addition to the systems available at levels 0–1 of automation, at level 2, the vehicles are equipped with partial Automated Parking System and Traffic Jam Assistance. The former is already available on the market, but the more advanced version of the system can include an option of remote parking via smartphone or via a remote control device by the driver located outside of the vehicle. The Traffic Jam Assistance controls movements of the vehicle in a traffic flow in speeds below 30 km/h. At the level 3, Highway and Traffic Jam Chauffeurs are added to the automated system. The Traffic Jam Chauffeur is an extension of Traffic Jam Assistance, and it allows automated driving in congested conditions at speeds up to 60 km/h. The Highway Chauffeur is even more advanced version, which allows automated driving at speeds up to 130 km/h, on all lanes, and is able to overtake other vehicles. The driver can switch on and off the system, but the system can ask the driver to take over in certain circumstances. At level 4 the Highway Chauffeur evolves into Highway Pilot, which never requests the driver to take any actions. At level 4 also, the vehicle is equipped with the Parking Garage Pilot that can drive the vehicle to and from the parking
place with and without the driver inside. Finally, at level 5, the fully automated vehicle should be able to perform all the driving tasks with no actions required from the passenger.

For the autonomous trucks, the deployment of vehicle platoons will be one of the main strategies as it will allow 10–15% of fuel savings. Level 2 Traffic Jam Assistance, level 3 Highway Chauffeur, and level 4 Highway Autopilot and Truck Terminal Parking system similar to the light-duty passenger vehicles are present at the corresponding steps of the truck deployment pathway. Additionally, the pathway implies Cooperative Adaptive Cruise Control platooning at level 1, full Truck platooning at level 3, and Truck Terminal Parking at level 4. The Cooperative Adaptive Cruise Control operates the engine and the brake for keeping a short but safe distance to the lead vehicle in the platoon. In addition to that, the full Truck platooning enables grouping the vehicles in a specific lane and handle vehicles leaving the platoon. Similarly to the light-duty vehicles, a fully automated truck should be able to perform all the driving tasks without a driver (ITF 2015).

Benefits and Negative Effects

Along most of the dimensions, the autonomous vehicles can bring either benefits or can have a negative impact on the lifestyles and society, depending on the concrete way of implementation. Potential benefits from the autonomous vehicle use can be, under certain conditions, increase of safety, cost, and traffic reduction, improved accessibility, more equitable land use, lower pollution, possibility of spending time onboard more productively for a driver, which becomes a passenger. The negative effects can be higher vehicle ownership and corresponding increased congestion and pollution, loss of jobs by truck, public transport and taxi drivers, urban sprawl, ethical issues when the vehicle makes decisions in unavoidable crashes, and reduced safety onboard of small autonomous public transport vehicles.

To avoid the negative effects and to enhance the advantages, cost-benefit analysis and impact assessments should be thoroughly performed along all the dimensions, and proper tests of the autonomous vehicles should be executed before their massive deployment. However, on practice, it may require a very complex modelling approach and numerous assumptions on uncertain aspects of the future.

Gruel and Stanford (2016) used a system dynamics model to test different long-term scenarios related to autonomous vehicles. The authors investigated how autonomous vehicles could influence the mode choice and how the changes in the mode choice might affect the transportation system in general. The three scenarios cover situations when (1) the mode choice does not change, (2) private car becomes more attractive, and (3) the vehicles are used in a shared scheme. In all the tested scenarios, safety increases, time spent in the car can be used differently, the situation of groups who currently have limited access to mobility would improve, and the cost per unit of distance and energy consumption decrease. The vehicle-kilometer travelled (VKT) vary significantly across the scenarios and, therefore, the levels of congestion and pollution.

