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Summary

20 years from now our roads will look very different. Zero Emission Vehicles and other low emission vehicles will no longer be a rarity and “drivers” will be seen working, watching a movie, or even facing away from the direction of travel. Technology is already making our roads safer and could soon enable predictive maintenance of road infrastructure and optimised traffic routing. This paper examines some of the technologies that are coming together to build this connected automotive infrastructure.

Government and industry are devoting substantial resources to developing, testing and proving innovative new technologies and services and there are significant opportunities for UK SMEs to get in on the action. The government-funded consortia trialling autonomous vehicles (AVs) in the UK are working in partnership with SMEs, while auto manufacturers are turning to providers of specialist technology that they have previously never needed to consider. There are also a number of adjacent services and those that will be layered on top as new transport models take shape.

But while the technology is largely ready, it can’t yet be manufactured cheaply enough for mass adoption and there are other non-technology issues that need to be resolved. Moving to AVs will require consumers to confront the accepted norm of having control of the vehicle, and the concept of cars as owned possessions. AVs will also present significant and complex legal implications, particularly around insurance.

This report will look at the electric vehicles, connected and autonomous vehicles and smart roads that will support intelligent road transport. The report will further detail the benefits each has the potential to deliver, the challenges presented by each and recent government-led initiatives that are underway to further the technology and tackle these issues.

As in the wider IoT sector, there are still issues facing the sector including interconnectivity, interoperability, security and data privacy and sharing. They are not unique to intelligent road transport and are therefore not discussed in this report but present further issues that must be overcome before a truly intelligent road transportation system will be in place.
What is Intelligent Road Transport?

Intelligent road transport is the combination of technologies including the internet of things (IoT), big data, artificial intelligence (AI) and low carbon and renewable energy to deliver smart roads and smart vehicles that run on them.

The vehicles of the future will become increasingly connected and automated until fully autonomous vehicles (AVs), also known as self-driving or driver-less, are able to drive themselves without human input.

An always-on ubiquitous network will have to be developed to ensure the vehicles can communicate not only with each other but also with road infrastructure, both in inhabited areas and along the roads that connect them.

Why do we need intelligent road transport?

Electric, connected and autonomous vehicles, coupled with intelligent road infrastructure, will tackle some serious environmental, social and economic issues which will only get worse if no action is taken. Combined, they could improve safety, travel efficiency and air quality, as well as enhance the journey experience for road users and contribute to economic growth.

It is a generally accepted statistic that human error is a factor in nearly 90% of deaths and injuries on our roads, so reducing and eventually removing the human element could make road travel safer. Machines don't get tired or distracted.

Currently, the number of vehicles on our roads continues to rise. As of June 2017 there were 37.81 million licensed vehicles in the UK, up 41.7% since 1997. Of the total, 31.2 million were cars, up 38.6% over the 20 year timeframe.

Congestion and pollution are already serious problems across most major towns and cities. Increased use of low carbon fuels will lower vehicle emissions and also reduce our reliance on expensive and scarce natural resources. However, the problem needs a three-pronged approach:

1. Reduce the total number of vehicles on the roads
2. Reduce the number of pollutants emitted by vehicles
3. Improve the efficiency of the road network by optimising traffic throughput.

The UK is a major automotive manufacturer and the industry is an important contributor to GDP. We need to keep up with the technologies feeding into next-generation vehicles, from batteries to sensors and software, as well as the road infrastructure they will travel on.

This is widely recognised by government, which has spearheaded research projects, set aside investment and enacted legislation designed to foster innovation. The government, matched by industry, recently launched the first phase of £100 million investment in connected and autonomous vehicle testing (CAV) infrastructure with the intention of cementing the UK’s status as the go-to destination for development of CAV technology.

Zero Emission Vehicles

Battery-powered electric vehicles (EVs) are the predominant form of low carbon vehicles (LCVs), although there are other low carbon fuels such as biofuels, natural gas and hydrogen. According to the Society of Motor Manufacturers and Traders (SMMT) over 2,000 new pure EVs were registered in the UK in September 2017, and over 11,000 in the year to September 2017, a 37.3% increase year-on-year.

EVs are cheap to run and have zero tailpipe emissions so are far cleaner than traditional internal combustion engine motors. Although they typically take more energy to manufacture, this is small compared to the energy used to power a vehicle over its lifetime. According to The Committee on Climate Change the total lifecycle emissions are around 50% lower than conventional vehicles, and this will increase as the UK’s electricity supply is decarbonised further, i.e. as we use more renewable energy sources.

