The Institution of Engineering and Technology

# Autonomous Vehicles: a road transport perspective

## Expected Impact

Highly or fully automated road transport will improve traffic safety, reduce congestion and provide both financial and environmental benefits. Vehicle automation will reduce the driver's workload, reduce accidents, increase vehicle density, minimise speed variations in urban areas and on motorways and reduce vehicle emissions and fuel consumption.

Steps towards automation are perceptible: Some vehicles offer features such as Adaptive Cruise Control (ACC), parking support and collision mitigation. There is also considerable R&D activity in vehicle to vehicle communication, which some commentators suggest as a necessary stepping stone for automated driving.

Nevertheless, significant technical challenges remain in order to achieve the necessary safety integrity (at affordable cost) for realistic deployment. There are also substantial legal issues to address but if progress continues, driving autonomously on public highways could become acceptable within the next ten to fifteen years.

**Transport**

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## Automation levels

To clarify terminology the following automation levels can be distinguished:

| Level | Description |
|---|---|
| Manual driving | Human driver undertakes the manual driving task. |
| Driver Assistance | The driver continuously monitors and controls all longitudinal or lateral support provided by systems that may automate aspects of the driving task e.g. ABS, ACC. |
| Partial Automation | The driver continuously monitors while the system takes over longitudinal and lateral control but the driver is expected to be able to take control back at any time. |
| High Automation | The system takes over longitudinal and lateral control of the vehicle; the driver is not required to continuously monitor the system but is expected to respond to a take-over request within a specific time window (yet to be defined). |
| Full Automation | The system takes over longitudinal and lateral control completely and permanently. When in full automation mode, drivers become “users”. |

More than 10 years ago, research in the US identified the need for dedicated highways for automated vehicles. Some commentators still feel that separation between automated and non-automated vehicles is necessary but it is widely assumed, in Europe at least, that the only viable deployment route involves essentially unmodified roads and deployment in mixed traffic.

## Worldwide deployment of automated road transport

Current technology for automated driving in controlled environments already exists; prototype vehicles capable of driving automatically in urban and highway environments are in operation in Europe and the US.

These vehicles use state-of-the-art sensors (radar, lidar, GPS and camera vision systems) combined with highly accurate maps such that onboard systems can identify navigation paths and avoid obstacles.

Implementation of automation through “platooning” is also quite mature from a technical point of view and is being assessed in various field operational tests across Europe, the US and Japan.

Similarly automation through vehicle cooperation (e.g. Cooperative ACC) has been demonstrated on UK roads. Easy interactions with road journeys would also encourage greater use of LCVs for longer journeys.

## Case Study

### MRG, University of Oxford

The Mobile Robotics Group at the University of Oxford is actively involved in the technologies that underpin autonomous cars and advanced driver assist systems and recently took delivery of an all-electric Nissan Leaf, demonstrating it driving itself around roads at Oxford's Begbroke Science Park.


Currently, the car perceives its environment and figures out where it is by using two infra-red laser-range finders hidden in the bumpers. One of these casts a vertical curtain of laser light returning to the car many thousands of range measurements, every second. As the car moves forward this plane sweeps out a volume and paints the car's local environment with laser light as it goes. The shape and characteristics of the swept volume - which can be thought of as a local map - can be matched against a learnt model of the road and nearby buildings. This matching process, which runs hundreds of times a second, provides a real-time estimate of the car's location.

This process requires the vehicle to have all necessary data to form a clear view of what the world should look like. This data is added to, when the vehicle is being driven by a human. In a very real sense then, the car is taught how to drive a route by its human driver. This experience is then utilised later to drive the human.

Any human driver can teach the car. Surveying routes doesn't have to be perfect. In a dynamic road environment - full of cars, bikes, people - and via appropriate statistical techniques, the navigation system can deal with multiple variables. The vehicle needs to know that the road ahead is clear of obstacles and so, in addition to the navigation laser, there is an obstacle detection unit, which identifies any hurdles and threats in front of the vehicle. If there is something in the way, the driver is alerted. If he or she does not take the car over, the system will plan a safe route or simply bring the car to a halt.

