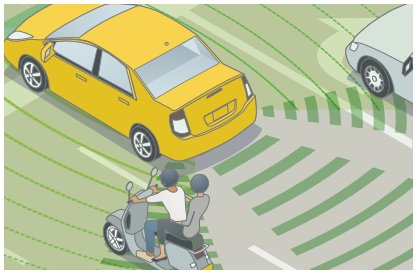
International Transport Forum

CPB
Corporate Partnership Board



Automated and Autonomous Driving

Regulation under uncertainty



Corporate Partnership Board Report

OECD

Automated and Autonomous Driving

Regulation under uncertainty



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Executive summary

Many cars sold today are already capable of some level of automated operation, and prototype cars capable of driving autonomously have been - and continue to be - tested on public roads in Europe, Japan and the United States. These technologies have arrived rapidly on the market and their future deployment is expected to accelerate. Autonomous driving promises many benefits: improved safety, reduced congestion and lower stress for car occupants, among others. Authorities will have to adapt existing rules and create new ones in order to ensure the full compatibility of these vehicles with the public's expectations regarding safety, legal responsibility and privacy. This report explores the strategic issues that will have to be considered by authorities as more fully automated and ultimately autonomous vehicles arrive on our streets and roads. It was drafted on the basis of expert input and discussions amongst project partners in addition to a review of relevant published research and position papers.

What we found

Automated driving technologies are mostly mature and some autonomous driving is here already

Most of the core technologies required for fully autonomous driving are available today, many are mature and some are already being deployed in commercially available vehicles.

Self-driving cars seem a near-term possibility but their range of capabilities is unclear

Many major car manufacturers and several technology firms have announced the commercial production of highly automated vehicles starting in 2017. Many observers expect there to be a wide range of such models on the market by 2030, and some of these may be self-driving. It is not clear at present, however, to what extent these vehicles will be capable of self-driving in all circumstances.

Road safety is expected to improve with vehicle automation. But this effect remains untested at a large scale and may not be immediate or linear

Most crashes involve human error. If greater autonomous operation reduces or eliminates these errors, then benefits for road safety may be substantial. However, most driving involves no crashes. The real safety test for autonomous cars will be how well they can replicate the crash-free performance of human drivers. While results from early prototypes are promising, new types of crashes may emerge as autonomous technologies become more common – for instance crashes resulting from the car handing control back to the driver or from mixing autonomous and conventional vehicles.

There are many possible technological configurations for autonomous driving

The move towards autonomous driving may involve different technological configurations. Some rely on greater connectivity between cars and between cars and infrastructure. These entail the development of common communication protocols, encrypted security standards and investment in new types of infrastructure or upgrading those which currently exist. Others rely more on vehicle-embarked sensor platforms and require little infrastructure investment. Both models require precise digital representations of their environment, including high definition maps.

There are two incremental paths towards full automation

The first path involves gradually improving the automation in conventional vehicles so that human drivers can shift more of the dynamic driving task to these systems. The second path involves deploying vehicles without a human driver in limited contexts and then gradually expanding the range and conditions of their use. The first path is generally embraced by traditional car manufacturers and the second by new entrants.

Use and business cases are closely linked to automation pathways

Incremental advances in automation in conventional vehicles are unlikely to fundamentally change vehicle market dynamics. It seems likely that individuals will buy and own such upgraded cars much as they do today. Automated driving will be available for certain situations – for instance when driving on motorways, parking a car, or handling stop-and-go traffic in case of congestion). Because the human driver must resume active control when prompted to do so, such conditional automation raises particularly difficult issues of human-machine interaction that have not been satisfactorily solved. Fully self-driving cars on the other hand, will not face the same issue of human-machine coordination, although their use will likely be confined to contexts where the vehicle can confidently handle the full range of driving complexity. Such highly specific contexts include particular routes and low-speed operations. Self-driving cars have a much higher potential for disruption. They may be deployed in fleet-wide systems that would fundamentally reshape individual travel and have an impact on industries such as public transport and taxis.

Some regulatory frameworks are being developed for prototype testing, but not for future use cases

Several jurisdictions have passed or are considering rules that enable the testing, licensing and operation of autonomous technologies and vehicles. Most address the safe operation of these vehicles on public roads, although with little coordination amongst jurisdictions. We could not find evidence of anticipatory regulatory action addressing the potential use cases that could result from large-scale deployment of highly autonomous vehicles, such as the provision of quasi-public transport or taxi-like operations.

Policy insights

Automated driving comprises a diverse set of emerging concepts that must be understood individually and as part of broader trends toward automation and connectivity

Vehicle automation is part of a much larger revolution in automation and connectivity. The recent hallmarks of these revolutions – personal computers, mobile telephones, and the Internet – have converged and are now blending with machines that sense and manipulate the physical environment. These machines include not just automated motor vehicles but also drones, personal care robots, 3D printers, surveillance devices, and many others. Vehicles will change with growing automation but so too will their role in society, and in ways that are hard to foresee. Policies should account for this uncertainty and ensure sufficient resilience to adapt to these changes or, at a minimum, not block changes that are desirable.

Uncertainty on market deployment strategies and pathways to automation complicates the regulatory task

Autonomous vehicle regulation should ensure safety and prevent, or at least mitigate, market failures. This task is complicated by uncertainty on what it is that should be regulated and the risk that regulation may in fact lock in one pathway to automation over a potentially better one. Though regulators may target autonomous vehicles as a special case out of convenience, it may be preferable to adapt existing rules as much as possible. While desirable, early regulatory action carries risks as well. Prematurely codifying requirements can freeze unrealistic expectations – high or low – into the law in a way that causes the legal framework to lag rather than to lead. Some regulatory flexibility seems desirable, for instance allowing circumscribed uses such as low speed urban operation or motorway platooning before implementing a blanket set of rules.

Incrementally shifting the driving task from humans to machines will require changes in insurance

Liability remains an important barrier for the manufacturers and designers of autonomous vehicles. Expanding public insurance and facilitating greater private insurance could provide sufficient compensation to those injured by an automated vehicle while relieving some of the pressure on the tort system to provide such a remedy. Enhanced vehicle insurance requirements by manufacturers, especially if combined with greater flexibility in the administration of this insurance, could also provide a third-party check on the

safety of automated systems. As automation increases, liability could gradually shift from drivers to manufacturers and Original Equipment Manufacturers (OEMs). However, the allocation of liability among these parties remains challenging and adjudication methods have yet to be developed.

The shift from human to machine may have an impact on what product information developers and manufacturers of autonomous vehicles share, and with whom

Education of public actors, and of the public at large, is essential for developing effective regulations and setting realistic expectations. Governments can facilitate public education by encouraging developers to share specific data about their products and processes in order to benefit from more flexible regulation. In some cases, it may be desirable to audit specific algorithms that directly impact public welfare, for instance those that govern loss-loss decisions (such as the choice between two unavoidable crash scenarios) by automated vehicles.

Regulators and developers should actively plan to minimise legacy risks

Vehicles with automated driving systems that are introduced in the next few years will not be perfect. Yet they will still be present on roads for years after they have become outdated. An important goal for both regulators and developers should be to limit the physical risk presented by legacy vehicles through a variety of technical and contractual tools. These could include monitoring, over-the-air updates, and even virtual recalls. Designing vehicles for future system upgrades like the addition of sensors may also help reduce legacy risks.

Introduction

This report examines various emerging regulatory issues surrounding the deployment of automated and autonomous vehicles. This work was based on the expert opinion of the authors and serves as a think piece regarding the nature, timing and scope of regulatory action regarding automated and, ultimately, self-driving vehicles.

The work for this report was carried out in the context of a project initiated and funded by the International Transport Forum's Corporate Partnership Board (CPB). CPB projects are designed to enrich policy discussion with a business perspective. They are launched in areas where CPB member companies identify an emerging issue in transport policy or an innovation challenge to the transport system. Led by the ITF, work is carried out in a collaborative fashion in working groups consisting of CPB member companies, external experts and ITF researchers.

The principal authors of this report were Dr Bryant Walker Smith, Assistant Professor at the University of South Carolina and affiliate scholar at the Center for Internet and Society at Stanford Law School, and Joakim Svensson, Director at Volvo Group. Substantial inputs were provided by Paulo Humanes of PTV AG, Gilbert Konzett and Alexander Paier of Kapsch TrafficCom, Takuma Mizuno of Nissan and Antigoni Lykotrafiti of ITF, who undertook valuable research in support of the work. The report was edited by Philippe Crist.

The project was coordinated by Philippe Crist and Sharon Masterson of the International Transport Forum.

