Freeing the Road:

Shaping the future for autonomous vehicles

A Policy Network Special Report

Florian Ranft, Martin Adler, Patrick Diamond,
Eugenia Guerrero and Matthew Laza

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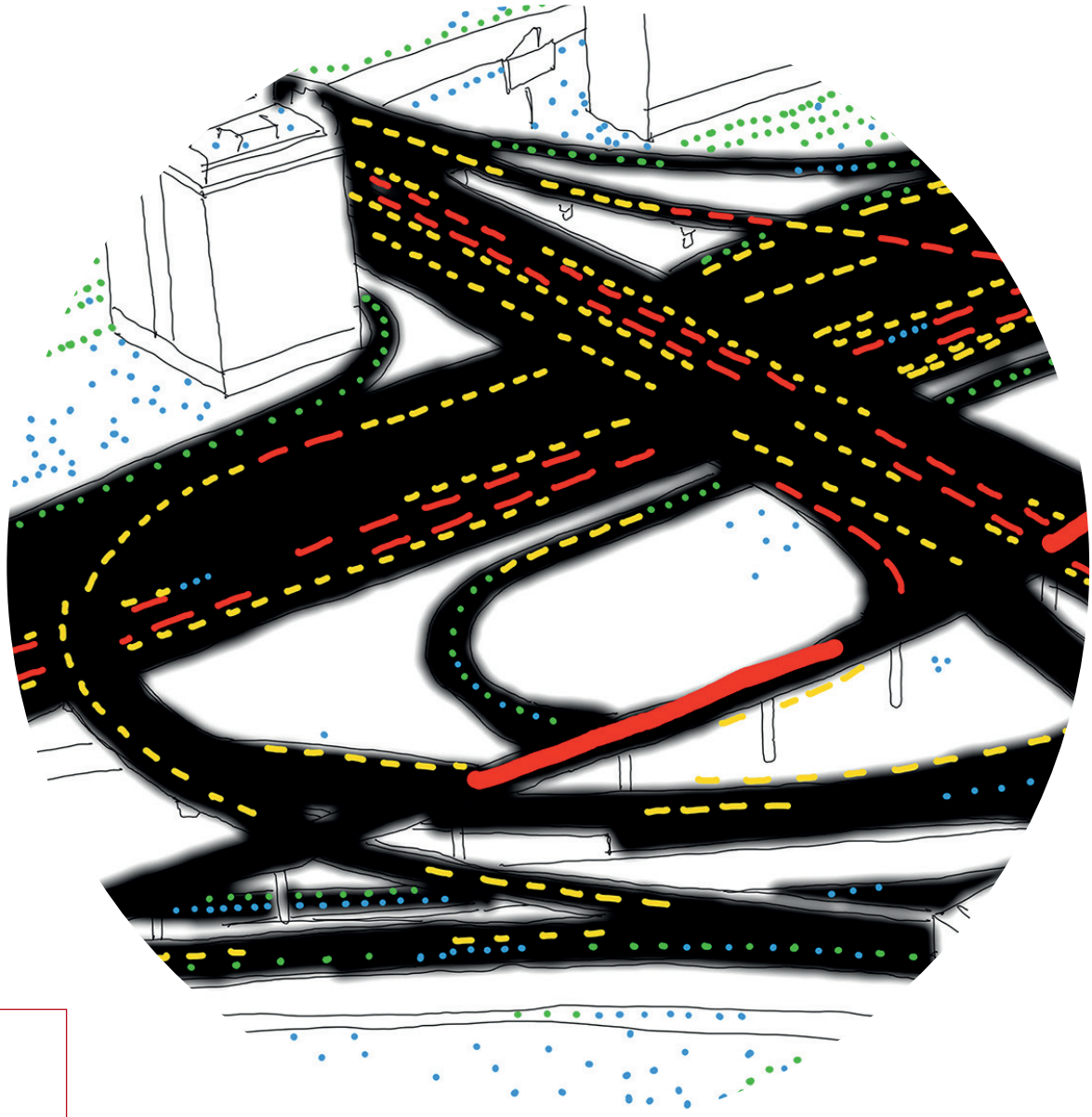

Policy Network
Second floor
11 Tufton Street
London SW1P 3QB
United Kingdom

t: +44 (0)20 7340 2200
f: +44 (0)20 7340 2211
e: info@policy-network.net

www.policy-network.net

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We are also grateful to Theo Möller who has contributed the original graphics used in this report. Theo is an interior architect and designer, a graduate of the famous Burg Giebichenstein, Halle, Germany. He is a freelance designer at Ikea, Sweden, and a 2014 award winner of the Ikea foundation.

Cover image credit: Theo Möller

Executive summary

This Policy Network report, prepared with support from Nissan Europe, analyses both the social and economic opportunities offered by the transformation to autonomous driving (AD) on Europe's roads. It also deals with the potential barriers faced and provides answers as to how governments and regulators should respond.

Focusing on three key countries – Germany, Spain and the UK – it highlights crucial features of the policy debate around autonomous vehicles (AVs) and assesses the likely economic impact for the continent as a whole.

The principle finding is that if – and this report outlines the reasons why this remains a big if – policymakers get the big picture right and put in place rules that properly promote the change, the economic benefits of AV for Europe will be overwhelming.

Our original economic analysis shows that, in such a scenario, autonomous vehicles will start adding 0.15 per cent Europe's annual growth rate in the decades to come. As a result, the European (EU-28) gross domestic product will, cumulatively, be 5.3 per cent higher in the year 2050 than currently, by which time autonomous vehicles will have contributed a total of €17tn to GDP.

Yet, the speed at which autonomous driving becomes a reality on Europe's roads depends at least as much on the regulatory framework as it does on technology itself. The main task for policymakers is to continue their efforts in shaping the necessary environment for the introduction of AVs – moving from the current support for research and testing to the concrete legal rules that keep pace with the continuing move towards ever more autonomous capability.

So far policymakers have not yet resolved the issues thrown up by full autonomy despite it being clear that we are within touching distance of manufacturers being able to produce vehicles with just such 'driverless' technology. Unless the pace of regulatory change rapidly picks up, Europe's policymakers risk falling behind the pace being set by the automotive industry. An initial priority must be a renewed push for the harmonisation of national and international regulation, in order to ensure a seamless move towards AD in Europe.

The main barrier expressed in the political and public discourse on AV is around safety and security; particularly how to achieve social acceptance from consumers. From our conversations with experts and policymakers it became clear that each country has adapted a distinct policy strategy.

German legislators have put safety and legal certainty first and might lead the way on settling these vital questions if they pass a bill that will require highly automated vehicles to install a 'black box'. The device would work as a data recorder that collects information on who is driving the vehicle at a certain time, removing the uncertainties over whether a person or machine is responsible in the case of an accident.

The UK, meanwhile, has adopted a 'rolling programme' approach to try and gain first-mover advantage by reforming policies step-by-step in line with technological progress.

During a prolonged period without a confirmed national government, Spain's policy leaders have sought to champion strong regional clusters that can set the pace for a nationwide adoption of AV technology.

As our economic cost-benefit analysis suggests, the implications of AV introduction for Europe's economies will be substantial. This change will be most heavily felt in urban centres. These lie at the core of economic productivity, but are also heavily affected by road congestion, land scarcity and environmental constraints. Municipal and city officials must understand that AD has the potential to offer significant solutions to each of these hitherto intractable problems, but this is contingent on decisive and consistent policy action. The public good is also set to benefit: rather than looking at the road, ambulance staff can look after their patients; and parents can engage with their kids' homework, rather than traffic lights on the school run.

As with other such significant technological revolutions, AV offers vast economic opportunities. But these do not come without any risks for society as a whole. The transition to a driverless future will require policymakers to properly embrace and understand the seismic impact not only on the automotive economy and the future transport, but also the much wider implications for research, work, and businesses, beyond those most obviously involved. Without concerted policy efforts, AV might play into the hands of populists preying on fears arising from globalisation, which would in turn stall the rollout of the new technology. It is essential, if we are to prevent populists focusing their fire on fears arising from digitalisation, that governments bring their populations with them on the AD journey by preparing for, rather than reacting to, the initial disruption to the labour market which is inevitable. Our research shows that, ultimately, the impact of AD on productivity and job growth will be positive, but the transition will need to be smoothed for those affected, or those who worry they will be affected.

AD is not just about economic change, it will also be a social revolution. The report shows how AD will play a key role in tackling social exclusion, by giving more people access to the freedom of vehicle transport and consequently access to educational and work opportunities. Crucially, if planning begins now, AD presents the opportunity for a genuinely integrated and localised public transport system that connects right to the front doors of homes and workplaces, even in areas which at present are cut off from such networks. And, perhaps most vitally of all, AD will be a huge tool in tackling the consequences of Europe's ageing society – ensuring that members of our increasingly ageing populations do not lose their mobility and connections to vital services.

Freeing the Road offers 11 concrete policy innovations that, if implemented, would not just aid a successful transition to automation but would also ensure that the benefits that arise will be spread as widely as possible.

Europe's policymakers should be under no illusion: a future of autonomous driving is upon us. It cannot be dismissed, and is not going to go away. There is a real chance for the continent to seize the chance to maximise the economic and social good. But it will require urgent, concerted and coordinated action. This report aims to show how.

Introduction

Autonomous vehicles (AV) have longed seemed like something from *Tomorrow's World* – a technological development that politicians, regulators and policymakers could put off thinking about until long into the future. Now, with the first manufactured AVs set to roll off the production line, Europe's policymakers must fast catch up with technological and commercial reality. AVs not only have the potential to fundamentally reshape Europe's strategically vital automotive industry; they will change how citizens interact with motor vehicles, transform patterns of connectivity, and offer social and environmental benefits to the whole of society. This future vision is of a driverless, safer and more efficient transport system that will connect individuals and businesses throughout Europe.

European countries are beginning to engage with the changes that AVs will bring. However, to reap the benefits of the new transport technology, leadership will be needed at all levels to maximise the potential of AVs in the 21st century. A number of countries – notably Germany, Spain and the UK – have 'dipped their toes in the water' by allowing test driving of AVs on their roads. But the measures needed for the widespread adoption of driverless technology will require a more rigorous response from European policymaking institutions at the EU, national, regional and city level. At all those levels of government, there is an imperative to act now.

Replicas of sci-fi character Michael Knight's famous autonomous car – AVs were once considered a futuristic dream

Making progress on AVs, like other new technologies, means acknowledging that there are always winners and losers from change; pro-active public policies are needed to ensure that everyone is equipped to cope with change, and that, ideally, no one is left behind. AVs can become a crucial tool in improving the connectivity of individuals and communities. In a 21st century economy and society, connectivity is crucial for success in linking people with employment, public services, social networks and cultural capital. AVs have the capacity to help integrate 'left behind' places and regions into the growth economy, ensuring that all our citizens have a better chance of joining the winner's circle of growth and prosperity.

Picture credit: The Conmunity - Pop Culture Geek

The adoption of autonomous drive (AD) will take place in the context of major structural shifts in Europe that are already impacting on the lives of consumers and citizens. First, demographic change will transform the consumer landscape. The increase in the number of older drivers will bring a heightened concern about how those increasingly elderly road users can safely maintain their independence and freedom. Ageing societies will increase the demand for new types of motor vehicle, including assisted driving technologies. Older people will also need more specialist services and support, including better connections with public services and public transport. There is a clear role for AD in meeting all of these challenges, with the potential to provide genuinely empowering solutions.

The second major structural shift is the growth of urban spaces and the emergence of 'megacities' which have the potential to transform how we travel and connect. Strategic planning will be needed to maintain quality of life and promote sustainability, including the development of high quality public transportation infrastructure. Autonomous vehicles promise to be great enablers in this transition.

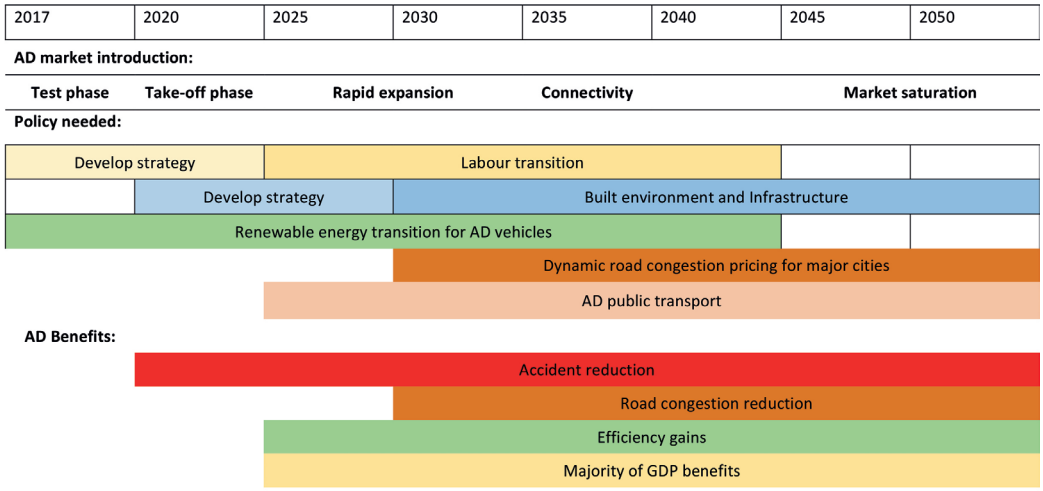
Yet for this to happen, for the full social good of AD to be unlocked, policymakers must ensure that citizens and communities embrace and do not fear this technological change. To do this, they will need to rewrite the rules for AVs and invent flexible and responsive regulations around them. The major challenges will be to fashion regulations that allow enough flexibility for the introduction of AV technology but that simultaneously recognise and meet the safety and security concerns of the public. At the same time, industries and SMEs need greater certainty about the impact of future legislation in order for the move to AV to be commercially viable.

Therefore, this report recommends the following priorities:

- **Raise awareness of AV technology in politics**, and bring it to the forefront of the modern economic policy agenda centred on higher productivity and growth.
- **Guarantee that regulations are in place** to create a safe environment for citizens and businesses.
- **Create new partnerships** between industry, businesses and the public sector to reap the benefits of AVs: car manufacturers, insurance companies, tech companies, higher education, but also SMEs and startups that specialise in AV technology, data transfer, smart engineering, and advanced manufacturing.
- **Engage with policymakers at all levels**, especially cities where mayors are set to be major decision-makers.
- **Continue to make smart investments in infrastructure, skills and the human capital** of the future.

In developing this agenda we examine the economic benefits of AV technology in Europe, and develop a detailed set of policy recommendations for local and national policymakers. The findings of this study are based on a comprehensive cost-benefit analysis using the latest economic models, as well as interviews with leading policymakers, politicians, officials and experts on AV technology in Germany, Spain, the UK and Brussels.

Figure 1: Timeline of AV adoption



Policy Network is grateful to Nissan Europe for supporting the development and dissemination of this work, but the study itself is firmly independent and Policy Network remains responsible for its findings.

Freeing the Road is the first attempt to lead a serious public debate about the economic and political opportunities and barriers to the adoption of AVs in Europe, and how best to overcome them. We hope it proves just that – the start of a debate about how this enormously exciting, if still for many slightly unreal and a occasionally scary, technology can play an enormously exciting role in both driving Europe's economy forward but also proving a genuine force for public good.

Regulations: debates and reforms in key countries

The policy challenge

Today we stand on the threshold of a revolution in mobility. But like any threshold it can seem both a little scary and a little unreal. For the revolution is not here just yet. At present, only a privileged few benefit from the technological advancements of autonomous driving – currently only a handful of super-luxury models are equipped with advanced automation and even then there can be waiting lists.

This means that for almost all of the world's 1.2 billion drivers[1] autonomous driving remains a futuristic concept – much discussed in the news, as well as motoring pages, but not yet seeming within reach, even less experienced. But that is now set to change, and change rapidly.

A number of car manufacturers have developed automated driving technology marking another step in the transition to AV. In 2017 a new variant of the Nissan Qashqai will roll off the production line in Sunderland, north east England. It will be equipped with 'ProPILOT' making it the first mass-market car in Europe to be equipped with 'level two' automated capability. In the premium segment Mercedes-Benz' launched the new E-Class in 2016 which comes, albeit as an optional feature, with the Drive Pilot, an partially automated driving system. Others will follow suit. Volkswagen has announced to equip the new Golf with a partially automated driving system. It will assist the driver in manoeuvring through traffic jams situations of up to 60 km/h. The model is expected to roll off in 2017.

> *"Technology advances faster than regulation"*
>
> *Industry insider, Spain.*

But when that new autonomous technology takes to Europe's roads it will be subject to a confusing web of regulation. Once again it is a case of technology and the market running ahead of politicians and regulators. Yet unlike in other areas of rapid tech evolution, like the internet itself, this is not a field where the market can gradually evolve and government can play de facto 'catch-up'. Quite rightly when it comes to our roads, regulators need to give the green light and agreement on rules needs to be reached before such a radical technological change can be fully embraced.

This gives European policy leaders a huge opportunity – to work with industry to shape those rules and help the continent gain world leadership in sector with huge commercial possibility. But with that opportunity comes a risk; a risk that the pace of regulatory evolution fails to keep pace with the technology and that Europe's opportunity ebbs away. The good news is that this is a revolution that is planned – in the sense that the technological direction of travel is now clear and the road-map and the timetable for the roll out of ever greater automation evident.

This amounts to an opportunity which must be seized now. The purpose of this report is to demonstrate how it can be, to show what needs to be done to genuinely 'free the road' for the autonomous driving revolution that is upon us. The speed at which autonomous driving becomes reality on Europe's roads depends at least as much on the regulatory framework as it does on technology itself.

1. Voelcker, John (2014): 1.2 Billion Vehicles On World's Roads Now, 2 Billion By 2035: Report, http://www.greencarreports.com/news/1093560_1-2-billion-vehicles-on-worlds-roads-now-2-billion-by-2035-report (last accessed: 9/11/2016).

What is autonomous driving?

An autonomous vehicle is one equipped with technology that allows it to drive and steer without the need of active control or supervision on behalf of the driver. This term is used to encompass cars with differing levels of automation which can be activated or deactivated in a permanent or temporary capacity.

To distinguish between the different levels of autonomous capability a 1-5 scale defining each stage is generally used (see Figure 2). At present only stage one has been achieved at any scale, where several manufacturers, mostly in the luxury market, have introduced 'parking assist' type technology. One or two luxury models are also equipped with capability that could be defined as stage two; now Nissan is set to bring such capability to a much wider public.

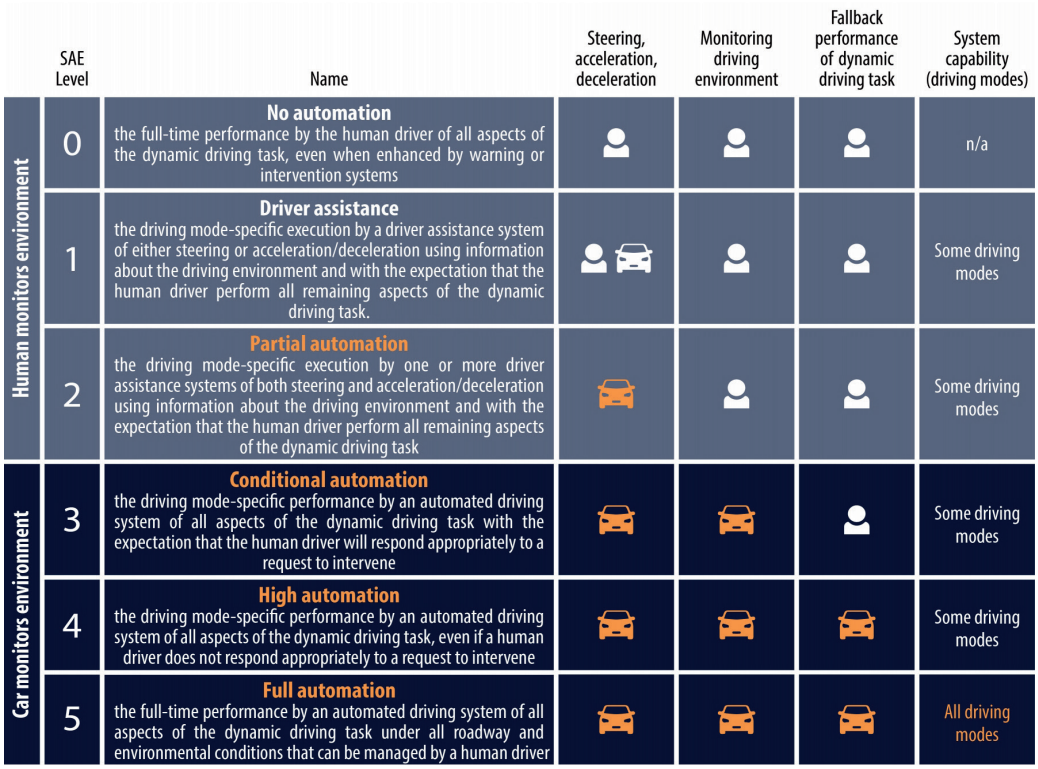
It is important to remember that vehicles will become automated step by step. While the term "driverless" is often used, and has rather caught on to the public imagination, the truth is we are, for now, some way away from entirely removing the need for a driver. The reality is that remains a longer-term goal for most vehicle types, as the technical challenges for manufacturers to produce fully automated vehicles that can operate without a driver in all types of traffic conditions are still very high. (And, as this report will show, regulation has a long way to go to evolve to cope with such truly 'driverless' vehicles.) Though something of the future at present, fully driverless cars are, if not quite round the corner, most certainly on the horizon. They should be regarded as a technology in sight, not the stuff of science fiction.