Safety

For the increase in safety human error associated with delayed reaction, distracted or aggressive driving is a cause of more than 90 percent of crashes (Bagloee et al. 2016). Therefore, at the level of full automation, the probability of collisions can be reduced substantially, given that the automated system reacts and operates steadily and properly. Besides saving the human lives and health, this would allow to reduce indirect negative impacts of road accidents such as medical costs, legal and court costs, emergency service costs, congestion, and vehicle and infrastructure damage. At the moment, however, the imperfection of the automated systems sometimes leads to road accidents with involvement of autonomous vehicles currently available on the market. The known and proved first fatal accident with an autonomous vehicle involved happened in 2016 in Florida, whereby a Tesla Model S electric sedan was in self-driving mode and the brakes were not applied on time leading to a crash with a tractor-
trailer (Vlasic and Boudette 2016). The NHTSA released its vision for safety of automated driving systems highlighting several priority safety elements and guidelines for voluntary self-assessment. The priority safety elements include system safety, operational design domain, object and event detection and response, cybersecurity, human–machine interface, etc. (NHTSA 2017).

If the automation is partial or conditional (i.e., at a level of automation below 5), the driver’s attention can be still requested by the automated system. In this case there is a risk that the driver might be too relaxed, even asleep, and will not react fast enough to a critical situation.

Safety onboard a public transport vehicle might become an issue in the case of autonomous vehicles, especially for some groups of users such as female public transport users, who might feel (and actually be) safer in a vehicle with a driver. While the high-capacity vehicles will probably have a large amount of passengers and, therefore, will be quite safe, such as currently existing driverless subway trains, in the case of smaller vehicles with fewer passengers, this might be a serious issue deterring people from using those services.

Vehicle-Kilometer Travelled
The changes in VKT will depend on the forms of deployment of the autonomous vehicles, their costs, and regulations. Availability of autonomous vehicles for everyone might lead to increase in vehicle ownership and VKT since some of the people who do not drive at the moment for different reasons might purchase a vehicle and start using it instead of public transport and taxies due to higher flexibility which a private vehicle provides. Decreased needs for parking and parking costs and fuel efficiency of autonomous vehicles are among other attractive factors which might increase VKT. Also additional VKT might be due to self-fueling and self-parking and due to unoccupied trips.

Several studies explored the increase in VKT due to different reasons. Wadud et al. (2016) estimated that the increase in annual VKT due to induced demand from underserved user groups (youth, elderly, disabled) will be between 2% and 10%. Harper et al. (2016) suggest that the upper bound of that increase will be equal to 14%; Brown et al. (2014) estimated much higher increase of 40%. Childress et al. (2015) estimated a 20% increase in VKT assuming 30% larger road capacity, 65% lower value of travel time, and 50% decrease in parking costs. Schoettle and Sivak (2015) estimated 75% increase in annual VKT per vehicle and 43% reduction in vehicle ownership. Fagnant and Kockelman (2015) estimated increase in VKT depending on the market penetration rate of autonomous vehicles. At a 10% market penetration rate, the estimated increase in total VKT is 2% and at a 90% penetration rate it is 90%.

Gruel and Stanford (2016) using a system dynamics approach showed that in all the scenarios they considered, VKT is likely to increase, leading to a potential increase in energy consumption and emissions in total. The order of magnitude of the increase differs significantly across the scenarios. In the scenario assuming that the mode choice is not affected, autonomous vehicles bring mostly benefits. In the scenario of highly increased attractiveness of travelling by car, the VKT grow significantly, with corresponding growth of congestion level and emissions and urban sprawl. In the sharing scenario, car ownership decreases but the VKT grow even more due to the reallocation trips. However, ITF (2016) in their simulation studies on shared mobility showed that if there is a centralized dispatcher optimizing the reallocation of the shared vehicles, the VKT will not grow. Parking spots and depots for idle vehicles will be needed across the city in this case.