Despite all the benefits, EVs do not solve the problem of congestion on our roads. However, with fully autonomous vehicles still years away from commercial reality, they are a good step towards reducing carbon emissions as well as nitrogen oxide (NOx) and particulates. They are also contributing indirectly to the development of AVs as the pod-type AVs currently being tested in the UK are battery powered.

Takeup and Development of the Electric Vehicle Market

The evolution of London-based EV charging SME Pod Point and its sales model give a very good indication of how the EV market has developed and where future growth is likely to come from. Set up in 2009, the company started out deploying a UK-wide public network of charging points. It reached its first 100 points in 2011 and operated a network of nearly 1,900 points by the end of 2017 (equivalent to 13.5% of the total in the country according to data from the Low Carbon Vehicle Partnership (LowCVP) – with partners including Sainsbury’s and Lidl. An important piece of the network is the ‘en-route’ segment, such as motorway filling stations and locations near main trunk roads, which allow rapid charging to boost the vehicle’s range for long journeys.

The home charge grant was introduced in April 2013 and provided a significant boost to EV takeup in the UK – Pod Point estimates it contributed to sales of at least 10,000 new home chargers. Since then the company’s main activity has been in the home market with some 700 units installed every month (with peaks around new car releases) and 50,000 units sold in the UK as of November 2017.

Pod Point estimates that 60% of all EV charging will be carried out at home and, for drivers who use their car to get to work, 30% at the workplace. The remaining 10% is split between destination and en-route. The latter, although a critical part of the infrastructure to give drivers complete freedom of movement, will only be used infrequently for long journeys.

Challenges

Takeup of electric vehicles has been steady. EV sales now represent 2% of new vehicle sales in the UK with more than 100,000 plug-in electronic vehicles registered in the UK until March, 2017. This placed the UK as the fourth largest in the European market although the fastest growth has been seen in the plug-in hybrid model, with pure-electric models experiencing slower growth. This could be due to a number of reasons. There needs to be

4 www.nextgreencar.com/electric-cars/statistics/
a change in mindset for generations of drivers used to going to a filling station to refuel when the gauge gets low. Proponents of EVs argue that being able to charge the vehicle when it is parked is far more convenient than going to a filling station, but it is a step-change for many to get their head around.

Aligned to this is the concept of the limited range of EVs. Filling up the fuel tank takes a matter of minutes, while charging a battery is a longer process. Early electric cars really did have limited range, however, newer models are heading towards and exceeding the 200 mile range. Vans have lower ranges because of the loads they carry, but the market is starting to pick up, with interest coming from fleet operators having an out-of-town depot and using EVs for inner city routes, such as deliveries.

Driver scepticism also extends to the battery. Consumers distrust batteries, largely down to their personal experience with smartphone and laptop batteries running out at the most inopportune moment and degrading over time. James McKemey from Pod Point said that while a laptop or phone battery is single-cell those for EVs have thousands of battery cells as well as an intelligent battery management system. The battery and charging infrastructure communicate so the car draws the right amount of power at the right current.

Cost

Although EVs are very cheap to run – a car can be charged for as little as 2 pence per mile – the purchase price is high and has been the main barrier limiting EV takeup. In Norway, Pod Point’s second largest market, the government solved the cost issue by waiving the sales tax on EVs while sales and other taxes on a new internal combustion engine car mount up to an eye watering 100%. The result: takeup of EVs is at 48%, far outstripping any other country where the best figures are in the low single digits.

However the price of EV batteries has fallen dramatically. A report published by McKinsey & Company in January 2017 McKinsey & Company’s Electrifying Insights estimated that the average battery pack price fell by over 77% in six years, from $1,000 per kWh in 2010 to $227 in 2016, far faster than all predictions.

When that figure nears $100 – and the indications are that might not be too far off – then there will be price parity between internal combustion engine and electric cars. It is believed that that is when the EV sector will really take off. Bloomberg projects price parity being reached in 2022 but others believe that could be a conservative estimate. In May 2017 UBS Evidence Lab projected that the total cost of ownership (TCO) – i.e. the

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![More Bang for your Buck](image_url)

Greater efficiency means a $1,000 battery in 2010 will cost $73 in 2030

Source: Bloomberg New Energy Finance

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Cost per kilowatt hour:

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purchase price plus running the car – could be the same for a traditional and electric car in 2018 and that it will be cheaper to buy an EV car than a traditional one by the early 2020s.

**Power constraints**

Another challenge to overcome is the electricity supply, which is already constrained at peak times and will not be able to support a mass of EV owners coming in from work and plugging in their car, at the same time as making a cup of tea, switching on the TV and turning on the oven for the evening meal.

