AUTONOMOUS AND DRIVERLESS CARS.

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION SHOWS THAT 95% OF ALL CRASHES OCCUR DUE TO DRIVER ERROR.

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This case study has been produced in the context of the Institution's strategic themes of education, energy, environment, healthcare, manufacturing, transport and its vision of 'Improving the world through engineering'.

Cover image
The Mercedes-Benz F015 Luxury in Motion research car with it's immersive user experience is an innovative perspective into the future of mobility.

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Autonomous and driverless cars

The fully autonomous (driverless) car is on its way, with today's new vehicles having increasing amounts of system automation and ability. It must be recognised that there will be no 'Big Bang' but rather an introduction of increasing levels of automation over a number of years. Our engineers face a huge challenge in the step change required to create highly, and then fully, autonomous vehicles; this creates uncertainty about the timing of their availability. There are societal questions that need to be addressed before highly and fully automated cars are both accepted and legally able to be positioned on our roads; this will include having the right regulatory framework in place. The modernisation of our current car fleet will take a long time. Currently it is estimated to take ten years to get a new technology on to the production line, with a further ten to fifteen years to get the majority of the UK fleet changed. Therefore the earliest we could predict a near 100% highly automated UK fleet is by 2040, and a fully autonomous UK fleet by 2050. Removing the drivers from our vehicles should ultimately mean there are less crashes on our roads, as data from the National Highway Traffic Safety Administration shows that 95% of all crashes occur due to driver error. But before our fleet changes, the impacts on risk and the provision of insurance products need to be addressed. Engineers believe that there will be a shift away from individual driver insurance towards insurance for the vehicle, ie towards product liability insurance. In the transition, risk-accurate information about the insured vehicle will become more important. For the moment, motor insurance remains essential as long as the driver is required to be in control.

The Institution of Mechanical Engineers recommends that:

- The Transport Systems Catapult conduct a public consultation, bringing together a working group that includes industry, legislators, regulators and members of the general public. This group should look at how we can integrate and implement new regulatory regimes.
- All car dealerships and garages must work with the vehicle manufacturers to ensure that they can provide adequate information, and give the required training, to any new purchaser of a vehicle. This practice has already been adopted by BMW.
- The Department for Transport needs to address the safety issues of autonomous vehicles, looking at how they can be integrated onto our road network with appropriate road signage and markings in place or updated.

The 2015 Hyundai Genesis features ASCC (Advanced Smart Cruise Control), AEB (Automatic Emergency Braking System), and LKAS (Lane Keep Assist System) technologies.

Autonomy

When the term 'autonomy' is applied to a car, we are referring to decisions taken by embedded intelligence in the vehicle systems. Embedded intelligence is logic (rules) based software: eg IF the forward-looking camera image contains a pre-defined pixel pattern associated with a car, AND the radar confirms that a reflection pattern is similar to a pre-defined pattern associated with a car, AND the reflection times indicate that the driven vehicle will converge with the reflection within a certain time, THEN the emergency brakes will be applied.

Embedded intelligence is common in a range of mainly electronically controlled systems across a range of engineered objects – from central heating to automated trains. On this basis we refer to 'driverless cars', the presumption being that the lack of driver is because the car has embedded intelligence equivalent or superior to that of a human driver.

With each increasing level of autonomy, new driving tasks will be possible for the vehicle to control, based on its embedded intelligence. **Table 1** shows the progression of this and where we are in 2015 in terms of level of autonomy.

Table 1: Levels of autonomy and where we are now.