Congestion
Three main factors related to autonomous vehicles can affect congestion in different ways: reduction in road accidents, optimized vehicle throughput, and changes in the total VKT (Anderson et al. 2014). The expected increase in VKT might increase the congestion level. Reduction in road accidents will lead to fewer delays and traffic jams when one lane is blocked because of the accident, and, therefore, the reliability of the entire transport system will increase. Positive effect on congestion decrease can be also achieved due to higher
possible speed limits of the autonomous vehicles, smoother rides, and decreased need for safe distance between the vehicles (Simonite 2013). Tientrakool et al. (2011) estimated in their study that use of autonomous vehicles can increase road capacity by 273%. Congestion pricing might help to regulate the traffic and reduce the congestions. High level of communication technologies and data availability can improve the efficiency, flexibility, and dynamism of the pricing schemes (Bagloee et al. 2016).

Traffic congestion can be reduced even more if autonomous vehicles are connected. This can be especially useful at intersections. Dresner and Stone (2004, 2007) proposed a special system which leads to decrease of traffic delays and showed that the connected autonomous vehicles can perform two to three times more efficiently when substituting traffic lights. According to the estimations of Tientrakool et al. (2011), in the case of connected vehicles using vehicle-to-vehicle communication, road capacity could reach up to 445% with vehicles traveling safely at 120 km/h. Connected autonomous vehicles will also increase the ability of authorities to manage traffic flow due to more data available and more predictability.

Value of Time and Accessibility
Autonomous vehicles let the driver divert attention from driving tasks to other activities and, therefore, allow saving time. This can be especially valuable for business travelers who will be able to keep working onboard. Autonomous vehicles used for on-demand door-to-door or street-corner-to-street-corner public transport can also help to increase accessibility and connectivity by reducing the number of transfers, walking time to and from a stop, and waiting time. Accessibility can be especially improved for disabled, elderly, and young passengers who do not have driving license and currently are using conventional public transport.

Land Use
Wide-scale deployment of autonomous vehicles can impact the land use in both negative and positive ways. Possible benefit is a release of parking spaces in the city center for other needs. However, improved accessibility and possibility for the driver to perform other activities instead of driving might stimulate urban sprawl and growth of suburbs with decrease of the population density of metropolitan areas. This, in turn, will lead to more VKT travelled and increase in related CO2 emissions, pollution, and energy use. Urban sprawl also leads to increase of inequity, over-consumption of water, and loss of biodiversity. The increased VKT might lead to higher congestion levels. The negative effects can be mitigated by appropriate policies, regulations, and urban design.

Environment
Similarly to other dimensions, autonomous vehicle use can lead to both benefits and costs for the environment. Those will depend on fuel efficiency of the vehicles, carbon intensity and pollutant emissions, and changes in VKT (Anderson et al. 2014). Adoption of full or even partial automation will lead to more efficient driving in terms of speed, smoother acceleration and deceleration, which, in turn, will reduce the fuel consumption. In the case of congestion reduction, the speed will be even more stable. This can lead to up to 10% of fuel economy (NRC 2010). The increased level of safety might also allow the manufacturers to produce lighter vehicles, and, due to that, the fuel consumption can be additionally reduced up to 14% (Bagloee et al. 2016). However, increased VKT will have the opposite effect. Fuel consumption can grow 10–40% according to different studies presented above (assuming that the fuel consumption increases proportionally to the VKT). Fagnant and Kockelman (2014) showed using their agent-based model that the estimated overall emissions will reduce if shared autonomous vehicles are introduced but an average individual trip will be longer.

Costs
Autonomous vehicle massive deployment will lead to reduction of both direct and external costs. The direct cost reduction will include reduction in fuel consumption, since the fuel efficiency can be improved due to driving with more stable
speed. The vehicle insurance and maintenance will be lower due to the improved safety and lower probability of an accident. The labor costs will be cut for public transport vehicles and taxis since there will be no need for drivers, and that will likely reduce the ticket prices. Other jobs related to the support of the autonomous vehicles and physical and digital infrastructures will appear, however.