The concept of "automated vehicles" is also often associated with "connected vehicles". However the two concepts, while complementary, are different but are predicted to converge in the eyes of many experts, including the European commission.

A vehicle does not necessarily need to be 'connected' to be 'autonomous'. On the one hand, partially automated vehicles are already available on the market and are able to sense their environment without necessarily being connected to a network, a road infrastructure or to other vehicles. On the other hand, those connected vehicles available on the market (internet surfing, traffic information, GPS, e-call, vehicle-to-vehicle and vehicle-to-infrastructure short-range communication, etc) do not carry out driving tasks for the driver, unlike like automated vehicles.[2]

2. Contrary to automated vehicles, connected vehicles need an interoperable communication network or standards that, depending on the application, can either be a dedicated communication standards (eg ETSI ITS-G5 in the case of vehicle-to-vehicle or vehicle-to-infrastructure communications where no third party network is needed) or can use a third party commercially available network like the cellular communication network. Note that in its report published in January 2016, the C-ITS platform concluded that currently neither ETSI ITS-G5 nor cellular systems can provide the full range of necessary services for C-ITS. Consequently a hybrid communication concept is therefore needed in order to take advantage of complementary technologies.

Figure 2: Levels of automation



Source: European parliament (2016): Briefing: Automated vehicles in the EU, p. 4.

The task for policymakers

Europe's policymakers are, thankfully, alive to the possibilities offered by autonomous driving, but their approach can fairly be described as cautious. EU transport commissioner, Violeta Bulc has expressed excitement about AD but, as recently as a public event in Brussels on 18 October 2016, has restated that her main concern is getting the right set of rules and regulations in place.

After recent difficulties with key industrial players violating existing norms and rules, such caution is, perhaps, understandable and the commission seems keen to learn from past mistakes. As commissioner Bulc has said, "my team has put strong emphasis on how to best use the new technologies, to maximise their value. I would think this is typically European: trying to understand what technology should actually serve for before putting in on the market. In the long term, this may prove to be an advantage."[3] In order to gain such an understanding the emphasis is being put on consulting all relevant stakeholders to find sustainable and safe policy solutions.

The question of AD regulation is complex; a cross-cutting policy challenge touching upon industrial policy, research and development, business and innovation, infrastructure and road traffic rules. On top of that, in order to successfully transition from manual to connected and autonomous vehicles, policymakers will need to think beyond traditional concepts of traffic policy. Product liability, cybersecurity, intellectual property and connectivity will all need to be taken into account. This chapter will give a detailed overview of the policy process behind these concepts and how policymakers can lay the legislative foundations for an autonomous future.

3. 2025 AD (2016): EU commissioner calls for intense G& cooperation on driverless cars, https://www.2025ad.com/in-the-news/blog/violeta-bulc-driverless-cars/ (last accessed: 9/11/2016).

Among the main regulatory challenges identified in our analysis – which concentrates on the key markets of Germany, Spain and UK – are public safety concerns and the harmonisation of existing international and national legislation. Most regulations currently in place date back to an era where connective technology played a mostly passive role in vehicles, making driving a more pleasant experience (eg parking sensors, navigation systems) or improving security overall (eg anti-lock-braking systems, adaptive cruise control or electronic stability control).

If machines are to, partially or fully, take over from the driver in an active manner then a key step must be to address public concerns over the security and reliability of AV technology. A key question will be who is responsible in case of an accident, a concern which has grown in the public consciousness since the fatal accident involving a Tesla autonomous drive model this summer. As a survey by the World Economic Forum[4] and the Global Automotive Consumer Study[5] show, consumers expect technology to significantly improve road safety and security. This is even more relevant for Generation Y, of which 79 per cent of respondents expect that in-vehicle assistance systems and road monitoring systems will be a great benefit for the overall safety of road users.[6] However, our study will show that public concerns over security and safety of highly automated and autonomous vehicles rank high in the political discourse which is arguably caused by the lack of first-hand driver experience of consumers and sometimes sensationalist media coverage.

In order to gain the necessary public confidence a robust and popularly respected regulatory regime will be essential, and for that international agreement and adoption will be essential.

International regulatory landscape

The regulation of vehicles is governed by national law but is heavily affected by European and international law. On the international level, the 1968 Vienna Convention on Road Traffic, designed to facilitate international road traffic, contains principles defining both the admissibility and liability of new technology.

As we will show, in the case of Spain and the United Kingdom, the international laws were less of an impediment to the implementation of self-driving technology because both countries are signatories to the Vienna Convention of Road and Traffic but have not ratified it. Germany's ratification of the Convention, however, means that its consequent laws present more of a challenge to the adoption of fully autonomous vehicles. In our conversations, experts emphasised that this gave the non-ratifying nations a head start until April 2014 when the international code was amended, making it easier for autonomous technology to be adopted even in those countries who had ratified the Vienna treaty.

Today the question of ratification or not of Vienna is having a more minor difference on the development of technology, because testing, and therefore research, is more or less allowed in most European countries. It may, however, have an impact on manufacturers in Germany and other ratifying countries once we enter the stage of full autonomy production – where the Vienna rules are much more cautious – if international law is not reformed in due course.

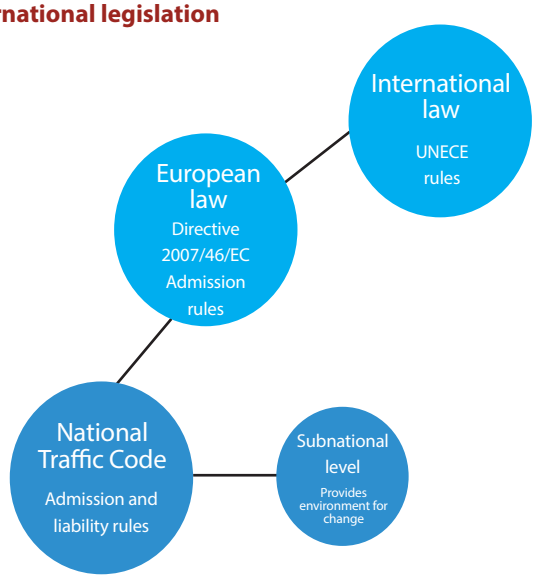
Covering the regulatory framework at the international (United Nations), intra-national (European Union), and national levels (Spain, UK, Germany) will give us a coherent picture of just how intertwined the regulations governing automated vehicle technology are.

4. World Economic Forum (2015): Self-Driving Vehicles in an Urban Context, http://www3.weforum.org/docs/WEF_Press%20release.pdf (last accessed: 27/10/2016), p. 16.

5. Deloitte (2014): Global Automotive Consumer Study Exploring consumers' mobility choices and transportation decisions, https://www.autonews.com/assets/PDF/CA92618116.PDF (last accessed: 27/10/2016), p. 15.

6. Ibidem.

Figure 3: National and international legislation



Source: based on Fraunhofer IAO (2015) Hochautomatisiertes Fahren auf Autobahnen, p 112.

United Nations: Geneva and Vienna conventions on road traffic

The United Nations' Vienna Convention on Road Traffic states that 'every moving vehicle or combination of vehicles shall have a driver' and that 'every driver shall at all times, be able to control his vehicle'. For that reason, it has been seen as an impediment to the deployment of self-driving cars on public roads in the 74 countries that have ratified the convention, including all European countries besides Spain and the United Kingdom[7].

In order to overcome this barrier, several European countries which are keen to implement self-driving cars have been pushing for an amendment to the convention – including the governments of Germany, Italy, France, Germany, Belgium and Austria. They highlight the evolved stage of the development of self-driving technology in Europe. In light of this effort, in March 2014 a new paragraph was added to Article 8 of the 1968 Convention on Road Traffic so as to allow a car to drive itself insofar as the vehicle's system "can be overridden or switched off by the driver". This amendment entered into force on 23 March 2016.

Yet this amendment, in using the term "driver", will still not fully allow autonomous cars to take to the road, as it explicitly states the driver has to remain in control while the autonomous system is operating. For this reason, Belgium and Sweden have pushed for additional amendments to the Vienna Convention. Crucially, their proposal calls for a redesign of Article 8, so as to clarify the differing levels of automated driving: distinguishing between the need for the driver to be able partially or completely to take over control from the vehicle for either a part or the whole of a journey.

Thus far, further proposals to amend the Vienna Convention so as to legalise totally autonomous cars (SAE level 5) have not passed. But in the longer term a new agreement could be accepted in the next session of the United Nations' Road Safety Forum in March 2017. This does, however, mean that any amendments would not take effect before the start of 2018.

7. United Nations Economic commission for Europe (2007): List of Contracting Parties to the Convention on Road Traffic, http://www.unece.org/fileadmin/DAM/trans/conventn/CP_Vienna_convention.pdf (last accessed: 27/10/2016).

Table 1: The current state of the UN discussions

SAE level		How to address
0	No Automation	NA (in compliance with the current regulation)
1	Driver Assistance	NA (in compliance with the current regulation)
2	Partial Automation	Mostly WP.29 will discuss each related standard (including guidelines) based on the assumption that the driver monitors the surroundings and is responsible for driving, and will share information on ACSF with WP.1 as necessary.
3	Conditional Automation	Mostly WP.1 will address issues such as the permissible range of sub-tasks for drivers. To support this discussion, WP.29 will share technical information for each applicable use case, etc.
4	High Automation	Since it is in the domain of almost fully automated driving and therefore the driver is not held responsible, it is likely that these levels cannot be addressed in the scope of the current Vienna and Geneva Conventions. Accordingly, WP.29 will start discussions after the results of WP.1's discussions are made available.
5	Full Automation	

Source: UN WP.29 Document No. ITS/AD-09-12 (9th ITS/AD, 22 June 2016, agenda item 3-2)

When the, fairly slow grinding, wheels of the UN finally reach agreement a key element of the process of rolling out AD in Europe will be the successful transposition of the updated Vienna Convention into EU law.

EU regulatory landscape

There exists no legislation at the European Union level that could be considered an overwhelming barrier for the upcoming roll out of partially automated vehicles, up to level 2 automation. However, higher levels of automation which cede full control of the driving from the driver to the vehicle, either for an extended or the full length of the driving time, would require changes to EU legislation. Here the EU sets the barriers for the use of automated cars on public roads which is permitted by law. Generally, the European commission (EC) approval for cars sold in member states follows Directive 2007/46 EC, and Regulation (EC) No 661/2009, which do only partially spell out technical requirements but refer to the applicability to the majority of ECE regulations.[8] This means that the UN regulations set the pace and the EU follows. In particular, legislation concerning connectivity, privacy, and data protection would need to be determined at the EU level for that greater level of automation to be adopted on Europe's roads.

At present, five Directorate-General groups within the EC are actively shaping the rules on autonomous driving for the single market. Directorate-General groups work together to achieve cross-cutting objectives, led by the commission vice-presidents:

- DG MOVE is tasked with delivering a safe, efficient, secure, and environmentally friendly mobility, which would set the conditions for a competitive industry generating growth and jobs.
- DG CONNECT is working to establish a digital single market in order to engender smart, sustainable and inclusive growth throughout Europe.

8. Lennart S. Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, http://www.genre.com/knowledge/publications/cmint16-1-en.html (last accessed: 22/10/2016).

- DG GROWTH is responsible for helping turn the EU into a smart, sustainable, and inclusive economy. It focuses on fostering entrepreneurship and growth, launching research actions to spur technological innovation and economic growth, and delivering the EU's space policy.

- DG JUSTICE seeks to build a European area of justice by upholding the rule of law and linking up Europe's justice systems.

- DG Research's role centres on establishing Europe as a leading hub for disruptive innovation and for scaling startups into world-beating businesses.

- DG FISMA (Financial Stability, Financial Services and Capital Markets Union) is responsible for initiating and implementing policy in the area of Banking and Finance.

This multi-headed approach did leave many of those we spoke to worried that there was a lack of overall leadership on the question of AD and that the shaping of future rules could be subject to friction and differently competing demands between the different DG.

"The commission's working group are operating like an animal on six legs"

-Senior official, European commission

GEAR up by 2030

Existing EU regulation does not pose a barrier to vehicles with level 2 automation. However, vehicles equipped with level 3 automation and beyond remain in a grey regulatory area. GEAR 2030 is an EU High Level Group for the automotive industry. Its overarching aim is to ensure a co-ordinated approach between member states, and to address the competitive challenges faced by the European automotive industry. GEAR 2030 focuses on three areas of work: the application of the value chain to new global challenges; a spotlight on trade, international harmonisation and global competitiveness; and, perhaps most importantly, the implementation of automated and connected vehicles.

This group will use existing platforms as much as possible. For instance, the Connected Driving platform ("C-ITS" platform), a discussion forum forvehicle connectivity, will inform the GEAR 2030 discussions. DG CONNECT's work connected to autonomous vehicles such as 5G coverage, cyber security, net neutrality, and roaming will also inform the discussions of GEAR 2030.

When the Netherlands held the presidency of the council of the European Union in the first half of 2016, it took a lead on trying to find compromises between the 28 EU member states and between EU institutions in several areas, one of which was automated driving. The work of the Dutch presidency resulted in The Amsterdam Declaration which is jointly backed by the European commission, EU member states and the transport industry. It aims to set out all the steps that are required for the development and implementation of self-driving technology in the European Union. The transport ministers of all 28 European Union member states signed it on 14 April 2016, during the informal meeting of the Transport Council in Amsterdam[9]. The overarching ambition is for the European Union to be ready by 2019 for the wide-scale implementation of self-driving connected vehicles – vehicles that can seamlessly communicate both with one another and with surrounding infrastructure. This is an ambition shared by policymakers and industry leaders across the continent.

9. The Netherlands EU presidency 2016 (2016): EU ministers to try out self-driving cars in Amsterdam, https://english.eu2016.nl/latest/news/2016/04/14/eu-ministers-to-try-out-self-driving-cars-in-amsterdam (last accessed: 09/11/2016).

"The government's role should be centred on making sure that there are similar regulations throughout different regions, so that autonomous vehicles can seamlessly circulate"

Industry leader, Spain.

The document underscores the importance of cooperation between EU member states, as a lack thereof could impair the equal applicability of rules concerning automated driving from one country to another. This cooperation could also strengthen the cohesiveness of agreements concerning liability, privacy, and data security issues – all very important issues at the heart of concerns around automated vehicle technology, but where in some cases national rules have greater sway.

As an expert transport figure in Spain explained to us:

"Two important aspects that are regulated at the EU level are the data security and protection mechanisms. Questions of cyber security and data protection would need to be decided and managed at this level."

Our conversations also highlighted the importance of industry participation in developing the EU strategy on connected and automated driving. This industry involvement was seen as essential to fostering the development of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems that would be interoperable on the EU scale and which could contribute to the availability of data for public tasks such as traffic management as well as heightening public awareness and acceptance of automated vehicles.

This Amsterdam declaration also recognised the need for the EU to cooperate with the United Nations in order to establish congruence between EU regulations and the Vienna Convention. This is especially important for EU countries that are signatories of the Vienna Convention and who wish to test and implement fully autonomous cars, because, as described above, the current phrasing of the Convention would limit their capacity to do so.

In order to fulfil these goals, the Amsterdam declaration proposes an informal high-level structural dialogue, open to all EU member states. This dialogue would not only discuss the issues and guidelines set out in the declaration, but it would also liaise with existing EU platforms and working groups related to automated driving, discuss national developments and the implementation of a regulatory framework in light of the aforementioned developments.

As most EU countries are largely complaint with UN regulations the envisaged reform of Directive 2007/46 EC –a proposal was tabled in January 2016 by the European commission – it will be mainly administrative in nature having a limited regulatory impact on Europe's driverless future.

From our conversations it was clear that that directive might be upgraded to an EU regulation making it legally binding for member states and immediately enforceable. More interestingly from an EU perspective will be the cybersecurity and data privacy when automated cars are connected with each other and to a network. A major concern and regulatory playing field for the EU is the access to vehicle data by a third party, which can jeopardise the safety of the car and passengers.

The EU has clearly made headway in preparing for AD it will need to ensure true coordination between its different areas of work and, as we shall see in chapter four, the issue of rules around data – which are a particular European concern, especially in the European parliament – will need to

be tackled and agreed.

German regulatory landscape

The automobile industry remains absolutely central to Germany's manufacturing sector and its export-orientated economy, employing nearly 800,000 highly qualified workers and generating more than €400bn in annual revenues in 2015. Despite domination for German manufacturers in their domestic market – four out of five cars bought in Germany are made on home soil – the country's automobile industry actually makes nearly two thirds of its revenues abroad.

Germany continues to dominate the highly profitable luxury car sector, but in order to maintain that dominance its manufacturers have recently come under considerable pressure to develop the technologies of the future: electric power and automated driving systems. Although German manufacturers are world leaders in research and development, investment in 2015 totalled of €20bn, in the area of electric and hybrid mobility foreign competitors have been perceived as setting the pace – producing a certain national soul searching and worrying policymakers in a country so reliant, almost defined, by the automotive sector.

Nowadays Nissan/Renault, Tesla and Toyota are seen by many in the German industry as claiming technological leadership in the development of electric and hybrid models with expanded driving range – the additional range making electric cars more attractive and leading to growing sales figures throughout the EU, even in Germany.

To address this concern a consortium was launched by the government in May 2010 (the German National Platform for Electric Mobility) with the aim of promoting the development of mass consumption of electric vehicles. Thus far, though, it is seen as having failed to deliver. The official target, of 1m electric vehicles on German roads by 2020, seems highly ambitious given that, according to official figures by the Federal Office for Motor Traffic, by January 2016 a total of just over 25,000 electric vehicles were registered, an increase of a mere 6,500 vehicles over 2015.

This seeming failure to stay 'ahead of the game' on electric mobility has only added to a determination among policymakers that Germany must not fall similarly behind in the emerging field of autonomous drive:

> *"The German automobile sector has lost its technological leadership on electric mobility, mainly to Asian competitors, but the government will stand firm behind efforts to make autonomous driving a success story"*
>
> *Government official, Germany.*

This perceived loss of touch with the latest developments in electric mobility can be in part explained by the more proactive and progressive industrial policy in countries such as Japan, China, South Korea or Singapore, where most metropolitan areas are extremely congested and air pollution exceeds any health guideline – giving added impetus to the need for electric vehicles.

The message that has been heeded in Germany from the relative failure of its policy on e-mobility is that the government can get automotive policy right only if it creates a friendly regulatory and

fiscal policy environment accompanied by public and private investment in changing infrastructure. These are the factors that have played a major role in increasing the number of electric vehicles in China, where the government offered customers purchase subsidies and exemptions from local vehicle admission restrictions which led to an increase in sales of 188,000 vehicles in 2015 alone. German policymakers are now determined to learn this lesson and not repeat mistakes when it comes to the autonomous future.

A coordinated government strategy for an autonomous future: Mobilität 4.0

In order to be well prepared for the autonomous future the German government launched an expert roundtable on automatic driving. Bringing together industry leaders, transport experts and policymakers the main purpose of this initiative was to assist the industrial transformation needed for the introduction of highly sophisticated automated vehicles on German roads.

Partly based on the discussions of this expert group, in September 2015 the ministry of transport published a white paper called the "Strategy for Automated and Connected Driving". This paper sets out a distinct German plan of action on autonomous drive, given the importance of automobiles for the economy as a whole. The goal is to make Germany the leading market for, and provider of automated driving technology. The agenda identifies five areas that it sees as crucial for the development and research of key technologies and the transition to an autonomous future:

1. Digital infrastructure and industrial standards that would allow an interference-free operation of automated systems on roads and motorways (eg high-speed broadband, sensors in signalling systems and near motorways)

2. Adjusting national and international legislation and reforming admission rules for automated driving systems and addressing liability issues, including driving education, technical surveillance and equipment tests

3. Setting up testing fields on motorways and promoting R&D to harness potential gains of technology

4. Actively encouraging connection and interaction of vehicles and infrastructure using geo-data and sophisticated mapping systems

5. Guaranteeing high levels of IT-security and data protection across boarders minimising risks of cyber-attacks and data violations by third parties.