Smart charging infrastructure will allow charging to be done when demand is low, i.e. in the middle of the night rather than at 6pm. But a truly intelligent energy management system could use the vehicle itself as a load management system. It would understand the household’s power needs and draw energy from the EV to power lighting and appliances in the home, for the car to be recharged when the household is in bed. This could be extended beyond the home, for example in cities where parking is constrained. EVs could be plugged into empty parking spaces at night, giving the owner a parking space, the infrastructure provider rent from the space, and electricity for the grid.

Tessa Darley, Head of Transport at Innovate UK’s Knowledge Transfer Network, said: “A lot of the technology is nearly there to allow bi-directional flow between the vehicle and charging infrastructure, but the business models still need to be investigated and there’s work to be done on the battery side to ensure such draining and recharging doesn’t degrade it.”

**Initiatives**

The government offers a range of financial incentives to encourage drivers to buy EVs, from exemption from vehicle tax to a range of grants ([details are available here](#)), while EV drivers in London are exempt from the congestion charge as well as the new T-charge (Toxicity Charge) introduced in October 2017.

In July 2017, the government published its final Air Quality Plan, which reiterated the intention, first announced in 2011, to ban the sale of conventional cars and vans from 2040. However, they will still be able to be driven on our roads.

This initiative focuses on the need to further reduce nitrogen oxide (NO₂) emissions from diesel vehicles, which are linked to lung and heart diseases. The buildup of NO₂ is concentrated in particular areas, typically large cities, so the proposals centred on providing funding to local authorities for the development of local air quality improvement plans, with a December 2018 deadline for final plans.

In October 2017 the Automated and Electric Vehicles Bill was introduced to Parliament, with measures to introduce charge-points for EVs at all UK motorway services and large petrol retailers and enable drivers of automated cars to be insured on UK roads. Further funding for local authorities to install charge-points in residential areas with street parking was announced the same month.

**The Office for Low Emission Vehicles (OLEV)** (part of the Department for Transport (DfT) and Department for Business, Energy and Strategy (BEIS)) has committed over £900 million for the development, manufacture and use of ultra-low emission vehicles (ULEV) in the UK, working with Innovate UK and others. Some recent projects include:

- In July 2017 funding of £20 million was announced for projects that develop future vehicle-to-grid (V2G) products, services and knowledge, to be shared between three competitions. V2G is a system whereby plug-in vehicles (encompassing EVs and hybrids) return electricity to the power grid, with the user’s permission and usually in return for a financial or other benefit.

- In September 2017 a £20m competition was announced (£2 million for feasibility studies and £18 million for R&D) for industry-led research into vehicle technologies that accelerate the transition to zero emission vehicles, particularly around the development of low-cost integrated systems to enable zero emission journeys. It is the 14th competition in the Integrated Delivery Programme (IDP) series and the first to allocate resources to goods vehicles, which cause one-third of transport CO₂ emissions in the UK.
Connected and Autonomous Vehicles

Connected and autonomous vehicles (CAVs) incorporate a range of different technologies with the aim of moving people and goods on our roads more safely and efficiently.

Progress is being made towards connected and self-driving vehicles and with a huge market opportunity, established automotive manufacturers are firmly in the race, with many top manufacturers in the UK offering EV as part of their model range. Numerous disruptor companies are also entering the market through an ‘evolution’ approach, working up from advanced driver assist systems to connected vehicles with self-driving. The UK is doing both, through backing from the government. Since 2014, the UK government has invested almost £100 million in CAV projects, with a further £56 million coming from industry.

Some of the larger projects underway are detailed later in this section.

Many cars currently rolling off the production line come with a degree of connectivity, even if it is largely in-vehicle for engine diagnostics or infotainment, or the ability to unlock doors remotely using a smartphone. This connectivity produces data – both from the vehicle and the user – and analysis of that data is enabling a wide range of new services. Car manufacturers, dealerships and garages are able to offer predictive maintenance. Telematics are being used for a wide range of services from fleet management to gathering insights on mobile workers to tracking road gritters. Further down the line, data analytics will open the door for new services such as car leasing or pay-as-you-drive insurance. Opportunities abound for third parties to develop and provide such services, as well as for customers, particularly local authorities, to reduce costs and optimise operations.

EXETER-BASED Lightfoot is an affiliate of Ashwoods Electrical Motors, which was developed to help drivers of Ashwoods hybrid vehicles drive so they would fully realise the benefits of the technology. Both companies have grown from very small roots, with Lightfoot planning to nearly double its team to over 40 by the end of 2017 after receiving nearly £1 million in Innovate UK funding in April 2017 to further develop its technology.