The external costs (or externalities) are indirect costs that will be imposed on society due to possible negative effects such as pollution, congestion, and changes in land use. In general, it is expected that the autonomous vehicle use will allow to reduce most of the externalities through creating benefits such as better accessibility and connectivity, release of parking spaces, lower congestion level, increased road capacity, etc. (Bagloee et al. 2016). Using autonomous vehicles in car-sharing schemes can provide to the users flexibility comparable with the one of a private car and, at the same time, will lead to cost reduction compared to vehicle ownership. Therefore, this can discourage car ownership and contribute to decrease of congestion. On the other hand, if the autonomous vehicles are used on individual basis, more VKT will be produced due to the induced demand, as it was shown above. In that case the use of autonomous vehicles can amplify the current negative externalities related to environment and congestion.

Cybersecurity and Privacy
Use of highly advanced information technologies for controlling and, especially, for connecting autonomous vehicles creates a cybersecurity threat. Petit and Shladover (2015) analyzed the potential threats and found out that the most likely or severe possible attacks are GNSS spoofing and injection of fake messages in cooperative automated vehicles. GNSS is responsible for positioning vehicles in space, and manipulating the GNSS data can lead to erratic actions of the automated system, which could endanger human lives. Similarly, injection of fake safety messages in cooperative automated vehicles can trigger inappropriate reaction of the automated system. To cope with the threats, security standards should be established, and additional software and misbehavior detection systems have to be installed on the vehicles and on related infrastructure. Combining multiple data sources can also help identifying the security threats.

Data collection for maintaining the system security and safety, as well as for general control and communications of the vehicles might, however, compromises individual privacy. Therefore, the vehicles and corresponding digital infrastructure should be designed taking into account this aspect. For that the vehicles can be technically prevented from collecting, storing, or transmitting specific information related to an individual, such as the vehicle’s location or home address. Data encryption and anonymization should be integrated into the automated system. Corresponding technical and legal standards should be developed (Glancy 2012).

Ethical Issues
Use of autonomous vehicles will likely eliminate most of the road accidents; however, there will always be a small probability of some critical situations to happen. Ethical and moral issues arise when an automated system is programmed to make decisions on actions in an unavoidable collision, in which the vehicle might need to make a choice among harming its passengers, passengers of another vehicle, or pedestrians. However, human drivers are also not always able to make ethical decisions due to slow reactions or other considerations in a critical moment.

Regulations
Autonomous vehicles are a highly disruptive technology which will bring substantial changes in lifestyles, car ownership, travel patterns, land use, etc. Therefore, authorities and policy makers are facing a great challenge of designing standards, legislation, and policies which could help to minimize risks, alleviate the negative effects, and amplify the positive ones.

Authorities should provide legal clarity regarding the rights, obligations, and liabilities of autonomous vehicle developers, operators, owners, and
insurance companies. This will include conditions under which developers can test and market the vehicles, criminal and civil liability rules and legal status for all the stakeholders, etc. (ITF 2015). On the operation side, the legislation will have to define liability of drivers, passengers, and vehicles in different situations (such as physical damage to a person or a property, personal data leak, or if a vehicle is used as a weapon of terror or for a crime), for an occupied and unoccupied vehicle. The insurance structure and compensation in case of an accident should be also defined.

Finally, the authorities will have to internalize costs of driving as much as possible and to stimulate individuals, companies, and organizations to own and operate the vehicles in a way which would allow to reduce both direct and external costs for the society, encouraging sharing rather than individual use of the vehicles.

Cross-References

▶ Mobility as a Service
▶ Public Transport
▶ Public Transport Modes

References

Brugeman VS, Dennis EP, Fard ZB, Schultz M, Wallace R (2018) Opportunities to encourage on-road connected and automated vehicle testing. Center for Automotive Research, Ann Arbor
SAE (2014) Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems. J3016, SAE International Standard, USA
Simonite T (2013) Data shows google’s robot cars are smoother, safer drivers than you or I. MIT Technol Rev. https://www.technologyreview.com/s/520746/data-

