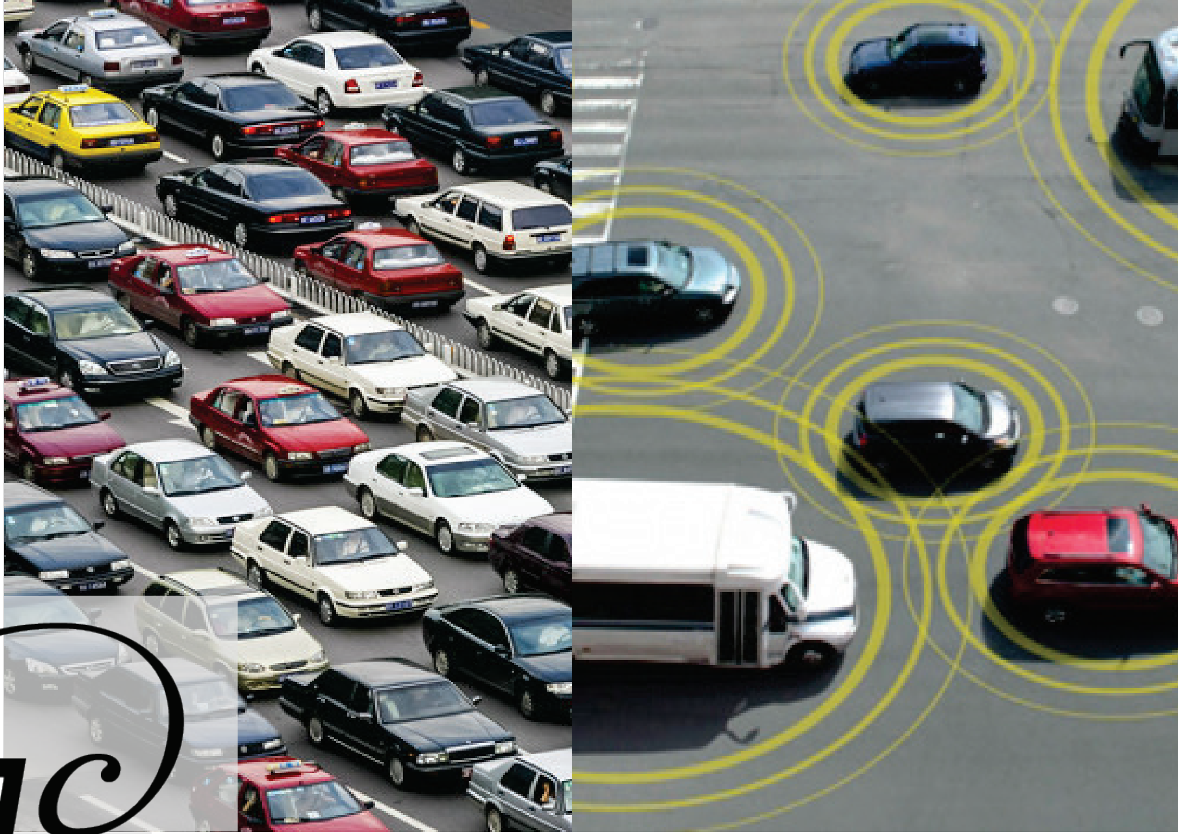


international risk
governance center

BACKGROUND PAPER

RISK AND OPPORTUNITY GOVERNANCE OF AUTONOMOUS CARS

Expert Workshop
Zurich, 15 – 16 June 2016

This workshop is organised by IRGC, with support from Swiss Re and AXA Technology Services, and hosted at the Swiss Re Centre for Global Dialogue.

This report is to support discussion at the workshop.
It is not for wider circulation.

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

The International Risk Governance Center (IRGC) and the Transportation Center of the École Polytechnique Fédérale de Lausanne (EPFL) are organising an expert workshop on 15-16 June 2016, about risk and opportunity governance of autonomous cars.

Autonomous cars have the potential to contribute solutions to a number of transportation challenges, including improving road safety, optimising traffic flow, allowing for transportation that is more efficient and new mobility models, and providing additional comfort for drivers and passengers.

However, policymakers, regulators and industry need to better understand the implications and associated uncertainties of current and evolving autonomous vehicles technologies for a wide range of actors and issues. Such uncertainties concern, among others, the overall cost-benefit of these technologies, public acceptance, insurance pricing, liability issues and new business models that autonomous driving will enable.

Regulators, in collaboration with the automotive industry, insurance companies, and safety administrations, will need to design and enact regulations that define the infrastructure necessary for autonomous driving, allocate liability in case of accidents and technical failures, and specify minimum technological requirements. Regulators will also need to set new safety standards and devise systems for testing and measuring them.

The speed of adoption of autonomous cars is dependent upon the acceptance by society and the confidence by regulators and industry that all major concerns will be overcome by key enabling technologies, consumer demand, positive cost dynamics, and by clarity over legal and insurance requirements. One of the challenges will be to incorporate uncertainty and adaptability into regulation.

Contents

Figures

Purpose of this paper

The purpose of this paper is to provide a non-technical overview of some of the governance issues that the workshop will discuss. We wish to emphasize that:

- The technologies associated with automated and autonomous driving raise high expectations, but in a context of complex technological challenges, high uncertainty and some ambiguity.
- Collaboration between stakeholders, and the design of adaptive pathways will be the key to success.
- The debate about autonomous vehicles must be informed (evidence-based) and critical. Most of the current developments concern automated vehicles, to pave the way towards autonomous driving. Some “hype” may be beneficial to make stakeholders move forward, but too much hype may create disappointments.

Notes & definitions

This document refers to the generic term of “autonomous vehicles” (AVs), within the context of “automated and autonomous driving”.

- ADAS, as Advanced Driving Assistance Systems, are safety devices and other features that assist a driver. These seek to enable safer driving through capabilities that may include providing drivers with awareness-enhancing information by detecting objects or hazardous conditions, and automating repetitive or difficult tasks
- By automated, we mean that a vehicle is programmed to carry out specific tasks, using a predefined course of actions, in a set of known operating conditions.
- By “autonomous” (and the prospect of autonomous driving) we mean that the system has a high intelligence, is able to adapt and operate correctly in an open and dynamic environment. The system has learning capabilities.
- Intelligence can be embedded in the vehicle itself and in road infrastructure. In the latter case, the vehicle must be connected: it is equipped with communication systems and information sharing capabilities.
- Vehicles can cooperate: they work together to accomplish a “shared” goal, such as going from point A to point B. In cooperation, information is accessed or shared in order to improve the localization or perception of a given vehicle.
- Vehicles can also collaborate: a cluster of vehicles work together to achieve a “common” goal, such as optimizing traffic flow or platooning. In collaboration, information is shared among all vehicles, their specific behaviour adapts to other vehicles’ behaviours.
- “AV technology” used in this paper refers to the various technologies that are necessary to move towards autonomous driving, including ADAS, automation, autonomy and (to a limited extent) connectivity.

1. Introduction: setting the scene

Benefits of autonomous vehicles

Autonomous vehicle (AV) technology has the potential to offer powerful solutions to a number of societal challenges. While the ultimate applications and impacts of AVs cannot be entirely predicted, it is widely accepted that applications could offer numerous social benefits, such as:

- **Safety:** The World Health Organization estimates that nearly 85.000 road traffic deaths occur every year in Europe and 34.000 in the US[1], and the National Highway and Transportation Safety Administration (NHTSA) of the United States attributes 94% of vehicular accidents within the United States to human error[2]. AV technology that mitigates human error by supplementing or replacing human drivers could significantly reduce the occurrence of vehicular accidents and associated human injury.
- **Traffic flow efficiency:** The potential decrease in accidents brought about by AVs would also lead to a reduction in traffic congestion caused by car accidents within cities and roadways. Reducing congestion and subsequent delays could lead towards optimised traffic flow and greater efficiency for road travel.
- **Potential reduction in the need for new road and parking infrastructures:** if the traffic density decreases, existing infrastructure could be used more efficiently.
- **Reduced emissions:** Road vehicles are a major contributor to global CO_2 emissions and other air pollutants. The potential greater efficiency in travel, and fuel conservation indirectly promoted by AVs would create positive externalities accruing to the public and environment through a reduction in vehicular emissions. As the progress of autonomous driving is expected to be accompanied by the growth of electric vehicle use, the aggregate reduction of emissions could prove even more significant and help address concerns of energy, air quality, and climate concerns facing society today.
- **Inclusivity of travel:** AVs open up new possibilities of travel for millions of non-drivers to include disabled, elderly, and underage persons, who are limited in their ability to drive vehicles themselves.
- **New and performant transportation and business models:** Self-driving technology opens the door to a wide array of new and innovative transportation and business models for vehicular usage. These new possibilities span from the potential for new and more efficient public transportation, to driverless taxi businesses, to traditional models for car ownership and usage. This may lead to entirely new mobility patterns.
- **Enhanced driving experience:** Driving creates an opportunity cost of time that could be spent on other preferential activities. Self-driving capabilities could allow the time previously dedicated to manoeuvring a vehicle to be used for accomplishing previously unattainable or unsafe tasks (e.g. texting, reading) while in a traveling vehicle.
- **Information about people's behaviour:** Connected vehicles will provide data that will give socially relevant information. Assuming that privacy and data protection will be respected, the data collected can *and should* be used to optimize transportation and inform other systems.

