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The Promise and Hype Regarding Automated Driving and MaaS

Figure 1.1 1950s image of highway of the future: *Popular Mechanics* magazine. Source: Popular Mechanics magazine.

1.1 The Promise

It is possible that the fully automated car was first seen in a road safety awareness film 'The Safest Place' (1935). *'The vehicle always stays in its lane, never forgets to signal when turning, obeys all stop signs and never overtakes on dangerous corners'* Kröger (2016).

By 1939, at the World's Fair, General Motors 'Futurama' featured a model of future transport systems with automated highways in an imagined world of 1960 Weber (2014). Please note with a smile, futurologists usually overestimate the speed of development and uptake of their subject (Figure 1.1).

Advances in computer technology have seen the rapid development of automation over the past 50 years. Combined with innovative engineering, this has led to developments from unmanned aerial vehicles (UAVs/drones) to armed robotic rovers. The US Armed Forces and DARPA built on the philosophy of 'development through competition' based on the early twentieth-century Orteig Prize (US$25 000) offered in 1919 by French hotelier Raymond Orteig for the first nonstop flight between New York City and Paris that helped prod the development of air flight, and that spurred Charles Lindbergh

Automated Vehicles and MaaS: Removing the Barriers, First Edition. Bob Williams.

to make his solo flight across the Atlantic Ocean in 1927. DARPA have sponsored a number of competitions to accelerate the development of everything from automatic weaponry to private sector space flight.

In 2004, DARPA established the 'Grand Challenge', a competition designed to encourage the development of technologies needed to create the first fully autonomous ground vehicles.

The first Grand Challenge took place on 13 March 2004 and involved 15 self-driving ground vehicles navigating a 228 km (142 mi) course across the desert in Primm, Nevada (https://www.wired.com/story/autonomous-car-chaos-2004-darpa-grand-challenge/). The prize was $1 million but the desert course proved to be too hard. No team finished the course, and the prize went unclaimed.

The second event was held on 8 October 2005 in southern Nevada with 5 of the original 195 teams completing the 212 km (132 mi) and the $2 million prize was won by Stanford University.

For the third event, held in November 2007, DARPA extended the challenge to include a mock urban environment. Driving in traffic and typical vehicle manoeuvres and highway crossings were involved. Tartan Racing, a team from Carnegie Mellon University in Pittsburgh, Pennsylvania, claimed the $2 million prize with their vehicle 'Boss', a converted Chevrolet Tahoe.

Thus the race to the development of automated vehicles kicked off and was incentivised, and its progress has only accelerated thereafter.

* * * * *

We already live in a world where vehicles are to some extent 'connected'. New model vehicles in Europe have a system called 'eCall', which automatically contacts and puts the occupants of the vehicle in touch with the emergency services in the event of an accident. Volvo Assistance, BMW Connected Drive, GM Onstar, Mercedes 'Me' and 'Rescue' as well as Citroen Assistance are examples of breakdown, emergency and driver support systems that are connected to resources outside of the vehicle, connected by 2G/3G/4G, and soon to be 5G, mobile telephony.

The modern vehicle also 'connects' to its environment in many ways, largely through sensors, to assist with the driving experience. Electronic stability control (ESC) is now mandatory on all new cars sold in Europe. Lane-keeping systems (LKS), adaptive cruise control (ACC), automated emergency braking (AEB), and intelligent speed assistance (ISA) systems are increasingly commonplace, as are automatic headlight dipping, traction control, tyre-pressure monitoring, etc. It is thought-provoking to consider that most of what these systems do is to use technology to compensate, to some extent, for human error, often taking some control away from the driver under certain circumstances.

Modern sat-nav systems download and take into account dynamic congestion and traffic incident information in their route planning, and guidance by sat-nav providers communicate this data wirelessly to the on-board sat-nav system. Researchers and developers are close to the fruition of car-to-car and car-to-infrastructure communication developments, that will enable a truly 'connected' vehicle ('cooperative ITS' or 'C-ITS' as it is known in the trade).

Moving beyond such connectivity-enabled functions, attention has now moved to the often misnomered 'autonomous' vehicle that will understand its environment and the requirements of its passengers, and the requirements of the road infrastructure, and operate the vehicle without the assistance of a driver (more correctly called the 'automated' vehicle). It will also 'learn' to react and adapt to different situations during the entire driving process.

Over the next 10–50 years, the transport sector may expect to undergo a significant change, and potentially, transformation, as connected and automated vehicle technology is introduced.

With the impending take-up and spread of cooperative ITS (C-ITS) systems in vehicles, informative features will be complemented by, or evolve, cooperative features that will enable vehicles to interact with each other and with the surrounding infrastructure (i.e. vehicle-to-vehicle V2V and vehicle-to-infrastructure V2I communication). Full-scale deployment of C-ITS enabled vehicles that communicate with other vehicles concerning potentially dangerous situations and communicate with local road infrastructure is expected in the near term, and indeed may be required by regulation (for new vehicles), at least in Europe, by the early 2020s.

Many future projections estimate that by 2025, high automation driving will be available on highways and by 2030 in cities. The EC's Joint Research Centre further forecasts the year 2050 as a realistic timescale for the transition to a future mobility paradigm.

In order to summarise the potential of automated driving, ETSC, the European Transport Safety Council refers to the European Road Transport Research Advisory Council, who have summarised "safety and the potential to reduce accidents caused by human error" is one of the main drivers for higher levels of automated driving. "Automated driving can therefore be considered as a key aspect to support several EU transport policy objectives including road safety".