1. Automated and autonomous driving: Technologies, contexts and capabilities

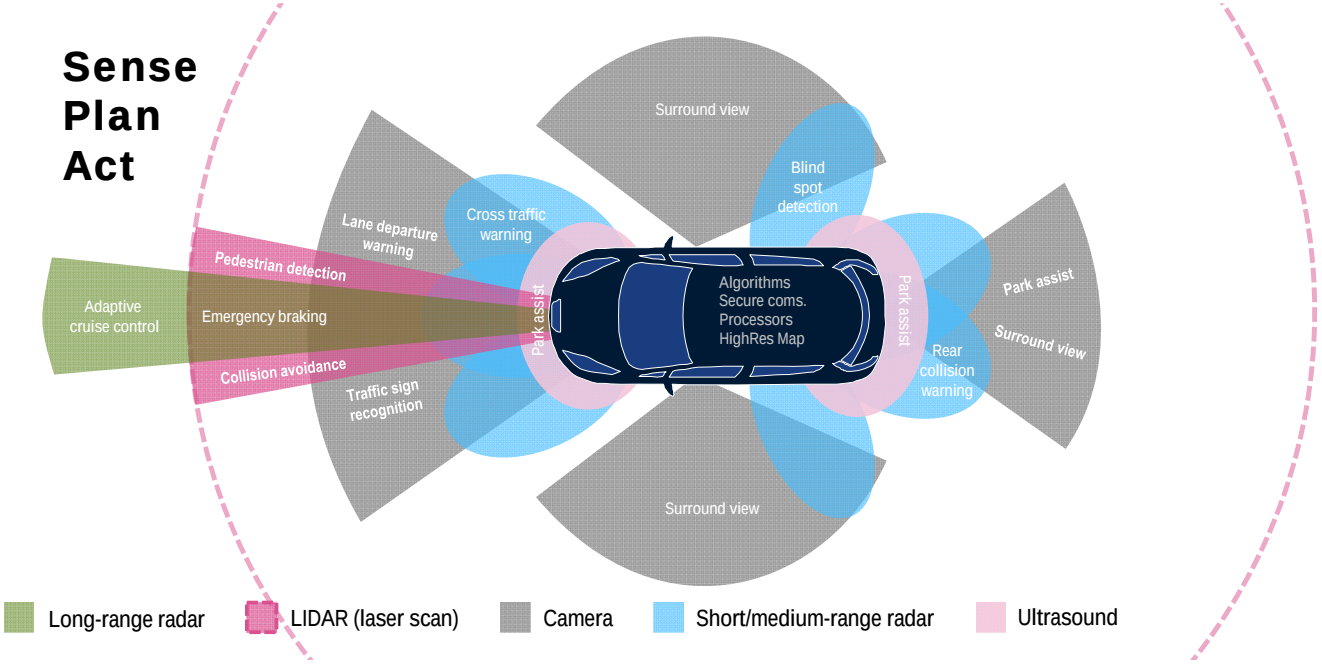
Automated driving encompasses a wide range of technologies and infrastructures, capabilities and contexts, use cases and business cases, and products and services. There is no single timeline for these developments: Some are here today, some may be distant, and some will depend on specific technical innovations or particular policy choices. This section surveys these potential developments in order to inform the policy choices that could enable or constrain them.

Importantly, vehicle automation is part of much larger revolutions in automation and connectivity (Smith, 2014b). The recent hallmarks of these revolutions – personal computers, mobile telephones, and the Internet – have converged with each other and are now blending with machines that sense and manipulate the physical environment. These machines include not just automated motor vehicles but also drones, personal care robots, 3D printers, surveillance devices, and many others. While addressing only vehicle automation, this report strives to anticipate these broader changes in both technology and society.

Technologies and infrastructures

An automated vehicle, like a human, must collect information, make a decision based on that information, and execute that decision. Information comes from vehicle equipment, physical infrastructure, physical-digital infrastructure, and digital infrastructure, any of which may be public or private. Many of these technologies exist today and are capable of guiding vehicles and in some cases drive vehicles with minimal or no driver input in test situations and across diverse driving environments.

Figure 1. **Technologies that allow vehicles to sense, plan and act in response to the dynamic driving environment**



Source: Adapted from (Parrish, 2015).

Many companies have carried out trials or are engaged in continuous on-road testing of highly automated vehicle prototypes whose capacities are evolving rapidly due to improved sensor-processing technologies, adaptive algorithms, high-definition mapping and in some cases, the deployment of vehicle-to-vehicle and infrastructure-to-vehicle communication technologies. Automated vehicles have crossed the United States almost solely in self-driving mode and have undertaken long-distance motorway and arterial trips in Europe and Japan.

From a technical point of view, current technology for highly automated driving in controlled environments is quite mature. These vehicles uses state-of-the-art sensors (radar, lidar, GPS and camera vision systems) combined with high accuracy maps allowing on-board systems to identify appropriate navigation paths, as well as obstacles and relevant signage. These prototypes operate with a driver that must stand ready to take control of the vehicle though reports from trials indicate that this option is rarely acted upon. As of 2015, there is yet no consensus on the commercial maturity of highly automated and ultimately fully automated driving. Some manufacturers have announced the arrival of highly automated and possibly fully automated vehicles by as early as 2016 while others have advanced much later dates (up to 2030). Clearly there will be a first-mover advantage for pioneers in the field of highly automated driving but there are also risks linked to the safety performance of these vehicles and the possibility of regulatory action that inhibits technology development and deployment.

A number of issues will have to be addressed in order to support the deployment of high-automation scenarios. These include:

- **Vehicle-to-X connectivity (V2X):** Connectivity is an important element of the automated vehicles especially secure V2X communication requiring low latency. V2X technologies encompass the use of wireless technologies to achieve real-time two-way communication among vehicles (V2V) and between vehicles and infrastructure (V2I). The convergence of sensor-based solutions (current advanced driver assistance - ADAS) and V2X connectivity will promote automated driving.
- **Decision and control algorithms:** These include decision, planning and control algorithms for a cooperative, safe, human compatible traffic automation.
- **Digital infrastructure:** Digital infrastructure (for road automation) includes static and dynamic digital representations of the physical world with which the automated vehicle will interact to operate. Issues to address include: sourcing, processing, quality control and information transmission.
- **Human factors:** Human factors in automation relate to understanding the interaction(s) of humans with all aspects of an automated road transport system (ART), both from within a vehicle, when taking the role of a driver/operator and also as a road user, when interacting with automated vehicles. Knowledge and theories from social-psychological and behavioural sciences are useful to understand how humans interact with such systems.
- **Evaluating road automation:** Automation of road vehicles has the potential to impact on lifestyles and society. Economic impacts too will be important and it will be necessary to gauge these impacts in a common cost-benefit framework with other transport investments when assessing public expenditure on supporting infrastructure or services.
- **Roadworthiness testing:** Roadworthiness testing, understood as the necessary tests to evaluate if a vehicle is legally allowed to drive on public roads is of capital importance for the deployment of new automated driving functionalities.

Capabilities and contexts

The wide variety of relevant technologies has inspired complex – and indeed competing – taxonomies of vehicle automation. Of these, International Society of Automotive Engineers' (SAE) Levels of Driving Automation capture the emerging descriptive consensus most systematically and are accordingly presented in detail here. Figure 2 (SAE, 2014) summarises these levels. The expert committee responsible for this taxonomy emphasises:

"These levels are descriptive rather than normative and technical rather than legal. They imply no particular order of market introduction. Elements indicate minimum rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at different levels depending upon the feature(s) that are engaged." (SAE, 2014)

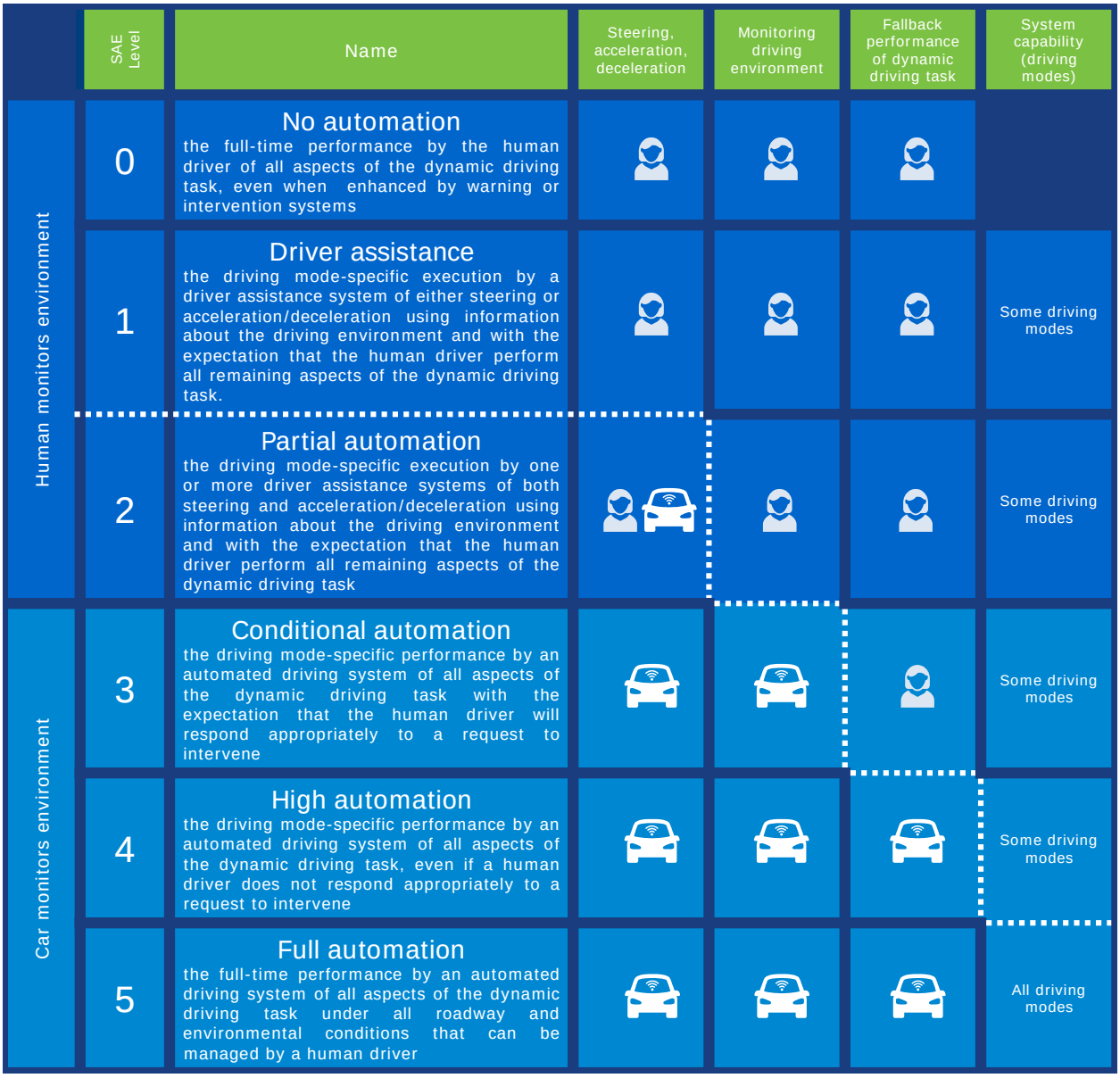
As with other approaches, these levels primarily identify how the "dynamic driving task" is divided between human and machine: It is performed entirely by a human driver at Level 0 (no automation) and entirely by an automated driving system at Level 5 (full automation). In the "mushy middle," (Smith, 2014a) this task is shared simultaneously or sequentially, raising difficult questions of human-machine interaction.