[1] Death on the roads, WHO global status report on road safety 2015, http://www.who.int/violence_injury_prevention/road_traffic/death-on-the-roads/en/#deaths/per_100k
[2] http://www-nrd.nhtsa.dot.gov/pubs/812115.pdf

Who are the stakeholders and what is their role in the decisions about autonomous cars?

The broad range of impacts that AVs may create also entails numerous stakeholders, including those with interests in the development and application of the AV technology. Others, however, with vested interests in old technology and transportation models, may try to delay the development of AV technology. Effective development and application of AVs thus requires engaging with a range of interested and influential actors, including:

- **Car manufacturers / Original Equipment Manufacturers (OEMs)** are ultimately responsible for assembling and selling vehicles with AV technology to be used by the public. The capabilities of these vehicles will directly affect the impact that AV technology has upon society.
- **Hardware suppliers and software developers** develop the technology and control systems needed to *assist* and ultimately *replace the human driver*: detecting surroundings, analysing and interpreting sensory information, identifying appropriate navigation paths, obstacles and signage, communicating with other cars and with infrastructure, and eventually driving the car.
- **Insurance and reinsurance companies** provide motor insurance coverage. Car owners have been told, and expect, that the cost of insurance will decline. However, before offering attractive pricing, insurers need to analyse fully the risk related to the new technologies, and develop full risk-based assessments to quantify the risk, based on which new risk transfer models would be established. In doing so, insurers can trigger innovation for improved risk management by industry. But if they face too much uncertainty in their evaluations, they may not encourage the fast development of autonomous cars before these uncertainties can be reduced with empirical analysis and evidence-based data collected through testing and experience.
- **Drivers and other representatives of the public** buy and utilise cars, and participate as citizens within important public decisions. They are also actors as operators of (autonomous) car sharing fleets.
- **Governments and regulatory agencies** decide what technologies are publicly allowed, and how they may be utilised. They invest and operate infrastructure. For example they will play a key role in the communication between vehicle and infrastructure (V2I). To a large extent, regulators also provide incentives for technological innovation and are instrumental in the development of safety standards. Regulatory decisions shape when, where, how, and to what extent technologies for autonomous driving are integrated into transportation.
- **Standard-setting organisations** design safety standards, and **certification agencies** certify that vehicles are safe to be driven on public roads. They too can drive technological improvement for increased safety.
- **Scientists and academics** develop the science and technology that can be used for industrial applications. They accomplish this through both fundamental and applied research. These new technologies must be checked for efficacy, safety and applicability before being considered for commercial, cost-effective use.

All of these actors will play important roles in the development and deployment of AV, and each offers its own abilities and influences on the technology and industrial applications.

Collaboration and communication between the varied AV stakeholders are needed to overcome technology challenges, to develop solutions for effective regulatory efforts that promote the benefits of AV while mitigating the risks, and to design attractive and viable business models.

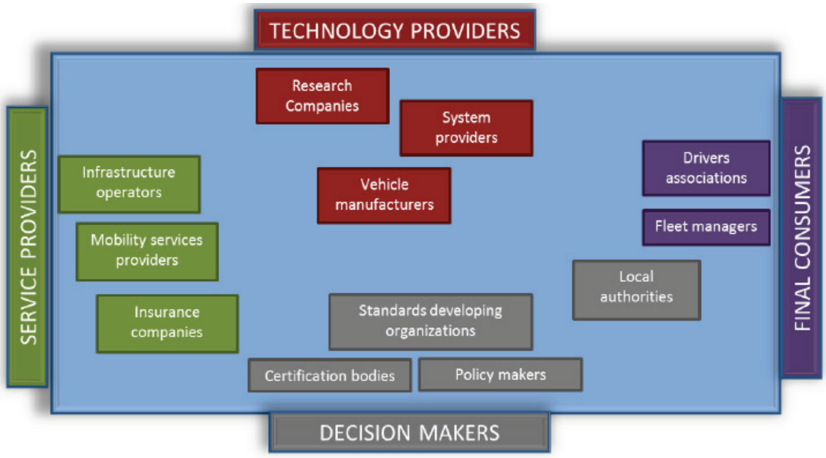


Figure 1: Illustration of stakeholder groups and their role in vehicle and road automation. Source: Ertico

Autonomous driving comes in steps and will take many years to be operational and allowed

The formal classification system for automated vehicles proposed by the SAE International[3] is now widely adopted (see Figure 2 below).

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**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*	System	System	System	**All driving modes**

Figure 2: Levels of automation for on-road vehicles, SAE International J3016, 2014

[3] http://www.sae.org/misc/pdfs/automated_driving.pdf

When will AVs be safe enough to be authorised on public roads?[4]

Allowing AVs on public roads depends on a calculus of risk and benefit over time, which public authorities and regulators supervise and control. Technical improvements are proposed by industry. Regulators, together with insurers who provide attractive insurance pricing for desired features, will decide when and how features of AVs are introduced. Regulators therefore must be reassured that all trade-offs (safety, reliability, performance, costs, and secondary impacts, etc.) will be resolved satisfactorily. Specifically, safety is an issue of preeminent concern that influences both the opportunities and challenges associated with AV technology.
The timing and pace of the introduction of AV technologies will thus depend on how relevant stakeholders answer the following questions:

1. *How safe should autonomous vehicles be before we allow them on roads?*
2. *When will AVs be safer than human drivers?*
3. *How can we reach that degree of safety as quickly as possible?*
4. *How can we ensure that autonomous vehicles can get on the road once they reach that safety level?*

- The answers to the first and second questions are not trivial. Indeed, lack of confidence regarding safety leads regulators to be cautious about allowing autonomous cars on public roads, even for testing. In most cases however, this solution is left to the courts and insurance, in particular to answer the liability question, discussed in Section 3.
  If we wait for perfection, then we will be saving the most number of lives per year that is possible with the technology. In the meantime, however, we would continue to accept the thousands of fatalities per year. If we accept AVs before they are perfect, we may have to accept accidents caused by imperfect AVs. In addition, while humans can make mistakes, there is a cultural aversion to 'letting machines make mistakes'. As soon as AVs are better than the average human driver, we begin to save lives. However, if we release the technology before it is better than average, we may have more crashes, potentially halting the development of AVs and create polarization. Also, other benefits (mobility, usefulness) might alter the long-term trajectory. The assessment is thus quite complex. The decision depends on a governance judgement, as much as on technical features.

- Question 3 requires testing and pilots in real road conditions. Testing serves to assess cars on a test track. Pilots test vehicles in real-life conditions.

- Question 4 suggests that the ecosystem of driving regulations needs rethinking. Performance-based regulations would probably be appropriate.

These questions summarise the debate between promoters of early introduction and promoters of safety first. At the core of the questions is the issue of uncertainty:

> *How to make a decision knowing that it won't be perfect, that it may incur more accidents of a new type that are yet poorly understood?*
> *How to allocate risk in a situation of significant uncertainty? How is the decision made, and how do stakeholders collaborate in the process?*
> *Which stakeholders are best placed to take the role of mediator, or arbitrator to resolve the trade-offs that have to be made?*

[4] This section elaborates from a presentation by Nidhi Kalra, Rand Corp. co-author with James Anderson et al. of *Autonomous Vehicle Technology, a guide for policymakers*, 2016 (version RR-443-2). Available on http://www.rand.org/pubs/research_reports/RR443-2.html. The presentation was made at the IRGC conference on Planned Adaptive Regulation, University College London, 7-8 January 2016

Uncertainty emphasizes the need to adapt the decisions as we collect empirical data from testing and monitoring.

Tempering expectations?