Automated and connected vehicles have the easy to understand potential to substantially reduce road accidents, traffic congestion, traffic pollution and energy use, and are therefore seem attractive to and are often encouraged/incentivised by governments. Automated vehicles also promise to increase productivity and comfort and to facilitate a greater inclusion in the mobility of specific groups of individuals such as disabled or elderly. But other projections for instantiation in other paradigms predict the opposite in respect of automated vehicles, i.e. an increase in traffic congestion, an increase in traffic pollution and an increase in energy use, and other studies indicate that, particularly in the early years, may also actually increase accidents (even though the accidents may not be the fault of the automated vehicle, but how others react to it).

What is clear is that we are not dealing solely with the efficiency of vehicle control functions to automatically drive vehicles, but with the road transport system as a whole, which is a complex one where road users, vehicles and infrastructure interact with each other and millions of decentralised decisions are taken every second, by human drivers, and other road users, and within which automated vehicles will have to operate as a managed part of the system.

Automated and connected vehicles potential contribution to reduce road accidents is achieved primarily by eliminating human errors, which are a contributing factor in a vast majority of road accidents. And it is also generally recognised that most accidents occur due to risks that human drivers continuously take (consciously and unconsciously) as a result of collective experience gained in more than 100 years of driving activities, and of past driving experiences of the driver over his/her lifetime.

But, as the C-ART report (EC JRC 2017) points out, '*if on the one hand these risks generate road accidents with all their negative consequences, on the other hand these risks usually have a positive effect on the capacity of the road transport system.*

The introduction of automated vehicles, which by definition will be designed to minimize the risk of accidents, could therefore have a negative effect on road capacity especially in a transition period where a mix of conventional and automated vehicles will be sharing the same infrastructure'.

Features most prominently making progress at the moment are so called ADAS (advanced driver assistance system) functions. These systems generally refer to systems such as automatic braking, collision protection and emergency assistance. As the technologies evolve and mature, ADAS will soon evolve into part of the automated driving package.

Telematics and infotainment services that are already in place in modern vehicles use connectivity features. These services will expand, probably rapidly, sometimes as part of the selling options, sometimes as subscription services, and sometimes simply through smartphone apps integration.

1.2 What Do We Mean by the Term 'Automated Driving'?

Automated driving combines a wide range of technologies and infrastructures, and importantly, connectivity. Automated driving should also be seen within the broader context, not just of taking the driving function away from the user of the vehicle, but also enabling new disruptive paradigms for mobility that may change the way we travel, change the vehicle ownership paradigm, change where we choose to live, etc., especially in urban environment.

Automated vehicles are those which blend autonomous control with communication with other vehicles and with the infrastructure in order to control and manage vehicle movements from start point to destination without direct driver input. Automated vehicles use a mix of on-board sensors, cameras, Global Navigation Satellite Systems (GNSS), and telecommunications to obtain information in order to make their own judgements regarding safety-critical situations and the general management of the journey.

Vehicle manufacturers frequently use the term 'autonomous vehicle' (the definition of autonomous is 'having the freedom to govern itself or control its own affairs' or similar), although what they go on to describe is clearly a vehicle communicating with its environment, and not one solely relying on the vehicle's own systems and without communicating with other vehicles or the infrastructure. The author observes that this highlights the shortcomings of the vehicle manufacturer's vehicle centric visions of the paradigm for automated driving, which is focussed on the vehicle controlling its movements through the environment, rather than the reality that the vehicle is only allowed to operate within the limits set by traffic management control and regulations.

While the auto manufacturers largely see the vehicle controlling its movements as the controller of the paradigm, in instantiation, automation has several key stakeholders, starting with the road authority or local/city administration (because they provide the road infrastructure, regulations, street equipment and signage and in the future may operate transport optimisation services). Transport optimisation services are key stakeholders (because they dynamically control all traffic movements through the network). Of course, the automotive manufacturers, and the users of the vehicle, while not being the sole controllers of the automated vehicle, are key stakeholders. Similarly, as these vehicles are communicating and receiving communications, communications providers are also key stakeholders, likewise, transport managers (road, rail, metro, parking facility operators, bus, cycle and scooter share, etc.).

With many ‘Mobility as a Service’ (MaaS) paradigms involving automated driving, vehicle-sharing service providers are another potentially key stakeholder. There are also other stakeholders such as technology providers, insurance companies, and aftermarket service providers. And there will be other actors involved such as driver clubs/associations, universities and research centres.

In Europe, EU Regulation adopts UNECE (United Nations, Economic Commission for Europe) type approval regulations to provide (and require) access to basic raw (on board diagnostic) data from the vehicle by regulation, and there is serious consideration as to what additional data should – will have to – be made available for cooperative safety services, and to enable a fair and open after-market (although the vehicle manufacturers continue to try to control access to data, and where possible use it to generate an income stream). In North America the situation is currently less regulated, therefore more unclear, but one way or another these ‘connected’ services will continue to develop, and push towards the automation of more and more services.

1.3 The Hype

Most of the leading vehicle manufacturers are bullish about the prospects for self-driving vehicles. So rather than my version of what they are claiming, I simply turn to what is on their websites:

The Ford Motor company website (2019) stated:

> *Looking Further*
>
> *Ford will have a fully autonomous vehicle in operation by 2021*
>
> *No driver required. Thanks to Ford, that statement will be possible in 2021, the year that we will have a fully autonomous vehicle in commercial operation. To make this possible, we have partnered or invested with four different technology companies, along with doubling our Silicon Valley presence.*
>
> *The effort to build fully autonomous vehicles by 2021 is a main pillar of Ford Smart Mobility: our plan to be a leader in autonomy, connectivity, mobility, customer experience, and analytics. The vehicle will operate without a steering wheel, gas pedal or brake pedal within geo-fenced areas as part of a ride sharing or ride hailing experience. By doing this, the vehicle will be classified as a SAE Level 4 capable-vehicle, or one of High Automation that can complete all aspects of driving without a human driver to intervene.*
>
> *The SAE International six levels of automation rating system is used by the U.S. Department of Transportation to classify a vehicle’s automation capabilities. The system starts at Level 0 – No Automation – which is defined as a vehicle that requires a human driver for all aspects of the driving task, and goes up to Level 5 – Full Automation – in which a vehicle can perform all driving tasks, no matter the environmental or roadway conditions. By mass producing a Level 4 capable vehicle, Ford will have achieved the highest level of automation by any automotive maker to date.*