Another issue that the roundtable discussed was that of public concern about robots taking control of steering wheels. With the July 2016 fatal accident involving a Tesla vehicle receiving widespread attention in the German media, it finally became clear to the public that immature automated driving technologies might bear a substantial risk not just to the driver but to all road users. As a consequence of this incident and studies indicating the level of public concern about the security of driverless cars the government acknowledged the importance of public acceptance in this debate adding it as a sixth policy dimension to the agenda.

"A major issue is that the public does not trust the technology yet although it is much better and safer already"

Senior government official, Germany.

"If we don't take public concerns of AV technology serious enough we might end up with another debate similar to the one over fracking"

Senior policy adviser, Germany.

As part of its deliberation process the roundtable commissioned a multinational driver survey; this showed that the public view of autonomous vehicles is much more positive in the US, where people have longer commutes, drive more defensively and more slowly than in Germany. Spending more time in the car also increases people's awareness of the potential benefits of not having to sit behind the wheel solely driving. Put simply, US drivers, who tend to have longer commutes, have the potential to gain more from spending less time in active control of a car. Allowing the machine to take over would allow them to focus on other things, such as leisure or work. In contrast, Germans travel less overall and drive more aggressively, causing motorists there to have doubts about whether the technology is safer overall and less benefit to be perceived in terms of time saved.

As part of the attempt to adopt an integrated approach to promoting the research and development of autonomous technologies, the Federal Ministry of Economic Affairs launched "Pegasus" in January 2016. This research project is devoted to the standardisation of testing and admission systems for highly automated driving assistance systems. If successful and applied internationally these test procedures would give German industry a considerable competitive edge, as others would have to follow those standardised rules.

The government has also invited car manufacturers, IT and telecommunications firms to develop and test new technologies under real-world conditions on the A9 motorway in Bavaria. Permission for testing can be obtained subject to a case-by-case analysis by the local authorities. In October federal transport minister Alexander Dobrindt (CSU) announced an extension of this testing regime to more complicated rural and urban roads. The transport ministry intends to support further research and real-world testing with a fund of €80m.

Picture credit: Wikimedia Commons

Existing rules and reforms in the pipeline: Verkehrspolitik 4.0

Across all five of the aspects of an autonomous future the German government has outlined that the priority is to actually get the regulatory framework in place. Alexander Dobrindt, the transport minister, has made it clear that he intends to table a legislative proposal to the federal cabinet by mid-December 2016. As legislation on AV was not included in the coalition agreement between the CDU/CSU and SPD partners, Dobrindt needed a sound and convincing argument as to why a reform was inevitable if he was to secure SPD backing.

His initial efforts in May 2016 were met with scepticism by SPD justice minister Heiko Maas, who instead favoured liability issues being resolved in the courts rather than in parliament. While the Social Democrats are largely in favour of promoting the changes of AV technology they feared that the ambitious transport minister would use this topic as an exercise in self-profiling/promotion. Dobrindt's attempts to introduce highway tolls for foreign drivers had proved popular with voters and raised the perception of an attempt at winning political favour. (Although in September 2016 the European commission questioned the legality of the potentially discriminatory road charge and announced it would take Germany to the European court of justice.) However, on AV reform the strong belief from government advisers that legal clarity on liability issues is crucial for the development and introduction of AV technology and, thus, in the national interest, trumped the political suspicion of Maas and other sceptics and Dobrindt is expected to achieve coalition support for his proposals.

In its current form the road German traffic law reflects the spirit of the manual driving age. It is designed for a world where humans rather than machines or computers assist or fully operate vehicles. For the use of AV technology on German roads this means that the driver has to be able to override any fully automated driving function at any time. At present this prerequisite of manual override is the main reason why fully automated driving functions are partially regarded in Germany as incompatible with existing national regulations. Greater regulatory clarity will be needed to pave the way for the wide-scale adaption of greater levels of AV technology.

At the core of minister Dobrindt's traffic code reform, which is currently under ministerial review, stands the delicate and tricky question of who is liable in case of an accident – people or machine/manufacturer. Whereas admission rules are regulated on EU-level legislative measures aiming to update existing liability rules are regulated on national level. The current debate on the reform best reflects the German tradition of creating 'Rechtssicherheit' (legal certainty). The legislative proposal stipulates that a highly or fully automated driving system can take over while the driver averts her attention to activities other than driving.

At the earliest, further reform of the traffic code can be expected during the next parliamentary term, following the 2017 federal election. It will need to take into account the conclusions of an ethics commission that was established in September 2016 and is chaired by Udo di Fabio, a former chair of the judges of the German federal constitutional court. The commission's goal is to lay the ethical foundations and investigate the moral issues of full vehicle autonomy of full vehicle autonomy, including the 'trolley dilemma' (see box), which is seen as crystallising the moral choices AD throws up. It will develop guidelines ahead of formal legislation on liability and the interaction of AV with humans on German roads. Dobrindt has indicated that there will be three key principles: property damage takes precedence over personal injuries, machines must not classify people by size, age or gender, and, in case of accident, the manufacturer is responsible.

"We still have concerns whether technology is ripe for fully autonomous vehicles on our roads"

Senior parliamentary adviser, Germany.

Assuming the proposed bill to reform the national traffic code passes its legislative hurdles in the Bundestag, it will clear the way for vehicles with conditional automation to take to German roads. However, it is not yet a complete solution for a fully autonomous future. In addition to updating national legislation, Dobrindt needs to continue pushing hard for a revision of the Vienna Convention by putting it on the international agenda, including in the G7 and in Brussels.

The trolley dilemma: self-driving vehicles and ethical considerations

As 90 per cent or more of traffic accidents are caused by human error, the implementation of self-driving vehicles holds the potential to significantly reduce the total number of car accidents with a consequent positive effect on lowering the level of death and injury on our roads. Although traffic accidents will become rarer, some incidents will be unavoidable and some of those will require the autonomous car to make the almost impossible choice between injuring (or even killing) one of two different parties. This choice embodies deep ethical debates, the outcome of which will need to be reflected in the technology of these self-driving cars. So which decision will autonomous vehicles be programmed to make?

The authors of a joint study between the Toulouse School of Economics, the University of Oregon, and MIT identified three key (potentially incompatible) objectives that the algorithms used by AVs need to accomplish: "being consistent, not causing public outrage, and not discouraging buyers"[1].

At the heart of this debate is the 'trolley problem', a hypothetical scenario consisting of a choice between killing one set of people or another. In this scenario, a trolley's brakes have malfunctioned. This forces the individual in the thought experiment to choose between letting the trolley advance, killing more than one person, or turning a lever that would change its direction into another track, killing a single person.

In the context of automated vehicles, the trolley problem refers to the choice that a self-driving vehicle would make when confronted with a scenario where it must choose between injuring or killing two different parties. Consumer opinion regarding the preferable outcome of the 'trolley problem' matters: gaining public acceptance for the 'moral' choices programmed into AV's will significantly impact propensity to purchase self-driving cars and is far from assured. Potential purchasers will need persuading before they buy a car which might sacrifice them in the event of an accident for the 'greater moral good'.

In summary, German policymakers have taken a pragmatic approach to getting rules in place that allow AV test drives and regulating commercial use of highly automated and autonomous driving systems. In what could serve as a blueprint for other countries, a new bill proposes the installation of black box recorders into vehicles to determine whether person or machine was in charge at the moment when an accident happened. However, regardless of the level of automatisation this will still require a human driver who must be prepared to take over the wheel given an optical and acoustic warning sign by the system. The proposed bill is yet to pass parliament, but as became clear in our interviews, it is likely that the bill will pass the legislative hurdle in both chambers of the federal parliament. Those laws that need to reflect the ethical, moral and consumer protection issues of full autonomy will be subject to the recommendations of an expert commission and dealt with at a later

[1] Jean-François Bonnefon, Azim Shariff and Iyad Rahwan (2015): The social dilemma of autonomous vehicles, https://arxiv.org/ftp/arxiv/papers/1510/1510.03346.pdf (last accessed: 09/11/2016).

stage, most likely after the general election in autumn 2017.

UK regulatory landscape

The automotive industry has been one of the success stories of the UK economy, and a solid contributor to the country's sometimes troubled manufacturing sector. Whereas manufacturing as a share of GDP declined by 8.4 per cent between 1995 and 2015 according to a study by the Centre for Progressive Capitalism,[10] the motor vehicle industry has been one of top five enablers of the productive sector.[11]

The most striking factor about the UK industry is its export orientation. As the original 'British' car manufacturers declined in the nineteen-eighties the then Thatcher government embarked on an explicit policy of attracting international investment. It was a strategy that worked – when the last UK volume marque Rover finally closed in the early noughties left was a thriving globally focused sector – often serving as the European base for international brands to export throughout the EU and beyond. In 2014, 142,000 employees worked directly in the vehicle manufacturing industry, making up one in 20 workers in the manufacturing sector overall.

Although a success story in the UK context, globally the sector has lost ground – between 1995 and 2008 the UK share of global vehicle production share fell by 25 per cent to 2.43 per cent, dropping more rapidly than either Germany or France.[13] Most recently, the car industry has bounced back, reaching a 10-year high in production figures, growing by 3.9 per cent to more than 1.58m vehicles in 2015, with increased demand at home and across the continent.[14]

However, the UK industry remains heavily dependent on overseas markets and open trade; 77.3 per cent of vehicles manufactured in the UK are exported and conversely more than 80 per cent of vehicles bought in the UK are imported, mainly from the EU.[15] As Britain departs from the EU, uncertainty about the future shape of trade relations is naturally concerning for both UK manufacturers and trading partners on the continent.

Seeking an autonomous future: rolling programme regulation

The British government has been explicit that, despite a hitherto more 'hands off' industrial policy compared to most other European countries, it is aiming for the UK to be at the forefront of the development of autonomous vehicles.

> *"The government has been deploying a strategy to support investments in R&D of AV technologies to become a world leader, mostly in areas where the economy is particularly strong"*
>
> *Senior government adviser, UK.*

Taking the UK lead in the debate on the development and introduction of AD is the Centre for Connected and Autonomous Vehicles, a joint policy unit between the Department for Business, Innovation & Skills (now the Department for Business, Energy and Industrial Strategy) and the Department for Transport. The aim is to create a seamless and prosperous autonomous future, to achieve which the British administration is developing a policy approach best described as 'rolling programme regulation'. The first target of this 'rolling' programme has been to develop a friendly environment for the responsible

10. Thomas Aubrey and Alastair Reed (2016): Rebalancing the UK economy: A post-Brexit industrial strategy, London, UK: Centre for Progressive Capitalism.

11. Cranfield University (2016): UK manufacturing growth and its economic contribution, https://www.cranfield.ac.uk/~/media/files/nmd/160525-corpnmdwhite-paper-2016.ashx (last accessed: 27/11/2016).

12. Chris Rhodes and Dominic Sear (2015): The motor industry: statistics and policy, in: House of Commons Library, http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN00611, p. 6 (last accessed 01/11/2016).

13. Matthias Holweg, Philip Davies and Dmitry Podpolny (2009): The competitive status of the UK automotive industry, Buckingham: PICSIE Books, p. 62.

14. SMMT (2016): Best year in a decade for British car manufacturing as exports reach record high, http://www.smmt.co.uk/2016/01/best-year-in-a-decade-for-british-car-manufacturing-as-exports-reach-record-high/ (last accessed: 24/10/2016).

15. Office for National Statistics (2015): The economic performance of the UK's motor vehicle manufacturing industry, http://webarchive.nationalarchives.gov.uk/20160105160709/ (last accessed: 24/10/2016).

testing of automated and autonomous technology on all types of British roads.
The government calculates that to build on this liberal regime for testing and ensure UK leadership of the next phase of AD development, which will see autonomous vehicles brought to market, legislators will need to be ready to take the necessary steps to change legislation as soon as appropriate and needed. Framing that legislation will involve keeping up with the most recent technological developments through engagement in constructive dialogue with industry leaders and representative bodies, such as the Automotive Council UK. This integrated approach should allow the government flexibility to adjust and evolve the rules on AV. This 'be on standby' stance aims to ensure the UK is not tied in legislatively before the detailed shape of AD is clear:

> *"As for now it is too uncertain as to how AV technology will shape up in the medium and long term which makes it difficult to put a comprehensive policy framework into place. It makes more sense to take in steps and adjust where necessary at the right time"*
>
> *Senior government adviser, UK.*

However, delaying decisions on legislation, while maintaining flexibility, brings some uncertainty to industry and consumers. The example of liability is instructive. If it remains unclear who is to blame in the case of an accident, car or machine, consumers will not have their confidence in the security and safety of AV assured. This is important because, thus far, road safety around AD remains a bigger concern in the UK than elsewhere. A recent study by the London School of Economics found that 55 per cent of drivers polled in the UK do not feel comfortable with the idea of driving alongside autonomous vehicles compared with 39 per cent of non-UK respondents.[16]

Given the uncertainty about exactly what technology will look like in a few years and therefore what infrastructure will be needed, UK government spending prioritises research and development rather than investment in infrastructure itself. As UK owned companies are not present in the top-20 Original Equipment Manufacturers (OEMs -the term used in the industry for car manufacturers, car suppliers and tech firms), although many of the international companies with significant UK presence are) the government is taking an approach that aims to best fit the British economy's core strengths in research, businesses development and services. This approach is similar to policy in Sweden and the Netherlands but different from Germany where the car manufacturing sector is more concentrated and capable of bringing forward its own R&D.

Despite the popular image of the UK as a 'post-manufacturing', service-led economy, the importance and diversity of the British car manufacturing sector can be seen in Table 2. It is striking that almost one third of all the EU-28's motor vehicle manufacturers are located in Britain, which together account for just under 10 per cent of the collective EU turnover, ranking the UK third only behind the dominant Germany, and then France.

16. London Schools of Economics (2016): Autonomous Vehicles - Negotiating a Place on the Road, http://www.lse.ac.uk/newsAndMedia/PDF/AVs-negociating-a-place-on-the-road-1110.pdf (last accessed: 21/10/2016).

Table 2: Top 10 EU vehicle and parts/accessories manufacturers (2014)

	Vehicle manufacturers	Turnover in %	Parts/accessories manufacturers	Turnover in %
Germany	262	51.8	1,264	34.1
France	171	11.9	764	9.1
United Kingdom	731	9.7	1,242	5.8
Spain	113	6.2	806	7.1
Italy	144	5.8	1,405	8.5
Sweden	174	4.2	629	2.2
Czech Republic	101	2.6	825	8.3
Slovakia	54	2	188	3.6
Poland	113	1.9	920	6.8
Hungary	47	1.9	333	4.3
Netherlands	152	0.1	167	0.1
EU-28	2,256	100	10,300	100

Source: Euorstat (2015).[17]

The UK has tried to enthusiastically embrace the development and implementation of connected and autonomous vehicles in its regulatory framework for the automotive sector. There is strong governmental support for research and testing of autonomous cars, facilitated by continued, targeted investment and, as technology is rolled out, through the publication of regulations for the testing of self-driving cars based on dialogue with industry. Ultimately the British strategy can be described as incremental.

"The UK government is very supportive of AVs which it sees as a solution to more efficient transport infrastructure and a big driver of social inclusion improving connectivity to communities shut out of conventional transport infrastructure."

Senior government official, UK.

The UK is also aided by not facing some of the restrictions on self-driving cars that those countries that have ratified the Vienna Convention do. Though the UK has signed the Vienna Convention, it has not ratified it and sees AV testing as compatible with the convention's requirement for proper driver control. Just as in Spain, this offered the UK a head start though this is now of less relevance because of the April 2014 amendments to the Vienna Convention which have sanctioned a more liberal testing regime in those countries which have ratified the agreement.

The Department for Transport's code of practice, The Pathway to Driverless Cars, was published in February 2015. The overarching aim of this code of practice was to set out recommendations that would minimise the potential risks of testing automated vehicle technology on public roads. In setting out guidelines on basic safety and insurance among other requirements, the UK government hopes that the evolution of automated technology will increase the safety of all road users. This code of practice makes clear that in order to test driverless vehicles in the UK it is not necessary to obtain

17. Eurostat (2015): Manufacturing statistics - NACE Rev. 2, http://ec.europa.eu/eurostat/statistics-explained/index.php/Manufacturing_statistics_-_NACE_Rev._2 (last accessed: 21/10/2016).

special permission so long as the appropriate licence requirements are met.
As part of the 2016 Queen's speech, the UK government also pledged it would work to review and amend domestic regulations pertaining to accommodating driverless vehicle technology before bringing forward legislation by summer 2017. It is seeking to clarify liabilities in the event of an AV collision, amend regulations on vehicle use (including amending the current Highway Code) and to promote safety (in order to avoid collisions and to avert cyber threats). Furthermore, at the international level, the UK government announced it would liaise with other countries with the aim of securing change to international regulations by the end of 2018.

In sum, the UK government is adopting a non-regulatory or light-touch approach to the testing and implementation of automated vehicle technology, with the aim of encouraging long distance and large scale testing on public roads in challenging and diverse traffic and weather conditions. The aim – a not unfamiliar one for UK policy – is that such a light-touch, industry-friendly approach makes the UK become seen as the most 'AV friendly' place to do business and, thus, continue to be an attractive location for foreign direct investment (FDI).

Taking the next step: testing in urban environments

This first round of UK government support for AV testing, announced by the then chancellor, George Osborne, in 2014, paid for an initial round of testing initiatives of driverless cars in four urban areas in the UK: Greenwich (south east London), Bristol, and Milton Keynes and Coventry (working jointly).

Realising that the next step on AD is detailed on road testing in 2015 he pledged further support for AV research and implementation through £100m in funding for the Intelligent Mobility Fund. This should be seen as significant in a country where overall direct government investment in business support is limited and has been significantly curtailed in the continuing spending squeeze.

"People need to experience AV technology first before they can trust it."

Research and innovation leader, UK.

This testing funding had two aims: first, to test driverless cars in real-life situations, establishing the UK as a premier hub for research into AVs. Second, it sought to favourably shape public opinion on self-driving cars. First-hand experience with autonomous vehicles in urban environments is expected to make people feel more comfortable and familiar with AV, increasing feelings of safety and security, thereby growing understanding of AV technology. The first results and feedback from this research are expected in spring/summer of 2017.

"Test and research environment is much more open and transparent than in other countries. We were the first to think about AV technology in an urban context, see the GATEway project in Greenwich or LUTZ pathfinder in Milton Keynes"

Project manager and AV expert, UK.

On February 2016, it was announced by then business secretary, Sajid Javid, and transport secretary, Patrick McLoughlin, that £20m of funding (from Innovate UK) would be awarded to eight projects aiming to develop the inter-vehicle communication and roadside infrastructure for intelligent information systems in metropolitan areas.

On August 2016, the government opened a competition backed by £35m of funding (£30m from the Centre for Connected and Autonomous Vehicles and £5m from Innovate UK) aimed at researching and developing new connected and autonomous vehicle technologies.

Bringing it to the cities: Autodrive, LUTZ and GATEway

UK Autodrive is a project in Coventry and Milton Keynes, running for three years until October 2018. It is the largest of the three separate research groups that are presently testing automated-vehicle technology as part of the government-backed competition. So far, it has launched its first public attitude survey (in early October 2016), and has completed the UK's first collaborative trials of autonomous vehicles (on October 21 2016). Successive trials and demonstrations are programmed to take place at a technology park in Nuneaton, Warwickshire during the spring of 2017, before advancing onto closed road trials in the areas of Coventry and Milton Keynes near the end of 2017. The project will conclude in 2018 with a succession of open-road trails and demonstrations in both Coventry and Milton Keynes.

A LUTZ pathfinder built by Transport Systems Catapult (TSC) was publicly trialled among pedestrians and cyclists on a 2km stretch of a pedestrianised area in Milton Keynes in October 2016, after being in development for 18 months. Selenium, the autonomy software running the LUTZ pathfinder, was developed by Oxford University's Oxford Robotics Institute, and was implemented by Oxbotica (the Oxford University spinout company). The goal of these driverless pods is to provide local transportation in urban areas. At the public trial, Business and Energy Secretary Greg Clark remarked that the trials represent "a ground-breaking moment and further evidence that Britain is at the forefront of innovation".