Prof. John Leonard (MIT) and others suggest that the science-fiction view on autonomous cars, which will come true one day, may need to be nuanced for the short to medium term, and users of autopilots should be cautious when they try to push the limits of their automated car. Industry also has a role to play in managing consumers' expectations[5].

There are so many obstacles to the development of autonomous cars that, even with the best intentions, things cannot happen quickly. In Section 6 we list some of the roadblocks that will need to be overcome. Here, we wish to set the tone that creating "hype" with science-fiction stories about autonomous cars should be avoided for a range of reasons, including the need to manage expectations, to be serious about safety and reliability concerns among the public and regulators, and to address resistance from consumers and other stakeholders in mobility and transportation (e.g. taxi drivers).

2. Technology for improving car and road safety

Some aspects of driverless technology

The idea of autonomous cars is not new, yet this idea has not seemed feasible until recent times, except for some transportation systems, such as automated metro systems, aviation, or for robots and drones (unmanned aerial vehicles, UAVs). Modern technology and computer processing are at the core of the advances in AV research and application, and the trajectory of innovation suggests that the shortfalls of current technology are not unconquerable challenges. Automation within cars fulfils many different functions, from highly automated driverless capabilities to anti-lock braking systems; different types of technological equipment are used to enable those capabilities.

Advanced driver assistance systems (ADAS) seek to enable safer driving through capabilities that may include providing drivers with awareness-enhancing information by detecting objects or hazardous conditions, and automating repetitive or difficult tasks. Examples of ADAS technologies include parking assistance and rear cameras, adaptive cruise control, adaptive light control, blind spot detection, lane departure warning, and automatic braking systems. While ADAS technology aims to augment human driver capabilities, other technological applications are moving to supplant the human driver.

It is now relatively common to see cars equipped with adaptive cruise control, parallel park-assist, automatic emergency braking, or lane departure warning. More advanced features such as single-lane highway pilot, highway autopilot with lane changing or traffic jam autopilot are progressively introduced. A survey among 1500 Americans who had recently purchased a car or who intend to buy one indicates that there is no strong preference for any given feature, but it seems realistic that single-

[5] See for example media interviews:
- Driverless cars are further away than you think, in Technology Review, October 22, 2013. Available on https://www.technologyreview.com/s/520431/driverless-cars-are-further-away-than-you-think/
- The high-stakes race to rid the world of human drivers, in The Atlantic, December 1, 2015. Available on http://www.theatlantic.com/technology/archive/2015/12/driverless-cars-are-this-centurys-space-race/417672/

lane autopilot and traffic jam autopilot could be introduced first, if OEMs can make them commercially attractive and viable[6].

Figure 3 below shows the evolution of Advanced Driver Assistance Systems towards Highly Automated Driving applications for each of the five levels of automation.[7]

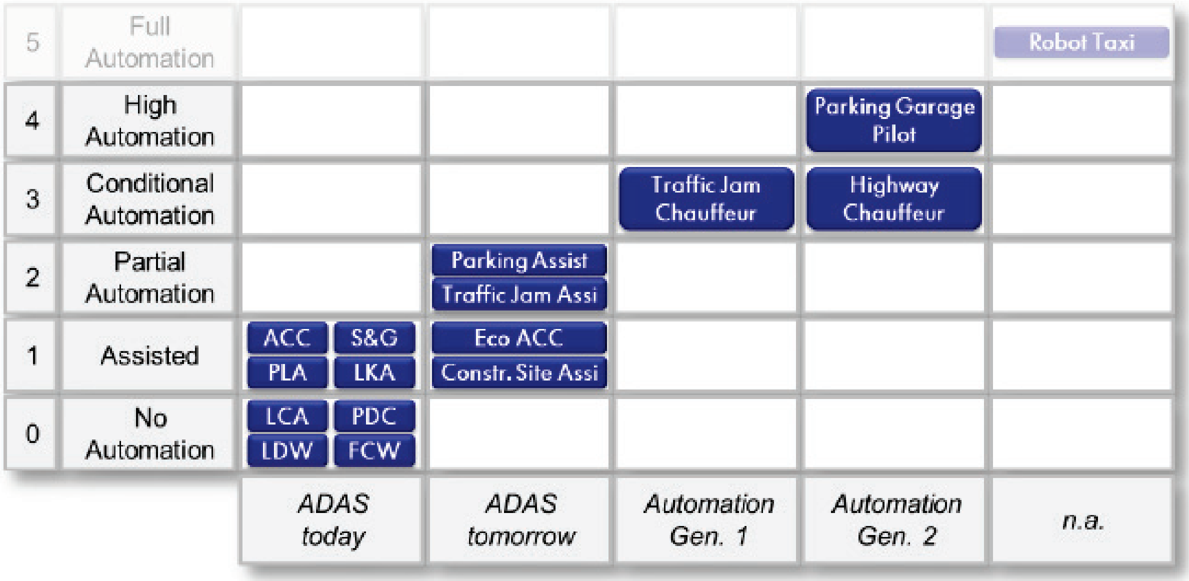


Figure 3: Evolution of Advanced Driver Assistance Systems towards Highly Automated Driving applications ©AdaptIVe project

[6] Boston Consulting Group, Revolution in the Driver's Seat, April 2015
[7] AdaptIVe project https://www.adaptive-ip.eu/

The five levels of automation are used to analyse a variety of issues that accompany the development from simple driving assistance to full autonomy. For example, an analysis by Frost and Sullivan indicates the types of technologies that will be needed to enable increasing autonomy (see Figure 4 below[8]). According to this analysis, the technologies at the bottom of Figure 4 are, as of yet, insufficiently developed to be used in autonomous vehicles, however they will be needed.

Applications Required for Various Levels of Vehicle Automation

The leap from semi- to highly-automated is fairly easy to accomplish as driver override exists; the leap to fully-automated driving requires artificial intelligence to replace the human driver.

Automated Vehicle Market: Requirements by Level of Automation, Europe and North America, 2013

Level of Automation	Assistance	Semi-automated	Highly Automated	Fully Automated
Adaptive headlamp control	Optional	Optional	Imperative	Optional
Radar	Imperative	Imperative	Imperative	Imperative
Ultrasonic sensors	Optional	Imperative	Imperative	Imperative
Forward-looking camera	Imperative	Imperative	Imperative	Imperative
Rear-vision camera	Optional	Imperative	Imperative	Imperative
Surround-view camera	Optional	Imperative	Imperative	Imperative
Night vision	Optional	Optional	Imperative	Imperative
LIDAR	Optional	Optional	Imperative	Imperative
Map-supported ADAS	Optional	Optional	Imperative	Imperative
Steering and braking automation	Optional	Imperative	Imperative	Imperative
Artificial intelligence	Optional	Optional	Optional	Imperative
Multiple redundancies	Optional	Optional	Optional	Imperative
Self-healing systems	Optional	Optional	Optional	Imperative

Source: Frost & Sullivan; MIRA Ltd

Figure 4: Applications required for various levels of vehicle automation. Source: Frost & Sullivan

[8] accessible on http://media.swissre.com/documents/Prana+Natarajan_From+vehicle+automation+to+autonomous+driving.pdf

Fully autonomous driverless vehicles rely upon various sensors and computational equipment to perceive the environment surrounding the car and inform autonomous navigation and decision making. Technological approaches for enabling driverless vehicles vary but all are based on a mix of sensors in radars, optical cameras, ultrasound and light detection and ranging (LiDAR) systems. It is likely that all of these technologies will be needed, and combined, to capture and process the information accurately, rapidly, and in every weather type and traffic condition. Critical enabling components such as LiDAR sensors need to be further developed to enhance capability and also lower costs. Figure 5 below shows some of the technologies and their costs[9].