> *In order to reach this ambitious goal, Ford has committed to expanding its research in advanced algorithms, 3-D mapping, radar technology and camera sensors. To help accelerate the development of these new technologies, we have announced four key investments and collaborations with Velodyne, SAIPS, Nirenberg Neuroscience LLC and Civil Maps. These companies bring their own unique skill sets and experiences to the table, and have proven to be dedicated to making the world a better place through their technological endeavors.*
>
> *Since becoming the first automaker to begin testing fully autonomous vehicles inside Mcity, the University of Michigan's simulate urban environment, Ford has made enormous strides in researching how these vehicles operate in hazardous conditions, such as snow and complete darkness. Over the next two years, we will have tripled our autonomous vehicle test fleet to 30 Fusion Hybrid sedans in 2017 and will have 90 by 2018. These sedans will be taking the roads in California, Arizona, and Michigan for extensive development and testing.*
>
> *In addition to the extensive testing of these vehicles and intensive collaboration with outside partners, Ford is focusing on expanding its Silicon Valley presence by creating a dedicated campus in Palo Alto to ensure that these innovations will be made. The Ford Research and Innovation Center that was initially created in 2015 will have two new buildings and 150,000 square feet of work and lab space added, and the current Palo Alto staff of 130 people will be doubled by the end of 2017.* (Source: Looking Further, Ford will have a fully autonomous vehicle in operation by 2021, Autonomous 2021. © 2019, Ford Motor Company.)

The Daimler/Mercedes (Figure 1.2) websites (2019) states :

> *Prototypes such as the Mercedes-Benz S-Class S 500 INTELLIGENT DRIVE, the F 015 Luxury in Motion or the Future Truck 2025 show that the technical conditions for autonomous driving are already well established. And demonstrations of our intelligent Highway Pilot in the Freightliner Inspiration Truck in Nevada (USA) and a series production Mercedes-Benz Actors in Germany have proven that it is ready for autonomous driving on public roads.*
>
> *The required sensors and cameras have long been used in series production vehicles and undertake increasing numbers of tasks on the driver's behalf. Today's discussion no longer revolves around whether the technology will deliver on its promise but whether people*

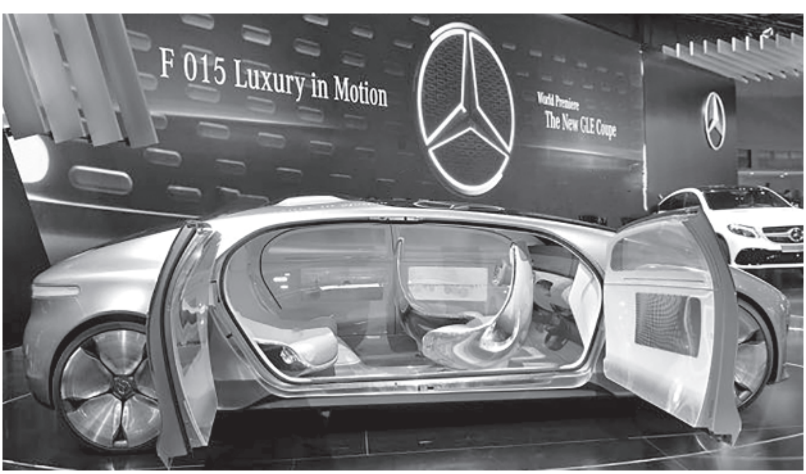

Figure 1.2 Mercedes F 015 concept AV at Detroit Motor Show (2015). Source: Mercedes-Benz.

want what the technology can deliver. And whether society and legislators are ready for this "revolution in automobility."

When it comes to passenger transport, autonomous driving ensures more safety, more comfort and more mobility. A purpose-designed research vehicle, the F 015 Luxury in Motion, shows what an autonomous Mercedes-Benz may look like in the future. We are convinced that the car can be more than just a means of transport: we see it as a private retreat that offers more freedom. Because autonomous driving allows us to use our time on the move as we wish. Naturally the design of this private retreat reflects the Mercedes-Benz brand.

When it comes to freight transport autonomous driving brings additional advantages. More efficiency: a more steady flow of traffic reduces fuel consumption and emissions. Better coordination of all processes: thanks to the connection to telematics solutions for fleets, routes and trips, diagnosis and servicing can be better planned. And what difference will it make for the drivers? On the one hand, time pressure will be reduced. After all, if all partners are informed about the progress of the journey in real time, there is no reason to explain a delay. On the other hand, drivers can "hand over control" on monotonous stretches of road. Anyone picturing a driver dozing in a moving truck at this point is very much on the wrong track, however. The driver is a key part of the system. In certain traffic situations, for example on motorways and rural roads, in city traffic and when connecting semitrailers and making deliveries, the driver must retain control of the truck.

Autonomous mobility will bring about major changes and involve many different parties. Psychological barriers must be overcome in the same way that social acceptance must be gained. This requires a sound legal basis across country borders that regulates autonomous traffic and covers questions of liability in the event of a collision.