In Greenwich (south-east London), GATEway (Greenwich Automated Transport Environment) is an £8m research project spearheaded by TRL. Its overarching aim is to recognise and overcome the technical, legal, and societal challenges posed by the operation of fully self-driving cars in an urban setting. GATEway's testing takes place in TRL's UK Smart Mobility Lab, validating a spectrum of differing uses for driverless cars, including shuttles and urban deliveries. In doing so, it also aims to assist both industry and regulatory figures appreciate the implications of autonomous cars, leading to the implementation of a safe and validated test environment that drives both job creation and investment in the current fast-paced-technology era.

The UK also has an ambition to play a role in the race for setting industrial standards. Our conversations have led us to believe that plans are under review to channel public funding into the development of testing and approval methods, similar to the Pegasus project in Germany.

The UK also aims to leverage its strengths in professional services to play a leading role in softer areas of expertise required by AD: such as cybersecurity, common law or insurance. Adrian Flux, an insurer based in Norfolk, was the first worldwide to launch driverless car insurance; protecting customers from cyber-attacks and software failures, such as automatic parking or cruise control.

The effects of Brexit on the future of autonomous vehicle policy

The UK has recently witnessed a change of government as Theresa May took over the premiership from David Cameron in the wake of the decision by British voters to leave the EU. Although the Conservatives have remained the governing party, May's administration has announced a major policy shift from a broadly laissez-faire approach towards an interventionist industrial policy. The new approach views the state as able to play a constructive role in fostering greater innovation and productivity in key growth sectors, while May is determined to ensure that the national economic interest is protected. Her decision to review the construction of a new power station at Hinckley Point using Chinese investment was symptomatic of this change in the policy landscape; she is determined to put 'British interests' first.

As a consequence, there is likely to be greater emphasis from the new government on safeguarding the strategic position of manufacturing in the UK economy, a message which is particularly appealing to the 'left behind' regions of Britain that are perceived to have been negatively affected by globalisation since the 1980s (and perhaps consequently the areas that tended to vote most heavily for Brexit). The falling value of the pound is expected to help manufacturing businesses, but government will want to use all of the levers at its disposal to strengthen the UK manufacturing sector. The argument is that Britain has more to do to 're-balance the economy' away from its historic dependence on financial services and the City of London.

This does not mean a return to the industrial policy of the 1970s in which the state sought to 'pick winners' and 'bail out' failing businesses to protect jobs and living standards, but it does mean government channelling investment and capital towards fledgling enterprises and innovations with long-term growth potential. It also means tackling long-standing issues such as rising energy costs by investing in infrastructure while UK borrowing rates remain historically low. The chancellor, Philip Hammond, has signalled he will abandon the previous target of achieving a fiscal surplus by the end of the decade in order to prioritise investment in physical infrastructure. According to Professor David Bailey, of the University of Coventry, 'The OECD sees the UK economy as one of the most deregulated in the world. But UK energy prices are far higher than continental Europe partly because of lack of investment in generation capacity and partly because of extra taxes piled on to energy costs. We lack a proper energy compensation scheme for manufacturing. This has been talked about by government but we've so far seen no real action'.

The emphasis of the UK government's industrial strategy is likely to be 'partnership' and 'collaboration' between the public and private sectors. There will be an effort to direct funding towards innovation and to share risks on new ventures: this may well create a propitious climate for the development of AV technology, with more active support from the British government than the £19m for research and development announced by Hammond's predecessor in the 2015 budget. The emphasis on devolution is likely to continue channelling investment and strategic support to those regions where the economy has been historically underperforming the rest of the country.

The new industrial policy agenda relates to the most significant issue in the current prime ministerial 'in-tray': the terms of Britain's departure from the European Union (EU). In a climate of political uncertainty, the government wants to reassure and support successful businesses located in the UK. In a post-Brexit Britain, manufacturers are chiefly concerned about access to the single market and the erection of potential tariff barriers.

There has been much speculation about a so-called 'hard Brexit', but the British government will want to maintain constructive relations with its European partners. In the negotiation, the government will seek to address the concerns of business while ensuring that the UK economy is in the best strategic position to do business across the world. For the transport sector and AV manufacturers in particular, it will be important as far as possible to maintain common regulatory standards with the EU so as to access European markets swiftly, while preserving the freedoms (such as 'light touch' border controls) that make it easier to preserve a European-wide transport infrastructure which includes the UK, despite Britain no longer being in the EU.

Spanish regulatory landscape

It may have developed later compared with other western European countries, but Spain's automotive sector has flourished over the past half century. It is now the second largest car manufacturer in Europe, behind Germany, which puts it in the eighth position in the global league table. This strength makes vehicle production absolutely vital to the Spanish economy, accounting for 8.7 per cent of national GDP in 2015 according to ANFAC, Spain's association of car manufacturers. The sector has played an especially significant part in Spain's growing recovery since the financial crisis - that 8.7 per cent of GDP marks a significant increase from five per cent in 2014.[18] Clearly if the Spanish economy is going to continue to rebound its relative international strength, the automotive sector will need to be preserved and built upon.

That means that as the role of autonomous drive develops, Spain will need to develop a policy regime that keeps pace with technological change. There are several factors specific to the country that will need to be taken into account if this is to be achieved.

First, to understand Spain's traffic policy regime it is crucial to take into account the nation's complicated governance structure. There are five levels of governance in Spain: the Spanish government, the autonomous regions (17 in total), followed by the provinces, districts, and municipalities of these autonomous regions. The Spanish government executes its competencies through the parliament (which elects the central government), the superior court of justice (the highest judicial institution in Spain with administrative, civil, criminal and social chambers) and the Government Office (which represents the central government in each autonomous region). The Statue of Autonomy of each autonomous region sets out the specific rights and duties of citizens and of the political institutions within that autonomous region, as well as the relationship between the central government and the financing of the autonomous region.

The competencies devolved to each of the autonomous communities vary greatly. Executive and legislative power is granted in varying degrees, so-called 'asymmetrical devolution'. However, when it comes to the regulations concerning autonomous cars, the legislation pertaining to tests of self-driving cars has been drafted and passed centrally by the Spanish Directorate General of Traffic, which is part of the Ministry of the Interior, rather than being independently passed by the autonomous regions individually.

18. Victor Mendez-Barrerira (2016): Car Makers Pour Money Into Spain, http://www.wsj.com/articles/car-makers-pour-money-into-spain-1470613487 (last accessed: 09/11/2016).

The government's vision for transport

In "Vital Security Strategy 2011-2020", the Spanish Directorate General of Traffic sets out its overarching vision for the future of transport. The vision stresses that all citizens have a right to a safetransport network in which all individuals have their respective responsibilities. This vision was backed by six main objectives that were elaborated to guide national directives and have the aim of reducing the socioeconomic impact of traffic accidents in the decade from 2011 to 2020:

1. Protect the most vulnerable road users: children, youngsters, the elderly, pedestrians, and cyclists;
2. Enable safe mobility within urban zones;
3. Increase motorists' safety;
4. Enhance safety on conventional motorways;
5. Augment the safety of work-related trips;
6. Improve alcohol-linked driving behaviour[19]

In November 2015, the General Directory of Traffic (DGT) announced its efforts to bring about intelligent mobility through the development and subsequent implementation of DGT 3.0, a digital platform facilitating the exchange of data in real time between all individuals on the move in some way (pedestrians, cyclists, or drivers). This digital platform would act as a reference point for vital traffic information, where all individuals who are involved in mobility (DGT, drivers, cyclists, motorists, pedestrians, manufacturers, insurers, and town halls/mayoral offices) will emit and receive information. The overarching aim of this directive was to further the Spanish government's aim of zero deaths, zero injured, xero congestion and zero emissions[20].

Legislation specific to self-driving cars

Like the UK, Spain is a signatory to the Vienna Convention, but has not ratified it. This means that, in theory, the convention does not pose a barrier to the introduction of driverless vehicles in Spain, allowing it to conduct tests as early as 2012. This gave Spain a head start on testing automated driving assistance and autonomous systems relative to countries that have ratified the Vienna Convention, who are still facing barriers to the testing and implementation of fully autonomous cars even in light of the most recent round of amendments of the Convention.

The DGT is keen to ensure that Spain takes advantage of the opportunities offered by autonomous drive. This was evident when, in November 2015, it introduced legislation for the testing of fully autonomous vehicles.[21] In the press release announcing the new draft the DGT was at pains to describe Spain as the ideal country for self-driving cars, citing as evidence:[22]

- Spain's status as one of the top five countries with the lowest rate of traffic-accident-related deaths per million inhabitants;
- Spain's presence in high level system intelligence projects;
- Spain's strong car manufacturing industry and its status as the eighth highest global exporter;
- Spain's capacity to attract investment and to create jobs;
- Spain's important network of research centres and universities focusing on vehicle

19. Dirección General de Tráfico (2011): Estrategia de Seguridad Vial 2011-2020: Resumen Ejecutivo, http://www.dgt.es/Galerias/seguridad-vial/politicas-viales/estrategicos-2011-2020/doc/estrategico_2020_003.pdf (last accessed: 09/11/2016).

20. Dirección General de Tráfico (2015): DGT 3.0: Hacia una movilidad inteligente, http://www.dgt.es/Galerias/prensa/2015/11/NP-Folleto-informativo-DGT-3.0-Movilidad-Inteligente.pdf (last accessed: 09/11/2016).

21. Minister of the Interior, INSTRUCCIÓN 15/V-113, 2015

22. Dirección General de Tráfico (2015): INSTRUCCIÓN 15/V-113, DGT website http://www.dgt.es/Galerias/seguridad-vial/normativa-legislacion/otras-normas/modificaciones/15.V-113-Vehiculos-Conduccion-automatizada.pdf (last accessed 11/11/16).

automatisation and mobility

This instrument authorised tests or trials involving self-driving cars on roads open to the general traffic. The only requirements were that the driver holds a valid driver's licence, that they have insurance (and accept civil liability for any damage caused), and that the car in question passes a technical service provision accredited by ENAC, the National Accreditation Body, or that they possess permission from any other EU authority authorising the tests in question[23]. If they satisfy the above requirements, cars can operate freely in Spanish roads insofar as they get approval from the General Branch for the Management of Mobility.[24]

Although this change in legislation is clearly very important in encouraging research into self-driving cars, at present no concrete legislation relating to the large-scale operation of autonomous vehicles exists. For this reason, there remains a real need to develop legislation guiding the operation of autonomous vehicles by the general public.

Autonomous vehicle testing in Spain

"In the ambition to develop autonomous vehicles, there has been a dialogue in Spain between the industry and the public administrations (at the state level, in Catalonia's case, and local in the rest of Barcelona), which explains why AV's commercial introduction is easier in Spain."

- Industry leader, Spain

Spain has been proactive in taking advantage of the liberal regime on testing to gain early mover advantage in autonomous R&D. To aid this it has utilised EU efforts to promote the competiveness of the union's economy; under the 'Seventh Framework Programme' (FP7), developed in order to build on the EU's potential to becoming the world's leading research area[25], funding was allocated to projects involving autonomous vehicles – including in Spain. For example, as part of the SARTRE project in May 2012, Volvo's 'platoon' of self-driving cars completed a 200km journey on a public motorway near Barcelona, Spain. This was considered a very successful endeavour by Linda Wahlstroem, the project manager, as it was completed alongside regular road drivers and in windy conditions[26].

Picture credit: Mariya Prokopyuk

23. Dirección General de Tráfico (2015): Nota de Prensa, 16 November, http://www.dgt.es/es/prensa/notas-de-prensa/2015/20151116-trafico-establece-marco-realizacion-pruebas-vehiculos-conduccion-automatizada-vias-abiertas-circulacion.shtml(last accessed 11/11/16).

24. Dirección General de Tráfico (2015): INSTRUCCIÓN 15/V-113, http://www.dgt.es/Galerias/seguridad-vial/normativa-legislacion/otras-normas/modificaciones/15.V-113-Vehiculos-Conduccion-automatizada.pdf (last accessed 11/11/16).

25. European commission (2006): Decision No 1982/2006/EC of the European parliament and of the council concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013), http://cordis.europa.eu/documents/documentlibrary/90798681EN6.pdf (last accessed 11/11/16).

26. BBC (2012): Volvo's self-drive 'convoy' hits the Spanish motorway, http://www.bbc.co.uk/news/technology-18248841 (last accessed 11/11/16).

In addition to projects completed thanks to funding under the FP7 framework, other projects have been conducted by car manufacturers themselves. In November 2015, a few weeks the regulation approving the testing autonomous vehicles (Instrument 15/V-113) entered into force, a driverless experiment was conducted by Citroen; it successfully spanned over 599km of the Vigo-Madrid route, making a trip from one of the group's factory to another.

In terms of funding for upcoming projects, Spain has benefitted from the announcement of a new funding platform under Europe's Horizon 2020 framework. Within the Horizon 2020 scheme, there is a dedicated stream for automated road transport, amounting to a budget €6 339m, to be distributed over two years[27]. This funding has enabled the implementation of several projects in Spain such as e-Awake, led by an SME aimed at creating an Advanced Driving Assistance Systems (ADAS), and SV2, also led by a Spanish SME, tasked with implementing a machine vision system for road safety inspection. Each project received €50,000 in funding from EU. Horizon 2020 funding has also enabled the fruition of projects not held in Spain, but where Spanish participation has been vital, such as SCOUT (Safe and COnnected aUtomation in road Transport), which aims to identify pathways for an accelerated proliferation of safe and connected high-degree automated driving in Europe[28].

Catalonia: a leader in the field of automated vehicle technology

"The initiative comes from the private side, especially from the automotive industry (which provides the testing and homologation centres) but also from the telecommunications and transport infrastructure industries. Notwithstanding, the state administrations (Centre for the Development of Industrial Technology) and regional administrations (government of Catalonia) support the development of this sector insofar as it is serves the public interest."

- Industry leader, Spain

Certain Spanish regions are aiming to become leaders in the field of autonomous vehicle technology by taking advantage of the possibility of regional investments and building on the already existing industry clusters that favour research and development alliances. In particular, Catalonia is emerging as the leading region for autonomous vehicle technology, as its strong automobile research and development cluster becomes an influential forum in shaping the discussion around autonomous technology, and the regional agencies are able to provide support for the technology.

ACCIO is the governmental agency responsible for attracting foreign investment to Catalonia. In 2015, it attracted €96.0m of investment for the automobile sector alone, or 18.9 per cent of the total foreign investment in Catalonia.

The Catalan automotive cluster (CIAC) is an example of a privately funded not-for-profit cluster that is open to all companies operating in the automotive industry that pursue research and development activities. The main aim of this cluster is to reinforce the competitiveness of the automotive industry and its impact on the Catalan economy. Over 150 companies are presently linked to the CIAC, which began in 2013.

27. European commission Community Research and Development Information Service (2014): H2020-EU.3.4. - SOCIETAL CHALLENGES - Smart, Green And Integrated Transport, http://cordis.europa.eu/programme/rcn/664357_en.html, (last accessed 11/11/16).

28. European commission Community Research and Development Information Service (2014): Safe and COnnected aUtomation in road Transport, http://cordis.europa.eu/project/rcn/204978_en.html, (last accessed 11/11/16).

In addition to this, there are several other influential forums based in Catalonia that aim to shape the discussion around the present and future of autonomous driving in Spain.

The Industrial Forum for the Connected Vehicle and Automated Driving (IFCVAD) is a public –private partnership that is led by the Catalonian Automated Industry Cluster, the government of Catalonia, and Mobile World Capital Barcelona. This forum includes participants from different sectors involved in the connectivity and automation of vehicles (Nissan, Abertis, Ajuntament de Barcelona, Carnet, Cellnex, Ficosa, Saba, Seat, and Applus IDIADA). The overarching aim of this forum is to coordinate different stakeholders and to create a platform for the development of AV technology, thus spurring the development of knowledge on vehicle connectivity and automated driving.

The Barcelona Board Cooperative and Automated Driving is another public-private partnership centring on the development of urban automated driving. It is led by the Ajuntament de Barcelona, URBIS, CELLNEX, Applus IDIADA, RACC and UPC. It seeks not only to generate discussion around urban automated driving initiatives, but to establish Barcelona as one of the top European cities for urban automated driving. For example, Applus IDIADA has a state of the art Euro NCAP laboratory with leading capabilities for commercial testing of active safety systems[29], while the Ajuntament de Barcelona has a strong track record for cooperating with private partners (such as the technology firm CISCO) to pioneer smart and connected technology that would facilitate the introduction of autonomous vehicle technology in an urban context[30]. The cooperation of these key players will allow for the creation of the infrastructure needed to advance and test automated vehicles, attracting investments and creating novel business opportunities.

The effects of this political instability on the future of autonomous vehicle policy

Spain had been without a permanent government for 10 months, ever since the inconclusive result of the December 2015 and June 2016 general elections. Only with the Socialist party's recent decision (following the ejection of its leader Pedro Sanchez) to abstain and thereby allow Prime Minister Manuel Rajoy to gain sufficient votes to be invested for a second term in office has a new government been appointed. Rajoy had continued in a caretaker capacity while parliament remained in deadlock with no party able to assemble a majority. Although the leadership change in the Socialists (Psoe) broke the impasse, it remains undoubtedly true that a year of political uncertainty has slowed momentum towards future legislation concerning the commercialised spread of autonomous vehicles, as it has in many other policy areas.

AsAV technology is still relatively new, it is not a topic that is explicitly touched upon in any of the political parties' manifestos. Notwithstanding this, certain policies, especially policies affecting the transport sector and innovation policies will indirectly impact upon the short- and long-term development and deployment of autonomous vehicles in Spain. Consequently, the formation of a stable government that is able to pursue at least a medium-term agenda will determine how quickly a detailed policy towards self-driving cars emerges.

All the major parties have policies that could similarly impact the deployment of self-driving cars. In terms of safety, the Psoe manifesto prioritises investments linked to the improvement of transport safety, while the manifesto of rime Minister Rajoy's conservative Popular Party (PP) supports the creation of a new state authority for transport safety. Both parties, alongside the leftwing populist 'Podemos' and the liberal Ciudadanos place an emphasis on public transport. Psoe especially focuses on urban transport and mobility, and on interconnected rather than compartmentalised forms of transport. The quest to enhance the safety of transport and increase the accessibility of transport could align with the support of the commercialisation of autonomous vehicles, which might mean

29. Applus IDIADA (2013): Proving ground, http://www.applusidiada.com/en/activity/Proving_ground-1328274726564 (last accessed 11/11/16).

30. Internet of Business (2016): Barcelona partners with Cisco to pioneer IoT smart city, https://internetofbusiness.com/barcelona-partners-with-cisco-to-pioneer-iot-smart-city/(last accessed 11/11/16)

greater governmental support for the deployment of AV technology.
With regards to investments in research and development, all three parties seek to increase spending, seeking to reach the EU goal of a total investment of three per cent of GDP. The PP states that they will pay special attention to the sectors that hold the biggest innovative potential, including the automotive sector. Podemos supports the pivotal role of clusters in reversing the deindustrialisation process: "clusters' role as instruments of cooperation between industry, govern-ment, research centres and universities must be used to extend best practices, spark innovation, and improve overall productivity." (Podemos Electoral Manifesto 2016, p54). This stance could spell strong incoming support for clusters supporting the development and implementation of autonomous vehicle technology, cementing Spain's position as a leading research and development location for autonomous vehicles. Additionally, Psoe also proposes the creation of a 'Council for Science and Innovation' to stimulate public-private research collaboration, and an increased participation in the Horizon 2020 programme (which has a specific call for autonomous cars). These points could indirectly lead to targeted support for the automated vehicle industry.

Yet some policy views in all theparties' manifestos could equally compete with or delay the implementation of autonomous vehicles. Psoe's focus on prioritising investment into maintaining existing infrastructures ahead of new infrastructure projects could have implications for the adaptability of new infrastructure to be developed to the needs of autonomous vehicles. Podemos's strong focus on rail transport and accessible public transport (with special or no tariffs for those at risk of social exclusion or poverty) might mean that autonomous vehicles are lower on their list of priorities.

The need for national leadership

More generally, although the regions and their clusters and research alliances can do much to try and shape the debate, it is ultimately the central government, through the DGT, which will need to propose further concrete legislation to shape the future of autonomous driving in Spain. Industry figures have acknowledged that although Spain is currently a favourable place in which automated vehicle testing can be undertaken, legislation covering the commercialised spread of AV technology needs to be addressed not far down the line.

"At the moment, the DGT allows testing for automated vehicles ranging from level 3 to level 5 autonomy. And though the DGT could instantly give a directive for AV circulation outside of testing, the driving code needs to be adapted"

Automotive cluster manager, Spain.