Current deployment and development necessarily focus on this middle. This is because full automation, "the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver," (SAE, 2014) remains elusive. Human drivers confront, and usually manage, an incredible variety of contexts—geographic areas, roadway types, traffic conditions, weather conditions, and events/incidents—for which automated vehicles have yet to be designed and demonstrated.

Efforts toward full automation tend to follow one of two incremental paths. The first involves gradually improving the automated driving systems available in conventional vehicles so that human drivers can shift more of the dynamic driving task to these systems. The second involves deploying vehicles without a human driver and gradually expanding this operation to more contexts. These two approaches can be simplistically described as "something everywhere" and "everything somewhere."

The "something everywhere" strategy is generally embraced by traditional car manufacturers and is well captured by the levels of automation. Many of today's production vehicles are capable of driver assistance (Level 1), typically through the use of adaptive cruise control to adjust speed based on following distance. A small number of vehicles also incorporate an active lane-keeping assist feature in a way that makes them capable of partial automation (Level 2). Notwithstanding the potential for and reality of driver distraction, both of these levels assume that the human driver continues to actively monitor the driving environment.

Figure 2. **Levels of driving automation according to the Society of Automotive Engineers**



Source: Adapted from SAE Standard J3016 (SAE, 2014).

The introduction of conventional cars and trucks capable of operating without this active monitoring will represent a significant technical and conceptual leap. This threshold between partial automation (Level 2) and conditional automation (Level 3) corresponds to the line that several US states have drawn between non-automated and automated vehicles. Because of its assumption that the human driver will resume actively driving shortly after being prompted to do so, conditional automation raises particularly difficult issues of human-machine interaction that have not been satisfactorily solved. A more normative taxonomy developed by the U.S. National Highway Traffic Safety Administration arguably passes over conditional automation altogether on its way to high automation (NHTSA, 2013).

Levels of automation beyond conditional automation (Level 3) may operate on the basis of inputs solely from vehicle-embarked sensors (self-sensing) or via a combination of self-sensor input and inputs from sensors embarked on other vehicles and infrastructure that are communicated to the vehicle to the vehicle in near real-time. The connected vehicle and connected infrastructure approach requires available data transmission frequencies, low-latency, trusted, secure and fail-safe data transmission protocols and harmonised data syntax that ensures safe interoperability. Work is underway to address all three of these requirements for connected vehicle operation and early efforts, like the development of a co-operative ITS corridor testbed reaching from the Netherlands through Germany to Austria – the ECoAT project (see box 1) – will lay the groundwork for future deployment of connected vehicles. The United States is similarly developing testbeds and trialling connected service frameworks, but it is not clear at present to what extent future autonomous vehicles will be connected or truly autonomous (relying minimally on external data inputs).

Box 1. **ECoAT Cooperative ITS corridor (Netherland, Germany, Austria)**

The ECoAT project provides a basis for standardised, international, future-oriented cooperative ITS services. These will be useful as vehicles become more automated and will likely spur at least partial automation in areas where these services are fully deployed. The project centres on the deployment of cooperative ITS services on a testbed corridor linking the Netherlands, Germany and Austria. The project sketches out a joint road map for the introduction of initial cooperative ITS services, promotes the development of connected ITS services by agreeing common functional descriptions of an initial set of cooperative ITS services as well as their technical specifications and frames the implementation of these services along the testbed corridor.

In its first phase, ECoAT will develop and deploy two cooperative ITS services: one based on standardised and machine-readable and interpretable warning data regarding road works and another service seeking to improve traffic management by exploiting vehicular and infrastructure data. These and further services yet to be developed by the ECoAT living lab will contribute to a comprehensive systems specification for co-operative ITS services developed by national authorities and industrial partners.

High automation (Level 4) is nonetheless challenging because it describes an automated driving system that, once engaged, can always revert to a “minimal risk condition” should a human driver not resume actively driving. Reverting to this minimal risk condition may be easier in some contexts (e.g. low-speed parking facilities) than in others (e.g. urban expressways) For this reason, a highly automated driving system is capable of operating in some, but not necessarily all, contexts or “driving modes”.

High automation (Level 4) is where the “everything somewhere” strategy begins. The custom vehicles that currently operate without any real-time input from human drivers are limited to highly specific contexts, including particular routes and low speeds. Examples include the CityMobil2 project supported by the European Union, the Navia shuttle marketed by Induct, and the buggies announced by Google. Such fully automated vehicles have also been deployed in restricted contexts for freight or industrial tasks, including tyre-based container repositioning vehicles in ports or fully automated ore trucks in some open-air mines.

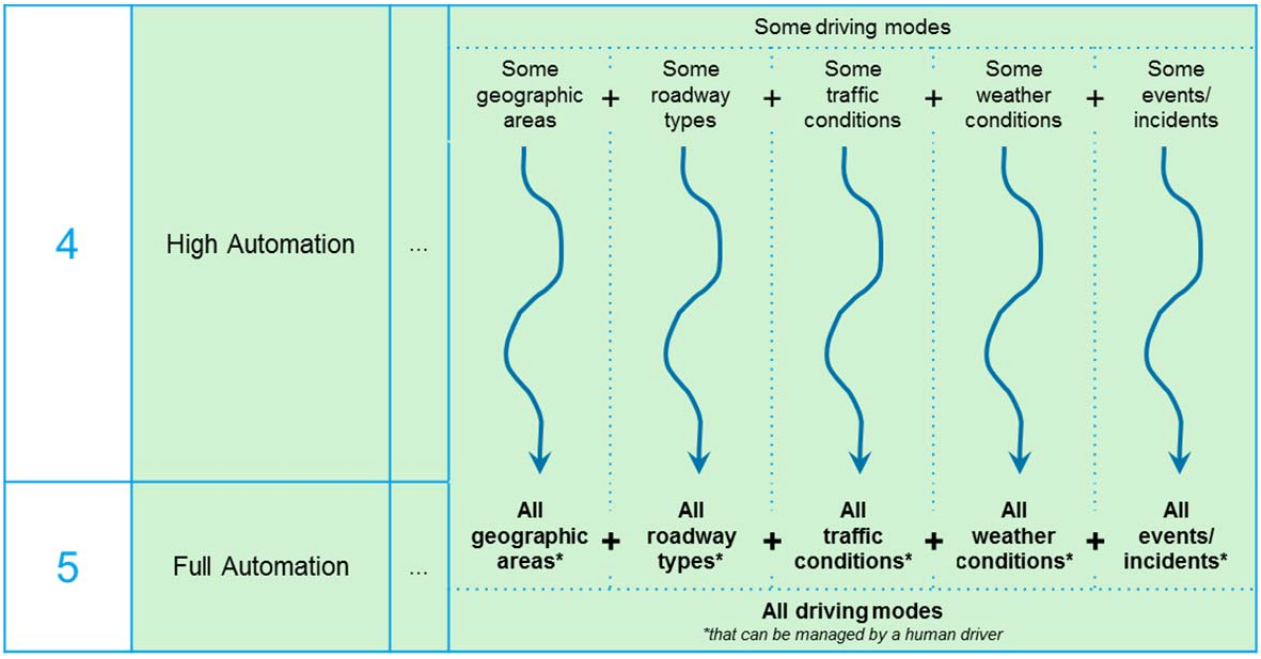
A key challenge is introducing these vehicles to more geographic areas, roadway types, traffic conditions, weather conditions, and events/incidents. One developer, for example, might initiate a pilot project in which his vehicles operate in good weather at neighbourhood speeds along a carefully mapped, maintained, and monitored corridor within its corporate campus. It might then expand the pilot to select streets within the local community and later to a handful of other communities. As the developer improved its technologies and increased public confidence in them, it might deploy vehicles at higher speeds and on more road types.

Such a system of automated vehicles might eventually function in many traffic and weather conditions on many roads in many communities. Nonetheless, these vehicles would not reach full automation (Level 5)

unless they handled "all roadway and environmental conditions that can be managed by a human driver." Figure 3 illustrates this long path from high automation to full automation across different driving modes.

One outcome of this context-conditional performance spectrum is that regulatory authorities may issue context-dependent operating licenses matching vehicle classes and specific contexts (e.g. non-motorway operation with maximum speeds of no more than 40 km/hr). At present though, it is not yet clear whether authorities will seek to follow this vehicle-context licensing path and if so, whether this would only be a short-term phenomenon or a more permanent aspect of automated vehicle regulation. What seems clear is that this approach would be easier to deploy on the basis of specified performance characteristics (safety, speed, road class), rather than on the specification of certain technologies.

Figure 3. **Transition from high to full driving automation across different contexts**



2. Use cases, business cases and potential deployment pathways

The two approaches outlined in the previous section correspond to different use cases and business cases. Whereas freeways may be the most promising early application for increasingly automated conventional cars and trucks, urban areas are well-suited for specialised passenger and delivery shuttles.