Computation occurs on two computers in the car. The first, called the LLC, has responsibility for system integrity. It constantly checks the health of all sensors and monitors the state of the vehicle's subsystems on its internal network. This machine is fed by the vehicle location and given a motion trajectory (over a small time period). It issues throttle and steering commands. If there is a fault, it brings the vehicle to a halt and or brings the driver back into the loop. The driver can tap the brake to regain complete control of the vehicle, at any time.

The second computer, which sits in the boot and is called the MVC, is a standard PC. It is responsible for the navigation and planning of the vehicle's motion. If the LLC computer is the cerebellum, this second computer is the cortex. All advanced and higher level functions are managed by this computer but basic functions, like safety, are run in the dedicated, perpetually paranoid yet vigilant LLC.

The Group's research heritage plays a big part in its approach to autonomy, in particular, its focus on infrastructure-free navigation. The idea is to allow cars (and for that matter all autonomous vehicles) to be able to operate with zero dependence on external bespoke infrastructure. There are no buried cables, GPS, transponders, special roads, channels or rails. All that is needed are existing roads and the built environment.

One might ask why not use GPS? GPS can be turned off or jammed, doesn't work near tall buildings, requires massive investment and cannot provide the precision navigation required (within a few centimetres).

The mantra is simple. Use what is available but depend on nothing external. If GPS is available, it can be used as a clue to position but it cannot be taken as an accurate or reliable indication of finite position. Similarly, if vehicle-to-vehicle communication or infrastructure communications e.g. 4G are available, these can be leveraged as optional feeds.


Total autonomy isn't the proposition. Building a complete end-to-end autonomous car is; one that has a single 'drive-me' button which can be pressed whenever the passenger demands it.

Supporting a graduated model is the way forward, one in which the car itself offers autonomy, when it believes the process will be safe, achievable and insurable. In the youth of the technology, this will be for only short stretches of road at a time in good conditions. But as the technology improves and adoption increases, as insurers get more data and people get busier, the duty cycle will increase.

Crucially, a 'no dependence on external infrastructure' and 'no cross sector technological co-ordination' approach is needed. Cars will operate by themselves and, if needs be, independently, on existing roads. No government or state intervention is needed. No massive spend on infrastructure or large scale integrated IT project is required. Let cars drive themselves in some of the places, some of the time. This is not a universally held view and it is certainly controversial. The job of a university research group such as ours is to see what can be done with modern robotics science techniques, lots of data and spritely computers.

"This is early stage work. Distances driven autonomously are measured in hundreds and not thousands of kilometres. But it does make the point that the future of autonomous driving lies in smart software and information engineering. We believe it is computing that will revolutionise and drive the future of transport - just like it has in healthcare, finance, entertainment and communications". (Prof. Paul Newman, University of Oxford)

## Research and Technology Challenges

Further research and technological development will be needed to achieve deployment of fully automated road vehicles. Some of the main areas are outlined below:

**Sensors and processing**

To enable reliable and safe automated driving sensing of the vehicle environment, including other road users, is extremely challenging. To reduce costs and to increase synergies, advanced signal processing and data fusion techniques will need to be applied. The special requirements of automated driving lead to increased needs for research and development in areas such as object recognition and tracking, data fusion and situation awareness (including future path determination).

**System Design**

Overall system design, including interaction with other road users, is a key factor in gaining acceptance for road use. Supported by technical component performance, system level integration will need to support overall design concepts such as rules for arbitration and interaction with other road users and the drivers/users of the system. New design, certification and testing regimes may be required to offer the assurance of system performance necessary under both expected and emergency conditions.

## Case Study
The SARTRE Project

Funded by the European Commission's Seventh Framework Programme for Research (FP7), SARTRE (SAfe Road TRains for the Environment) developed strategies and technologies to allow vehicle platoons to operate on normal public highways with significant environmental, safety and comfort benefits.