French manufacturer Renault, says on its website (2019):

"Our goal is to provide our customers with models that feature a delegated autonomous driving mode from 2020 onward. This technology will make driving safer and more pleasant while also freeing up time for drivers." Laurent Taupin, Chief Engineer – Autonomous Vehicle

From ADAS to Autonomous Driving

Groupe Renault currently offers advanced driver assistance systems on its vehicles. These ADAS improve safety and act for the most part without human input, as is the case for automatic emergency braking (AEBS). They serve as a gateway to autonomous vehicles, even though they are initially only there to provide assistance to the driver, who remains in charge of the vehicle.

Eyes off/hands off technology

"Eyes Off/Hands Off" technology is a form of autonomous driving with no driver supervision. When drivers delegate driving activities, they no longer need to watch the road or have their hands on the steering Wheel - driving is now fully delegated to the vehicle. This feature is intended for the most boring kinds of driving - driving in stop-and-go traffic, for instance - and only on approved highways.

Eyes off/hands off mode

When autonomous driving mode is activated, a set of sensors monitor the road and provide 360° surveillance of the vehicle: lidars (long-range laser scanners), long-range frontal radar, medium-range corner radar, frontal digital cameras, four 180° digital cameras, an ultrasound belt and more. The data collected by these sensors is analyzed by the many embedded software "brains" that tell the vehicle what to do.

Figure 1.3 Screenclip from Renault website. Source: Renault.

> *Eyes off/ hands off benefits*
>
> *With the autonomous "Eyes Off/Hands Off" mode, Renault's goal is to change the experience of riding in cars, making it more pleasant, more interesting and safer. This will significantly reduce the risk of accidents! Trips will be less stressful and more productive. Drivers can make better use of their time by using in-vehicle connectivity to answer emails or watch videos. They can do so safely, outside conditions permitting, as long as applicable laws and regulations are followed, once these are updated to authorize these new features*. (Source: Renault, Autonomous Vehicle, © 2019, Renault.)
>
> *EZ-GO Concept*
>
> *The robot-vehicle that reinvents the relationship between space and time. In an urban environment, EZ-GO Concept is the first incarnation of autonomous, connected and shared mobility using an electric engine, without a steering wheel or a driver (Figure* 1.3*).*
>
> *Mobility on demand for everyone*
>
> *EZ-GO Concept is a "robot-vehicle": both a vehicle and a transport service but also plays an integral part of the urban ecosystem. It has a positive impact on city life by providing mobility that is more respectful of the environment. The use of this autonomous vehicle for public transport takes it to the forefront of a new urban way of life. A facilitator for everyday life, EZ-GO Concept offers a genuinely connected and customised experience to its passengers. With frontal doors, limited speed and autonomous driving, EZ-GO Concept puts the safety of passengers at the forefront. The AD lighting signature, messages from the illuminated scrolling displays and the vehicle's exterior sounds ensure the safety of pedestrians*. (Source: Renault, EZ-GO Concept, © 2019, Renault.)

The Verge, an online multimedia publication designed to examine how technology will change life in the future, recently posted (2019)

> *General Motors plans to mass-produce self-driving cars that lack traditional controls like steering wheels and pedals by 2019, the company announced today. It's a bold declaration for the future of driving from one of the country's Big Three automakers, and one that is sure to shake things up for the industry as the annual Detroit Auto Show kicks off next week*.

> *The car will be the fourth generation of its driverless, all-electric Chevy Bolts, which are currently being tested on public roads in San Francisco and Phoenix. And when they roll off the assembly line of GM's manufacturing plant in Orion, Michigan, they'll be deployed as ride-hailing vehicles in a number of cities.*
>
> *"It's a pretty exciting moment in the history of the path to wide scale [autonomous vehicle] deployment and having the first production car with no driver controls," GM President Dan Ammann told The Verge. "And it's an interesting thing to share with everybody."*
>
> *"THE FIRST PRODUCTION CAR WITH NO DRIVER CONTROLS"*
>
> *The announcement coincides with the tail end of CES, where a number of big companies announced their own plans to deploy autonomous vehicles, and right before the Detroit Auto Show, where the industry will have on display all the trucks and SUVs that make its profits.*
>
> *By committing to rolling out fully driverless cars in a shortened timeframe, GM is seeking to outmaneuver rivals both old and new in the increasingly hyper competitive race to build and deploy robot cars. Ford has said it will build a steering-wheel-and-pedal-less autonomous car by 2021, while Waymo, the self-driving unit of Google parent Alphabet, is preparing to launch its first commercial ride-hailing service in Phoenix featuring fully driverless minivans (though still with traditional controls).*
>
> *Unlike those other companies, GM provided a sneak peek at how its new, futuristic cars will look on the inside. In some ways, [it's] the vehicular version of a [Rorschach] inkblot test. The bilateral symmetry of the interior looks both unnerving and yet completely normal at the same time. Instead of a steering wheel, in its place is blank real estate. Under the dash, more empty space.*
>
> *The automaker submitted a petition to the National Highway Traffic Safety Administration for permission to deploy a car that doesn't comply with all federal safety standards. Ammann said the company wasn't seeking an exemption from the Federal Motor Vehicle Safety Standards — something the government caps at 2,500 — just a new way around a few of the requirements.*
>
> *GM is proposing to "meet that standard in a different kind of way," Ammann said. "A car without a steering wheel can't have a steering wheel airbag," he said. "What we can do is put the equivalent of the passenger side airbag on that side as well. So its to meet the standards but meet them in a way that's different than what's exactly prescribed, and that's what the petition seeks to get approval for."* (Source: Andrew J. Hawkins, GM will make an autonomous car without steering wheel or pedals by 2019, Jan 12, © 2018, Vox Media.)