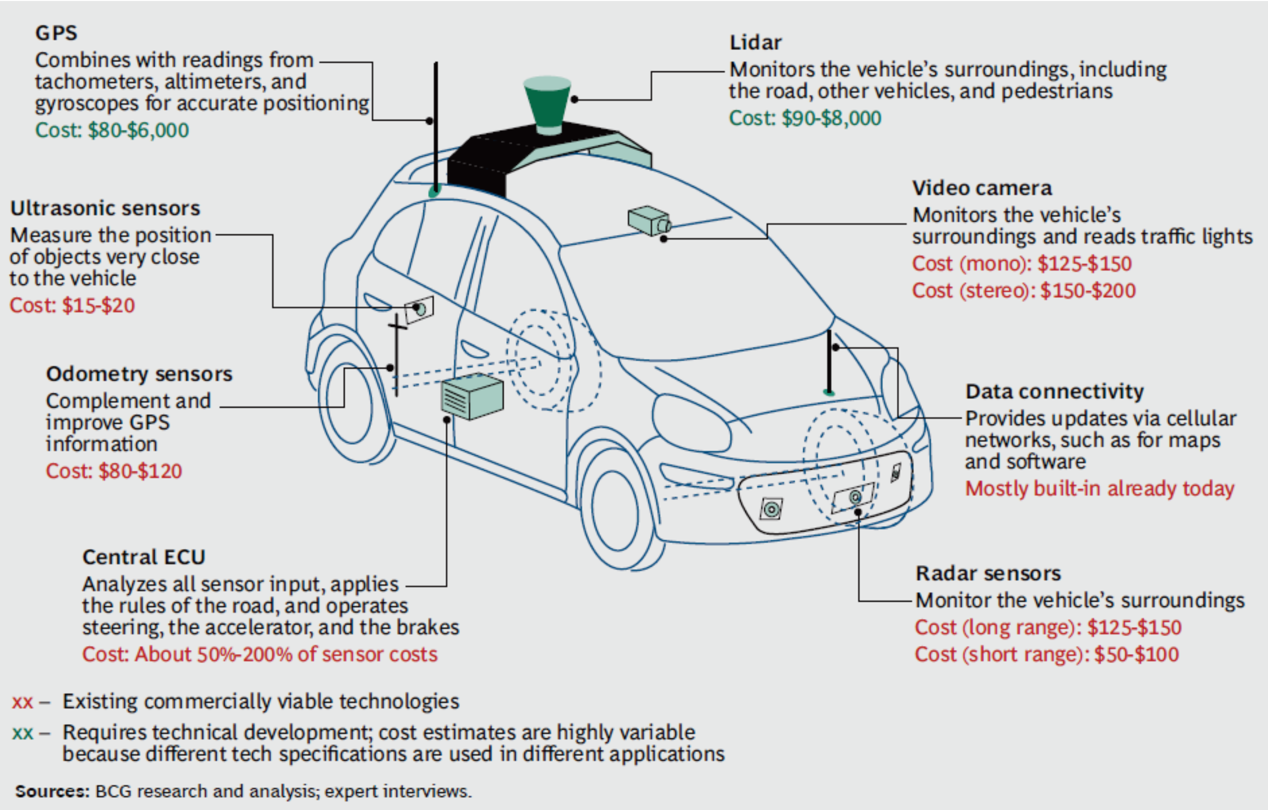


Figure 5: Sensors and unit costs. Source: Revolution in the driver's seat, Boston Consulting Group, 2015.

[9] As estimated by the Boston Consulting Group in 2015. The cost of ADAS safety features vary among sources and tends to decrease with time.

Is V2X needed?

Cars can be autonomous and/or connected. These are two different things.
Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), all together called V2X technologies, envision communication between vehicles on the roadway and between vehicles and roadway infrastructure to aid in safe and efficient driving. Cooperation between vehicles and with infrastructure may come before full automation. A convergence of automated driving technologies with cooperative technologies like V2X provides an opportunity for greater awareness-enhancement, leading to safer and more efficient driving possibilities.

> *However, are V2X technologies needed for the first generation of AVs?*
> *Is the lack of interconnectivity of road infrastructure and vehicles and their respective data a roadblock to bringing autonomous vehicles on the road?[10] If there are concerns about hacking or malicious acts via V2X, can we wait until confidence in basic AV technology is built before introducing V2X?*

Ultimately, it is the capabilities and limitations of technological devices and systems that will determine the ability and applicability of autonomous driving. An understanding of the current state of technology along with an accurate forecast of where the technology is heading is crucial for developing appropriate expectations for the future of AVs.

High-definition digital maps

Many driverless approaches rely upon pre-uploaded, detailed maps in conjunction with real-time data processing to assist the vehicle in determining its relation to its environment.

As we move towards autonomous driving, increasingly detailed and accurate maps may be needed. These advanced mapping systems will also need to be very regularly updated. Collaboration between actors will be critical in order to guarantee standardisation and interoperability.

Artificial intelligence and self-learning/healing systems

One of the greatest technical challenges for moving towards fully autonomous cars involves enabling the vehicle to make better driving decisions. Regardless of their technical prowess, programmers cannot account for all scenarios AVs will encounter, creating a need for artificial intelligence (AI) to replace the human driver. A human's ability to learn from experiences (and become a better driver) is a major asset that AI must replicate on some level. Along with learning from experiences, AI systems must also be capable of making decisions in difficult and ethically questionable situations, like choosing between hitting a tree, a biker, or a pedestrian if faced with an unavoidable collision. How exactly to achieve satisfactory AI systems is a major technical hurdle that must be cleared.

---

[10] See: The future of motor insurance - How car connectivity and ADAS are impacting the market. A joint whitepaper by HERE and Swiss Re. Available on http://media.swissre.com/documents/HERE_Swiss+Re_white+paper_final.pdf

3. Identifying and evaluating new or changing risks

Uncertainty and risk surround various facets of AV technology from the risk of technological failure to uncertainty concerning the impact of AVs on society. These risks, and our understanding of them, will change and evolve as the technology and its implementation progress. Some low-probability, yet high-consequences risks, such as those potentially caused by cyber hacking, may be difficult to assess, yet important to identify and accept before those who sell autonomous cars are given a full "licence to operate".

How will the frequency and severity of collisions evolve?
What will be the response when an inevitable accident occurs?
How will other risks evolve?

Safety of technology and arc of technological development

While vehicle automation is expected to improve road safety, more learning from tests and pilot studies is needed to determine whether this is true on a large scale. Furthermore, improvements may not be immediate or linear. We understand that most crashes involve, or sometimes are due to human errors, but we also know that most driving involves no crashes, and we cannot yet discern whether autonomous vehicles will be able to "replicate the crash-free performance of human drivers"[11]. While **"**to err is human," machines are not excluded from the capacity to err as well. Sensor suites and algorithmic capabilities of AV are not immune to failure, creating the potential for significant known and unknown safety risks. Risks identified to affect AVs include environmental factors such as snow and heavy rain, potentially hindering the ability of AVs to perceive their environment accurately. Even detecting elementary obstacles, for example potholes and uncovered manholes, and differentiating between certain objects, like a rock and a crumpled piece of paper, prove to be challenging for AV technology. Furthermore, while detecting a pedestrian is possible in theory, it can become a challenge in winter, or when the person is moving, or quickly emerging from behind an object[12].

What are the main safety concerns and challenges for current AV technology?
Are these challenges solvable in the near future or is their resolution uncertain?

Human-machine interaction

Many studies have been conducted to assess the impact of "self-driving" functions on a "human driver," to understand how a person can resume active control when prompted to do so, most likely in an urgent situation. The passive role of monitoring an automated system may be less satisfactory than the active role of manual control, yet it may provide additional comfort. The interaction between AVs and pedestrians or other road users also needs to be understood.

Questions remain regarding how a driver that is not in control would be able to take over from the car if needed, and whether, when and how this option must be given to him.

[11] Automated and autonomous driving, regulation under uncertainty, OECD International Transport Forum / Corporate Partnership Board, 2015. Available on http://www.itf-oecd.org/automated-and-autonomous-driving-regulation-under-uncertainty

[12] Euro NCAP puts autonomous pedestrian detection to the test. Press release, 10 November 2015. http://www.euroncap.com/en/press-media/press-releases/euro-ncap-puts-autonomous-pedestrian-detection-to-the-test/

Medium levels of vehicle automation can result in reduced driver situation awareness, but can also enhance safety by reducing driver workload. This depends on how the automation is designed[13]. Car makers that transfer the control to the driver as soon as the vehicle faces a difficult situation (and where there may be an issue of liability), may ultimately not promote responsible development of autonomous driving. However, the other case where the vehicle retains control because the driver would not be able to react quickly enough, is not good either.

Public perception of safety and reliability, risk and benefits; need to create societal acceptance

Inappropriate attention by decision-makers to concerns and perceptions may slow or hinder the move towards autonomous driving.

How to deal with perceived risks, when they differ from actual risk?

For AVs to make any sort of impact upon society, individuals will actually need to use them. However, surveys indicate that people are concerned primarily with issues of safety, reliability and cybersecurity, and there is some social resistance for AVs to overcome. Perception of the benefits and risks involved with autonomous driving has the power to influence who will and will not be inclined to use the technology. Inaccurate perceptions can lead to improper use of technology, including underuse and not realizing AVs' full benefits, or overuse, placing unnecessary risks on users and the public.