Increasing level of Autonomy

Driver Control	The driver is completely in control but there are some automated systems	– Cruise Control – ABS – ESC	
Assisted Driving	The steering and/or braking and acceleration are automated but the driver controls other functions	– Cruise Control – ABS – ESC	– AEB – Adaptive Cruise Control – Parking and Lane Keep Assistance
Partial Autonomy	The steering, braking and acceleration are automated and require no intervention from the driver	– Cruise Control – ABS – ESC – AEB – Adaptive Cruise Control – Parking and Lane Keep Assistance	– Adaptive Cruise Control with lane keeping – Traffic Jam Assistance
High Autonomy	The vehicle can complete sections of a journey autonomously, the driver is given and takes control	– Cruise Control – ABS – ESC – AEB – Adaptive Cruise Control – Parking and Lane Keep Assistance – Adaptive Cruise Control with lane keeping – Traffic Jam Assistance	– Road following – Junction decisioning – Hazard detection and evasive decisioning – Mapping of other road users, intention prediction monitoring and decisioning – Ethical decisioning
Full Autonomy	The vehicle completes the journey with no human intervention	– Cruise Control – ABS – ESC – AEB – Adaptive Cruise Control – Parking and Lane Keep Assistance – Adaptive Cruise Control with lane keeping – Traffic Jam Assistance	– Road following – Junction decisioning – Hazard detection and evasive decisioning – Mapping of other road users, intention prediction monitoring and decisioning – Ethical decisioning

TECHNICAL AND PUBLIC CONFIDENCE

Where we are now

Step change

Embedded intelligence NOT artificial intelligence

Embedded intelligence is not to be confused with artificial intelligence. Embedded intelligence is usually defined as a machine that is a truly independent agent, which can, among other things, reason, problem solve, plan and learn. Researchers in the field are considering other intelligence attributes as part of this emerging definition, areas such as perception and creativity.

It may be that some manifestations of vehicle-embedded intelligence will have a learning capability upon which the vehicle performance will depend in future; some researchers state that this capability may be a prerequisite for the embedded intelligence required to drive a vehicle, due to the enormous numbers of logic ‘rules’ which would otherwise have to be written. However, it is unlikely that this would be easy to manage within current product or liability regulation, as it would be difficult to guarantee the vehicle system performance.

The Audi RS 7 piloted driving concept car is a technology platform with which Audi is exploring the possibilities of piloted driving at its most dynamic.

Stakeholders

With the development of autonomous vehicles, there becomes a number of affected stakeholders. The societal risk for use of these vehicles is managed by a legal framework with agreed liabilities, and it is here that insurers can play their part in the development of these vehicles; details can be seen below in **Table 2**.

Table 2: A map of affected stakeholders.

The legal situation

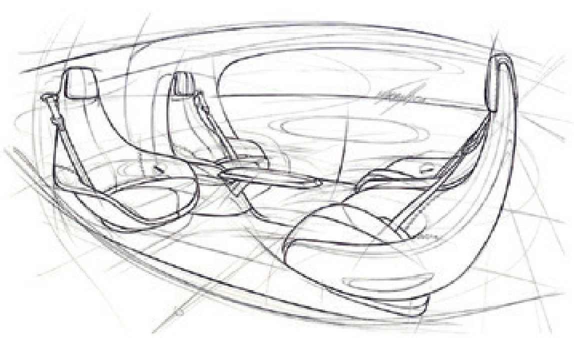
Road traffic regulation

The Road Traffic Act 1988 regulates vehicles used on UK roads, but it does not state that the driver must be in control. The UK's Department for Transport is reviewing the issue of control, and the regulatory framework for testing and use of autonomous cars, insurance liability, tax, MoT, driving licence and revamped Highway Code. This is to be agreed by summer 2017. This follows on from the provision of funding in autumn 2014 to four cities (Bristol, Milton Keynes, Coventry and London Greenwich) which received the go-ahead to pilot autonomous car trials.

The United Nations Economic Commission for Europe (UNECE) has a working party (WP.1) on Road Traffic Safety, which is developing a new clause referring to the technical regulations, as well as a definition of 'Driver Assistance Systems'. In the USA, only Nevada, California and Florida have passed legislation supporting testing of driverless cars.