The "something everywhere" strategy for conventional cars and trucks points to increasingly sophisticated advanced driver assistance systems (ADASs) that are marketed in terms of safety, fuel efficiency, driver comfort, driver convenience, and ultimately driver productivity (assuming these benefits are realised). Automated emergency intervention systems (AEISs), which momentarily perform all or part of the dynamic driving task to avoid an imminent crash but which are excluded from SAE's taxonomy, are also likely to be offered in combination with advanced driver assistance systems.

Motorway automation may be an early use case for conditional or high automation in conventional vehicles. Although speeds are high, motorways tend to be more uniformly designed and better maintained. Vehicle flows are more organised, and bicyclists and pedestrians are generally absent. There are two relevant notes on motorway automation: dedicated facilities and vehicle platoons.

Dedicated facilities are occasionally proposed for automated freeway vehicles, but retrofitting existing facilities is likely to be prohibitively expensive and may ultimately prove unnecessary. Separation may be more viable on newly constructed roadways in rapidly urbanising countries, on existing managed lanes (such as those for high-occupancy vehicles) between major employment and residential areas, and on specialised facilities serving exceptionally large numbers of trucks.

Vehicle platoons are a particularly promising application for freeways. As typically envisioned, a platoon consists of two to six cars or trucks that are closely spaced and tightly coordinated through both vehicle-to-vehicle communication and some degree of automation. A driver may sit in each vehicle, in only the lead vehicle, or eventually in none of the vehicles. Benefits may include significant fuel savings and, for fleet operators, potentially lower labour costs.

Vehicle automation systems and especially automated emergency intervention systems may also have early applications beyond freeways. Automation may be appropriate for low-speed travel during peak periods. Particular parking facilities may support automated valet functions. And conventional cars assigned to car sharing programmes might eventually reposition themselves by traveling at low speeds on particular roads during non-peak periods.

Many urban and suburban applications, however, might be realised earlier through an "everything somewhere" strategy of nonconventional vehicles. Passenger shuttles and taxis might operate at low speeds in central business districts, corporate campuses, university campuses, military bases, retirement communities, resorts, shopping centres, airports, and other semi closed environments as well as for first- and last-mile transit applications.

Delivery shuttles might likewise travel at low speeds along particular routes and at particular times. Depending on their size and purpose, these robotic delivery systems might conceivably use pathways rather than or in addition to roadways. Indeed, the potential proliferation of service robots might bring a new kind of nonhuman user to the urban environment.

Some of these urban applications may benefit from specialised infrastructure. Physical infrastructure might include vehicle-to-vehicle and vehicle-to-infrastructure communications equipment, ground-based units for global navigation systems, dedicated facilities comparable to bus and bicycle lanes, on-street parking restrictions, and specific roadway or pavement modifications. Digital infrastructure might include the

maintenance of highly detailed roadway maps and pertinent traffic operations data. This specialised infrastructure, if actually required, could be limited to a manageable set of corridors actually used by a particular urban mobility system.

Whereas wealthy consumers and fleet operators are likely to be early adopters of "something everywhere" vehicles, an "everything somewhere" approach might reach a more diverse group of users. Especially if its fuel and labour costs are lower and its usage is higher, an extensive urban mobility system might compare favourably with private vehicle ownership, conventional taxis, and conventional public transit. Residents who cannot afford to buy and maintain a private car or who are unable to drive may be some of the earliest adopters of these shared systems.

Products and services

Vehicle automation could give rise to particular consumer-oriented products and services. The "something everywhere" strategy for conventional cars and trucks is likely to rely primarily on a traditional model of selling and especially leasing vehicles to individual consumers or fleet operators. However, manufacturers are likely to be more closely connected to the owners and users of their vehicles through a variety of contractual and technical tools (Smith, 2014b). These may include terms of use, end-user license agreements, and subscription agreements on the contractual side and advanced telematics, driver monitoring, and over-the-air updates on the technical side. Manufacturers might also pursue new revenue streams via automation subscription services, consumer-facing advertising, or the marketing of user data.

In addition, companies other than car manufacturers may seek to add, enhance, or customise vehicle automation systems through aftermarket conversions and modifications. Production vehicles already provide a platform for many automated vehicle research efforts, at least one start-up company has announced its intention to add a partial automation feature to certain production vehicles, and legislatures in several US states have expressly limited a car manufacturer's civil liability for injuries caused by a third-party's addition of automated driving technology to one of its production vehicles.

An "everything somewhere" strategy could more fully embrace a variety of service models. Passenger shuttles, automated taxis, delivery services, and other urban concepts are likely to involve some kind of central ownership, management, maintenance, and dispatch. These services may be public, private, or hybridised, and they may complement or compete with conventional public transit.

Deployment paths and technologies

As noted above, deployment pathways will follow either an incremental evolution of traditional vehicles leading to higher and higher levels of automation or a radical technology-shift approach that would lead to the near-term deployment of highly automated urban mobility vehicles. These pathways are illustrated in Figures 4, 5 and 6. The remainder of this section describes the technical aspects relating to the deployment of these pathways without pre-judging their likelihood or impact.

All pathways build on the range of automated driving technologies and systems already commercially deployed today. These include:

Current and future vehicle systems on Level 0 (no automation)

- **Systems beyond human capability to act:** There are several systems on the market today that intervene beyond the human capability to act. These systems, like ABS (Anti-Lock System), ESC (Electronic Stability Control) and emergency braking are active safety systems that allow higher levels of automation and will facilitate deployment. Future version of these systems will include emergency evasion and emergency stopping.

- **Lane Change Assist (LCA):** The system monitors the areas to the left and right of the car and up to 50 metres behind it and warns the driver of a potentially hazardous situation by means of flashing warning lights in the exterior mirrors.
- **Park Distance Control (PDC):** The Park Distance Control system assists the driver to manoeuvre into tight spaces and reduces stress by communicating distance from obstacles by means of acoustic or, depending on vehicle, optical signals.
- **Lane Departure Warning (LDW):** Lane Departure Warning helps to prevent accidents caused by unintentional wandering out of traffic lanes. It represents a major safety gain on motorways and major trunk roads. If there is an indication that the vehicle is about to leave the lane unintentionally, the driver is alerted visually and in some cases by a signal on the steering wheel.
- **Front Collision Warning (FCW):** The Front Collision Warning monitoring system uses a radar sensor to detect situations where the distance to the vehicle in front is critical and helps to reduce the vehicle's stopping distance. In dangerous situations the system alerts the driver by means of visual and acoustic signals and/or with a warning jolt of the brakes. Front Collision Warning operates independently of the adaptive cruise control or automatic distance control.

Current and future vehicle systems on Level 1 (driver assistance)

- **Adaptive Cruise Control (ACC):** The cruise control system with "automatic distance control ACC" uses a distance sensor to measure the distance and speed relative to vehicles driving ahead. The driver sets the speed and the required time gap with buttons on the multifunction steering wheel or with the steering column stalk (depending on model). The target and actual distance from following traffic can be shown as a comparison in the multifunction display.
- **ACC including stop-and-go function:** Adaptive cruise control with stop and go function includes automatic distance control (control range 0–250 km/h) and, within the limits of the system, detects a preceding vehicle. It maintains a safe distance by automatically applying the brakes and accelerating. In slow-moving traffic and congestion it governs braking and acceleration.
- **Lane Keeping Assist (LKA):** Lane Keeping Assist automatically becomes active from a specific speed (normally from around 60 km/h) and upwards. The system detects the lane markings and works out the position of the vehicle. If the car starts to drift off lane, the LKA takes corrective action. If the maximum action it can take is not enough to stay in lane, or the speed falls below 60 km/h, the LKA function warns the driver, for instance with a vibration of the steering wheel. It is then for the driver to take correcting action.
- **Park Assist (PA):** The Park Assist function automatically steers the car into parallel and bay parking spaces, and also out of parallel parking spaces. The system assists the driver by automatically carrying out the optimum steering movements in order to reverse-park on the ideal line. The measurement of the parking space, the allocation of the starting position and the steering movements are automatically undertaken by Park Assist – all the driver has to do is operate the accelerator and the brake. This means that the driver retains control of the car at all times.

Urban mobility pathway

This pathway encompasses the types of initially low-speed, fully automated but limited operation vehicles that could be deployed in urban areas. Current high automation systems have been deployed in limited areas or on dedicated infrastructure. This will be the base for going to higher and higher vehicles speeds and perhaps less specific requirements on the infrastructure. Possible use cases include:

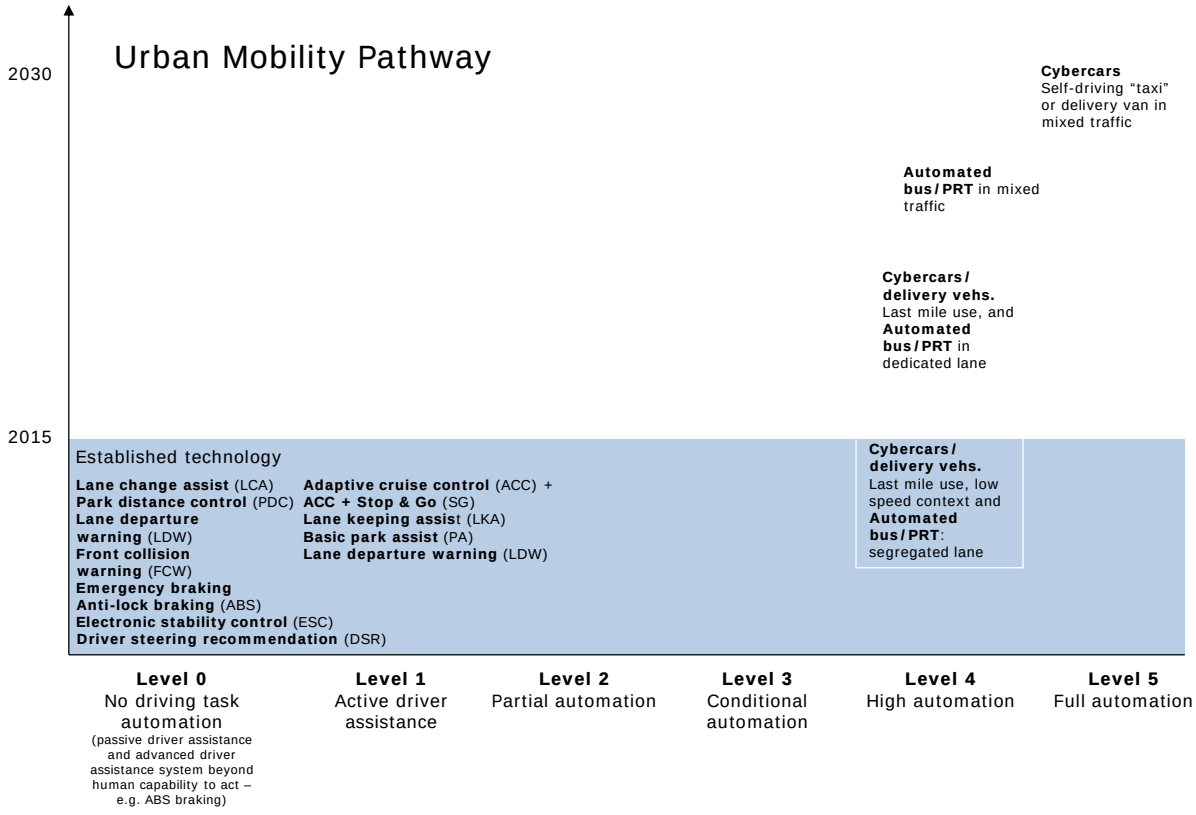
- **Cyber cars, cyber vans, cyber minibuses.** These are small-to-medium-sized automated vehicles for individual or collective transport of people or goods with the following characteristics: a) They are fully automated on demand transport systems that under normal operating conditions do not require human interaction; b) they can be fully autonomous or make use of information from a traffic control centre, information from infrastructure or information from other road users; c) they are small vehicles, either for individual transport (1-4 people) or for transport of small groups (up to 20 people); d) they can either use a separated infrastructure or a shared space.
- **High-Tech Buses.** These are buses on rubber wheels, operating more like trams than like traditional buses, with the following characteristics: a) They are vehicles for mass transport (more than 20 people); b) they use an infrastructure, which can be either exclusive for the buses or shared with other road users; c) they can use various types of automated systems, either for guidance or for driver assistance; d) they always have a driver, who can take over control of the vehicle at any time, allowing the vehicles to use the public road.
- **Personal Rapid Transit (PRT).** This is a transport system featuring small fully automatic vehicles for the transport of people, with the following characteristics: a) PRT systems operate on its own exclusive infrastructure, so there is no interaction with other traffic; b) they are fully automated systems that under normal operating conditions do not require human interaction; c) they are small with a capacity usually limited to 4 to 6 persons per vehicle; d) PRT offer on-demand service, where people are transported directly from origin station to destination station without stopping at intermediate stations, without changing vehicles and ideally without waiting time.
- **Advanced City Cars (ACC).** New city vehicles integrating zero or ultra-low pollution mode and driver assistance such as ISA (Intelligent Speed Adaptation), parking assistance, collision avoidance, stop-and-go function, etc. These vehicles should also incorporate access control coupled with advanced communications in order to integrate them easily into car-sharing services.
- **Dual-mode vehicles.** Developed from traditional cars but able to support both fully automatic and manual driving. The first applications of automatic driving will be for relocation of shared cars using platooning techniques, but dual-mode vehicles could become full cyber cars in specific areas or infrastructures. They represent the migration path from traditional cars to automatic driving.

Figure 4 below illustrates a potential pathway for automated urban mobility systems. This pathway encompasses both cyber cars (including cyber vans and cyber minibuses) and automated buses and personal rapid transit systems.

With first-generation cyber cars (Level 4), the last mile taxi or delivery vehicle is fully automated in its area of operations, taking a limited number of passengers with a maximum speed of 40 km/h. It operates in a specific area with dedicated infrastructure. For second-generation cyber cars (Level 4), the last mile taxi or delivery vehicle is fully automated in its area of operations taking a limited number of passengers. It operates in a specific area with adapted infrastructure. Automated taxis (Level 5) offer fully automated driving that can in principle take its passenger to all places. It should be noted that no realistic time estimation for the availability of this system exits.

For automated buses or Personal Rapid Transit, the pathway begins at Level 4 with first-generation vehicles driving in segregated lanes and using dedicated infrastructure, with a maximum speed of 40km/h. Second-generation automated buses and PRT (Level 4) use dedicated bus lanes and supporting infrastructure at normal city vehicle speeds. Additional functionality such as adaptive urban traffic control systems that control the traffic lights and gives speed advice and priority can be introduced when these systems reach the market. At the next stage, still at Level 4, an automated bus drives in mixed traffic in the defined area of operation.

Figure 4. **Urban mobility pathway from human to fully automated driving**



Source: Based on CityMobil2 project (CityMobil2, 2015).

Automated private vehicle pathway

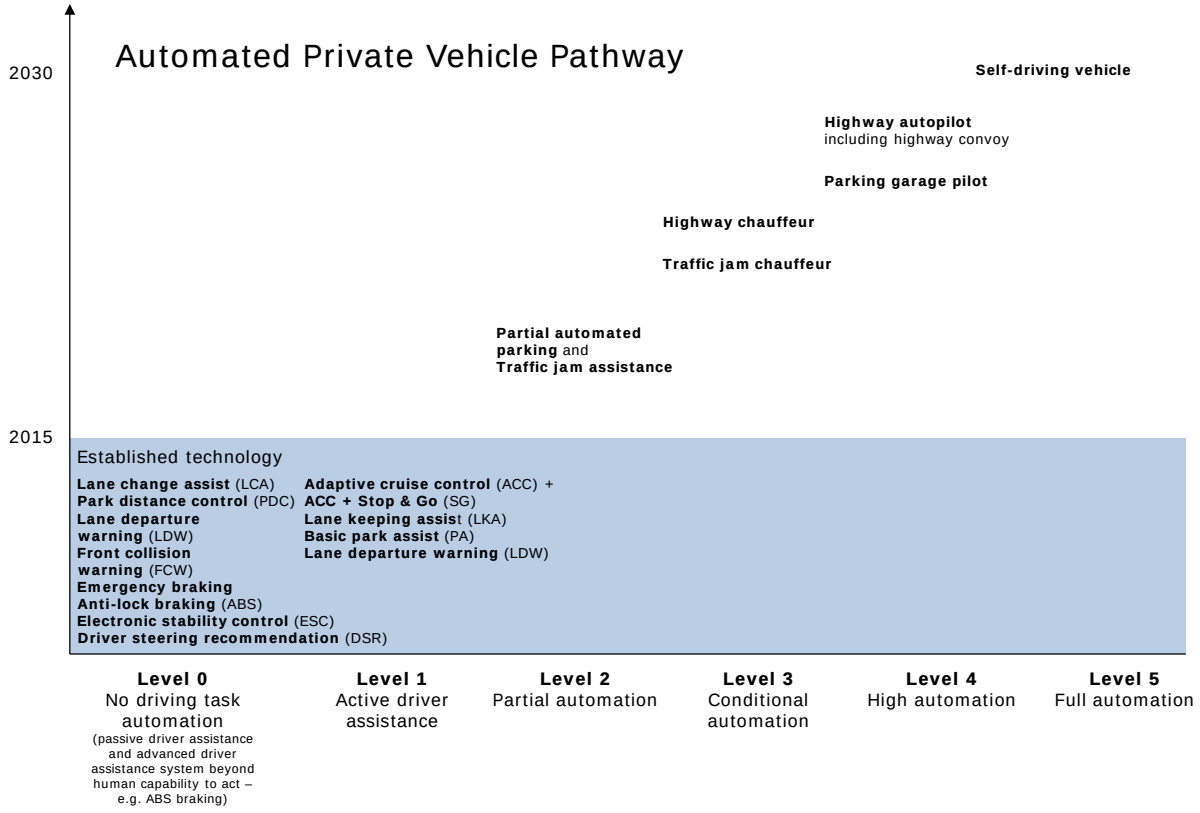
Figure 5 illustrates a potential pathway for the automation of private individually owned vehicles. This pathway leads from existing commercially-deployed systems to a fully self-driving car in incremental steps.

- **Automated Parking Assistance**: Automated parking assistance is available on the market today.
- **Park Assist** (Level 2): Partial automated parking into and out of a parking space in a public or private parking area or garage. The process is initiated remotely, e.g. via smartphone or adapted remote key. The vehicle carries out the manoeuvre by itself. The driver can be located outside of the vehicle, but has to monitor the system and can stop the parking manoeuvre if required.
- **Parking Garage Pilot** (Level 4): Highly automated parking including manoeuvring to and from parking place (driverless valet parking). In parking garages, the driver does not have to monitor the operation and may leave once the system is active. The process is initiated remotely, for instance via a smartphone or an adapted remote key.
- **Traffic Jam Assist** (Level 2): The function controls the forward/backward and sideways movement of the vehicle in order to follow traffic flow in low speeds below 30 km/h. The system can be seen as an extension of the ACC with stop-and-go functionality.
- **Traffic Jam Chauffeur** (Level 3): Conditional automated driving in congested conditions up to 60 km/h on motorways and motorway-like roads. The system controls the forward/backward and lateral movements of the vehicle up to the threshold speed. The driver must deliberately activate

the system, but does not have to monitor the system constantly. The driver can override or switch the system off at all times. There is no take over request to the driver from the system.