The Volvo website (2019) offers:

> *What is autonomous driving?*
>
> *We believe that mobility should be safer, sustainable and more convenient. For Volvo Cars, technology should make people's lives easier. That's why our approach to autonomous driving is all about the people that will use them. Our future cars will be able to navigate without human input, equipped with sensors that read the surroundings, adapting to changing traffic conditions.*
>
> *Unsupervised driving*
>
> *In unsupervised autonomous mode, a vehicle performs all the driving because it is safe to rely on the technology to steer, brake and accelerate. People on board the vehicle are not expected to have control of the car.*

> *Why autonomous cars?*
>
> *Unsupervised autonomous cars will revolutionise society, boost global economies and transform the way we manage our time. As the biggest change to personal mobility since the invention of the car 130 years ago, we think there's a lot to look forward to. At Volvo Cars we believe that our first unsupervised autonomous vehicles will be in the market by 2021. What makes our approach to autonomous driving so unique is that we focus on people – not just on technology* (Source: Volvo, Autonomous Driving. © 2019, Volvo Car Corporation.)

Even the austerity-following UK Chancellor of the Exchequer, Phillip Hammond, not one noted for his optimism, quoted early in 2019, that…. "the autonomous car, probably powered by an electric motor, will be on British roads, unsupervised, by 2021." (*The Guardian* 2019)

Anthony Cuthbertson writing for the middle of the road UK newspaper, *The Independent*, shortly after, (2019) reported:

> *Driverless cars to be rolled out on UK roads by end of 2019, government announces*
>
> *'Key priority must be ensuring cyber security defences are deployed so this fantastic, ground-breaking technology does not fall victim to hackers,'* …….
>
> *Self-driving cars without a human supervisor will be tested on public roads in the UK by the end of the year, under government plans*.
>
> *Fully driverless trials have previously only taken place on a limited scale in the US and Europe*.
>
> *The Department of Transport said the move towards advanced trials would push the UK to the forefront of the industry*.
>
> *'Thanks to the UK's world class research base, this country is in the vanguard of the development of new transport technologies, including automation,' said Jesse Norman, the transport minister*.
>
> *'The government is supporting the safe, transparent trialling of this pioneering technology, which could transform the way we travel.'*
>
> *'The UK has a rich heritage in automotive development and manufacturing, with automated and electric vehicles set to transform the way we all live our lives,' said Richard Harrington, the automotive minister*.
>
> *Uber plans self-driving bicycles and scooters*.
>
> *'We need to ensure we take the public with us as we move towards having self-driving cars on our roads by 2021. The update to the code of practice will provide clearer guidance to those looking to carry out trials on public roads.'*
>
> *Advanced driverless trials on UK roads by the end of 2019 will also help the government keep to its commitment of having self-driving vehicles on UK roads by 2021, ministers said*. (Source: Anthony Cuthbertson, Driverless cars to be rolled out on UK roads by end of 2019, government announces, 6 February. © 2019, The Independent.)

And even the normally staid departments of government are getting excited. The UK Government Actuaries Dept (GAD), in September 2017 published:

> *Self-Driving Cars*
>
> *Once just viewed as part of science fiction, self-driving cars, perhaps more correctly referred to as connected and autonomous vehicles (CAVs), are already here in various forms. Connected vehicles are those which are able to communicate with their surroundings providing information on road, traffic and weather conditions. The next level is automation where the*

vehicle uses its connection to assist the driver, examples include autonomous emergency braking, adaptive cruise control and park assist. Testing is now also well under way for vehicles that take full control from start to finish – fully autonomous vehicles.

The vast majority of road accidents relate to human error and reducing such accidents is projected to contribute £2 billion of savings to the economy by 2030. The total projected economic benefits from all sources are in excess of £51 billion. These figures highlight the importance of developing this technology.

The UK Society of Motor Manufacturers and Traders (SMMT) issued a report (2019). This report 'offers a detailed assessment of connected and autonomous vehicle (CAV) development, and crucially deployment, in the UK'. The report envisages the economic benefit to the UK from the deployment of CAVs (connected and automated vehicles), to be in the region of £62 billion per annum by 2030. The SMMT report forecasts the benefits, just for UK, to be (Figure 1.4):

'The emergence of CAVs will bring unprecedented change to the automotive industry worldwide. More than 18 million new automated vehicles are expected to be added to the global motor parc by 2030, significantly changing the way people commute. Over the next decade, for instance, new mobility modes such as automated shuttles could address gaps in first and last mile mobility'.

……………'As this happens, disruption is likely to occur across traditional, ownership focused vehicles as well as shared mobility services such as taxis and shuttles. For example, it is estimated that there will be a 15% reduction in all collisions across major markets, including in

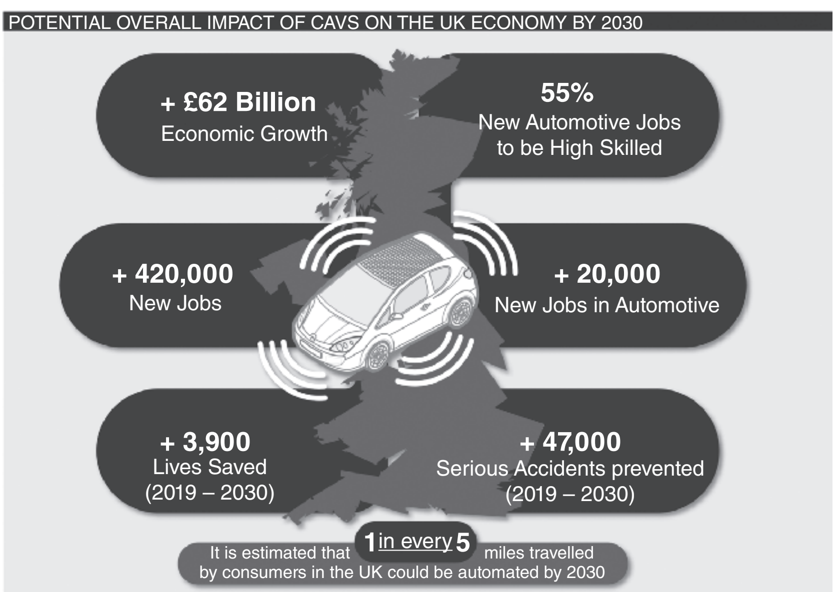

Figure 1.4 SMMT Potential overall impact of CAV's on the UK economy (screenclip from public website). Source: The UK Society of Motor Manufacturers and Traders (SMMT) issued a Report "Connected and Autonomous Vehicles 2019 Report / Winning the Global Race to Market. © 2019, SMMT".