What matters for people's perception of risk and benefit related to autonomous vehicles?
Does the prospect of in-car entertainment or increased efficiency and productivity for passengers affect their attitude towards autonomous vehicles?
Is it important that drivers have the ability to stay in control? If yes, how can this realistically be achieved?
Could autonomous capabilities foster perceptions of invulnerability or overestimation of safety, leading to more aggressive and riskier driving?

Cyber security, data security and privacy issues

As vehicles become increasingly digitally connected, both internally and externally, potential vulnerabilities emerge that may make AVs susceptible to cyber attacks. AVs rely upon internal communications and data transfer between sensors, data processors, and control systems. Externally, AVs will likely become more connected with the Internet, and potentially with other vehicles and infrastructure. As autonomous driving will foreseeably depend on reliable and accurate flows of information through many of these communication pathways, disruption or manipulation of information flow presents serious risks. As an example, most modern cars utilize the Controller Area Network (or CAN bus) as a central networking system through which various modules within the car communicate. The data flowing through the CAN bus, however, is *currently* largely unencrypted and unauthenticated, clearly presenting a reason for concern.

What must we be concerned about, with regard to the risks involved in car-to-car and car-to-infrastructure connectivity?
What are the risks of hacking via interfaces including telematics, cellular, and Bluetooth, and what are the potential consequences of cyber-attacks on functional safety, infrastructure and privacy?

[13] Jamson, A. Hamish et al. Behavioural changes in drivers experiencing highly-automated vehicle control in varying traffic conditions, Transportation Research part C 30 (2013) 116-125. Available on http://www.sciencedirect.com/science/article/pii/S0968090X13000387

Methods for mitigating these risks *must* be deployed and required.

> *What are the technologies, innovations and strategies for managing the risk (avoid, prevent or mitigate), and implementing automotive cyber security through all interfaces?*

New or changing liability attribution

The existing system of attributing vehicular accident liability is well established, yet autonomous technology threatens to disrupt existing conventions. Currently, when individuals operate vehicles they assume liability for any accidents *of their causing* since they are voluntarily taking control of the car and the responsibilities associated with such control (personal/tort/criminal liability). Manufacturers, on the other hand, must create vehicles that meet given standards and expectations of performance; thus, they can be liable for accidents if a defect or failure in their manufactured vehicle contributes to an accident (product liability). Ultimately, individuals and manufacturers serve as proxies for their respective insurance companies, who bear the majority of the burdens of liability and hence have a vested interest in a liability policy.

AV technology, however, requires a reassessment of vehicular liability. The central issue surrounding liability and autonomous driving concerns where to place liability in the event of an accident. While formulations of strict liability may seem reasonable for accidents occurring under fully driverless conditions, the situation becomes less clear when considering accident scenarios involving vehicles using semi-autonomous technology. Any mode that is not fully driverless necessarily infers some degree of human control and interaction, and any level of human control introduces the possibility of human error and, consequentially, liability.

Differences between the US and European liability regimes must be noted. Liability issues are particularly important in the US.

Difference also occurs between new entrants and traditional car manufacturers. New entrants (e.g. Tesla, Google) are prompt to dictate their own rules (e.g. "as soon as the driver touches the brake pedal, he takes over control... and liability"). Traditional car makers have a different attitude to product liability, which they endorse. Safety and reputation matter highly to them.

> *What will be the manufacturer's and driver's responsibility with automated (partially autonomous) and fully autonomous cars (levels 3, 4 and 5 accidents)? What is the current status?*
> *Can car manufacturers take the civil liability if they cannot take the criminal liability?*

Moral hazard occurs when an individual engages in riskier activities than they otherwise would have because another party bears the burden of costs incurred by the risks taken.

> *If the burden of product liability for accidents shifts from drivers to manufacturers, could the shift in responsibility induce moral hazard in drivers of vehicles with autonomous capabilities?*

Risk of regulatory capture

Regulation creates rules that can directly or indirectly encourage or stifle innovation and technological development. As with every fast moving technological progress in a large industry, the risk of regulatory capture must not be ignored. Regulatory capture can occur when a regulatory agency does not act only in the public interest, but inappropriately promotes certain commercial or political interests or concerns of specific interest groups. An example would be if regulators created a standard requiring that AVs use a certain technology although other different, competing technologies are also capable of accomplishing the same goal. AVs present a distinct challenge for policymakers in that appropriate regulation must be based upon a proper understanding of the current and future capabilities and limitations of AV technology. Gaining this appropriate understanding requires communication with industry, insurance, and researchers, however, which may create opportunities for self-interested parties to bias policymakers' decisions in favour of specific economic or political interests. To mitigate this potential for regulatory capture, regulators must seek to understand the current and future landscape of AV technology and refrain from establishing regulations that create technological lock-in, but, rather, focus on performance.

Business risks

Investing in new technology incurs business risks: the technology may not work out as hoped, resulting in a loss of profit. Conversely, failure to invest in new and potentially transformative technology can make businesses irrelevant, or at best, set them behind their competitors. The uncertainty surrounding AV technology and its applications requires businesses within the automotive industry to take risks that align with their best predictions of how the technology will develop and be used. It is not yet known when features of autonomous driving will be commercially attractive and viable.

When is it expected that fully autonomous driving reaches commercial scale?

Additionally, for an industry that typically operates from traditional car ownership-based models, the new capabilities promised by AV suggest a progressive shift to more service-centric business models.

How will (and should) the automotive industry change?
How will it be affected by the probable progressive shift from the traditional car ownership-based model to a service-centric business model?
How will both traditional and new models co-exist?
How will car and mobility sharing (taxis) businesses adapt, or not?

4. Insurance: role and challenges

IRGC regards providers of motor insurances or re-insurance as among the most important drivers of the move towards autonomous driving. As insurers and reinsurers will need to learn to use data gathered by connected vehicles to assess the risk of partly autonomous vehicles, reinsurers could even play a more important role in paving the road towards autonomous driving, as they will have a global perspective and most likely more risks in their portfolio that can be learned from. At one stage, they may be able to say “we believe that a sufficient level of safety has been reached. Based upon the data gathered in pilot programmes, we are in a position to assess risks with a good-enough level of accuracy and offer motor insurance to autonomous vehicles.”

> *What does the insurance industry know about car driving and safety with regards to automated and autonomous vehicles?*
> *How will the total cost of dealing with accidents evolve?*

Insurance has a key role to play

Insurance companies can have a leading role in requiring certain features or devices (e.g. black boxes to collect data on car and driver behaviour and failures) or technologies, or levels of performance, that *de facto* become norms in industry and business. By setting premiums, insurance firms can encourage the development of sound risk management practices, beneficial to car owners/drivers and industry. They stand at the interface between industry (including car manufacturers and software providers), drivers (current insurance holders) and regulators (who impose rules and standards).

The insurance expertise in risk management will be a key factor in the adoption of autonomous cars. In an area where regulations and standards are yet to be fully developed, the insurance sector can encourage prudent progress by making its own risk assessments and providing policies that are adapted to the new conditions.

Insurers need data to quantify risk

Like regulators and industry, insurers need to collect data[14], and gain empirical insight into AV operation, which in turn will suggest technical improvements as well as insurance and regulatory changes, and more accurate risk pricing. A large on-going pilot programme in the UK aims to collect information for that purpose[15]. The data collected will be used to develop cars that can cope with “real world conditions”, as opposed to test tracks[16]. It will also inform regulators and insurers.
Insurers collect data from vehicles and other sources, but agreement from the automotive industry is needed to determine a standard way for vehicle sensor data to be transmitted to the cloud for aggregation and analysis. It will be essential that, in the case of an accident, it is easy and cheap for the insurer to find out who is responsible for the accident. Therefore it is necessary that a vehicle with automated features has a data collector (black box) that produces a standardized data set which is easy to interpret and the insurer will have access to this data. Regulation is needed here.

---

[14] About data partnerships between carmakers and insurers and usage-based insurance (UBI), whose penetration has stalled: http://analysis.tu-auto.com/insurance-legal/could-carmaker-data-turnaround-fortunes-ubi

[15] Eleven insurance companies in the UK are collaborating (in the Automated Driving Insurer Group - ADIG) to deal with the changes needed to regulatory (liability) and insurance. The ADIG has already identified issues surrounding driverless cars, including who could be held liable after an accident and how to cope with vehicles at different levels of automation. Concerns have also been raised over how data from individual vehicles will be recorded and used to improve safety and clarify liability, and what changes to existing road traffic laws would be needed. See http://www.autonomous-car.com/2016/01/allianz-zurich-and-axa-unite-to.html

[16] Volvo will test driverless cars on London’s roads next year, Wired.co.uk, 27 April 2016

How do insurers collect data?
How is the data standardized?
What can regulators mandate?