In addition, although Spain currently has established a set of leading automated driving clusters, if political uncertainty was to engender a prolonged delay in the development of such legislation, it could have the potential to erode the rate of foreign and national investment in the automobile sector in general and in the self-driving sector in particular. The seeming resolution of the political deadlock could positively impact on Spain's position as one of the European countries leading in self-driving technology.

Excursus: the future of driving in Russia

The Russian car manufacturing sector has been through turbulences and triumphs over the past decade. Following the 2008 financial crisis the Russian vehicle industry bounced back to move up to number six in the global ranking of vehicle sales, behind only China, the USA, Japan, Brazil and Germany. However, troubled by an ongoing recession and economic slowdown, Russia's car industry has contracted significantly, falling from sixth to 12th in the world ranking between 2013 and 2015, output decreasing by nearly 58 per cent.[31]

The Russian government's automobile industry development plan ("Strategic plan of the Russian automobile industry development") was developed with a special focus on revitalising the automobile industry in the wake of the 2010 economic downturn[32]. It is designed to be implemented in three consecutive phases. The first, initiated in 2010, aimed to overcome the consequences of the economic crisis. The second phase spanned from 2011 to 2014 and focused on the post-crisis recovery of the industry, as well as on forming the foundations for innovative development. The third and final phase is planned from 2015-20, and aims to both develop competitive automotive industry conditions and ensure market stabilisation. The strategic plan highlighted the importance of research and development funding, regional cluster initiatives, and partnerships between global and domestic firms in developing innovative vehicles. These initiatives have the vital potential to lift Russia out of the overcapacity slump it is currently experiencing, generate more research and develop centres, and enable global investors and companies to take advantage of Russia's pool of talented engineers (whose salary is on average ¼ to 1/3 that of their counterparts in Europe and in the US).[33]

Regulation concerning autonomous vehicles

In Russian media and discussions, self-driving or automated vehicles are commonly referred to as drones or unmanned vehicles, alluding to a high (SAE level 4/5) level of automation that would not require human intervention or input[34]. This explains why we can expect most of the regulation to be developed for fully autonomous vehicles as opposed to vehicles with some autonomous features.

The State Duma held a roundtable in March 2016 to discuss the legal issues surrounding the use of unmanned transport systems in Russia. The two main points arising from this roundtable were the need for 'black box' requirements and the necessity to amend the legislation to cover the liability of the 'driver drone' (autonomous mode). Black box requirements refer to the data, video, and audio recorders that should be installed in unmanned vehicles so as to track the autonomous vehicles' movements. The need to amend the legislation, including the Administrative code, the Traffic Rules, the Criminal Code, and the Civil Code, stems from the liability of the autonomous system in case of a crash or failure.

Other suggestions stemming from this roundtable included making it mandatory to have the ability to disable the autonomous mode, and the potential desirability of identifying self-driving cars thanks to a physical "unmanned vehicle" identifier or similar.

31. Vladislav Boutenko, Nikolaus Lang, Onstantin Polunin and Arturs Smilkstins (2016): https://www.bcgperspectives.com/content/articles/automotive-globalization-two-priorities-build-russia-auto-industry/ (last accessed: 27/10/2016).

32. Russian Industry and Trade Ministry (2013): Strategic plan of the Russian automobile industry development, p. 1-2, http://nami.ru/uploads/docs/prognozirovanie_otrasli_docs/55a6238a3a686Strategy_auto_2020.pdf, (last accessed 11/11/16)

33. BCG Perspectives (2016): Two Priorities to Build up Russia's Auto Industry: Exports and Innovation, https://www.bcgperspectives.com/content/articles/automotive-globalization-two-priorities-build-russia-auto-industry/, (last accessed 11/11/16)

34. For example, see Bolshefaktov.ru (2015): KamAZ has launched an unmanned truck, http://bolshefaktov.ru/avto/kamaz-zapustil-bespilotnyy-gruzovik-609, (last accessed 11/11/16)

Key players and partnerships

- NAMI is a government-backed automotive research facility currently looking at the development and implementation of autonomous cars. NAMI develops software that recognises road signs and marking, warns the driver if it leaves the driving lane, and more. In doing so, NAMI aims to simultaneously enhance vehicle safety and improve passenger's comfort.

- Kamaz is a Russian truck manufacturer whose shareholders include the Russian government, Daimler, and NAMI. In association with Cognitive pilot, a Russian software development company, Kamaz is undertaking a project reportedly requiring $6.5m in investment, of which the Russian Ministry of Education and Science will provide $5m and Kamaz will provide the remaining $1.5m. Oleg Savin, the project manager, highlighted that as opposed to other international projects that test on optimal road conditions, their project aims to test in difficult and harsh road conditions, including scenarios where no road markings are present.

- Yandex, Google's competitor in Russia, announced a separate partnership with Kamaz. This partnership revolves around the development of a driverless minibus shuttle that would accommodate a maximum of 12 passengers on a single charge range of 200 kilometres. Although not many details have been released, NAMI has signalled that it expects to begin testing in early2017.

- Russian bus company Volgabus has also been working to develop an electric, unmanned bus By the end of 2016, it hopes to deploy a six-metre bus capable of navigating closed campuses, exhibition centres, and hotels. From 2017 to 2018, Volgabus aims to have an autonomous bus capable of driving through open urban routes, in time for the 2018 World Cup. Andrei Bocharov, the city's governor, has supported this vision.

Conclusion: in need for more reforms and harmonisation

There are three key messages emerging from this chapter. The first is that all four of the countries examined have laid the foundations for the testing of highly automated and autonomous vehicles on both test sites and public roads, but have not yet resolved the issue of full autonomy for public use. This means that in any vehicle regardless of its level of automatisation a driver has to be present and take responsibility for the safe operation of the vehicle. For full 'driverless' autonomy to be introduced considerable further legislative and regulatory change will be needed.

For the next step into a connected and driverless future to be taken the challenge for policymakers will be to find answers to the question of who is responsible and who pays for the damage in the case of an accident involving an AD. A key objective in this process is to tackle public concerns around safety on security on board. If citizens do not feel safe with technology it will delay the take-up of AV on Europe's roads. German legislators might lead the way if they pass legislation in 2017 that will require highly automated and autonomous vehicles to install a data recorder. This "black box" would record whether person or machine were behind the wheel at the time of a crash and, as necessary hand information over to the required authorities.

The second key point is that the industrial policy behind AV technology reflects, to a considerable extent, individual national and cultural circumstances – both the particular patterns of domestic manufacturers, research clusters and business landscape but also political culture. In the UK the government has identified and supported pocket industries which can take the lead in areas in which they excel, including business development, research and law and insurance services. The German government encourages the salience of national industrial clusters and champions in a

traditionally strong car industry that seeks to set international standards in the development and testing of AV technology. And in Spain, some regions, such as Catalonia, have developed thought leadership and gathered expertise in the AV debate that will be central to influencing policy of the newly elected central government.

"In the UK policymakers are aware that with limited manufacturing capacities of the economy they won't be able to boil the ocean. Instead the government will focus on developing a strategy that brings the strengths of the British economy to the forefront"

Industry expert, UK.

Third, it is clear from our analysis that arguably the biggest task for policymakers is the harmonisation of international and national legislation. It was a recurring theme throughout our conversations with policymakers, regardless of country, that whatever initiatives were taken on the national level only international coordination will allow full adoption of AD.

The 'division of labour' between the national and international level is, thankfully, reasonably clear. Our research showed that national legislation will primarily be concerned with traffic rules and liability issues, including the development of new insurance schemes. Whereas, on an international level it is mainly admission rights and development standards for highly automated and autonomous vehicles that will need to be defined.

"Adjustment of legislation has to take place on international level – we are always worse off with national solutions"
Senior policymaker, Germany.

The development of such rules would allow the admission and development of vehicles with automated driving assistance across the European single market.

In order to fully take advantage of all the economic potential of connected and autonomous vehicles new regulations must also guarantee a level playing field for manufacturers, promote competition and show ensure the digital infrastructure is updated; only then will Europe achieve a seamless introduction of AD across the continent.

Economics: making AD count for everyone

The coming autonomous drive revolution is not just going to impact on individual's driving experience or the nature of the vehicle industry, it will also have profound consequences for the economy as a whole. The effects will be felt far beyond those parts of economic life most obviously impacted.

It is fair to say that over the next three decades automated vehicles will alter our lives permanently; a transformation every bit as fundamental as that brought forth by the advent of the railways in the 19th century or aeroplanes in the 20th. Indeed that comparison may well prove an understatement as car automation will affect the everyday life of everyone, everywhere in Europe – not just those who currently hold a driver's licence.

The existing market for personal transport is vast – worth as much as $10tn a year globally, according to the Economist. If by the year 2050, the majority of vehicles on European roads are fully automated – that is to say 'driverless' – clearly this will have substantial ramifications for the transportation sector that accounts by itself for 15 per cent of economic activity – let alone the greater economy. Since transportation is an essential input to almost every other sector we can predict that the knock-on effects to productivity of a fundamental change in the nature of mobility will be very significant indeed.

This report shows how autonomous vehicles will start adding 0.15 per cent Europe's annual growth rate in the decades to come. As a result, the European (EU-28) gross domestic product will, cumulatively, be 5.3 per cent larger in the year 2050 than currently, by which time autonomous vehicles will have contributed a total of €17tn to GDP.

This may seem a large sum but in fact the productivity growth scenario used in this report is rather conservative and even somewhat lower than that used for two independent forecasts for the US and the UK or that utilised in historical growth studies for the comparable airline industry.[35]

The benefits of autonomous vehicles will be enormous but they remain to a degree uncertain. The three sources of uncertainty originate from consumers, car manufacturers and policymakers – each with different, but interlocking, perspectives. Car manufacturers aim to best harness technology to satisfy consumer preference and, thereby, maximise sales but all the time are necessarily guided by public policy. Consumers choose products that they believe best fit their needs and which they feel comfortable and secure with. Whereas policymakers have a substantial range of alternative strategies to choose between the need to balance consumer interests, the public good and the need for economic innovation.

How the demands and wishes of these three different groups come to mesh and exactly how they manifest themselves will be the key to determining the speed and penetration of the takeup of autonomous drive and the consequent economic impact.

35. Our study is more conservative in assumptions, methodology and results than the studies by Morgan Stanley (2013) for the United States and KPMG for the United Kingdom. By comparison, the airline industry has increased gross domestic product by eight per cent. KPMG (2015): Connected and Autonomous Vehicles – The UK Economic Opportunity

Three scenarios

For the purpose of our economic analysis we have categorised into specific scenarios three possible ways in which the commercial, consumer and policy variables over autonomous drive could play out:

1) PROACTIVE: In this scenario autonomous vehicles are swiftly introduced and accompanied by benevolent policy with foresight that aims at maximising benefits. Public sector offers R&D support, supplies necessary infrastructure as well as engages spatial and labour market opportunities pro-actively. Consumers rapidly feel comfortable with AD and manufacturers are able to deliver mass market models that satisfy emerging public appetite.

2) GRADUAL: Autonomous vehicles are introduced at pace forecast by the industry; consumer scepticism is overcome, but slowly. Public policy only reacts to market failures meaning the accrual of autonomous vehicle benefits are permitted but not aided.

3) REACTIVE: Autonomous vehicle technology development is delayed by unforeseen developments. Policy aims to promote status quo in the industry by subsidising current incumbents and stringent regulation for the labour market in the transport sector.

The progress of autonomous vehicle development and which policy decisions are taken will determine which costs and benefits translate to society.

The pace of AD adoption

There is, naturally, some uncertainty about the speed with which autonomous vehicles will be both introduced and adopted. Hitherto, most media attention has focused on the progress of AD in the cargo-transportation and taxi industries, where there have been substantial advances in autonomous vehicle technology over the recent years, with the first vehicles currently in the final test phase. In these industries the operational hours of the vehicles are much higher compared to private cars and the consequent profits can thereby justify large up-front investments. It is therefore reasonable to assume that market adoption in these segments proceeds at an initially higher pace than for private passenger cars. For private cars – driven by manufacturers understandably keen to bring consumers with them – a step-by-step move to partial automation is the current trend which results in some but not all possible advantages immediately accessible.

There remains some uncertainty about the future speed of introduction into the market and subsequent market adaptation to AD. However, according to industry experts it is reasonable to assume that by 2022 autonomous vehicle sales will start substantially increasing.[36] This phase of 'rapid' adaptation will be similar to the pattern of uptake seen with other ground-breaking innovative technology such as smart phones. On the basis of a 'turnover' time in Europe for private cars of 18 years – that is the period over which it typically takes to 'naturally' replace the vehicle stock of more than 250m cars in the EU – by 2038, 80 per cent of the vehicles on Europe's roads will be fully autonomous, after which adaptation slows towards 2050 by which point market saturation reaches 95 per cent.

How will AD impact productivity?

In looking at the economic impact of AD assessing the productivity potential of automated vehicle technology is central.

36. The beginning and uptake rate of large scale autonomous vehicle sales is less debated then the extent of automatisation. Whereas some in the industry expect fully automated car sales to start by 2019, such as Elon Musk in the Wall Street Journal, others forecast vehicles with conditional automation to be the majority of cars sales up to 2025 (KPMG). We base our model on an average of the industry forecasts available on DCMW. Wall Street Journal (2014): Tesla CEO Musk sees fully autonomous car ready in five or six years, http://www.wsj.com/articles/tesla-ceo-sees-fully-autonomous-car-ready-in-five-or-six-years-1410990887 . KPMG (2015): Connected and Autonomous Vehicles – The UK Economic Opportunity. DCMW (2016). Driverless car market watch forecast, http://www.driverless-future.com/?page_id=384 .

To forecast the productivity benefits up to the year 2050, we have used an open-economy model that takes into account demand and supply side effects that are well documented in the scientific literature.

Table 3: Autonomous vehicle supply-side effects on the economy

Effect	Market mechanism	Maximum Productivity impact
Value of in-vehicle time	Travel cost, labour supply	2% - 3%
Road congestion	Travel cost, commuting distance	0.5% - 1%
Road accidents	Expected travel cost	2%
Fuel-efficiency	Environment, public health, travel cost	0.5%
Road infrastructure	-	-
Build environment	Urban structure, city density	2% - 4%
Labour market	Labour supply	1% - 5%

On the road the demand-side effects are likely to outweigh the supply-side effect. In other words, the travel cost reduction from autonomous vehicle will increase demand for travel more than it will improve efficient use of road infrastructure. Demand side effects are mostly direct consequences of autonomous vehicle use to the consumer, whereas supply side benefits are indirect benefits to overall productivity that are shared by society as a whole.

For productivity implications the supply side is more relevant. Seven of the supply side effects that will have large ramifications to productivity are listed in Table 3 and are explained in more detail below.

Value of in-vehicle time

The car is the dominant mode of transport across the European Union used for 80 per cent of ground-based journeys. Annually, EU citizen collectively spend around 100bn hours inside vehicles of which 41bn hours can be attributed to drivers who commute for an average 30 minutes per day, road congestion adds another 10 minutes. Among economists it is common practice to attribute a monetary value to time that is equivalent to the median wage.

When it comes to AD this is based on the assumption that the driver has the option to work inside the automated vehicle instead of driving. Given the time spent in driving currently and the monetary value above, the maximum potential time gains by drivers would be equivalent to three per cent of Europe's €16.2tn GDP in 2016.[37]

The critical reader might argue that in-vehicle productivity depends on the automated vehicle itself and to many drivers the act of driving is leisure and hence when removed not directly transferable to work. Such arguments, while true, also should consider the potential additional benefits to drivers during all non-commuting trips that can be used purposefully. Furthermore, all in-vehicle time benefits that do not translate into productivity gains are automatically welfare gains to the consumer.

Road congestion

Traffic jams and rush hour road congestion are the common enemy of commuters in urban areas.

37. In our model, the maximum productivity gains from in-vehicle time are limited to 1.8 per cent by 2050 which is arguably rather conservative.

Road congestion is a result of car travel demand exceeding the supply of infrastructure, ie road space. Excess car travel has a high cost to society and additional road infrastructure is not feasible in most dense urban areas. The European commission and independent studies estimate that at least one per cent of GDP is lost due to road congestion annually in terms of fuel and in-vehicle time.

Road accidents

Road accidents are a frequent cause of death, injury or material loss, over 90 per cent of them are caused by humans. Statistically, each of us is involved in a road accident every 20 years. Therefore, it is not surprising that the World Health Organisation believes that accidents reduce a nation's GDP by two per cent annually. There is evidence that even the first generation of automated vehicles is already safer than human drivers. Hence, it is not too optimistic to expect that accidents can be substantially reduced producing, as well as the much more important reduction in death and injury, a gain in productivity.

Fuel-efficiency

The energy consumption of road transport in Europe is equivalent to one-quarter of all energy demand. The efficiency gains from autonomous vehicles, which would allow this rate to reduce, are currently, necessarily, speculative.

First, it is crucial to distinguish between those efficiency gains that are directly associated with the autonomous technology itself – such as better power management or communication with road infrastructure, like traffic lights or the envisioned possibility of driving in close proximity in 'road trains' on highways in order to reduce air resistance – from technological advances that are indirectly associated with autonomous vehicles, such as alternative fuel sources. Therefore, for the purposes of this study we only consider the direct benefits from autonomous vehicles.

It is often argued that current fuel taxes already act to mitigate the negative repercussions fuel consumption has for the environment and human health. Studies[38] show that – even if AD continued to be petrol or diesel powered – autonomous vehicles can increase fuel efficiency of cars by up to 30 per cent. Such an increase in efficiency would reduce the negative repercussions to the environment and health by the equivalent of 0.5 per cent of GDP.

This may seem a surprisingly low percentage, but is a consequence of the low price of CO2 emissions and stark discounting to take account future climate change events, such as the reduction in arable land and losses from an increase in frequency and strength of extreme weather.

However, it is widely perceived that the predicted rollout of autonomous vehicles is at least on broadly similar trajectory to the rollout of predominantly or even entirely electric powered vehicles. In which case the environmental discussion would move away from the car industry to energy producers, although the question of how efficiently vehicles consume electricity would remain one for the manufacturers.

Investments in road infrastructure

For now, the cost of adapting road and city infrastructure to accommodate a larger number of autonomous vehicles is unknown. Although it is crucial to factor into any such calculation the necessary mandatory renewal of road infrastructure that takes place over a 20- to 25-year cycle and

38. Agent based models by Fagnant and Kockelman forecast fuel savings between 23-39 per cent, similar to Johnson and Walker.
Fagnant, D. J., & Kockelman, K. (2015): Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. Transportation Research Part A: Policy and Practice, 77, pp. 167-181.
Fagnant, D. J., & Kockelman, K. M. (2014): The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transportation Research Part C: Emerging Technologies, 40, pp. 1-13.
C. Johnson and J. Walker (2016): Peak car ownership – The market opportunity of electric automated mobility services.

hence many of the necessary adjustments can be accommodated within this existing anticipated expenditure. Given this together with the large number of users and the ever diminishing cost of IT technology adaptation costs can be assumed to be negligible.

Built environment

An important supply side effect of AD concerns the built environment. Parking surface and car infrastructure exclusive of roads varies from between 5 per cent to 10 per cent of city surface depending on the specific urban structure and country. Space used for parking is currently unproductive and calculations need to be based on releasing this space for productive use as AD changes patterns of car ownership and reduces the need for such provision. This is particularly the case in dense urban cities where space has a much higher value than in rural areas. So in that sense this is more of an issue for the 80 per cent of EU citizens living in an urban world.

The effect of density on productivity is complicated to estimate as we need to identify various potential mechanisms. However, it is known that the annual cost of an employee parking space in dense urban areas of the Netherlands €3,000. Density benefits are manifold and not just economic – partly affecting the wellbeing of citizens, for example through greater release of space for private gardens. Consumer benefit from space for a larger house or additional garden space does not constitute a productivity surplus per se, but rather should be regarded as a welfare gain.

It is the knock on effects that result from these changes which increase productivity. For example, more residential and commercial space allows a larger concentration of economic activity and a denser labour market that fosters productivity. This productivity gain is believed to be proportional to the additional space, where a one per cent increase in density increases productivity by one per cent. Because of autonomous vehicles, up to three per cent of urban surface area becomes available when superfluous on-street parking is moved outside of cities with a consequent mirrored uptake in productivity.

Labour market

Ensuring a strong level of fulfilling employment is integral to creating a harmonious society. Autonomous vehicles will serve as a litmus test to the extent governments can adequately transform the pressure of technological change into positive results in the labour market rather than the threat to employment some of the popular perception fears.