> *Europe and North America, within a span of 10 years of Automated Emergency Braking (AEB) being mandated in Europe (expected between 2021 and 2025).'*
>
> *The report assesses the Global situation and reports that 'milestones reached in nations around the globe in 2018'.*
>
> *GLOBAL OVERVIEW OF CAV DEVELOPMENT*
>
> *Several countries are currently exploring the impact of AVs on their cities and highways. Crucial to building this understanding is real world testing. Accordingly, many test beds have been set up to help collect vital data on how AVs interact with their surroundings, with a series of major milestones reached in nations around the globe in 2018.*
>
> ***Europe***
>
> - *AV testing on public roads was legalised in several countries, including France, Germany, the Netherlands, Norway, Sweden and the UK.*
> - *A legal framework for AVs, including driving licence equivalents for self-driving vehicles, was reviewed*
> - *in the UK, the Netherlands, and Germany. The UK Parliament approved further clarity on liability in self-driving mode, introducing the world's first insurance legislation for AVs* (2019)
> - *Oxbotica, a UK start-up focused on AV software stack and related services, began on-road testing for Level 4 automated grocery delivery vehicles, taxis and shuttles at locations across the UK.*
>
> ***North America***
>
> - *California passes state level approval for driverless vehicle testing with no safety driver present.*
> - *The US Department of Transportation issued guidance for automated driving pilot programmes.*
> - *GM and Ford set up new automated driving divisions to accelerate AV deployment. Tesla rollout Level 2 and Level2+ features with Level 3 and Level 4 features planned for 2020.*
> - *Waymo, a spinoff from technology giant Google, starts first AV commercial business model in Arizona.*
>
> ***Asia Pacific***
>
> - *Japan considered policies related to liabilities, driving licenses and cybersecurity laws.*
> - *In China, 11 roads were added to the existing 33 roads in Beijing designated for autonomous driving tests. AVs were required to complete 5000 km of daily driving in designated closed test fields before being allowed to apply for public road testing permits.*
> - *China granted permission to Audi, BMW and Daimler to test AVs in Beijing and Shanghai.*

So the report, generated by the manufacturer's association, is significantly more conservative in timescale than the claims of the individual manufacturers.

> *However, the report goes on to predict that "...... From 2021 onwards, some early generation Level 4 automation features may be introduced. These could include highly automated highway pilot, automated valet parking and automated vehicles such as taxis operating within virtually defined or 'geofenced' zones in urban areas.*

> …….
> …………… *ECONOMIC IMPACT OF CAVS ON THE UK ECONOMY BY 2030*
> ……*a reduction of over 47,000 in serious collisions and a further 3,900 lives saved. According to current projections, a total of almost 56,000 crashes of all kinds can be eliminated via AV related technologies by 2030 alone. These are expected to be further augmented in years to come when V2X applications, such as intersection collision warning and road hazard warning, complement the safety benefits that automation will bring*.
> *CREATION OF MORE THAN 420,000 JOBS ACROSS THE ECONOMY*
> *Digitisation of the automotive value chain is forecast to help create more than 20,000 new jobs in the automotive sector alone. Of these, 11,000 (55%) are expected to be highly skilled across both upstream and downstream services. Rewarding new job opportunities are expected to emerge in software and hardware development for automated and connected technologies in the upstream, and in vehicle fleet and network management in the downstream along the value chain*.
> *Over the next decade, testing, validation and digital technology-based jobs are likely to enjoy significant growth, helping to offset changes elsewhere in traditional manufacturing and production. Current CAV development trends indicate that market-specific validation and testing will be critical for successful deployment of CAVs and this will lead to emergence of a new set of automotive jobs in vehicle system testing in the UK that does not exist currently*.
> *The wider impact on the UK job sector within adjacent industries, including in telecommunications, content creation, logistics and others, is likely to be even more pronounced; more than 400,000 new jobs are expected to be created. These assessments are predicated on the UK leaving the EU with a favourable Brexit deal that maintains the £145 billion economic impact by 2035, instead of the currently forecast 2040*.
> ……... *However, all of this will only be possible with active and sustained support from the government, especially in terms of investment in infrastructure and regulatory support*. (Source: The UK Society of Motor Manufacturers and Traders (SMMT) issued a Report "Connected and Autonomous Vehicles 2019 Report / Winning the Global Race to Market. © 2019, SMMT.)"

The UK newspaper, *The Guardian*, reported that, at the launch of the report:

> *Mike Hawes, the chief executive of the SMMT, said more than £500 m had been invested in research and development by industry and government, and another £740m in communications infrastructure to enable autonomous cars to work*.
> *He said: 'The opportunities are dramatic – new jobs, economic growth and improvements across society'*.
> *Hawes said widespread trials of autonomous vehicles were already under way and the industry would attempt to achieve the government's ambition of driverless vehicles on the roads by 2021*. (Source: Gwyn Topham, Self-driving cars could provide £62bn boost to UK economy by 2030, April, © 2019, Guardian News & Media Limited.)

The French government has stated its support for the development of automated vehicles, with the aim of deploying 'highly automated' vehicles on public roads between 2020 and 2022. The government has made 40 million euros ($46 million) available to help subsidise new projects. According to Automotive News Europe (2019), more than 50 autonomous-vehicle test projects have taken place in France since 2014, including robotaxis, buses and private vehicles.