Insurance policyholders may change

The future of the motor insurance industry will likely look very different with the development of AVs.

- One scenario may be that car manufacturers manage and pool risk, thus self-insuring risk.
- A second scenario is that insurance companies will contract with car manufacturers.
- In a third scenario, contracts will remain with individual car owners (although drivers are not always the policyholders).

Which of the three scenarios seems the most plausible?
How will ADAS, automated and autonomous vehicles change the car insurance landscape and business models, and how will the resulting change affect the development of autonomous cars?

Insurers need to know who is responsible in case of accident

Autonomous vehicle technology facilitates a transfer of control from direct human input to automated or remote controls. This has implications for the determination of liability in the event of an accident, and will be a key factor in the pricing and structure of risk transfer. Car manufacturers may claim that they will bear the responsibility in case of an accident, while the law may dictate that the driver (i.e. a person or a “remote control system”) is responsible. There is also the possibility of subrogation between the different parties.

Will risk transfer models change, especially considering possible changes in product (civil) and personal (criminal) liability and the possible liability of a provider (e.g. software provider)?

The lack of clarity about liability attribution may significantly slow the introduction of AV technologies that are likely to change or increase that liability, even if those technologies are socially desirable.

Will the cost of accidents and of insurance increase or decrease?

It is expected that car safety will improve as the number of accidents will decrease. On the other hand:

- Each accident may cost more, due to the many parties involved, the cascading consequences and the larger extent of each accident (if for example an entire plateau/train of autonomous cars crashes because of system malfunction).
- The costs for analysing each case should decrease, if the data capture the cause of the accident. Data collected from each case would also make attribution of responsibility easier, and help determine how the claim has to be split between different parties.

Insurers expect that claims frequencies will decrease. On the other hand they expect that the average cost of claims will increase[17].

With automated and autonomous vehicles, will the cost of motor insurance increase or decrease?

[17] The future of motor insurance - How car connectivity and ADAS are impacting the market. A joint whitepaper by HERE and Swiss Re. Available on http://media.swissre.com/documents/HERE_Swiss+Re_white+paper_final.pdf

5. Regulation and standardization: advancing the agenda for regulatory frameworks that are adaptive, yet predictable

Domestic and international policies governing road traffic and car safety are varied and the landscape of regulatory institutions is quite complex. This adds to the fact that regulators do not yet have a good understanding of the new technology that they must regulate. Adaptive pathways may be a relevant option, for two main purposes: to adapt to the evolving technology and to accommodate mixed traffic situations with conventional as well as automated / autonomous cars. However they will be difficult to implement.

Regulations are designed to deal with:

- Traffic regulation to allow operation on public roads. This includes the level and type of autonomy that is allowed (e.g. self-parking, lane departure warning), but also insurance policy needed for car makers, operators, owners or drivers;
- Any provision for ensuring safety during driving and for proving performance. This includes the technical set of rules and testing procedures for certifying vehicles are roadworthy;
- Liability in case of accident. As seen above, the burden of liability could be partially transferred to manufacturers;
- To a certain extent, the kind of business model that is authorised.

Thus regulation can also serve as an incentive to internalise the risk related to AV technology, so that the risk is not passed to drivers or others.

> *What has to be changed in the legislations to allow autonomous driving, in particular at levels 4 and 5?*
> *How to design a co-evolution of regulation and technology, so that regulation does not hamper the development of the technology and associated services to society, but also does not allow the technology before it is safe enough?*

If regulators and standard-setting organisations do not establish safety requirements, but authorise AVs on public roads, even if it is only for testing, this will be good for collecting data and improving knowledge about AV behaviour. On the other hand, this means that safety requirements will be defined by judges and juries, if and when incidents and accidents occur.

> *Is this what we want?*

Various types of regulation

It is now a common understanding that regulation is not only decision of public authorities. Private regulation is valuable. It is often close to industry and best-available technology.
Another useful distinction is between prospective (ex-ante) and retrospective (ex-post) regulation, as illustrated in Table 1 below.

Table 1: Quadrants of regulation[18]

<table>
<tr><td colspan="4">Public</td></tr>
<tr><td rowspan="2">Prospective</td><td>Performance standards
Process requirements
Regulatory entry barriers</td><td>Criminal and civil sanctions
Regulatory recalls
Investigations and hearings</td><td rowspan="2">Retrospective</td></tr>
<tr><td>Private standards
Industry practice
Insurance conditions</td><td>Tort and warranty claims
Reputation impacts
Sales impacts</td></tr>
<tr><td colspan="4">Private</td></tr>
</table>

The complex network of road and car safety regulations

Ongoing regulatory changes affect issues such as:

- road traffic rules (e.g. whether a special permit or licence would be needed for autonomous vehicles[19]),
- vehicle safety standards (including whether a "black box" would be required to record driving and car behaviour),
- cross-border issues and conventions,
- data security/ownership (addressing data protection and privacy concerns),
- cybersecurity (e.g. imposing data encryption requirements), and
- over-the-air updates.

The Vienna Convention on Road Traffic from 1968 is a treaty ratified by 73 countries worldwide which establishes various standards for road traffic that all associated countries must abide by. The US is not part of the Convention and has developed its own road traffic laws. The Vienna Convention seeks to establish rules that allow the harmonization of national regulations; however, inappropriate national regulations could hinder appropriate use and development of AV technology within the 73 countries under its stipulations. The Vienna convention has been amended to make room for autonomous driving, and additional changes are on their way.

- Article 8 of the 1968 Convention on Road Traffic, which stipulated: "Every driver shall at all times be able to control his vehicle" was amended in 2014, with effect from March 2016. The amendment agreed by the U.N. Working Party on Road Traffic Safety (WP29) allows a car to drive itself, as long as the system "can be overridden or switched off by the driver". Therefore, a driver must still be present and able to take the steering wheel at any time.
- Further amendments are planned to introduce technical provisions that allow self-steering systems which, under specific driving circumstances, can take over the *control* of the vehicle, under the *supervision* of the driver. This includes, for example, Lane Keeping Assist Systems that would *take corrective measures*, instead of just *warning* the driver, or also self-parking

[18] Bryant Walker Smith, Regulation and the Risk of Inaction, in: M. Maurer et al., Autonomous Farhren, Springer, 2015, DOI 10.1007/978-3-662-45854-9_27
[19] Will car drivers need special training in an automated vehicle, specifically about the handover back from automated mode?

functions and highway autopilots. Regulation 79 must be amended to allow electric steering and the use of automated controls at speed over 10 kilometres per hour.[20]

In Europe, The Declaration of Amsterdam of 14 April 2016, on cooperation in the field of connected and automated driving, paves the way to specific agreements that are necessary for the development of self-driving technology in the EU. The Netherlands, the European Commission, EU member states and the transport industry have provided a strong political push to drawing up rules and regulations that will allow autonomous vehicles to be used on the roads[21]. Furthermore, after the Cooperative Intelligent Transport Systems (C-ITS) platform[22], the Round Table on Connected and Automated Driving and the High Level Group on Automotive Industry 'GEAR 2030' initiative[23] now provide opportunities for collaboration among stakeholders.

In selected EU countries:

- **Germany** has developed licensing regulations that permit the testing of automated vehicles, but stipulate that a driver must remain in the driver's seat and assume full responsibility for the operation of the vehicle.
- **The United Kingdom** signed, but never ratified the Vienna Convention and thus is not obligated to follow the treaty's regulations. The UK has become a potential leader in the development and implementation of AV technology. The Review of Regulations and Code of Practice published in spring 2015 makes room for driverless vehicles, which can be legally tested on public roads in the UK today[24]. Insurers are actively involved in the monitoring and data collection.
  In general UK legislation is risk-based and performance driven. For example, the minimum safe distance between two vehicles, which many countries refer to as the "2-second rule", exists in the UK (although not as a legal requirement), however a driver in the UK could be prosecuted for "driving without due care and attention"[25].
- **France and the Netherlands** allow testing of autonomous cars on public roads
- **Sweden** has authorized a project allowing real-world customer use of 100 self-driving vehicles by 2017[26].

In the US, a system of federalism divides regulatory powers between the federal government and the state governments[27].