Combining truck, bus and taxi drivers about five per cent of the EU-27 labour force (Eurostat) is currently employed in road transportation. There is no escaping the reality that the adoption of AD will prove disruptive for many of these workers. It is clear though that it can also provide benefits for those that remain in the sector and the release of labour for productive use in other sectors, especially where labour shortages are forecast, will result in a positive economic impact overall.
For those working in transportation, autonomous vehicles offer a chance to make some existing jobs healthier and more productive – with productivity leading to the possibility of consequent wage increases. For example, it is easy to imagine that personnel on board an automated cargo transporter could transport larger quantities of cargo over longer distance with increased safety and under healthier conditions. Similarly, workers currently deployed as drivers of public transport could in an autonomous drive future be redeployed to provide additional utility to passenger, for example through improvement of on-board safety and service or revenue collection with a subsequent increase in productivity. (As has happened in the rail industry: with the redeployment of guards from traditional 'mechanical' tasks such as opening train doors to more customer focused roles such as selling tickets).

The most obvious area of the labour market where levels of employment would be effected is taxi driving – whereas for now autonomous taxis require drivers, it is probable that in the future cabs will be fully autonomous and independent with no need for drivers.

Yet even this, while taking into account the initial consequences of displacement for individual workers, ultimately even this 'loss of jobs' can be expected to ultimately benefit the economy as a whole, because where jobs disappear, new jobs usually become available in the same or other sectors as productive capacity is released back into the labour market. Take the forecast shortage of care workers across Europe as the population sharply ages – those displaced by vehicle automation can be redeployed to growth sectors such as elderly care. This transfer of labour fully contributes to productivity growth. Taking into account frictions during the transition process – such as time spent retraining and because some share of the labour remains in transportation – we assume that a maximum productivity of three per cent is feasible in the medium term from the impact of AD on the employment market.

The complexity of AD's economic impact

The effects of autonomous vehicles on the economy are complex since various sectors will be simultaneously affected. The resulting interactions between sectors gives rise to potential multiplier effects but also mean that productivity effects and market mechanisms are interlinked and co-dependent.

Take, for example, AD's impact on the prevalence of traffic accidents and the employment in the auto part and repair industry. Through a reduction in vehicle accidents, labour previously employed in vehicle repairs is freed up to work for example in maintenance of automated vehicles but there may be a consequent impact on employment in the manufacture of replacement auto parts as fewer accidents means a need for fewer spare parts.

Critical to the economic benefits of autonomous vehicles will be the effect on the price of travel. By price we mean a composite of the time cost to the user (previously referred to as in-vehicle time), the cost of fuel, the costs associated with the potential risks of travel and vehicle fixed costs (such as insurance, repairs and taxes). The sum of these costs is an important criteria that users consciously or subconsciously weight in comparison to alternative modes of transportation – such as choosing whether to run a car versus using a bicycle or public transport.

As efficiency gains in AV technology kick-in, the price of using autonomous vehicles compared to alternative transport modes will decreases, passing certain milestone 'tipping points' – such as the moment when travelling in an autonomous cab becomes cheaper than in a cab with driver, which has been speculated as likely to occur sometime around 2025.

Whenever tipping points are crossed, large scale readjustments of consumer choices are the inevitable consequence.

It is important to remember here that various aspects of autonomous vehicle technology will determine the price while also, conversely, the price itself in part determines the deployment of that technology. It is likely that the decrease in cost of automated vehicle travel induces an increase in demand for vehicle travel which in itself would see greater use, and consequent further price falls, of that technology.

Some studies imagine that prices for newly automated travel below the current cost of non-automated vehicle travel might see travel demand double. This additional demand for travel will have

obvious repercussions on some of the aforementioned economic factors such as road congestion and efficiency.

Similarly, increased travel demand resulting from lower prices might reduce environmental gains if the energy source being drawn upon for this additional travel is not fully renewable. In addition, lower prices for transportation are likely to result in releasing economic resources for larger consumer spending on other products that require energy – for example onboard devices in the vehicle. Both these unintended consequences from efficiency gains are known as the 'rebound effect' and likely reduce the direct fuel efficiency gains by 30 per cent to 50 per cent. One other very significant potential economic gain from the widespread use of autonomous vehicles – and one which will need the adoption of full automation with no driving ability/qualification required to use an autonomous vehicle – is the productivity effect from providing access to vehicle mobility to consumers currently without access to such transport, such as the elderly, children and people without a drivers' license or use of a car. The possible social and monetary gain could be very significant indeed – if, for instance, the long-term unemployed can be more easily connected with workplaces they cannot currently access or elderly workers are able to work longer into life as the need to 'drive' is displaced.

Furthermore, if efficiency gains in travel make longer travel distances cheaper and more feasible then the number of available workplace opportunities would increase by a factor of five – again with further productivity gains.

Overall productivity and GDP gains from autonomous vehicles

The productivity gains from autonomous vehicles are set to be substantial. Figure 4 shows the overall economic benefits for Europe's economy, given the supply-side effects for the three scenarios outlined above.

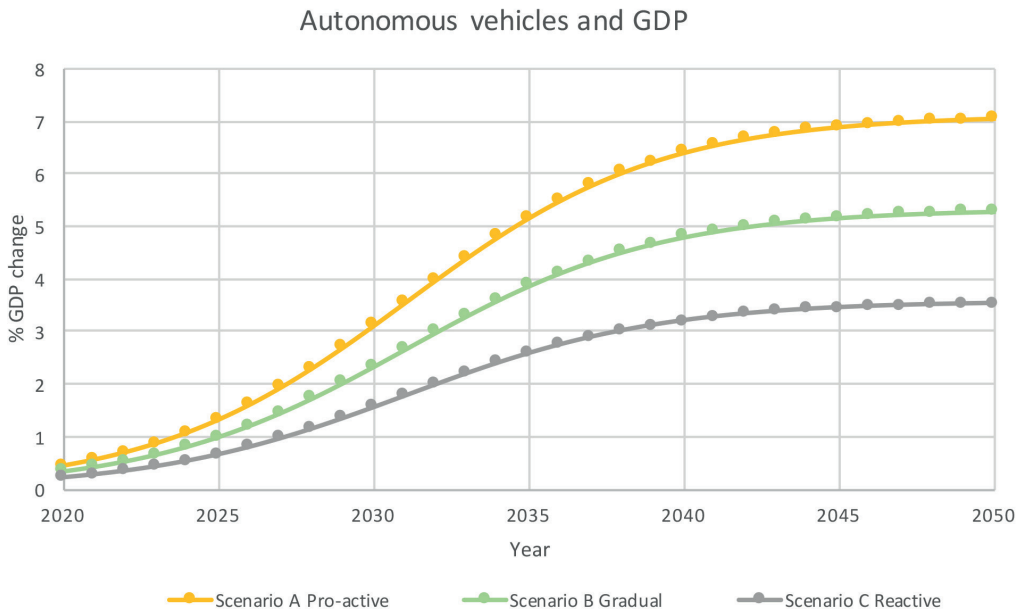
In scenario A, with a **proactive** policy landscape across Europe and swift implementation of the technology, as well as adaptation to the new urban reality, accumulative gross domestic productivity gains of €23tn are possible over the 33 year forecast period. By 2045, GDP would be seven per cent larger in comparison than the current GDP of €16tn (EU-27).

In a more **gradual** scenario B, where policy adjusts to market realities and the adaptation to autonomous vehicles encounters only mild challenges, GDP has grown by four per cent in 2035. In the decade up to 2035, autonomous vehicles have thereby added 0.3 per cent to the annual GDP growth and accumulated gains of roughly €17tn are achieved by the year 2050.

In **reactive** scenario C, where autonomous vehicles encounter substantial technological and political hurdles, GDP increases by 3.5 per cent. Note hereby that accident and road congestion savings would by themselves almost account for this GDP increase as the other benefits are slower to be realised.

In each of the three scenarios the forecasted GDP change is robust in the initial 'take-off period' but the later accumulated GDP gains vary somewhat.

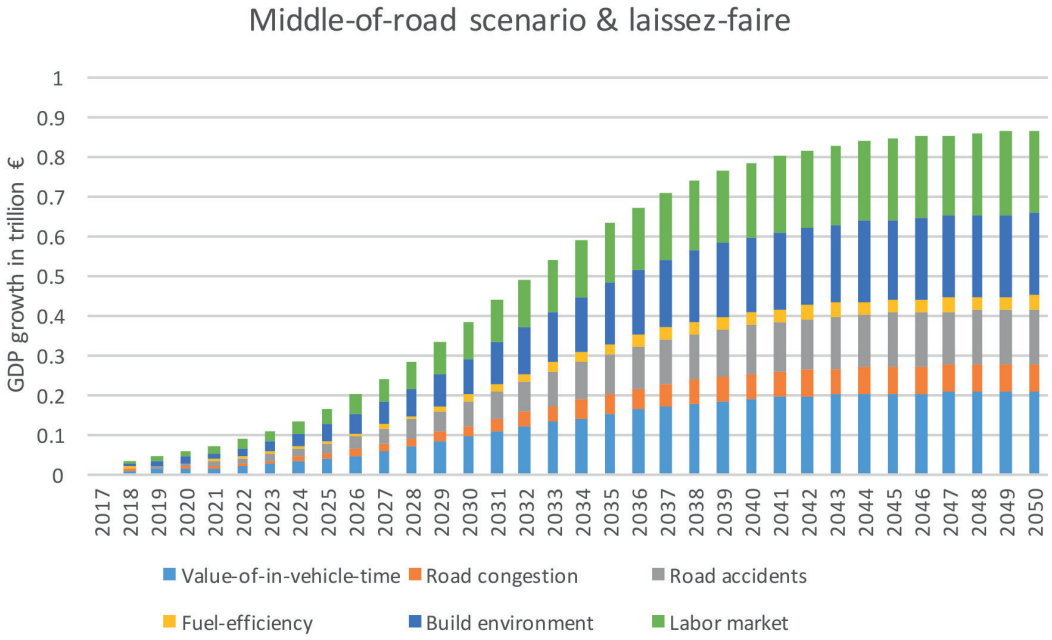
Figure 4: GDP growth



In Figure 5, the productivity gains for the gradual scenario are shown broken down by the different aspects of productivity gain in our model.

What is striking is that the largest productivity gains stem from the built environment in cities and the labour market. These gains are in addition to the traditional and more obviously anticipated benefits – the decrease in road accidents; the 'in-vehicle' time gains and road congestion reduction. Although not as large as the employment and built environment gains they remain significant; for example, in the year 2030 reduced road congestion and accident prevention produce an annual gain GDP gain of around €100bn.

Figure 5: Productivity gains



A 'wake-up call' for policymakers - the economic consequences of AD

We have demonstrated that in numerical terms the economic consequences and benefits of AD will be huge. Autonomous vehicle technology will affect the entire population and thereby its consequences will be felt at all levels of government: from the mayor to the ministry.

Therefore, our strong message to policymakers is to get ready and prepare for what is, literally, just down the road. Government at all levels needs to be aware of the, ultimately positive but significant and potentially temporarily destabilising, economic consequences of so significant an economic revolution. Strong policy positions, as we outline in the rest of this report, will be needed to adequately prepare and ensure Europe takes full advantage of the opportunities opening up and minimises the level of disruption, especially to the labour market.

Municipal and city officials are, perhaps, the most directly involved governmental actors. The implications of autonomous vehicles in terms of both potential benefits and suitable policy are very much specific to different levels of population size and density

No matter where autonomous vehicles emerge first, they will offer the greatest advantages to cities with high population density but perhaps also bring with them the greatest challenges. Urban centres are the cores of economic productivity, but simultaneously the areas most hampered by road congestion, available land and environmental constraints. Autonomous vehicles have the potential to be a remedy to all three of these limitations but will require decisive and consistent policy action to do so.

The fight against road congestion is an ancient struggle. It is not just today's mayors who have to tackle the issue – take Rome, 2 millennia ago Julius Cesar already felt the need to take action against unsustainable levels of cart travel in the eternal city.

Modern policymakers are using a mix of measures, such as public transport, bicycle schemes, parking fees and congestion pricing. Automated vehicles can help reduce road congestion in various forms. For example, on highways, more efficient use of road supply through road-trains can increase traffic throughput. In inner cities this benefit is limited and so efficiency gains are likely to be lower.

However, for citizens in towns that have already accepted road pricing, such as London and Stockholm, it should be possible to get rid of road congestion once and for all with substantial cost saving to drivers and large additional improvements to other road users. How? Autonomous vehicle congestion pricing is a more direct form of pricing than current congestion zones. Prices would be calculated in real-time according to the travel distance and the current traffic situation and then transparently communicated to the user before using the vehicle. In this way, travel costs are fairer and more efficient than current 'one-size-fits-all' congestion zone prices. If such schemes are implemented correctly, greater social equality could be achieved by using the revenue raised to improve infrastructure and public (automated) transport.

In cities especially, land is a scarce and costly resource. Autonomous vehicles can reduce on-street parking space and in the long term private car ownership. Municipalities should start now to take into account in their city planning the space that will become available in central locations, so as to utilise this space productively in the future. There is a large body of evidence that suggests that tax revenues can be maximised through the creation of green areas, public space and low-impact commercial use. Co-creation and smart land use are keywords that might shape the policy debate in this area; for example, companies and local governments can engage residents to start an inclusive, so-called co-creation process for finding new, better uses of parking space.

Fortunately, for now, in the main, investment decisions by local governments do not yet need to take account on-going autonomous vehicle developments. There is one exception – the construction of parking facilities. These long-term investments have a horizon well into the autonomous vehicle period. Which means designs of any forthcoming parking facilities should already take into account autonomous vehicle allows – by reducing the distance between parked cars by the amount it takes to safely park for a human driver and to open the door. Autonomous vehicles will not need this extra space and therefore close-proximity parking is imaginable in the near future so parking garage designs need to be flexible and acknowledge this future change – cost savings of up to €4,000 per car parking space and year are imaginable.

(Technical appendix)

Model aspect	**Assumption(s)**	**Data Source**
Adaptation rate	Rogers diffusion of innovation Sigmoid function Start of fast growth 2022 Take-over time 18 years Saturation 95 per cent	Industry data
Value of in-vehicle time	Transport economics	Eurostat
Road congestion	Economics	European commission
Accidents	Accident prevention	World Health Organization
Efficiency	Environmental literature	Industry data
Road infrastructure	Transportation science	National transport ministries
Build environment	Urban economics	Municipal data
Labor	Labor economics	Eurostat

Politics: overcoming the barriers to adoption

The previous chapters have shown the vast economic potential of AV: if politicians get the right regulatory framework in place. But, like most political questions, that remains a big if.

As the discussion on reforming traffic codes and road regulations unfold in countries across Europe policymakers need to urgently start 'thinking driverless'. If they do not, Europe risks throwing away the opportunity to take the lead in defining a future of autonomous mobility which promises to be a genuine global economic and social revolution.

The transition to a driverless future will require those policymakers to properly embrace and understand the seismic impact on the economy and the future of not just transport but research, work, and businesses beyond those most obviously involved. They will need to focus their policy changes on making the transition as beneficial as possible for the population as a whole, not just early adopters. Put simply this means that the transformation of transport from conventional to autonomous vehicles must be understood in a wider context of societal and political change, making sure that reforms are supported by the public. Not only is that, rightly, necessary for the public good but it is also a necessary pre-condition for the transition to AD to itself be a success. One will not happen without the other.

In Europe the imperative to capitalise on AD's potential to transform economies comes at a time when global economic power is shifting east and the European 'project' is at a turning point. Election results (and dare we mention the Brexit referendum) are testament to rising fears among voters across the continent that the winners of yesterday will be the losers of tomorrow.

If politicians do not take the concerns of the economically vulnerable seriously, populism will spread even further across Europe and North America. The doubts about technology have clear potential to add to that populism imperative – after all the 'luddites' who raged against the technology of the first industrial revolution did so because they felt economically threatened. The danger is that scepticism about technology (including AD) resonates most strongly with those who believe that they have lost out to globalisation.

Just as populists have made significant gains in recent years by playing on fears arising from globalisation, they may soon focus their fire on fears arising from digitalisation. This might lead to a situation where low-skilled workers take to the streets in protest of artificial intelligence and robots; accusing them of taking away their jobs. A scenario most recently portrayed in Humans, a popular UK sci-fi television drama featuring synthetic humans. If policymakers cannot demonstrate that they are able to make technology work for everyone, there is a real danger of anti-tech, anti-growth and anti-establishment populist sentiment spreading through the electorate.

This chapter will present a number of policy innovations that, if implemented, would do just that – guide not only the successful transition to automation but also ensure that the benefits arising are spread as widely as possible.

We will consider political and social issues that will change societies and industries on local and national level. In doing so we are convinced that a successful transportation model for the 21st century must work for society as well as industry – proving a boon for Europe's car manufacturers as well as the elderly taking a driverless bus to their GP practice in Newcastle, Essen or Valladolid. Overcoming the barriers of AV adoption will do more than avoid the risk of society getting stuck in a populist technology trap; it can prove a genuinely liberating social force.

One size won't fit all: promoting dialogue between local and regional stakeholders

At the moment the discourse on AV is mainly an insider conversation – taking place on the national level and in metropolitan areas with highly sophisticated transport regimes already in existence, such as the TFL in London. As with other major technological shifts this poses the risk that some cities or regions will pull ahead while others are left behind.

Across Europe a seamless and driverless transport model by 2050 is achievable, but likely to be very different and more diverse than we imagine it to be, in particular across urban and rural space. In order to meet the needs of highly diversified urban structures cities will need to have implementation scenarios at hand which have a clear vision of investment in infrastructure, engagement with citizens and evolving modes of transportations at hand (eg pods in cities, ride-sharing models in rural areas).

Oslo: Look mum, no cars

Oslo has recently announced its ambition to ban all private cars in the inner city by 2019 – aiming at the overall reduction elimination of private car use by 2030. Public transport coupled with autonomous technology can provide more efficient means of transport without doing away with cars altogether. For instance public self-diving small pods like the LUTZ pathfinder (currently being trialled in the UK), or public autonomous shuttle buses, which operate in harmony with pedestrians and cyclists, could help achieve Oslo's ban on private cars. On a national level, adopting electric self-driving vehicles is consistent with Norway's aim to cut carbon emissions by 40 per cent by 2030, and to be completely carbon neutral by 2050.

From a consumer standpoint, the plans for Oslo's driverless future are supported by a progressive policy agenda promoting sales of electronic and highly automated vehicles with generous government subsidies. These incentives have resulted in rocketing sales of Tesla models, with other electric vehicles such as the Nissan Leaf and VW e-Golf also being bestsellers. In the government's National Transport Plan 2018-2029, Norway's overarching transport policy is to foster "a transport system that is safe, promotes economic growth and contributes to the transition into a low-emission society"[39].

In line with this overarching aim, the National Transport Plan stresses the importance of 'Vision zero', a concept of no fatalities or serious injuries in the transport system. The Norwegian Ministry of Transport is currently working on a bill that would make testing autonomous driving on certain specific public roads legal sometime in 2017. However, this bill needs to be approved by the country's parliament in spring 2017. The adoption of AV technology could be advantageous due to Norway's difficult winter road conditions, which would put autonomous vehicles through an especially challenging test of snow and other extreme weather.

To avoid a growing digital divide and exploit the economic potential of AV., policymakers need to make sure that they encourage dialogue in local town halls across Europe and authorities have the means to promote change on the local level. As outlined in the economic analysis most of the decision can be made once AV technology is ready for markets. However, individual solutions for towns and cities on how to best make use of new technology will be required.

"The best advice I can give local decision-makers is to have a conversation with each other. I don't

39. Norwegian National Transport authority, English Summary of the National Transport Plan 2018-2029, February 2016.

know what their demands are on the ground. They need to tailor individual solutions for their urban environments and connect them with other cities and regions" Government adviser, UK.

Fostering integration of AV technology in public and private transport

Currently the debate on AV technology centres primarily on the impact on privately owned cars. However, the benefits of AV technology for society as a whole may go far beyond if policymakers envisage the full integration of AV technology with cars, public transport systems and bicycles as well as pedestrians.

"It is easier to modify existing infrastructure for public transport needs compared to private transport needs" Senior adviser, Association of Car and Truck Manufacturers, Spain.

A key question is how public transport provision will work in combination with autonomous vehicles. These can serve as a substitute or complement to public transit. For large and medium sized cities that offer high-quality public transit, autonomous vehicles will be a complement to transit that allows large welfare benefits, eg greater provision for those who, for whatever reason, cannot use currently designed public transport, but who would find an autonomous vehicle easier (eg making current door-to-school disabled transport easier and cheaper). Whereas in small cities and rural areas autonomous vehicles will enable cost-realistic demand-responsive public transport to be provided where currently the costs of drivers make such provision unrealistic.