For the foreseeable future there will continue to be a requirement that the driver retains the ability to take control of the vehicle at any time. Similarly, requirements on the use of seat belts and prohibition of driving under the influence of drugs or alcohol, or using a phone, remain. Any development of the applicable regulations must provide for the different levels of automation in vehicles all occupying the same road space.

The F015 interior features variable seating, allowing occupants to rotate their lounge chairs.



Product regulation

Product regulation in many countries does not allow highly or fully automated driving, and therefore will have to be revised in the near future. As an example, we are likely to see increased vehicle-to-vehicle communication which will require regulation of both the shared system architecture and use of data.

In the UK, the approach adopted by lawmakers has been one of gradual accommodation of new technologies, and the challenges presented by fully automated driving are unlikely to be any different. One of the challenges for the immediate future for an international original equipment manufacturer, component or technology supplier, will be the variety of regulatory regimes adopted in different jurisdictions.

The F015 cabin is framed by six display screens, which use proximity sensors and gesture control.

Insurance

Early legal opinion is forming the view that existing product liability law can be applied to highly and fully automated driving, and it is not expected that a special liability law will be required. The Consumer Protection Act 1987 provides a framework for redress where a defect exists within the car, placing liability on the producer.

Vehicle manufacturers will have to review their insurance position very carefully. There will be an increasing focus on the provision of information and training to car purchasers/users as to the level of automation in a particular product, and what level of participation is required by the driver/user. There will be the requirement for a greater level of after-sales care, technical updates and upgrades. Data protection laws will need to be reviewed, as there may be a need to gather a greater deal of commercially valuable and personally sensitive data during the use of a fully automated car. To ensure that vehicle-to-vehicle communication works effectively will require collaboration between providers. Test cases where accidents still occur may ultimately lead to industry agreements regarding apportionment of liability, and consideration of a no-fault compensation scheme.

With an increasing number of autonomous vehicles on our roads, there will be a need for a common infrastructure/architecture of support systems, and the role of local (and national) government in supporting/adopting these in conjunction with private sector suppliers. There will be new commercial application data collected, however, with this will come the increased risk of cyber security and data protection. Autumn 2015 saw the introduction of driverless ‘pods’ on the (pedestrianised) roads of Milton Keynes. These pods are to be managed by the Transport Systems Catapult who, having accumulated all the data from the test, will be able to assess both the opportunities and threats that these vehicles pose. These trials will give increased visibility of what the future may look like. In addition, they will start to build the trust required by society to adopt this technology in the future – a major hurdle as many people still do not believe computers can make the driving decisions equal in quality to those made by human drivers.

The Institution recommends that the Transport Systems Catapult conduct a public consultation bringing together a working group that includes industry, legislators, regulators and members of the general public. This group should look at how we can integrate and implement new regulatory regimes.

LUTZ Pathfinder
Self-driving pods projects

Self-driving vehicles are expected to bring massive benefits for road users. However, there is still much work to be done before we have fully automated vehicles capable of achieving these ambitious goals. The LUTZ Pathfinder trail of three electric-powered automated ‘pods’ in pedestrianised areas of Milton Keynes was set up to accelerate that work, and to help ensure that the UK stays at the forefront of this exciting and potentially disruptive field.

Overseen by the Transport Systems Catapult on behalf of the UK Automotive Council, the pods are the result of a multi-team collaboration involving the University of Oxford’s Mobile Robotics Group, Coventry-based manufacturers RDM, and Milton Keynes Council.