The scheme focussed on vehicle platoons, groups of automated vehicles, following a lead vehicle, a truck or bus, with a professional driver, taking responsibility for the platoon. The 'following' vehicles would enter a semi-autonomous control mode with automated longitudinal and lateral control. This allowed the driver of the 'following' vehicle to take on other activities that would normally be prohibited for safety reasons e.g. operate a phone, read a book or watch a movie. The potential benefits for drivers and companies could be huge and, conceivably, could result in a new business model for road use, with 'following' vehicles being charged to join a platoon.

A vehicle traffic simulation tool, PELOPS, was used to investigate important aspects of platooning, such as:

- the proper gap size for joining and leaving;
- the time needed for creating, joining or leaving a platoon;
- platoon stability; and
- the influence on the traffic flow e.g. at highway entrances and exits, fuel consumption etc.

SARTRE proposed that the platoons would operate on un-modified public highways and interact with other traffic. In addition to investigating the concept, SARTRE developed a demonstrator system consisting of five vehicles: a lead truck, a 'following' truck, and three 'following' cars.

An off-board system was also developed to allow a potential SARTRE driver to find, and navigate to, a suitable platoon. This was not fully integrated into the vehicle system. However, using these vehicles, a potential energy-saving of 10-20 per cent was identified.

The project investigated the human factors associated with platooning. A safety analysis was carried out on the system considering not only the effects of potential faults, but also the effects of potential misinterpretation by a driver, as well as deliberate malicious actions by third parties.

The demonstration system was successfully tested on test tracks and public motorways, and presented to industry stakeholders as well as members of the press. The commercial viability of systems based on platooning was also studied, looking at a range of options for trucks and for cars.

The SARTRE project was led by Ricardo UK Ltd with collaboration from Idiada and Robotiker-Tecnalia (Spain), Institut for Kraftfahrwesen Aachen IKA (Germany), SP Technical Research Institute (Sweden), Volvo Car Corporation and Volvo Technology (Sweden).

For further information visit **www.sartre-project.eu**

**Interaction with Traffic Management**

Cooperative highly automated driving offers additional potential benefits if combined with traffic management, especially within urban environments. Traffic management could, in the future, include intervention such as vehicle route guidance.

**Modelling of impacts**

Modelling can test the operation of automated functions, under different conditions, and predict impacts e.g. on safety, traffic flow and emissions etc. However, models need data on system and human performance, and these are yet to be well characterized, particularly for mixed traffic operation.

**Human Factors**

Researching human factors is essential since partially and highly automated driving involves the driver at certain phases. Hence, the system behaviour and Human Machine Interface (HMI) must take into account the role of the driver in highly automated vehicles and an appropriate interaction design should be tailored to the driver's needs. In addition, research on the perception, expectations and anticipation of other traffic participants when encountering high or fully automated vehicles or transport systems is needed.

**Techno-Legal issues**

Legal and regulatory frameworks for automated driving do not currently exist. The Vienna Convention requires drivers to be in control of their vehicle, although this requirement is, itself, open to interpretation. Specific automated driving legislation has been enacted in some US states to allow for vehicle deployment under certain conditions. Liability issues are well understood in the automotive sector and, in the automation area, are likely to be informed by technical and certification developments.

## The Future

There is currently enormous interest around highly and fully automated driving. Some commentators see it as a natural next step for road transport following the precedents in other transport areas such as light rail and aviation. Others point to the enormous technological and legal challenges and to the important issue of driver acceptance.

In this Insight, the case studies illustrate two distinct approaches to increased driving automation; one focusing on single vehicle autonomy, the other on increased cooperation between vehicles, and it seems likely that both approaches will be pursued. So, whilst the timetable for on-road deployment of such vehicles is unclear, research and technology progress will continue in parallel with broader policy and commercial development.



This IET Transport Sector Insight was written by Dr Alan Stevens, Chief Research Scientist and Research Director, Transportation at TRL and a Member of the IET's Transport Policy Panel. The Mobile Robotics Group case study was written by Prof. Paul Newman, BP Professor of Information Engineering and EPSRC Leadership Fellow, Department of Engineering Science, University of Oxford. With thanks to Volvo Car UK, John Cairns, the Mobile Robotics Group and Department of Engineering Science (University of Oxford) for providing the images used in this Sector Insight.