But if the AD future may presage exciting developments ahead for public transport, it also contains possible dangers in the short term. If AV results in those who today rely on public transport (either because of economic, health reasons or simple choice they do not have a driving licence or access to a car) switching to automated private vehicles, especially in areas which do not get exciting new public transport (as described above) the danger is that a deterioration occurs in public transport in small and medium-sized cities as enough current passengers switch to cars, rendering the current level of service unsustainable.

Policymakers must be alive to this danger and see AV as an opportunity not a threat to public services by developing innovative services that take advantage of the new technological possibilities before there is any 'flight to cars'. If they, forgive the pun, 'miss the bus', by only thinking about the issue when it is too late the most vulnerable in society will suffer.

Image credit: Theo Möller

The good news is there are interesting examples of non-automated demand-responsive public transit already in operation, for example, Connect2Wiltshire in the United Kingdom and Anruf-Linien-Bus in Germany. The efficiency gains AD offers can unlock even greater social benefits for rural areas through improvements in financially sustainable connectivity at the same time as alleviating stressed municipal transport budgets.

"Public transport would be a lot more flexible and efficient with automated vehicles, small and large: buses could take shorter journeys as they can react better to passenger demands" - AV expert, UK.

As well as the focus of on local public transport there are opportunities to integrate autonomous vehicles with longer-distance travel, especially trains. It will take planning but the creative use of AVs could, for instance, reconnect into the railway timetable those towns and cities in the UK which lost their rail connection in the infamous 'Beeching' cuts, but where the use of traditional driver-led solutions to connect into rail heads (the start of lines) has hitherto been cost prohibitive.

For larger cities, though, there is a danger that if, in the medium term, remaining traditional, conventional cars are in a mix with autonomous vehicles it will make it harder to reach the full productivity and welfare benefits of the latter. Therefore, it is possible that at some point municipalities will need to introduce mandatory autonomous vehicle zones to fully utilise the cumulative benefits of AD.

There are though possible dangers from the 'advantages' autonomous vehicles will bring. One obvious is that the easing of longer distance travel may encourage movement into suburbs. But outer low-density suburbs are less efficient, less productive and are argued to reduce welfare, for example, by increasing divorce rates. Policy decisions should abstain from subsidising low-density suburban living if it stores up negative consequences.

Let the citizens decide: democratise the development of urban space for AD to shape the city of the future

> *"The reduction of the risk associated with wheeled transport will help foster the use of sustainable means of transport, such as cycles or low-speed electric cars for individuals with reduced mobility"*
>
> *- Automotive industry expert, Spain.*

It is undoubted that the coming of AD will entail a very serious review of the way we use space, road and otherwise, especially in urban areas. The process of that review offers great opportunities to not only accommodate the needs of AD but to utilise the very process, and the space liberated, to make a wider impact on improving the urban experience for all.

Citizens are the ones with the most in-depth and intimate knowledge of the particularities of private and public transport within their own communities. As such, and because urban planning has the greatest potential to impact their day-to-day lives, those citizens are best placed to offer solutions or innovative ways to both integrate autonomous vehicles into their communities and how to alter urban space in light of the opportunities that autonomous vehicles usher in.

Traditional methods of public consultation can be time-intensive for the participants as well as for the organisers, restricting the ability to hear from those who have full-time jobs or who are unable to make it to the physical location of the consultation (for instance, because of transport delays or mobility restrictions) all of which limits how representative the views acquired actually are. These costs, coupled with the fact that most consultations do not pay their participants, bar sometimes transport costs, often lead to problems of dropout rates.[40]

New technologies – such as web and smartphone apps offer a cost effective, open way of understanding what commuters and citizens think of autonomous vehicles within their communities. Commonplace is a web application used in the Greenwich GATEway project in the UK, allowing participants to share their thoughts instantly and be a part of modelling future mobility. As it is a virtual platform, it increases the openness (everyone can see everyone else's comments) and inclusiveness (it does not necessitate making it to a meeting point for face-to-face consultation, and the website is accessible at any time) of the decision-making process. It allows participants to drop a pin on an area in their neighbourhood they feel would be positively or negatively impacted through the introduction of autonomous vehicles, and provide further comments and clarifications on why they have made this choice.

Governments and regional authorities should adapt this digital platform to provide answers and information on their particular needs, democratising the urban planning process consequent on the transition to AD. For instance, in light of the influence of autonomous vehicles on urban space, a regional authority could ask citizens what they should do with the freed up parking spaces, or what they should do with the increase in green space. In doing so, governmental and regional authorities would enhance the richness of information that could emanate from these digital consultations strengthening their policymaking.

Additionally, the very process of consultation is an opportunity to educate the public about the benefits and drawbacks of autonomous driving technology, potentially heightening consumer acceptance and enriching the national debate on the impact of autonomous technology.

Ensure equitable access to mobility for all and balance prices between transport modes

"Politicians in Whitehall and town halls across Britain worry about anything that undermines the universalism of public transport. There are social factors here. We do not want segregation. Cars can create a bubble. The risk is that cars in any form do make people more atomised. In the United States the people who use public transport are black people and poor whites. We have to think about the ways that we can continue to promote social integration and prevent segregation as modes of public transportation shift in response to new technologies." - Senior parliamentary adviser, UK.

There is a danger that policymakers get carried away and that the headline social inclusion benefits of AD seize the imagination without the wider and longer term social effects, not all of which will be instantly positive, being thought through. As highlighted in the quotation above one of those dangers is that AD leads to a new form of social 'apartheid'. As AD spreads private car use to those who currently do not use private cars it is likely that the social range, as well as absolute numbers, of public transport users narrows. That risks public transport becoming the preserve of only the very poor, reinforcing social divides, making services less financially sustainable, seeing a lessening of political support for public transport and leading to a wider sense of the 'privatisation' of the transport space/ narrowing of social connections. Put simply, if more people are buzzing around in self-driven pods, do we risk an even more atomised society – we may be sitting with headphones in swiping our screens when we are sat on Europe's buses and trams but we do, at least, partly interact with each other.

40. Claudia Chwalisz (2015): The Populist Signal: Why Politics and Democracy Need to Change, Rowman & Littlefield , p. 68.

Therefore, as apart of integrating autonomous vehicles with public transport systems, there might be a strong case to design pricing structures in a way that aligns with the objectives of social inclusion. Public subsidies can help ensure that low-income consumers are also able to benefit from public autonomous vehicle systems through innovative price incentives (such as concession travel cards for categories prone to social exclusion). Beyond the provision of inclusive public transport, shared ownership models are a good complement for a model of social inclusion. Above all, governmental policy has to actively prevent the emergence of a two-tier public transportation system.

Mobility as a service: connecting the less well-off in the suburbs

According to UN research into the link between transport and poverty, the least well-off in society are often concentrated on the periphery of urban areas, where rents are relatively low.[1] However, this means that travel times for the poorest are often the longest, heightening their need for accessible public transportation. Relatedly, deficiencies in public transport in urban areas have a disproportionate impact on the least well-off compared to all other social groups. Constrained mobility leads to further social exclusion, as it makes it harder for the poor to access basic goods, services, activities, and employment all of which could partially help improve their socioeconomic condition.

Often, the concern surrounding equitable transport accessibility is centred on 'last mile connectivity', the legs of the commute spent getting to the public transport access points (the bus or tram stop or metro or rail station), and from the transport access points to the final destination. This disproportionately affects the disabled and the elderly. Additionally, larger cities often have complex transportation and interchange schedules, often involving lengthy walking and waiting times, which places a higher burden on the poor relative to other social groups.

Autonomous ride sharing, matching individuals going in similar directions, could help solve this problem, as could public pods modelled on the LUTZ Pathfinder (trialled in Milton Keynes, UK): both could shuttle individuals from one frequently used public transport spot to another, or to their final destination. This would help cut commuting times, if accompanied by public funding it could increase social mobility and make up for excessive rents in inner cities.

Make IT-skills a priority in education at all levels, in particularly apprenticeship level, to be prepared for the shifts in domestic and international labour markets

The labour market is, in general, perceived to be under pressure from IT and robotic technology and, as our research shows, AV may add to this challenge.

The challenge for policymakers is that previous projections about the future of work have not always come to fruition. It was assumed that the knowledge economy would increase the overall demand for skills. But the reality is that there has been much more evidence of labour market polarisation and there are likely to be heightened tensions and distributional conflicts between labour market 'outsiders' and 'insiders' – those with stable jobs and solid career prospects, and those in more precarious employment or without a job.[41]

The daily work routine of motorists, couriers and even bus drivers will look very different in a world of connected and autonomous cars and will demand a different, more technical, skillset. In a driverless future, governments must make it a priority to identify skills shortages and close skills gaps. The demand for technical workers is already significant. In the UK for instance, there were 2 million technical job vacancies in the year from August 2015 to 2016 – up by 46 per cent since 2012/2013.[42]

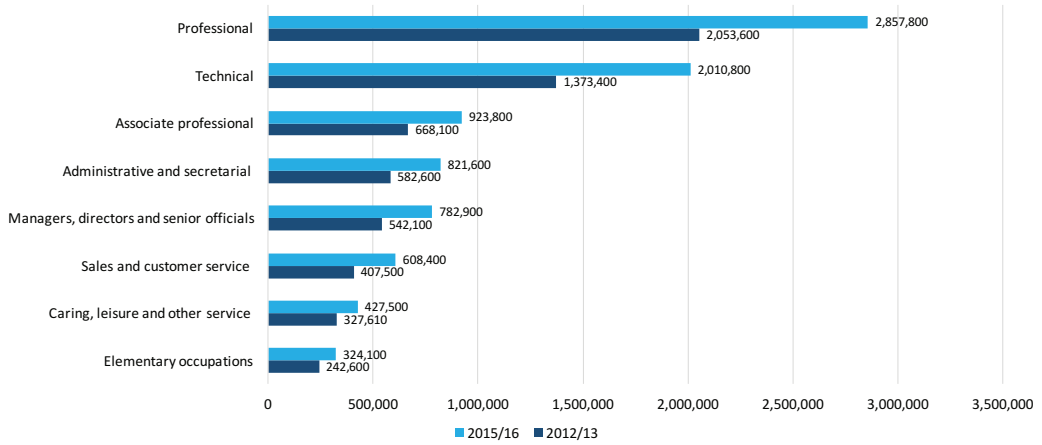
[1]. United Nations Human Settlements Programme (2013): Planning and Design for Sustainable Urban Mobility: Global Report on Human Settlements 2013; Routledge: Oxon, UK, p.109

41. Ranft, Florian and Renaud Thillaye (2015): Rapidly changing labour markets: is EU flexicurity still the answer?, in: Conny Reuter (ed.) "Progressive Structural Reforms. Proposals for European reforms to reduce inequalities and promote jobs, growth and social investment". Brussels: SOLIDAR.

42. Thomas Aubrey and Reed, Alastair (2016): Rebalancing the UK economy: A post-Brexit industrial strategy, Centre for Progressive Capitalism: London, UK, p66.

These technical vacancies offer those without university degrees the greatest opportunity for reasonably paid work. Policy must be developed to allow those without higher education access to the necessary vocational lifelong learning that can best match them to the higher skillset needed the autonomous world.

Figure 6: UK job vacancies by occupation level, 2015/2016 and 2012/2013



Source: Thomas Aubrey and Alastair Reed, (2016).[43]

As the requirements for jobs in public and private transport move up the skills ladder technical education and training for young people must be improved to develop the skills the economy is in need of. To close the skills gap governments must make greater efforts in supporting coding and IT skills in schools, universities and vocational training. This also means that education systems will require teachers with specialisms in computing or informatics. Estonia introduced coding into the primary school curriculum as early as 2012, the UK followed in 2014. Other countries will have to follow suit teaching computational thinking and algorithms to even the youngest pupils if they are to be fit for the IT economy by the time they hit the labour market.

Another key issue will be how to provide high-quality retraining for those that are forced to change jobs. Assuming the first fully autonomous, that is driverless, vehicles will be hitting our roads by 2025 there will have an immediate knock-on effect on jobs in the transport and logistics sector. There is not much time for act before those drivers, be it of taxis or trucks, will need new jobs. Governments need to explore how training systems will have to be adjusted to bring back into work those who have lost their jobs as drivers.

As technical jobs are not only in demand but also offer a pay premium compared to other sectors there is a strong case for a plan ready to up-skill those displaced drivers to help fill the technical skill/labour shortage that exists in most European countries. According to PwC, consumers time, which would have been spent driving will be freed up creating e new business and job opportunities in consumer services (internet- and cloud-based services, including music, tv, social media, e-commerce) but also in maintenance services. Experts predict that in the autonomous era profits in the vehicle industry from digital services, new technology and software will increase, as a share of overall revenue in the sector, from less than four per cent in 2015 to 16 per cent in 2030 – opening up vast job opportunities but also the need to retrain the workforce.[44]

It will also be up to national governments to provide adequate social safety measures to avoid unnecessary upheaval and stress to workers during the transition process and reduce market

43. Ibidem.

44. Richard Viereckl; Koster, Alex; Hirsh, Evan and Dieter Ahlemann: Connected car report 2016: opportunities, risk, and turmoil on the road to autonomous vehicles, http://www.strategyand.pwc.com/media/file/Connected-car-report-2016.pdf (last accessed 28/10/2016).

barriers to job creation in the new emerging areas. They will need to ensure the provision of high quality education and training to unlock opportunities in jobs that are undergoing a transformation. Politicians will need to make sure that they embrace technology and innovation, but not at all costs and regardless of the social consequences.

At a time when AD will be adding to the already very rapid pace in the change of the nature of employment, EU governments should consider the revision of the 'flexicurity' concept. This concept has been seen recently as a catalyst to increasing employment by easing job protection, but not as a sufficient social safety net for those who cannot keep track with the skills demanded in a digital economy. Therefore, to ensure greater public acceptance of a more flexible label market the security in 'flexicurity' will need to be underlined as much as the flexibility. To do that it will be vital that in the public debate political and business leaders underline that one of the main drivers of automatisation is the improvement of working conditions and social welfare not just benefits to the bottom line.

Make greater efforts to invest in European data infrastructure (free flow of data) within and across borders.

The clear message from our research is that there need to be jointly agreed connectivity standards in order to ensure seamless cross-border operation of AVs. An automated, connected car should not stop working just because it crosses over from one European region to another.

"The government's role should be centred on making sure that there are similar regulations throughout different regions, so that autonomous vehicles can seamlessly circulate."

- Automotive industry expert, Spain

When connected autonomous vehicles process their surroundings, they can generate up to 1 gigabyte of data per second[45]. This vast quantity of information helps all other autonomous cars learn to drive better, and is sent out to the car manufacturer's network instead of remaining stored in the car's memory. Additionally, as autonomous cars become more prevalent, it will be crucial for them to be able to communicate between themselves, with other cars, and with other road users. Thus, rolling out 5G connectivity across Europe is imperative for the realisation of V2V (vehicle to vehicle), V2I (vehicle to infrastructure), V2X (vehicle to everything) communications, facilitating the safe rollout of autonomous vehicles.

"At the level where connectivity is concerned, the EU needs to push for the expansion of 5G networks."

- Automotive industry expert, Spain

Satellite systems will play a vital role in securing reliable mapping tools for autonomous vehicles, according to the European commission. Internal market commissioner Elżbieta Bieńkowska

45. The Economist Intelligence Unit (2016): The information driving driverless cars, https://www.eiuperspectives.economist.com/technology-innovation/data-dimension-robotics-and-automation/blog/information-driving-driverless-cars (last accessed 28/10/2016).

explained that as autonomous vehicles become more numerous in urban areas, which are marked by frequent cellular disruption, it might be more difficult for AVs to communicate between themselves and with the surrounding infrastructure.

The solution to this would be to adopt a combination of 5G networks as well as data coming from space, meaning the European commission might use the Galileo satellite network to improve driverless technology. Having the European commission move as close as possible to its 2020 target of 30 satellites in place, an increase from its current network of 14, will make the signal stronger and thus will ensure the heightened reliability of autonomous vehicle technology[46].

Thus, EU progress in the wider area of high-speed data and satellite technology will likely impact on AD almost as much as sector specific regulations.

Protection of the drivers and passengers

As has been seen in other sectors the security, safety, access and sharing of data has become a very important issue in Europe, especially for the key EU institutions of the commission and parliament – just look at the current European action on data sharing between Facebook and Whatssap.

Unlike other data and location transmission services presently available on cars – which transmit a car's location in case of a crash or other emergency – the continuous recording and emission of the autonomous vehicle's location constitutes personal and private information, as it could be used to identify and track individuals as they go about their everyday business (eg home, work, hospital and children's schools), information they may regard as sensitive. In order to overcome this vulnerability, this data will need to be anonymised and encrypted and consent will have to be secured for access to this data (by either the car manufacturer or by third parties).

Additionally, the wider cybersecurity of autonomous vehicle technology will have to be subject to rigorous standards. A breach in the autonomous vehicle's software is not the same as a breach in other devices such as computers or smartphones, as the security consequences of a malicious breach could be immediately life threatening. These standards will need to be decided, and policed, at the European level.

"Two important aspects that are regulated at the EU level are the data security and protection mechanisms. Questions of cyber security and data protection would need to be decided and managed at this level."

- Automotive industry expert, Spain

Protection of by-standers

Last but not least, the protection of agents external to the autonomous vehicle is also pivotal. For example, how should the external video and audio be stored? What if it could lead to the identification of individuals generally, but especially individuals in vulnerable positions? For example, when an autonomous car drives by a rehabilitation centre, it would sense and record people in this scenario. What happens to this footage? How can the EU make sure that the identity of those people is

46. http://www.politico.com/tipsheets/morning-transportation/2016/10/tsa-hits-the-brakes-on-precheck-expansion-search-217085

protected? In order to address these concerns, the EU should host a roundtable with the appropriate directorate-general groups and industry and concerned civil society, so as to draft policies that are coherent with current European privacy laws.

Foster research and development partnerships between small (SMEs) and large car manufacturers and suppliers, IT firms, academia and insurers

The implementation of autonomous vehicle technology will require the formation of broader alliances for research and development (in the short term) and manufacturing (in the medium/long term). These alliances should seek to bring together the traditionally dominating OEMs with technology companies, platforms, academics, insurance companies, and SMEs. It is essential that research and development related to autonomous cars is supported by governments, and that the positive and disruptive impact that including SMEs in these research consortiums is appreciated. Doing so will positively influence the adoption rates of autonomous vehicle technology in each country.

Two very different commercial forces, OEMs and technology companies, today dominate research into and implementation of AV technology. But the wall between tech and manufacturing (software and hardware) is set to crumble rapidly.

The shift in focus from the physical qualities of a vehicle towards the innovative technology within a vehicle will be stark. Fifty-six per cent of new car buyers say they would switch their purchasing choice from one vehicle to another if their initial choice did not have the technology and features they realise are up to speed. Research and industrial alliances need initial government support on local and national level in order to collaborate and deliver the safest and most efficient technology for Europe's roads. The announcement of a new funding platform for upcoming projects in Europe under the Horizon 2020 framework brought about a devoted call for research into automated road transport, with an associated budget of over €100mover the span of two years. Just as the industry itself, through things like mergers and acquisition activity, will begin to bridge the gap between manufacturers and tech services so will government at all levels – EU, national and regional – need to be more innovative and sector bridging in the way it supports the nascent AD industry. It has become easy for politicians to want to be seen supporting traditional 'car factories', they will need to quickly realise that the tech start up may end up being as significant in the sector as traditional mass manufacturing plants.