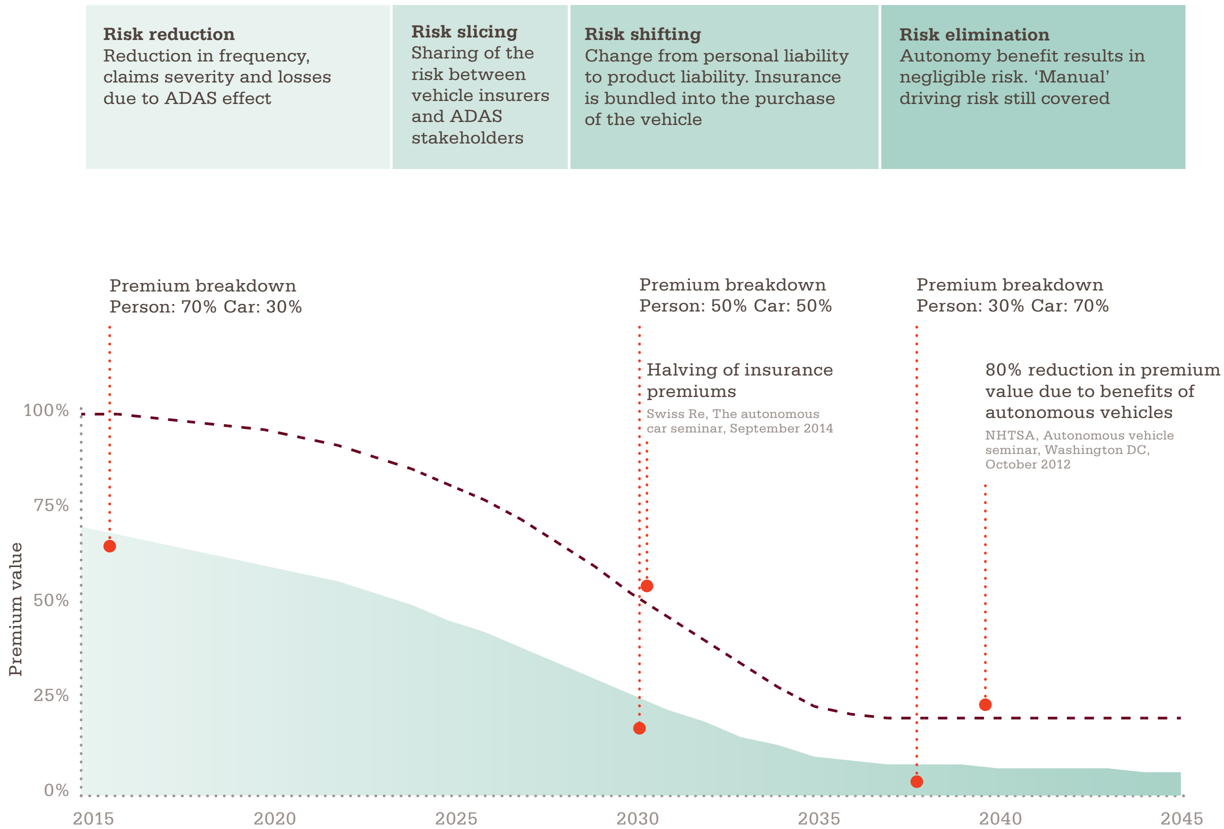
Designed from scratch for automated driving, the two-seater pods are equipped with a wide range of sensors – including stereo cameras, lidar and radar-based detectors, enabling them to navigate without recourse to GPS or any other external resource. As well as trialing the future technology requirements for fully autonomous vehicles, LUTZ Pathfinder is also examining public attitudes towards the technology, and considering the legislative barriers that still have to be overcome before such vehicles can enter the mainstream.

Funding has already been secured for the next level of trails, with findings from the LUTZ Pathfinder project feeding into the larger-scale UK Autodrive programme, which will oversee a three-year trial in two cities (Milton Keynes and Coventry), involving a fleet of 40 automated pods along with seven regular road-based cars.

Preliminary model of the change in personal risk over time

Table 3 shows the preliminary model of the impact of emerging collision avoidance technologies with the change of personal risk overtime. This is expected to reduce significantly over the next 30 years.

Table 3: Preliminary model of the change in personal risk over time.
Source: Thatcham Research.