- **Highway Chauffeur** (Level 3): Conditional automated driving up to 130 km/h on motorways or motorway-like roads. The Highway Chauffeur operates from entrance to exit, on all lanes, including overtaking movements. The driver must deliberately activate the system, but does not have to monitor it constantly. The driver can override or switch off the system at all times. The system can request the driver to take over within a specific time, if automation reaches the system limits.
- **Highway Pilot** (Level 4): Automated driving up to 130 km/h on motorways or motorway-like roads from entrance to exit, on all lanes, including overtaking movements. The driver must deliberately activate the system, but does not have to monitor it constantly. The driver can override or switch off the system at all times. There are no requests from the system to the driver to take over when the system is in its normal operation area on the motorway. Depending on the deployment of vehicle-to-vehicle communication and cooperative systems, ad-hoc convoys of vehicles (platoons) could also be created.
- **Fully automated private vehicle** (Level 5): The fully automated vehicle should be able to handle all driving from point A to B, without any input from the passenger. The driver can at all times override or switch off the system. No consensus exists as to when such systems will become commercially available.

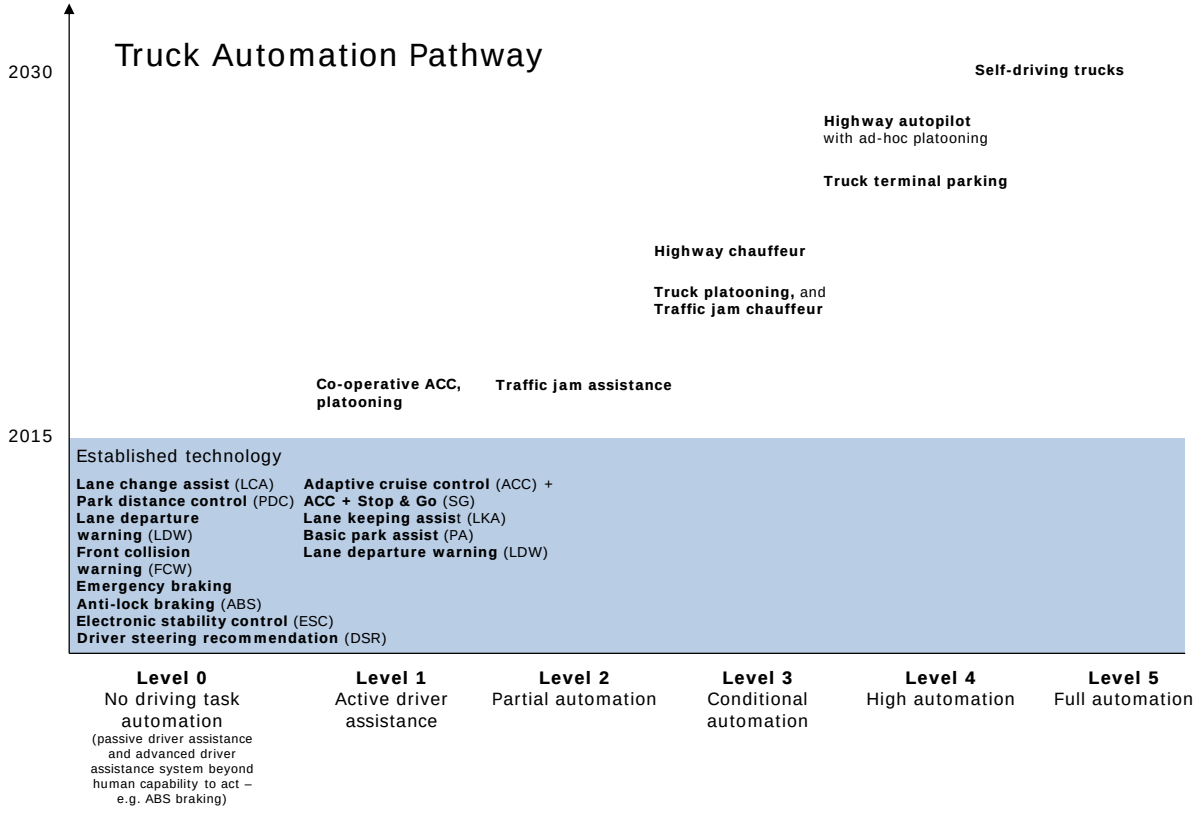
Figure 5. **Automated private vehicle pathway from human to fully automated driving**



Truck automation pathway

Figure 6 below outlines an automation pathway for heavy-duty trucks. One of the key automation strategies here will be the deployment of truck platoons or "road trains". These could include not only other trucks but could also serve to tether individual vehicles in mixed truck and car platoons.

Figure 6. **Heavy-duty truck automation pathway from human to fully automated driving**



- **CACC Platooning:** Partially automated truck platooning in which trucks are coupled by cooperative ACC (CACC). Engine and brake control keeps a short but safe distance to the lead vehicle. Drivers remain responsible for all other driving functions.
- **Truck platooning:** This function enables platooning in a specific lane. The vehicle should be able to keep its position in the platoon with a fixed distance or fixed time difference from the front vehicle. The behaviour of the first vehicle, such as braking and steering, should be transmitted by vehicle-to-vehicle communication. The function should also smoothly handle vehicles leaving the platoon. Dedicated "perpetual" truck platoons that allow vehicles to join and leave at specified stations could also prove an interesting future application of this technology for long-distance motorway trips. Up-scaling and deployment can be reached as follows:
  - Start with trucks, as there is a strong financial incentive due to 10% to 15% fuel savings.
  - Start with small platoons of only two trucks and co-operation with fleet-owners in high density trucking areas.
  - For legal reasons, start with a system where the following truck still has a driver in it.
  - Set up an (open) fleet management system for trip matching between equipped trucks of different fleet owners.

- **Traffic Jam Assist** (Level 2): Identical function as for passenger vehicles (see previous section).
- **Traffic Jam Chauffeur** (Level 3): Identical function as for passenger vehicles (see previous section).
- **Highway Chauffeur** (Level 3): Identical function as for passenger vehicles (see previous section).
- **Highway Pilot with ad-hoc platooning** (Level 4): In addition to the functions described for passenger vehicles above, ad-hoc convoys could also be created. This requires availability of vehicle-to-vehicle communication and depends on the deployment of cooperative systems.
- **Fully automated truck** (Level 5): The fully automated truck should be able to handle all driving from point A to B. The driver can at all times override or switch off the system. No consensus exists as to when such systems will become commercially available.

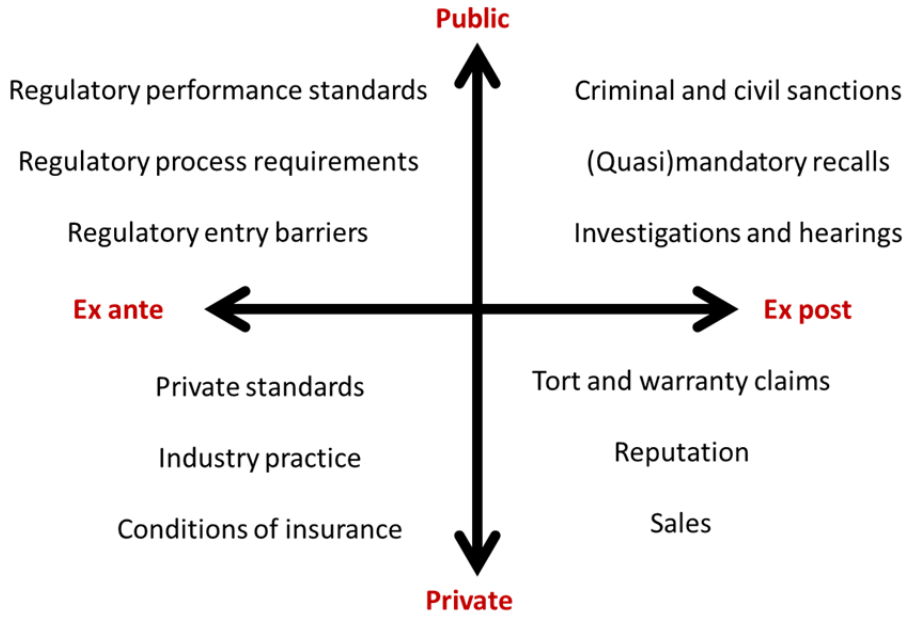
3. Regulatory environment

Types of regulation

Encouraging desirable conduct and deterring undesirable conduct are among the most important goals of regulation. In a narrow sense, regulation is simply the enactment of a binding rule by a public authority. This narrow definition, however, denies other key regulatory tools that warrant attention. Figure 7 arranges several of these tools according to whether the actor wielding them is public or private and whether the action taken is forward looking (*ex ante*) or backward looking (*ex post*).

Any of these tools could impact whether automated driving systems are deployed and, if they are, what kinds, when, where, how, and by whom. For example, imposing an insurance requirement on developers of automated vehicles, as several US states have now done, could advantage larger companies that self-insure as well as private insurers to whom smaller developers may turn.

Figure 7. **Types of regulation for automated driving**



Source: Smith B. W., 2013.

Regulatory approaches

Today's motorists and motor vehicles already pass through a number of regulatory gates. For transport products, particularly non-commercial vehicles, these can include first sale (which typically requires manufacturers to either self-certify or to obtain type approval), vehicle registration and subsequent renewal by the owner, driver licensing and subsequent renewal for the operator, provision of vehicle insurance, traffic and vehicle enforcement, investigations into vehicle defects, recall of vehicles or components that are not reasonably safe, and litigation over traffic injuries and fatalities.

For transport services, including public transit, taxicab operations, and commercial trucking, these gates can include all of those listed above as well as construction of facilities, procurement of rolling stock, awards of concessions, professional drivers licensing and funding of projects and programmes.