- **The US federal government**, through the National Highway and Transportation Safety Administration (NHTSA), establishes overarching safety standards for motor vehicles. In 2013, NHTSA issued a preliminary statement of policy concerning AV technology. This document acknowledged the vast uncertainty in the developing technology and recommended that

[20] UNECE paves the way for automated driving by updating UN international convention, Press release published 23 March 2016. http://www.unece.org/info/media/presscurrent-press-h/transport/2016/unece-paves-the-way-for-automated-driving-by-updating-un-international-convention/doc.html

[21] http://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam

[22] See January 2016 report http://ec.europa.eu/transport/themes/its/doc/c-its-platform-final-report-january-2016.pdf

[23] http://ec.europa.eu/growth/sectors/automotive/policy-strategy/index_en.htm

[24] The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies, UK Department of Transport, February 2015. Available on https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401565/pathway-driverless-cars-main.pdf

[25] Safe distance between vehicles, CEDR, 2010. Available on http://www.cedr.fr/home/fileadmin/user_upload/Publications/2010/e_Distance_between_vehicles.pdf

[26] http://www.volvocars.com/au/about/innovations/intellisafe/autopilot

[27] For details, see G. Weiner and B.W. Smith, Automated driving: Legislative and Regulatory Action, available on http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action

states refrain from prematurely setting standards which could hamper the development of AVs and associated potential societal benefits. NHTSA is slated to release an additional AV policy document in the summer of 2016 that is projected to address safety and testing standards. In March 2016, it released a report indicating possible conflicts between driverless cars and existing safety rules, such as requirements for brake pedals, thus highlighting that automated and autonomous vehicles and driverless vehicles are not the same[28].

- **US states** may establish safety standards that are not in conflict with federal regulations. States also create legislation that governs the implementation and use of vehicles within each specific state – this introduces the potential for a "patchwork" of conflicting and cumbersome AV regulations within the US.
- **California** is currently developing legislation that will establish standards for safety and testing of AV, ultimately permitting public use of AVs that satisfy those requirements. A released draft of the legislation requires the presence of a human driver who has the ability to take control of the vehicle.
- **Texas and many other states** have neither specifically permitted nor restricted AVs through legislation. This potentially allows testing and use of AVs within those states' borders without requiring changes to current laws.

Standards

Developed at the national or regional level, standards provide the basis for authorising a vehicle on the roads. All features of automated driving need specific authorisations. With respect to governance of risk and opportunities, standards must be robust (meaningful and positive) and preferably performance-based (in contrast to technology-based). This will be essential for remaining flexible to the different technology concepts developed.

While some specific features of automated driving are authorised and installed on cars, there is no general safety standard that has been made explicit yet. In the US, this question may be left to be decided in tort cases. In Europe, Euro NCAP is progressively developing its guidance about the benefits of new and advanced safety technologies, and rates vehicles with its "advanced rewards"[29].

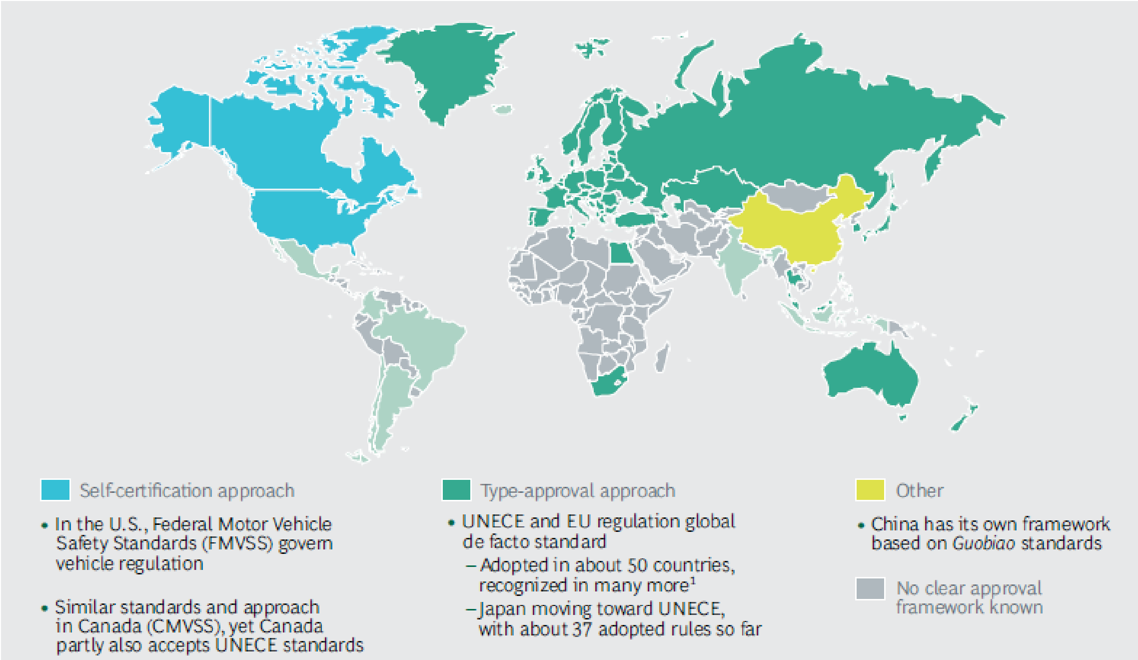
> *Where do we stand with regard to institutional evaluation criteria and procedures allowing to assess the performance/ reliability of autonomous vehicles as the basis for official approval and homologation?*
> *How to develop and ensure fail-safe and robust systems that can handle the wide variety of roads and road markings?*

[28] Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles - Identifying potential barriers and challenges for the certification of automated vehicles using existing FMVSS. Preliminary report for the Intelligent Transportation Systems Joint Program Office (ITS JPO), National Highway Traffic Safety Administration (NHTSA). Available on http://ntl.bts.gov/lib/57000/57000/57076/Review_FMVSS_AV_Scan.pdf

[29] See: "Euro NCAP Advanced Rewards": http://www.euroncap.com/en/vehicle-safety/the-rewards-explained/ and "Driver Assistance Systems"

Differences between the US and the European approach to car safety homologation

Figure 6 below illustrates various approaches to vehicle approval certification.



Sources: UNECE; expert interviews; BCG analysis.
Note: UNECE = United Nations Economic Commission for Europe. EU = European Union. Even though Australia is part of the UNECE 1958 contract, it uses only the technical requirements of the contract, not the type-approval approach.
[1]Indicated in light green; list not exhaustive.

Figure 6: Approaches to vehicle approval certification. Source: Revolution versus Regulation, Boston Consulting Group, 2015

Differences between the US-type and the European-type of car safety standards include that:

- The US regulates on the basis of "self-certification." Industry self-certifies that the vehicle and its components comply with the Federal Motor Vehicle Safety Standards (FNMSS), disseminated by US NHTSA. If a technology component proves not to be aligned with the standard, NHTSA can order its recall, which will be expensive to the OEM.
- Europe (EC and UNECE) regulates on the basis of "prior approval." Agencies set the standards before a technology reaches the market and manufacturers must demonstrate compliance before a vehicle is allowed on the market.

> *Does the regulatory approach have an impact on the speed and adoption of features of autonomous driving?*
> *Which regulatory approach is best suited to fast-moving technologies such as those developed for autonomous driving?*
> *How do regulators become "confident" that a technology or safety feature is safe and reliable enough to be authorised?*

Adaptive regulation

Although mandates and prohibition provide certainty to industry, they are in general not supportive of technological innovation. The significant uncertainty surrounding AVs creates a need for adaptive rulemaking, with planned and consistent government review of existing policies as the technology matures and safety reviews become available. Regulation of AVs is expected to be smart, flexible, and adaptive, while also remaining predictable, in particular to industry. At a minimum, specific exemptions or authorisations can prepare future regulation.

While some forms of uncertainty cannot be resolved until AVs are actually deployed in the real-world, consistent monitoring of managed deployments, or pilot studies, offer opportunities to learn from real-world experience. In order for regulation to adapt and learn from experience, mechanisms for "planned adaptation" must be established.

Planned adaptation acknowledges the fact that mistakes will be made when creating regulations under uncertainty, but also seeks to actively mitigate and improve upon mistakes made. Rather than changing policies in a reactionary manner, organizations committed to planned adaptation must have a "*prior commitment to subject an existing policy to de novo re-evaluation*" in addition to creating a "systematic effort […] to mobilize new factual information for use when the re-evaluation takes place." Such mechanisms for planned and informed change, if committed to, create a means for policymakers to continue pushing towards the ever-elusive goals of maximized social benefit and minimized risk[30]. Adaptive regulatory strategies take the form of regular ex-post risk and impact assessment, to integrate learning from accidents, near-accidents and non-accidents.