French president Emmanuel Macron has appointed a senior official, Anne-Marie Idrac, to develop a national strategy for driverless mobility – including new laws, regulations for experiments and pilot projects, and cybersecurity and privacy issues. France's Transport Minister Élisabeth Borne has announced a plan to develop transit with autonomous electric vehicles

According to the Europe Autonews report, 'the first legal proposals are expected by the end of this year and once approved will allow Level 3 and 4 passenger vehicles, driverless mass transit such as robotaxis, and automated delivery vehicles'.

Small, driverless shuttle buses built by Nayva – which has financial backing from French supplier Valeo, among others – have been operating on closed road circuits in La Defense, the business zone outside Paris, since 2017. (Source: Peter Sigal, France pushes for 'highly automated' vehicles by 2022, August 08, © 2018, Crain Communications, Inc.)

A contact in the Conseil Général de l'Environnement et du Développement Durable advised that a proposal called LOM (la loi d'orientation des mobilités or, mobility orientation law) has already made it through the senate. It will allow autonomous shuttles to circulate freely from 2020 on the entire public road network.

Germany enacted the 'Autonomous Vehicle Bill' in June 2017, modifying the existing Road Traffic Act defining the requirements for highly and fully automated vehicles, while also addressing the rights of the driver. The legislation will define what an automated vehicle is and states that such technology must comply with traffic regulations, recognise when the driver needs to resume control, and inform him or her with sufficient lead time as well as at any time permitting the driver to manually override or deactivate the automated driving mode.

In highly decentralised Germany, autonomous testing legislation is handed out by city regulatory authorities, rather than central government. Several sources advise that the current federal government plans to create an infrastructure suitable for Level 5 fully autonomous vehicles by the end of the current legislative period.

Looking behind the marketing hype of the auto manufacturers, it would seem to be reasonable to summarise that a major of auto manufacturers are focussing on the partial automation of high-end cars with a short-term objective of 2020, though 2021–2022 may be a more achievable goal for most manufacturers. These are probably about the earliest years that Level 4 automation is most likely to be available.

At Level 3 automation, the driver will still need to be alert and ready to 'immediately' take over control if the driving system encounters a situation it cannot resolve. In a situation where the driver is not driving for considerable periods of time, just how long it takes for a driver to be able to take over and recover what is probably an emergency stop or avoidance manoeuvre, remains the subject of further research and debate. Despite the hype of the motor manufacturers websites, and their claims at motor shows, in reality, full automation is expected to debut much later – but whether that is the 2020s, 2030s or 2040s is still under debate.

That said, the car manufacturer Tesla, already a pioneer in deployed degrees of automation, continues to press ahead (2019).

All new Tesla cars come standard with advanced hardware capable of providing Autopilot features today, and full self-driving capabilities in the future—through software updates designed to improve functionality over time.

Advanced Sensor Coverage

Eight surround cameras provide 360 degrees of visibility around the car at up to 250 meters of range. Twelve updated ultrasonic sensors complement this vision, allowing for detection of both hard and soft objects at nearly twice the distance of the prior system. A forward-facing radar with enhanced processing provides additional data about the world on a redundant wavelength that is able to see through heavy rain, fog, dust and even the car ahead.

Processing Power Increased 40x

To make sense of all of this data, a new onboard computer with over 40 times the computing power of the previous generation runs the new Tesla-developed neural net for vision, sonar and radar processing software. Together, this system provides a view of the world that a driver alone cannot access, seeing in every direction simultaneously, and on wavelengths that go far beyond the human senses.

Tesla Vision

To make use of a camera suite this powerful, the new hardware introduces an entirely new and powerful set of vision processing tools developed by Tesla. Built on a deep neural network, Tesla Vision deconstructs the car's environment at greater levels of reliability than those achievable with classical vision processing techniques.

Autopilot

Autopilot advanced safety and convenience features are designed to assist you with the most burdensome parts of driving. Autopilot introduces new features and improves existing functionality to make your Tesla safer and more capable over time. Autopilot enables your car to steer, accelerate and brake automatically within its lane.

Navigate on Autopilot

Navigate on Autopilot suggests lane changes to optimize your route, and makes adjustments so you don't get stuck behind slow cars or trucks. When active, Navigate on Autopilot will also automatically steer your vehicle toward highway interchanges and exits based on your destination.

Current Autopilot features require active driver supervision and do not make the vehicle autonomous.

Full Self-Driving Capability

All new Tesla cars have the hardware needed in the future for full self-driving in almost all circumstances. The system is designed to be able to conduct short and long distance trips with no action required by the person in the driver's seat.

All you will need to do is get in and tell your car where to go. If you don't say anything, the car will look at your calendar and take you there as the assumed destination or just home if nothing is on the calendar. Your Tesla will figure out the optimal route, navigate urban streets (even without lane markings), manage complex intersections with traffic lights, stop signs and roundabouts, and handle densely packed freeways with cars moving at high speed. When you arrive at your destination, simply step out at the entrance and your car will enter park seek *mode, automatically search for a spot and park itself. A tap on your phone summons it back to you.*

Some features require turn signals and are limited in range. The future use of these features without supervision is dependent on achieving reliability far in excess of human drivers as demonstrated by billions of miles of experience, as well as regulatory approval, which may take longer in some jurisdictions. As these self-driving capabilities are introduced, your car will be continuously upgraded through over-the-air software updates. (Source: Tesla.com, Future of Driving. © 2019, Tesla.)

In a podcast interview with the money management firm ARK Invest, Elon Musk, the Tesla CEO, made a prediction that the Tesla's full self-driving feature will be completed by the end of 2019. And by the end of 2020, he added, it will be so capable, you'll be able to snooze in the driver's seat while it takes you from your parking lot to wherever you're going.