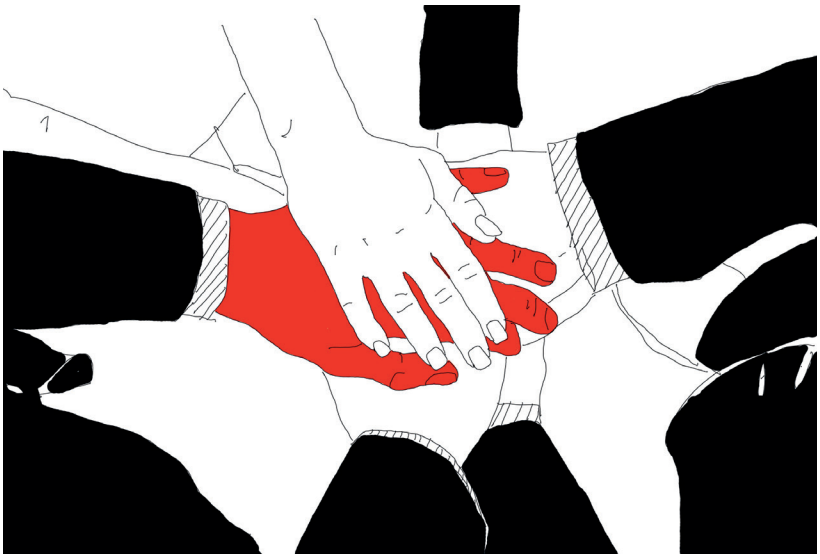


Image credit: Theo Möller

Not withstanding, government-backed research and industrial alliances are usually comprised of large research projects, both in volume and in partnerships, and easily exclude smaller companies or startups. Special funding given to SMEs involved in research projects under the European commission's Horizon 2020 funding framework currently aims to address this, but it is crucial that the inclusivity of SMEs in the field of automated vehicles carries on.

The most innovative technology breakthroughs stem often from publicly-funded research projects which are applied by SMEs, who have the flexibility and capacity to take bigger risks than corporate entities. The big OEMs have understood this trend. For instance, startup Autobahn is a spin-off from Daimler, which gives up to 10 innovative tech entrepreneurs access to a global network, expertise and venture capital. In doing so, it has supported the development of flexible and disruptive startups that are, among other things, influencing the cybersecurity of cars (Argus) and analysing car drivers' behaviour (blicksift). Government needs to appreciate this new way of working as much as industry already is.

Since 2008, the tech startup sector has consistently added jobs to European economies.[47] Both thrive on innovations, the availability of new data sources and the internet. Such resources have made it much easier, faster and cheaper for creators and innovators to build businesses which are rapidly changing the rules on who can trade, what can be traded and how trading can be done. Thus, in order to exploit the economic and innovative benefits of the automated car industry, policymakers have to make sure that SMEs are part of research and industrial partnerships.

"At the moment SMEs are not part of the research equation. They are mainly seen as doing the stand by production. Including in research partnerships will help to unleash the full economic benefit of automated driving."

- AV expert, Germany.

In the UK, in light of Brexit autonomous vehicle research and development funding needs to be secured. Chancellor Philip Hammond has guaranteed that EU funding will be matched following the UK's decision to leave the European Union, allowing British businesses and universities to continue bidding for competitive EU funds while the UK remains a member of the EU.

Although this is a solution protecting projects under the Horizon 2020 funding framework, it does not address the future funding of autonomous vehicle research or the impact that Brexit has already had on excluding UK businesses and universities from European research projects. For this reason, the UK should set out a comprehensive report detailing how the government will support research and development after the UK has been out of the EU for a while. Doing so will provide certainty and assurance over the viability of investing in research projects involving UK businesses and universities.

Think service: Provide the conditions for shared-ownership and ride-sharing models, especially in urban spaces and in addition to public transport, bicycles and pedestrians

The breaking down of barriers between tech and manufacturing will influence not just business models but patterns of consumption as well.

47. Sergey Filippov and Paul Hofheinz (2016): From Startup to Scale-up: Growing Europe's Digital Economy, the Lisbon Council and Nesta, Brussels.

It is not just the OEMs who have been developing AD, several of the major tech giants – including Amazon, Uber and Google – have been turning the wheels of change, investing heavily in next-generation AV technology. Their vision is to make use of their vast existing platforms and data resources to guide their consumers into a frictionless future of transportation. Yet traditional car manufacturers have also been shaping research and development on autonomous technology in recent years and not just in the cars themselves – collaborating with universities, software companies, and research consortia to bring about significant advancements in self-driving vehicle technology.

"Usually disruption happens from outside a sector rather than from within it: the co-operators of today might be the competitors of tomorrow."

- Senior government adviser, UK.

From our conversations it is evident we can expect significant shifts in the shape automobile industry caused by two developments which will change the way how we understand mobility. First, it will emerge that over time individual owners feel they are buying a service rather than a vehicle.

Second, as car-sharing and ride-sharing offer greater economic benefits to some users than traditional ownership models, we can expect to see younger 'early adopters' use these methods to fulfil their transport needs. The same is true for rapidly expanding metropolitan areas in emerging markets, such as in China or India, with huge traffic problems where car-sharing offers a more efficient and cleaner way of transport.

Such a significant change in the nature of the automotive industry makes it far from certain whether traditional OEMs or tech companies will win the race for the driverless future – if the OEMs are to thrive they will need to evolve into new tech/manufacturing hybrids. OEMs might even have to alter their business models from the sale of cars towards the sale of access to a fleet of automated cars on a "subscription basis", perhaps forming partnerships with existing car sharing services or developing a service of their own.

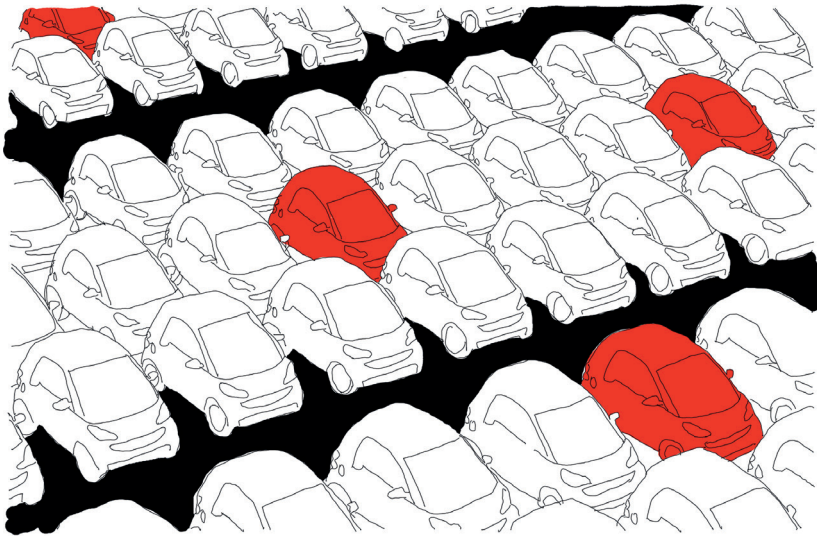


Image credit: Theo Möller

"Most car manufacturers have understood the shifting trends in transport. They are restructuring their firms in a way that they will offer a service rather than a product in the future. But also governments change their way of thinking. In the Chinese administration there are policymakers who are very open to support car- and ride-sharing models to solve the traffic problems in cities, such as Bejing, Jinan or Hanhzhou" - AV thought leader, Germany.

Owning a car is long associated with notions of individual freedom and increased transport flexibility – fuelling the exponential rise in the number of cars sold worldwide, and the clamour by consumers in newly developing markets to take to the road. For many across the globe their choice of car has become an extension of self, a way of displaying and defining yourself to the world through a status symbol.

> *"Unclear whether traditional car manufacturers will be able to defend their market position"*
>
> *- Industry leader, UK.*

Traditionally, OEMs develop cars over a five year cycle, leading consumers into a pattern of changing their cars every five to 10 years (the average car in the UK is, for example, 7.8 years old). However, the introduction of autonomous technology has the potential to change people's behaviour towards ownership models – it is possible that the tech, not the metal and plastic, will come to be the status symbol.

The degree and speed of automated vehicle adoption will depend on the cultural and national peculiarities (for example, cars are still widely seen as status symbols) and generational change (as younger people are more adaptable to the idea of car-sharing and ride-sharing). There is more potential and appetite for autonomous vehicle technology in emerging markets as markets are not saturated, pressure on metropolitan areas is even greater and consumers might be more willing to share their rides. A survey by the World Economic Forum highlighted that China and India have the highest willingness to use a shared self-driving taxi. Twenty per cent and 42 per cent of Chinese individuals are very likely and likely respectively to consider a self-driving taxi, while 32 per cent and 35 per cent of Indian individuals are very likely and likely respectively to consider a self-driving taxi.

Consequently, consumer attitudes towards new ownership models in connection with AV technology on Europe's roads will be somewhat ambiguous. They will prefer autonomous cars when it comes to security and other benefits, but might be initially reluctant to share their cars or rides with others. For these reasons, government and private industries can play a pivotal role in incentivising the shift towards shared-ownership and ride-sharing models, prompting less traffic in Europe's metropolitan areas and an increase in transportation flexibility. This can become a reality if governments provide the conditions for shared-ownership and ride-sharing models in conjunction with public transport, bicycles, and pedestrians, will help avoid global gridlock.

As the technology behind self-driving cars becomes more widespread and more cost effective, it could free up a lot of the capital used on public transport by the municipal and regional authorities, allowing them to invest it in more useful and effective areas. The government could lend their support to private providers of transport, who can incentivise the shift towards automated ride sharing by fostering competitive prices (as is the case with Uber pool, for example, where your ride is heavily discounted if you decide to ride-share with other individuals). Due to the scarcity of space in urban areas individuals in dense metropolitan areas will have to shift away from the traditional

private ownership models that no longer offer them unparalleled personal mobility. They need to move on from the out-dated concept of owning a private car towards private and public modes of transport that combine AV with ride-sharing or car-sharing models.

Beyond Europe's borders: Avoiding "global gridlock"

Bill Ford calls "global gridlock" the possibility of a global traffic gridlock caused by the surge in the number of cars from 1bn to a projected 4bn by 2050. Due to the rise in global consumer power and of the status symbols of cars, car sales have boomed, especially in emerging countries. In China, heavy pollution and poor air quality caused in parts part by the increase of cars on the road has prompted officials to introduce vehicle-ownership restrictions in many cities. These schemes have been more or less successful depending on whether expanded and improved transit services were developed in tandem with the restrictions. In Mumbai, the traffic is so severe that over half of the commuters squeeze into 2,000 passenger trains, which are responsible for moving 7.6 million people around the 603 km2 city. Twenty-three per cent of commuters ride buses and only 14 per cent of commutes are done by personal car.

Think green: promote the introduction of electric and hybrid powertrains

It is a declared goal of all EU countries and the post-Paris global community to reduce the emission of local and global pollutants from transport. Autonomous vehicles will contribute substantially to achieving this goal, in particular if the industry succeeds in making autonomous vehicles fully electric. The problem is then energy generation and the emission of global pollutants.

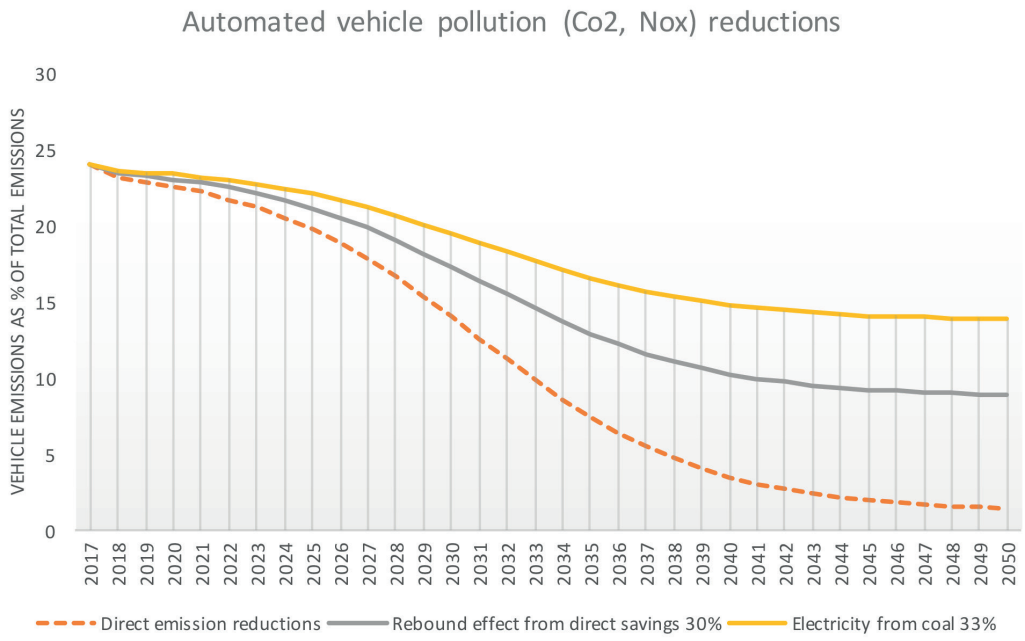
We show in Figure 7 the impact of autonomous vehicles on emissions for two scenarios: one scenario where autonomous vehicle electricity is generated fully through renewables and one where 33 per cent of autonomous vehicle electricity stems from coal. Clearly, the environmental benefits crucially hinge on the mode of energy generation. For example, Denmark is already generating a substantial proportion of its energy needs from renewable sources. But to go further and achieve their goal of a Co2 neutral economy will depend on the introduction of fully electric autonomous vehicles.

Governments should bring forward incentives for purchasing electric autonomous cars; building on tax exemptions and subsidies many governments already offer for electric vehicles (eg in London electric cars are exempt from vehicle tax as well as the congestion charge) This could increase the accessibility of electric autonomous cars for many individuals who, due to the distance between their home and workplace, have no other choice but to acquire a car.

Vehicle-to-grid (V2G)

V2G technology consists of an intelligent energy management system capable of both charging cars and permitting vehicles to transmit stored energy from its battery back to the electric grid. The main advantage of this technology would be its capacity to help stabilise demand for energy during peak hours. The owners of vehicles with V2G capacity would be able to earn an income from the electricity fed back into the grid, empowering consumers and incentivising the introduction of electric and autonomous vehicles.

Figure 7: Emissions of AV



Shaping the future of AV: 12 policy recommendations

1. **Adjust national legislation and strike a balance between public concerns about safety and security and the development of technology.**

   Harmonise national and international legislation while striking a balance between the need for a rapid pace of technological development, and the requirement to assuage public concerns about the safety and security of AVs. The evidence is that the advance of 'general purpose technologies', which have had the potential to revolutionise our economies since the late 19th century, need the enabling role of activist public policy to set the framework and provide regulatory oversight.

2. **Harmonise international and national legislation to promote common European traffic policy; and exploit vast economic benefits of AV technology to ensure Europe triumphs in the global race of a driverless future.**

   Exploit the vast economic benefits of these technologies to ensure that Europe can lead the 'global race' in AVs by 2030. Put the development of AVs at the heart of European and national industrial policy. Governments need to champion AVs as part of their growth strategies for the future given the capacity of AVs to transform economic life by creating new systems of production and distribution in goods and services. When combined with the internet, AVs will radically change how consumers relate to key services and product markets, with the potential to reduce prices and improve the customer experience.

3. **Think green: promote the introduction of electric and hybrid powertrains.**

   For government to take the lead in investing in a new generation of electrification infrastructure for motor vehicles, so as to fully realise the environmental benefits of AV by ensuring that a growing proportion of AVs are electrically powered by 2030.

4. **One size will not fit all: Encourage dialogue between local stakeholders in municipalities and regions to promote connectivity and individual local policy and infrastructure solutions.**

   Promote a devolved approach to strategic planning for AVs recognising the diverse needs of cities, as well as urban and rural areas. There should be active dialogue with local and regional political representatives and stakeholders to ensure communities are prepared for an AV future, and actively engaged in the process. Many European countries are devolving power and responsibility to cities and regions, while creating powerful mayors with the authority and mandate to take the lead in strategic planning, particularly for transport. Mayors can be leaders in pioneering AV developments.

5. **Foster integration of AV technology in public and private transport sector to create seamlessly frictionless world of transport.**

   Support the integration of technology across the public and private sectors to create a seamless transport infrastructure embracing different modes including 'shared ownership' and 'ride-sharing' models, particularly in cities, while linking AV with public rail, bus and bicycle systems. The transport infrastructure of the future will have to be digital as well as physical to co-ordinate systems and meet the diverse needs of cities.

6. **Let the citizens decide: democratise the developments of urban space to shape the city of the future.**

   Enable citizens to participate in redesigning the cities of the future as AV use becomes more widespread, 'repurposing' car parks and highways that are no longer required in order to meet social and environmental sustainability objectives. New forms of democratic participation can help to give citizens a genuine voice in this process.

7. **Ensure equitable access to mobility for all and develop strategies of how to balance prices between transport providers.**

   Ensure that AV does not exacerbate the 'digital divide' by enabling some communities to get better connected and integrated into local economies than others. Public policy can help to ensure that AV technologies better link peripheral areas into mainstream economic zones in cities, while making it easier for workers to link up with labour markets on a wider geographical scale, creating new employment opportunities and widening the winner's circle of economic prosperity.

8. **Make IT-skills a priority in education at all levels, in particular at apprenticeship level, to be prepared for the shifts in domestic and international labour markets.**

   Develop skills policy to ensure that the workforce is available across countries to power the advance of AV technologies in Europe, particularly by investing in apprenticeship and technical level skills and qualifications. To lead the world in AVs, Europe has to have the best educated workforce in the world, and governments have to actively invest in human capital. As AV applications accelerate, it is likely that certain jobs (for example, delivery or haulage drivers) might become scarcer, or even obsolete. Public policy has to ensure that no one is left behind by the advance of new technologies, equipping people with skills throughout life.

9. **Make greater efforts to invest in European data infrastructure (free flow of data) within and across borders.**

   Invest in EU-wide data infrastructure to ensure information and data can be shared and flow easily across national borders. Governments need to oversee the management of data, not least to ensure that 'cybersecurity' is maintained, while enabling public authorities to use data to better manage local and regional transport systems, for example to reduce rush hour congestion around cities.

10. **Foster research and development partnerships between small (SMEs) and large car manufacturers and suppliers, IT firms, academia and insurers.**

    Government and the public sector should actively invest in collaborative partnerships between large manufacturers, SMEs, ICT companies, and higher education institutions to power the next wave of AV technologies. The role of government is to invest in research and development, to ensure a long-term strategic framework, while co-ordinating all of the key players across the public and private sectors.

11. **Think service: Provide the conditions for shared-ownership and ride-sharing models, especially in urban spaces and in addition to public transport, bicycles and pedestrians.**

    AV can help to create more productive, more personalised and more responsive public services. If drivers of emergency vehicles are freed up to complete other tasks, for example,

they can better look after the patient who needs treatment, or the elderly person who needs care. Postal services could be revolutionised by the application of AV technologies making possible a '24/7' delivery service to households and businesses. AVs will be key to modernising the public sector for the future challenges of social and fiscal sustainability against the backdrop of long-term demographic and structural change.

12. Encourage public acceptance and behavioural change

The government can help nudge consumers towards the adoption of new technologies. This push can be established not only through tax credit or deduction schemes, such as the ones presently in place for electric vehicles, but also through a government backed behavioural analysis tracking human behaviour in relation to exposure to AD technology. This will help underpin situations in which individuals are more sceptical or adverse to AV, and establish programmes and approaches to help counter negative reactions to AD.

About the authors

Florian Ranft
Florian leads Policy Network's work on European policy, focusing on the political economy, future of work, labour markets and regulatory frameworks. He holds a diploma and a PhD in politics from the University of Potsdam and the University of Greifswald, respectively. He has lectured and researched in international politics at a number of universities, research institutes and international organisations in Europe, America and Africa.

Martin Adler
Martin Adler is an economist and works as an external research advisor for the VU University Amsterdam. He is also the founder of the consultancy AtAdlerAdvisory which specialises in transportation and urban issues. Among others, he has advised the OECD, European governments, European commission and international firms on the cost and benefits of public transit, road congestion management policies, accident prevention and urban transformation. He has received the Edwin-von-Böventer prize for his contributions to regional science.

Patrick Diamond
Patrick is co-chair of Policy Network. He is lecturer in Public Policy at Queen Mary, University of London; Gwilym Gibbon fellow at Nuffield College, Oxford; and a visiting fellow in the Department of Politics at the University of Oxford. He is the former head of policy planning in 10 Downing Street and senior policy adviser to the prime minister. Patrick has spent ten years as a special adviser in various roles at the heart of British government, including 10 Downing Street, the Cabinet Office, and the Northern Ireland Office.

Eugenia Guerrero
Eugenia is a policy researcher at Policy Network. She holds a diploma in Political Economy, King's College London. Previously, she was a research assistant at King's College London, working on understanding and quantifying violence trends under authoritarian governments. She also has worked in financial start-ups (Elixium), in development banks (Nafinsa), in trade promotion (ProMexico) and in diplomacy (Mexican Embassy of London).

Matthew Laza
Matthew is the director of Policy Network and an experienced broadcast journalist who spent more than a dozen years as a BBC current affairs programme maker before becoming a senior adviser to the UK Leader of the Opposition in the run up to the 2015 election. Before entering television he led the main Labour Party pro-European organisation, campaigning for Britain's leading role in Europe.