Effective adaptation of regulation for automated/autonomous vehicles would require consistent and continuous *monitoring* of AV technology and use, learning from testing the car behaviour in real-world conditions, and i*ntegrating feedback into regulatory reviews*. Flexibility would create uncertainty to industry, so early collaboration between developers (in industry and elsewhere) and regulators (including standard setting organisations) is needed to avoid "all-or-nothing approval decisions at the end of product development"[31]

Regardless of what specific form it takes, planned adaptation requires a commitment to gathering and monitoring information with the intent of adapting policies to reflect the enhanced understanding appropriately. As an example relevant to AVs, the US National Transportation Safety Board (NTSB) aims to promote transportation safety by serving as an independent knowledge-assessing body that presents safety recommendations to policymakers. NTSB can suggest regulatory review or adaptation if needed, as a result of independent safety assessment. While NHTSA wields the federal regulatory power within the US, NSTB provides a third-party perspective that offers to enhance the decision making of NHTSA and guard against inadequate understandings or biases. Such a relationship could prove influential for effective knowledge gathering and adaptation of AV regulation within the US[32].

What does it mean in practice? Is this a realistic endeavour?
Are regulators interested in planned adaptive regulation?

[30] See: McCray, Lawrence E., Oye, Kenneth, Petersen, Arthur. "Planned adaptation in risk regulation: An initial survey of US environmental, health, and safety regulation." Technological Forecasting and Social Change 77.6 (2010): 951-959. http://www.sciencedirect.com/science/article/pii/S0040162509001942

[31] Bryant Walker Smith, Regulation and the Risk of Inaction, in: M. Maurer et al., Autonomous Farhren, Springer, 2015, DOI 10.1007/978-3-662-45854-9_27

[32] Ken Oye et al., ON REVISION OF THE COORDINATED FRAMEWORK FOR THE REGULATION OF BIOTECHNOLOGY. See in particular Part II and Appendix B in Version 12 March 2016. Available from: http://poet.mit.edu/sites/default/files/images/ON%20REVISIONOFCF2016-03-22-FINAL.pdf

6. Governance and policy

AV policy goals should seek to leverage existing information to maximize social benefits while minimizing risk. Overregulation could hinder the development of the technology and prevent potential benefits, yet naively optimistic policies could place the public at undue risk. A consistently improving understanding of the risks and benefits surrounding AV is needed to foster an environment that effectively promotes the benefits of AV technology.

Many actors are interested in pursuing appropriate, benefit-maximizing regulation – how can they drive the development towards appropriate and effective regulation?
How to design a forward-looking governance agenda that derives from a vision of a desired future (backcasting approach)?

Roadblocks and incentives

The main roadblocks that must be overcome or incidents that could negatively affect the developments of AV on the roads include:

- A well-publicised system failure
- The setting of adverse legal precedent(s)
- Successful "anti-autonomous" campaigns led by special interests (including those professions which may lose business)
- The marginal cost of technology exceeds the mass market's perceived value ("willingness to pay")
- General disruption to innovation in the automotive industry (vested interest in current technology for human-driven vehicle)

What are the key incentives points across the value chain?

- Bold legislative or regulatory change mandating safety improvement
- Significant infrastructure investment from government
- Global / multilateral agreement on standards to allow autonomous vehicles
- Significant advances in autonomous driving technology and/or manufacturing methods
- Tax incentives for individual consumers or businesses to make the investment

Vested interests and conflicting agendas

Under these two headings, we suggest that the risk of certain actors to block or deliberately slow down the development of autonomous vehicles must not be neglected. It is a priority not to block changes that are overall desirable.

Many of the significant potential benefits of AVs constitute a public good. Public goods (like fresh water, health or education) are usually managed by public authorities that impose rules for their management, and many of the rules are not cost-efficient. Reducing road accidents will benefit society overall (and tax payer in particular), yet the cost of reducing road accidents thanks to vehicle automation incurs most to those who purchase cars. AVs are more expensive than regular cars.

Are drivers or those who purchase cars, willing to pay more for an automated vehicle than for a conventional vehicle, and how much?

Selected incentives must target every individual who will buy the technology.

> *Will public authorities be willing to contribute financially to individual decisions to invest in a technology that saves other people's life, in addition to financing the new infrastructure needed (sensors and network connections)?*

Also, some **car manufacturers** may be tempted to stay with conventional technology, because there is a market for it and first-mover advantage has not been demonstrated yet. Similarly, **insurance companies** may decide to wait and see before engaging. Finally, as demonstrated by the precautionary attitudes in many states, **policymakers** may welcome the idea of societal benefits, but be reluctant to engage in actual decisions about promoting the technology. They have conflicting agendas and other tougher priorities, so why change the current system where the balancing of cost and benefits is well organised?

Adaptive pathways

In order to avoid technological lock-in, performance-based regulations for AVs will be key. Such regulations would allow for flexibility in the technology chosen to meet the desired objective (e.g. safety) and flexibility in the type of autonomy that a vehicle offers. Even if there will be dedicated areas or lanes for AVs, it must be possible to have on the roads conventional (not automated) cars, partly autonomous cars and fully autonomous cars. Rulemaking must adapt as technology progresses and new products are offered, and as new and socially desired business models appear. Pilot studies that allow AVs on public roads will provide informed and empirical data, which must be leveraged to update relevant regulations to reflect the increased understanding and to inform the public to create societal support.

Two models of AV development

In "Revolution versus Regulation", a report written in collaboration with the World Economic Forum, the BCG[33] describes two different approaches to the development of autonomous vehicles in increasingly complex traffic situations:

- Industry "incumbents" (i.e. OEMs) gradually add more and more autonomous driving features to increase the level of automation in private cars sold to drivers. In doing so, they progressively accustom their consumers and build confidence over time.
- Industry "challengers" (e.g. tech companies) prefer to start with self-driving capabilities in narrowly defined traffic situations, such as urban environments, and with conventional fleet operators. Then they plan to expand these traffic situations over time. They collect data from limited experimentation fields, which is used for building new services to replace existing ones (e.g. shuttle services in place of conventional taxis). In doing so, they opt for disruptive business models.

The OECD / ITC report "Automated and autonomous driving, regulation under uncertainty" describes a similar incremental path[34].
Without commenting or evaluating the pros and cons of these models, we believe that allowing different approaches to co-exist during the learning phase is a constructive approach to adaptive pathways.

---

[33] Revolution versus Regulation, Boston Consulting Group, September 2015

[34] Automated and autonomous driving, regulation under uncertainty, OECD International Transport Forum / Corporate Partnership Board, 2015. Page 13. Available on http://www.itf-oecd.org/automated-and-autonomous-driving-regulation-under-uncertainty

Public sector strategies

In "How governments can promote automated driving", Bryant Walker Smith[35] suggests that a progressive approach to autonomous driving should see:

- On the side of the industry a "candid" attitude revealing how the industry defines and explains what reasonable safety means to them, how they are satisfied with their performance on important safety issues, and how they engage in a lifetime improvement of their systems.
- On the side of governments, a combination of (i) administrative strategies, including preparing agencies, public infrastructure and advocacy for safety mandates; (ii) legal strategies, to clarify existing laws and incentivize AVs; and (iii) community strategies, to account for local needs, opportunities and resources relevant to AVs.

Conclusion

As seen in the introduction, the pace and timing of AV's authorisation depend on political and economic decisions as well as technical features and design, safety and reliability performance, and public perception. This paper has provided some insights on various aspects, including the need to collect data from testing and pilots, to provide the evidence needed to decision makers. A combination of technical evidence, regulatory and insurance support should in turn create the necessary confidence among the public and drivers, which is ultimately the final requirement for people to buy, drive or travel in autonomous cars.

Acknowledgments

This paper was written by the IRGC secretariat (Marie-Valentine Florin) for the purpose of informing discussion at an expert workshop to be held on 15-16 June 2016, at the Swiss Re Centre for Global Dialogue, in Zurich. The paper was reviewed and improved thanks to comments received from Simone Amorosi (EPFL), Shane German, Arnaud de La Fortelle (University Mines-ParisTech), Kenneth Oye (MIT), and Andrea Keller, Gerhard Schuster and Roland Voggenhauer (Swiss Re).
It was also informed by answers to a question asked to workshop participants: *"in your opinion, what are some of the most important roadblocks to and/or incentives for the development of autonomous vehicles, which require collaboration between various stakeholders (industry, insurance, regulation and research)?"*

[35] Published on March 17, 2016, available from newlypossible.org

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

international risk
governance center

http://irgc.epfl.ch www.irgc.org irgc@epfl.ch