These gates enable governments to monitor, influence, or impede particular vehicle automation concepts. They may also obligate public actors to address automation sooner than they are ready. Consider the following examples:

- A police officer observes a driver operating a vehicle without touching the steering wheel.
- An agency charged with registering only those vehicles that are "reasonably safe" receives an application for a vehicle with automation capabilities that have been added by its owner.
- A driver licensing agency receives an application from a disabled person who cannot legally drive under existing rules but who asserts the right to operate an automated vehicle under an accommodations law.
- A transport agency that has completed an environmental review for a major infrastructure project faces a legal challenge by an opponent of the project who contends that the agency failed to account for the impacts of automation on demand, capacity, and revenue assumptions.

These examples suggest that an effective response to automated vehicle technologies requires an early and ongoing dialogue between regulators and developers.

As of late 2014, almost all regulatory action regarding automated cars and other on-road vehicles has focused on the conditions in which on-road testing and operation of these vehicles takes place, including vehicle and driver licensing (see annex). This is of course an essential element in the progression towards the commercial deployment of increasingly automated and ultimately self-driving vehicles. Crucially, however, driver and vehicle licensing are not the only regulatory elements that will be challenged by the deployment of highly automated vehicles. As noted earlier, the urban mobility pathway leading to the deployment of on-demand automated vehicle services is a plausible development in many urban areas. In these cases, automated on-demand mobility systems will provide services similar to those provided by taxis and public transport, two highly regulated industries. Authorities will have to adapt - and possibly rethink - their approaches to regulating these activities in order to avoid conflicts. Failure to do so might even prevent the deployment of the urban mobility pathway for autonomous vehicles which would stifle innovative uses for this technology and potentially lead to welfare losses.

Regulatory considerations and policy choices

Treat automated vehicles specifically or generally?

A government seeking to expressly regulate automated driving could carefully examine and, as needed, modify each existing law to clarify its application to vehicle automation. It could locate each regulatory function in the agency ordinarily assigned to perform it. And it could seek, wherever possible, to apply similar requirements to automated vehicles and their operators as would be applied to all others.

Alternately, such a government could promulgate a specific package of largely standalone rules that apply exclusively to vehicle automation. It could give authority to implement these rules to a more limited set of new or existing agencies. And it could intentionally differentiate between automated and non-automated driving with respect to particular rights, obligations, and liabilities.

A general approach will likely seem more appropriate as automation becomes more widespread and ordinary. Nonetheless, a specific approach, which more closely mirrors recent legislative and regulatory

output in the United States, may be a simpler and cleaner method of addressing a nascent set of technologies that require development of particular expertise.

The paper "Automated vehicles are probably legal in the United States" (Smith, 2014c) contains model language to clarify the legal status of automated driving that integrates existing vehicle codes wherever possible and yet treats automated driving specifically when needed. For example, the language embraces and expands existing registration obligations and standards rather than introducing wholly new ones.

Let policy lead or lag technology?

Proactive policy, including specific rules, can provide companies the legal clarity they need to make investment and deployment decisions and can enable governments to appropriately handle automation technologies at each of the regulatory gates described above.

Nonetheless, prematurely codifying requirements can freeze unrealistically high or low expectations into the law in a way that ultimately causes that law to lag rather than to lead. Furthermore, duplicative or repeat efforts to develop rules can force developers to invest resources in lengthy legislative debates and regulatory processes.

For these reasons, informal dialogue may often be preferable to specific rules. Importantly, countries and regions with a specific "automated driving law" are not necessarily ahead of those without one. The US state of Michigan, for example, recently enacted a law that explicitly prohibits the operation of automated vehicles for any purpose other than research and development testing. Where other US states may have flexibility to accommodate new kinds of pilot projects that do not qualify strictly as testing, Michigan will have none.

Privilege uniformity or flexibility?

Uniform regulation across multiple jurisdictions can reduce the cost and complexity for developers of systems that will necessarily cross national or subnational borders. Designing for one set of rules and roads is daunting enough; designing for dozens only amplifies this challenge. Flexible regulation, however, might more easily accommodate existing regional differences, local start-ups, and unique demonstration projects. It may also foster more national ownership over what is viewed by some as an area of international competition.

Recently endorsed amendments to the 1968 Vienna Convention on Road Traffic strike an impressive balance by delegating some relevant decisions to an international administrative structure. Another hybrid approach, developed more below, would embrace significant regional flexibility for testing and pilot projects but would emphasise consistency and reciprocity for production vehicles.

Emphasise ex-ante or ex-post regulation?

The choice between ex-ante regulation (particularly regulatory standards) and ex-post regulation (particularly recalls and civil suits) also implicates flexibility. Forward-looking rules provide more certainty but less flexibility; backward-looking measures provide more flexibility but less certainty. These trade-offs are particularly relevant to concerns raised about the liability of automated vehicle manufacturers and associated companies for injuries related to their products. These concerns, however, likely derive at least as much from technical uncertainty (how will these eventual products actually perform) as from legal uncertainty (how will courts determine liability)?

Key challenges

Provide sufficient legal clarity

Governments should seek to provide sufficient legal clarity with respect to:

- Obligations of developers: Under what conditions can a developer test and market its vehicles?
- Obligations of operators: Who or what determines whether the operator of an automated vehicle must be vigilant?
- Liabilities of developers: Are any ex-ante deviations from existing rules of criminal and civil liability demonstrably justifiable?
- Liabilities of operators and owners: Are existing rules of civil liability sufficiently clear for companies that provide motor vehicle insurance?
- Nonconventional operators: Is the operator of an automated vehicle sufficiently clear in existing law, and are the requirements on that person sufficiently flexible to adjust based to emerging technologies?
- Nonconventional motor vehicles: Is the legal status of low-speed passenger and delivery shuttles sufficiently clear and appropriate?
- Nonconventional transport services: Is the legal status of ride sharing, car sharing, and non-traditional taxicab services sufficiently clear and appropriate?
- Identify and correct market failures.[1]

Driving can impose costs on others - particularly through injuries and pollution - that are not internalised by vehicle drivers or owners. Moreover, some of the costs that drivers and owners do bear, like vehicle insurance, have an attenuated connection to the nature or extent of their driving. These mismatches can change incentives in ways that encourage more driving.

Moreover, if automated vehicles actually do represent an improvement in safety or fuel efficiency, these mismatches may also obscure financial benefit of these gains. For this reason, internalising more of the costs of driving on an incremental basis (such as per kilometre travelled) may strengthen the individual economic case for purchasing or using an automated vehicle.

Rationalise insurance

Expanding public insurance and facilitating greater private insurance could provide at least three benefits. First, providing sufficient compensation to those injured by an automated vehicle could relieve some of the pressure on the tort system to provide such a remedy. Second, enhanced vehicle insurance requirements, especially if combined with greater flexibility in the administration of this insurance, could provide a third-party check on the safety of automated systems. Third, such requirements could also help remedy the potential market failures referenced above. Ultimately, however, as automation increases, liability could gradually shift from drivers to manufacturers and OEMs although the allocation of liability among these parties remains challenging and adjudication methods have yet to be developed.

Encourage information sharing by private developers

Education of public actors and of the public at large is essential to the development of effective regulations and realistic expectations. Governments can facilitate this education by encouraging developers to share

[1] This and the following challenges are adapted from (Smith, 2014d).

specific data about their products and processes. This can take at least two forms. First, companies that request specific legal changes, particularly with respect to tort liability, should be expected to produce information justifying these requests: If liability is an impediment, for example, the company should point to specific products that it would release absent that liability. Second, if regulatory approval is required, a key part of that approval could involve review of a specific safety case, preferably a public one, made by a developer on behalf of its product. Pointing to particular processes for development, verification, and monitoring, for example, could contribute to greater regulatory competence and greater public confidence.

Limit the duration of risk associated with early development stages

Vehicles with automated driving systems that are introduced in the next few years will be neither perfect nor stay with us for only a few years. Years after they have become outdated, many of these vehicles will still be on the road. A key goal for both regulators and developers should be limiting the physical risk of these systems through a variety of technical and contractual tools to enable monitoring, over-the-air updates, and even virtual recalls.

Expect as much from non-automated systems as from automated systems

Finally, automated driving has inspired much excitement and trepidation. Unfortunately, the shocking toll of motor vehicle crashes today is often lost in these discussions. Regulators that impose heightened requirements on automated vehicles should also expect more from the designers and drivers of non-automated vehicles. Strategies to reduce intoxicated driving, distracted driving, speeding, poor vehicle maintenance, and other common behaviours that substantially increase crash and injury risk can also increase the attraction of automated driving.

Proposals for different automation strategies

Key measures for “something everywhere” automation

Because the “something everywhere” approach embraced by car manufacturers depends more on large markets than on local conditions, sufficient consistency across jurisdictions in terms of physical, physical-digital, digital, and legal infrastructure may facilitate smoother deployment. Moreover, ensuring that the costs of driving are internalised, as noted above, can enable automated vehicles, if actually safer and more fuel efficient, to claim an advantage over their non-automated counterparts.

Key measures for “everything somewhere” automation

In contrast to the “something everywhere” approach, the “everything somewhere” approach depends much more on local conditions. For this reason, flexibility for individually tailored solutions and specialised pilot projects are particularly important. Local, regional, and national actors can also facilitate this approach to automation by clarifying the legal status of non-conventional vehicles (such as low-speed neighbourhood shuttles) and services (for instance ride sharing and alternatives to traditional taxi service) by identifying specific needs and opportunities, by modifying physical and digital infrastructures accordingly, and by deploying particular resources such as road space or taxi concessions strategically.

Annex: Current regulatory frameworks for the testing of autonomous vehicles

The following overview reflects the state of regulation in early 2015.