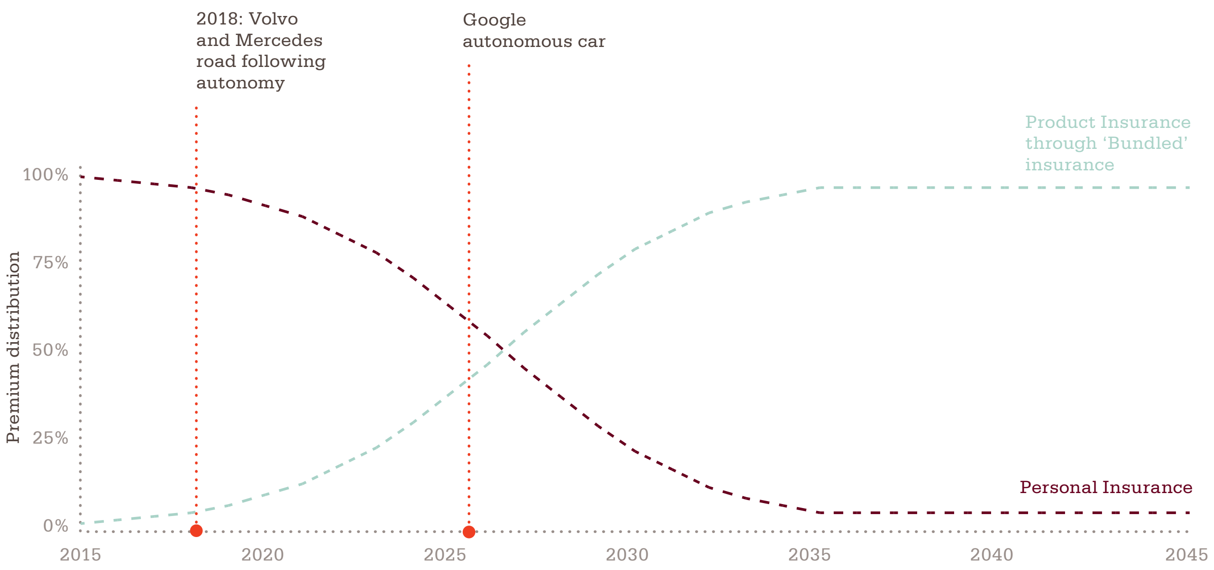


Preliminary model of the increase in product liability insurance

Table 4 gives the preliminary model of the increase in product liability insurance, and shows how we expect an increase in the liability taken by the vehicle manufacturer over the next 30 years as the vehicle-embedded intelligence takes more and more of the risk exposure.

Table 4: Preliminary model of the increase in product liability insurance over time. Source: Thatcham Research.

Risk reduction	Risk slicing	Risk shifting	Risk elimination
Reduction in frequency, claims severity and losses due to ADAS effect	Sharing of the risk between vehicle insurers and ADAS stakeholders	Change from personal liability to product liability. Insurance is bundled into the purchase of the vehicle	Autonomy benefit results in negligible risk. 'Manual' driving risk still covered