> I think we will be "feature-complete" on full self-driving this year, meaning the car will be able to find you in a parking lot, pick you up, take you all the way to your destination without an intervention this year, I am certain of that. That is not a question mark.

Today, for an extra $5000 at purchase, owners can unlock their vehicles' 'enhanced autopilot feature'. The technology 'guides a car from a highway's on-ramp to off-ramp, including suggesting and making lane changes, navigating highway interchanges, and taking exits', according to the driver's manual for the S and X models.

However, Tesla has had to send notification to all owners, and add into every Tesla drivers manual *'Traffic-Aware Cruise Control cannot detect all objects and may not brake/decelerate for stationary vehicles, especially in situations when you are driving over 50 mph (80 km/h) and a vehicle you are following moves out of your driving path and a stationary vehicle or object is in front of you instead'.*

A stark and basic warning, made as the result of several crashes (Figure 1.5).

Figure 1.5 Screenclip from press report. Source: Dailymail.co.uk.

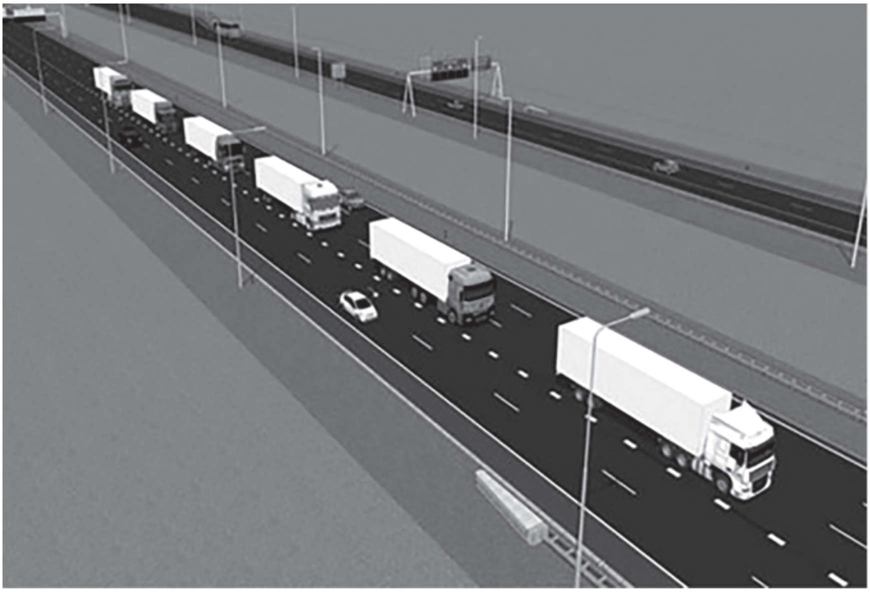

Figure 1.6 Publicly available EC Document from EC project Ensemble. Source: ENSEMBLE, ENabling SafE Multi-Brand pLatooning for Europe, European Union, 2017. Licensed under CC By 4.0.

Moving attention from cars to large goods vehicles, there has been much attention to, research and investment in truck platooning. Truck platooning is the linking of two or more trucks in convoy, using connectivity technology and automated driving support systems. Much as with adaptive cruise control, but with communication between vehicles, rather than just sensors, these vehicles automatically maintain a set, close distance between each other when they are connected for certain parts of a journey, for instance on motorways (Figure 1.6).

The truck at the head of the platoon acts as the leader, with the vehicles behind reacting and adapting to changes in its movement – requiring little to no action from drivers. In the first instance, drivers will remain in control at all times, so they can also decide to leave the platoon and drive independently. However, according to Commercial Fleet News, and after investing some €50 million (£44 m) on platoon testing,

> *Mercedes-Benz Trucks has concluded that there is no business case for truck platooning, saying that the technology failed to deliver appreciable fuel savings in its on-the-road tests'*. (2019)
>
> *Although the manufacturer will remain committed to ongoing platooning projects with partners, such as Ensemble in Europe, it now plans to refocus its resources on developing autonomous, self-driving technologies in its trucks.*
>
> *It told delegates at this month's Consumer Electronics Show (CES) in Las Vegas that results show fuel savings, even in perfect platooning conditions, were less than expected. Savings were further diminished when the platoon was disconnected and the trucks had to accelerate to reconnect. In at least four US long-distance applications, analysis showed no business case for driving platoons with new, aerodynamic trucks*. (Source: Commercialfleet.com, Mercedes switches focus away from platooning trials. © 2019, Bauer Consumer Media.)

Congestion and the nature of the UK and many European countries networks have always been highlighted as possible barriers to vehicle platooning working effectively/realising benefits in Europe.

While platooning looks good as a concept on paper, in the real world it is weighed down by practical issues like pairing trucks from different fleets with incompatible hardware and software, and Mercedes experience shows that it is difficult to actually realise the apparent benefits, such as fuel savings. Other manufacturers are likely to turn their attention to the longer term goals of fully automated driving as fleet operator interest in its potential savings declines.

Vehicles that drive themselves could bring dramatic shifts in car ownership, public transport, employment patterns, business and urban development.

The theoretical safety benefits are huge. 'Autonomous' viz. 'automated' vehicles won't drink and drive or get distracted by telephone calls, Facebook posts, or children in the back. They will be programmed to drive at appropriate and legal speeds, and will pay attention to their environment in 360 degrees at millions of times every second.

Whether for cars, vans or large commercial vehicles, the adoption and take up of these technologies will mitigate some risks; but it is likely that they may also create new risks. And there are still many operational, research and regulatory questions that partly automated and fully automated vehicles present, that remain unsolved.