United States

Four US states (California, the District of Columbia, Florida and Nevada) have passed laws allowing and setting the conditions for the testing of automated and highly autonomous vehicles. Eleven states are considering legislation addressing the testing of these vehicles and an equal number of states have failed to pass bills allowing the on-road testing of autonomous vehicles.

There is, as of yet, no uniform approach to regulating autonomous vehicles among those states that have passed legislation. All four states that have passed autonomous vehicle legislation allow non-testing use of those vehicles, though in the case of Michigan, the driver/operator must be a representative of the manufacturer. In California, Nevada and Florida, vehicles must meet Federal Motor Vehicle Safety Standards. California, Nevada and the District of Columba require autonomous vehicles to have an easy to trigger auto-drive disengage switch and an alert system for system failures. Both California and Nevada require vehicles to store sensor data 30 seconds before a collision. Nevada restricts testing to specific geographic contexts and California reserves the right to do so. Neither Florida nor the District of Columbia impose geographic restrictions. Nevada only issues registration permits explicitly for testing whereas Michigan only issues registration certificates to manufacturers.

More at http://www.aamva.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=5827&libID=5803 and http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action.

Europe

Jurisdictions where an ad hoc regulatory framework is in the making:

United Kingdom: As part of the 2013 National Infrastructure Plan, the UK government pledged a review of the legislative and regulatory framework to enable trialling of driverless cars on UK roads. The review is part of wider government action that includes a proposal to invest up to GBP 10 m in collaborative R&D projects to research this area in the UK.

On 30 July 2014, the government announced a driverless cars competition, inviting UK cities to join together with businesses and research organisations and host vehicle trials locally. On 4 August 2014, the Department for Transport launched a public consultation concerning the review of the legislative and regulatory framework for testing driverless cars. The scope of the review is limited to the testing of driverless cars with high automation (as opposed to fully autonomous cars), that is to say, of cars which are capable of operating on the road network without human intervention, but are fitted with a full set of driving controls, and in which a driver must be able and ready to assume control. The consultation closed on 19 September 2014. The review was published by the Secretary of State for Transport in December 2014. Relevant information and discussion document, available at: https://www.gov.uk/government/consultations/driverless-cars-regulatory-testing-framework.

In February 2015, the UK Department for Transport released the results of this consultation in a set of reports under the heading of “Driverless Cars in the UK: A Regulatory Review”. This review found that those wishing to test automated and highly autonomous vehicles are not limited to test tracks or specific geographic areas, nor are they required to obtain special certificates or permits. Further, they are not

required to post surety bonds provided they have adequate insurance coverage. These reports can be found at https://www.gov.uk/government/publications/driverless-cars-in-the-uk-a-regulatory-review.

France: The French Government announced the adoption of the necessary legal framework to enable the testing of driverless cars on public roads as of 2015 under strict conditions (see press release no. 194, 2 July 2014, available at: http://proxy-pubminefi.diffusion.finances.gouv.fr/pub/document/18/17720.pdf.

The Netherlands: On 16 June 2014, the Dutch Minister of Infrastructure and Environment wrote a letter to the Dutch House of Representatives, announcing that regulations are in the making to make large-scale public road tests legal. Currently, Dutch drivers have limited abilities to hand control of their steering wheel over to a car's computer. Automatic parking for instance is permitted, but to make more extensive manoeuvres possible regulation needs to change. The Minister plans to propose changes to the current regulations by early 2015. Until then, only small scale tests are possible. Letter and relevant info available at: http://www.techhive.com/article/2363920/large-scale-tests-with-self-driving-cars-to-hit-dutch-roads.html.

Finland: In a press release of 21 May 2014, it was announced that the Ministry of Transport and Communications is preparing an amendment to the Road Traffic Act that would allow for driverless robotic cars to drive within a restricted area on public roads. The act in question would constitute experimental legislation that would be in force for five years starting at the beginning of 2015. Robotic cars could be tested, subject to a permit, in areas defined by the Finnish Transport Safety Agency. The testing of robotic cars in public road traffic would be possible within limited time periods and in predetermined areas. Press release available at: http://www.lvm.fi/pressreleases/4404066/mintc-to-launch-an-experiment-that-would-allow-for-robotic-cars.

Jurisdictions without ad hoc regulatory framework, but where testing is permitted or has been permitted:

Sweden: In Sweden, there is no AV testing-specific regulatory framework. Yet, apparently, testing is allowed. For instance, the Swedish city of Gothenburg has given Volvo permission to test 100 driverless cars, as part of a two-year test scheme, called "Drive Me", scheduled to start on 1 January 2017.The test scheme will be the first in the world to put autonomous cars into the hands of ordinary drivers, in amongst normal daily traffic, in significant numbers. Nevertheless, there seems to be no legal clarity at the moment as to the conditions under which such testing will be carried out. Reportedly, a Volvo technical specialist admitted that the company is not yet sure how Swedish law might need to be changed in order to enable the public to take part in Drive Me and added that without legislative clarity the launch in 2017 will not be able to go ahead (see: http://www.wired.co.uk/news/archive/2014-05/30/eu-embrace-self-driving-cars).

Germany: In Germany there is no specific legal framework on the testing of AVs, but testing in traffic is allowed on the basis of a special permission. Several local and long-distance tests have been undertaken by car manufacturers and original equipment manufacturers. Germany has also announced the creation of an autonomous vehicle testing corridor on the A9 motorway between Berlin and Munich. This corridor will allow testing of connected and autonomous vehicles and vehicle to infrastructure communication. The absence of an ad hoc legal framework might be due to the strict interpretation of the Vienna Convention followed in Germany. On this point, see: http://www.research-in-germany.org/en/research-landscape/news/news-archive/2014/02/2014-02-18-who-should-be-legally-responsible-for-autonomous-cars-.html.

Spain: Testing of autonomous vehicles has also occurred in Spain, most notably in the context of the SARTRE project, funded by the European Commission and aiming to develop strategies and technologies to allow vehicle platoons to operate on normal public highways. The first tests of these technologies occurred on Spanish motorways, see: http://www.sartre-project.eu.

Singapore and Japan

Singapore: In August 2014, the Singaporean Ministry of Transport announced the launch of CARTS – the Committee for Autonomous Road Transport for Singapore. CARTS' stated goals include "studying and test-bedding the various AV technologies in our environment, laying the legal, regulatory and liability framework to govern the operations of AVs, and exploring industry development and business opportunities". Relevant information available at: http://thinkingcities.com/new-era-of-self-driving-cars-will-transform-cities and http://vulcanpost.com/18369/driverless-vehicles-next-step-future-singapore.

On 27 August 2014, the Land Transport Authority (LTA) announced that it had signed a Memorandum of Understanding (MOU) with the lead agency for R&D in Singapore for a joint partnership to set up the Singapore Autonomous Vehicle Initiative (SAVI). The formation of SAVI will support CARTS to holistically chart the strategic direction for AV-enabled land mobility concepts in Singapore. To support the R&D of AV technology, LTA will work towards a framework that will allow the testing of AVs on the public road network over 2015 (see: http://app.lta.gov.sg/apps/news/page.aspx?c=2&id=29525082-5265-4139-bc3b-0241a4639d46).

Japan: Public road tests of AVs have been carried out also in Japan. In 2013, Nissan carried out Japan's first public road test of an autonomous vehicle on a highway (relevant information available at: http://www.bbc.com/news/technology-28551069). Reportedly, self-driving trucks have also been tested in Japan (see: http://www.theverge.com/2013/2/27/4037568/self-driving-trucks-tested-in-japan).

Bibliography

CityMobil2, 2015. *CityMobil2: Cities demonstrating automated road passenger transport.* [Online]
Available at: http://www.citymobil2.eu/
[Accessed 10 April 2015].

NHTSA, 2013. *U.S. Department of Transportation Releases Policy on Automated Vehicle Development.* [Online]
Available at:
http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development
[Accessed 15 October 2014].

Parrish, K., 2015. *http://schedule.sxsw.com/2015/events/event_IAP37302.* [Online]
Available at: http://schedule.sxsw.com/2015/events/event_IAP37302
[Accessed 10 April 2015].

SAE, 2014. *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.* [Online]
Available at: http://standards.sae.org/j3016_201401/
[Accessed 15 October 2014].

Smith, B. W., 2013. *Testing, certification, and licensing.* [Online]
Available at: http://bit.ly/1dUIvvn
[Accessed 15 October 2015].

Smith, B. W., 2014a. A Legal Perspective on Three Misconceptions in Vehicle Automation. In: G. a. B. S. Meyer, ed. *Road Vehicle Automation Lecture Notes in Mobility.* s.l.:Springer.

Smith, B. W., 2014b. Proximity-Driven Liability. *Georgetown Law Journal,* Issue 102.

Smith, B. W., 2014c. Automated Vehicles Are Probably Legal in the United States. *Texas A&M Law Journal,* Volume 1.

Smith, B. W., 2014d. *Regulation and the Risk of Inaction.* [Online]
Available at: http://www.aamva.org/Autonomous-Vehicle-Information-Library/
[Accessed 15 October 2014].

International Transport Forum

Automated and Autonomous Driving

Regulation under uncertainty

Many cars sold today are already capable of some level of automated operation, and prototype cars capable of driving autonomously have been and continue to be tested on public roads in Europe, Japan and the United States. These technologies have arrived rapidly on the market and their future deployment is expected to accelerate. Autonomous driving promises many benefits: improved safety, reduced congestion and lower stress for car occupants, among others.

But authorities will have to adapt existing rules and create new ones in order to ensure the full compatibility of these vehicles with the public's expectations regarding safety, legal responsibility and privacy. This report explores the strategic issues that will have to be considered by authorities as more fully automated, and ultimately autonomous, vehicles arrive on our streets and roads. The report was drafted on the basis of expert input and discussions amongst project partners in addition to a review of relevant published research and position papers.

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