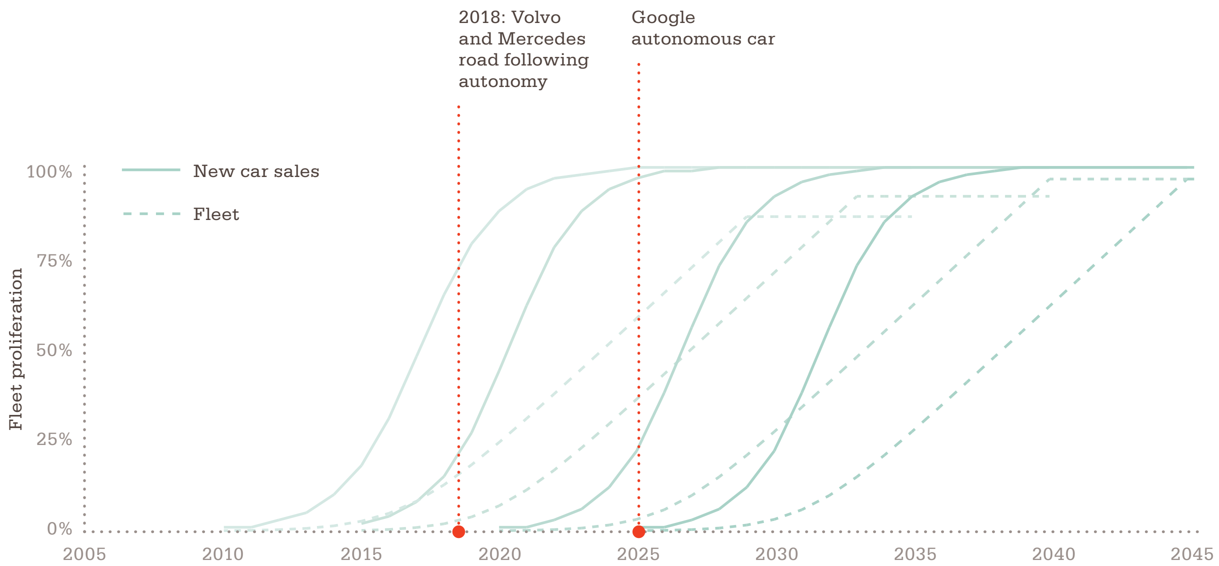


Preliminary model of the development of the autonomous fleet

Table 5 details a preliminary model which shows the time taken for each new level of autonomous capability to penetrate the fleet, each level taking approximately 15 years to achieve 100% of new car sales. This model estimates that the 100% new car sales of fully autonomous vehicles would not occur until about 2040.

Table 5: Preliminary model of the development of the autonomous fleet. Source: Thatcham Research.

Level 1	Level 2	Level 3	Level 4	Level 5
Driver Control Cruise Control. ABS ESC	**Assisted driving** AEB Adaptive Cruise Control. Parking and Lane Keep Assistance	**Partial autonomy** Adaptive Cruise Control with lane keeping. Traffic Jam Assistance	**High Autonomy** Road following. Juction decisioning. Hazard detection and evasive decisioning	**Full autonomy** Combination of all functions and Artificial Intelligence and multiple redundancies – no driver monitoring



Views from industry

Neil Fulton
Programme Director
Transport Systems Catapult

Transport Systems Catapult
The Transport Systems Catapult is one of ten elite technology and innovation centres established and overseen by the UK's innovation agency, Innovate UK, and created to drive and promote Intelligent Mobility – using new and emerging technologies to transport people and goods more smartly and efficiently. We are helping UK businesses create products and services that meet the needs of the world's transport systems as they respond to ever-stretching demands. We help sell UK capability on the global stage, while also promoting the UK as a superb test-bed for the transportation industry. With clear emphasis on collaboration, we are bringing together diverse organisations across different modes of transport, breaking down barriers and providing a unique platform for meeting the world's most pressing transport challenges.

Stephen Stass
Senior Vice President
Business Unit Driver Assistance
Bosch

Future of Automated Driving
For Bosch, automated driving is above all about making road traffic safer. Currently, nine out of ten accidents can be attributed to human error. Research indicates that increasing automation can lower accident rates by up to a third in Germany alone. In automated driving, the car becomes the chauffeur, and the driver the passenger. At the same time, automated driving places great demands on technical reliability and requires fundamental changes to vehicles architecture.

Bosch is working to make this technically possible, and by 2020 targeting to offer a system that will allow cars to drive themselves on freeways. Automated driving makes road traffic more efficient as well, applying predictive driving strategies on the freeway can improve fuel economy by up to 39 percent. But without changes to the law, automated driving cannot become a reality. Bosch is confident that governments and associations will make the right move soon.

Andrew Miller
Chief Technical Officer
Thatcham Research

Now, in the early decades of the 21st century, we are on the cusp of the most revolutionary change in road transport for 120 years. There is a strong possibility that children born in the 2020's will always expect a new car to drive itself – this could be normal. There are also new players entering the vehicle engineering arena, shaking up the existing car makers. Google has cars on public roads, and has been more recently followed by Apple who have an electric autonomous car project. Tesla has made history by providing autonomous functionality by over-the-air software updates, and customers are reporting that their vehicles are 'learning' to drive better on their normal routes. Henry Ford once said 'if I'd asked my customers what they wanted, they'd have said 'a faster horse'' – in other words, we don't know what we want until we have it. There is the potential for the market to demand this technology faster than we in industry and Government can keep up with. In 2014, sales of smartphones worldwide topped 1.2 billion, which is up a staggering 28% from 2013 – a fact not lost on Apple and key to their success. What could the future hold for driverless cars if we get a taste for the benefits that they bring?

Dr John McCarthy
Technical Director Highways and Transportation
Atkins Global

Connected and Autonomous Vehicles
Connected and Autonomous Vehicles, CAVs for short, offer a number of opportunities both in the short and medium term, for both the individual and the network operator. With an ever-expanding level of data being held, consumed and accessed within the car itself, there exists the potential to exploit this data externally and create extra layers of intelligence about the road network that will both help manage the network more efficiently, and offer new services that will enable the journey itself become very customer centric.

However, to get to this point, it is important that the issue trust, both around the systems in use, such as their cyber security capabilities, redundancies in the overall system to mitigate failures, and use of data etc, are played out. In addition, we must understand the human element and the behaviours that drive change and adoption of a new technology, and what CAVs mean to different user groups and communities.

Predictions

Major vehicle manufacturers and technology companies have made numerous predictions for the development of autonomous car technology in the near future. The new Volvo XC90 features 'Adaptive Cruise Control with Steer Assist' which will automatically follow the vehicle ahead in queues, however, currently there is no obligation for any of the car manufacturers or dealers to train the consumer on how to use these technologies.

The Institute of Electrical and Electronics Engineers has estimated that up to 75% of all vehicles will be autonomous by 2040. We therefore need to review how we ensure that the drivers interfacing with the vehicle know how to use the technology and reap the benefits it can offer.[1]

The Institution recommends that all car dealerships and garages work with the vehicle manufacturers to ensure that they can provide adequate information, and give the required training to any new purchaser of a vehicle. This practice has already been adopted by BMW.

The services and offerings that the manufacturers provide will change. This is already being witnessed by Tesla, who have launched its 'autopilot' feature with its 6.1 over-the-air software update.

Estimates by Morgan Stanley indicate that autonomous cars could save the United States $1.3 trillion annually through lower fuel consumption ($169 billion), reducing crash costs ($488 billion) and productivity increases ($645 billion).[2]

KPMG and the Centre for Automotive Research predict new business models, and improvements in productivity and energy efficiency, will occur as we move towards full vehicle automation.[3]

The introduction of increasing levels of automation can be considered in two categories: the near future (next five years) and longer term (2020-2040). In the near term, there will be gradual introduction of automation, leading to vehicles of all types sharing the same road space. The risks associated with this are therefore higher, and it is likely that the regulatory framework will adapt slowly to mirror the requirements on the ground.

As tables 3,4 and 5 demonstrate, as vehicles become more fully automated, the risks of collisions diminish with a transference of risk from the driver/user to the vehicle itself, and associated product liabilities.

The way in which vehicles are used will likely change, from individual ownership to shared ownership or car service schemes. There will remain different systems and therefore types or use of cars in various locations. The urban model will look very different from that on rural roads, and probably differ from country to country. As such, the regulatory framework will need substantial amendment.

The UK Government is keen to get ahead, and there are significant opportunities for those businesses that react earliest.

The Institution recommends that the Department for Transport address the safety issues of autonomous vehicles, looking at how they can be integrated onto the road network with appropriate road signage and markings in place or updated.

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Image credits

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