Lightfoot is based on the premise that engine technology is not alone in causing pollution: a smoother driving style instantly reduces emissions in all vehicle types. It aims to improve the driver side of the equation by using analytics to identify the optimum efficiency of the specific vehicle, and then giving the driver both visual and verbal alerts when they move away from that sweet spot. If the alerts are ignored, the driver receives a ‘penalty’ which is visible to management through the reporting system. The driver quickly learns – and sustains – more efficient and safer driving habits. In addition to the driver behaviour aspect, Lightfoot also provides a web-based fleet management portal which provides data such as real-time GPS tracking, historical journey details and timesheet verification.

Since its launch in 2012, Lightfoot has been deployed in over 20,000 vehicles across the UK, by private companies as well as local authorities and other transportation bodies. It claims to help customers reduce fuel consumption by 15-20% and accident rates by up to 60%.

Northumberland County Council achieved 13.5% fuel cost savings in a two-week trial and has now deployed Lightfoot technology across its fleet of 250 light vehicles, which provides services ranging from the upkeep of highways and street lighting to cash collection and dog patrols. It worked with Lightfoot to develop an e-learning package for its drivers. In addition to reducing its fuel spend, the council expects to see improvements in the residual value of vehicles and fewer insurance claims.

Lightfoot is now developing a consumer version to reward good driving with prizes, cheaper insurance and other incentives. Part of the government funding will be used to bring more partners into its Driver Ecosystem to widen the range of driver incentives.

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5 www.nextgreencar.com/electric-cars/statistics/
With increased connectivity, vehicles are able to communicate with their surrounding environment, providing information to the driver such as road, traffic and weather conditions. The next step is on-board sensors and systems which can gather more data from the environment which the car can use so it can operate with less input from the driver. This functionality is already available in cars with self-parking features. They are automated – to a point – but not autonomous. For example, parking in a marked spot in an empty car park is currently beyond their capability because they need to be able to sense physical objects, lines on the road surface are not enough.

In future, vehicle-to-vehicle (V2V) connectivity will enable vehicles to detect those in front and behind when travelling. Connectivity will ultimately be vehicle-to-everything (V2E) so all vehicles on the roads and the road infrastructure are connected, enabling the exchange of information to the point where traffic will be automatically routed faster, safer and more smoothly.

For Darley, the potential for managing capacity on the road network is the really interesting part of connected vehicles. While connectivity is largely focused around driver safety at the moment, those who consider themselves safe drivers are unlikely to fork out for the expensive advanced driver assist systems that are currently on the market.

AVs are not a new concept – vehicles such as driverless trains and airport shuttles have been around for years, but they run along enclosed routes rather than open roads. Their movements are therefore strictly limited, as is their interaction with other vehicles or people other than passengers. The AVs of the future will have no such constraints and will free up significant human resources that can be devoted to something other than driving.

Ultimately car ownership could become a thing of the past as we move to a model of shared ownership. The rationale will be why own a car and have it sitting on your driveway when you don’t need it, when you can have access to shared on-demand vehicles and only pay for what you use?

In addition to reducing the number of vehicles, it could also give greater independence and mobility to those unable to drive themselves, such as the elderly or those with reduced mobility or a physical impairment like epilepsy. The challenge here will be to ensure the shared vehicle gives the ‘driver’ the same utility as their own car would, otherwise people won’t sign up.

Driverless vehicles are already being used in industrial situations for short, repetitive trips while self-driving passenger vehicle trials are already underway in the UK (See Initiatives, below, for details).

Challenges

Much of CAV technology is already available on the market or under development. One limiting factor at present is the lack of sophisticated simulation and modelling at scale. Currently AVs like the Google car are being physically driven on roads to collect data so that developers can understand how they would operate on roads safely, for example, if a child ran in front.

The transition to a next-generation 5G network that will incorporate fixed and a range of different mobile
technologies is vital for the future of connected road transport. 5G trials are underway globally but the technology is some way off and it will be years before full coverage is possible. Darley cites the example of eCall, a system designed to help emergency services respond quickly and appropriately to a road accident anywhere in the EU. From April 2018 all new cars in the EU must be equipped with an eCall device, but according to Darley there is currently an over-reliance on mobile phone coverage.

Many of the AV projects underway in the UK are also considering issues such as legislation, insurance, communications and cyber security requirements, as well as public attitudes to self-driving vehicles.

In July 2016, the government opened a public consultation on proposed changes to legislation to prepare for the arrival of CAVs. The Highway Code, first published in 1931, will need to be revised to accommodate even early advanced driver assist functions such as hands-free parking, otherwise drivers will routinely break rule 160, the requirement to have both hands on the wheel where possible when the car is in motion.

Changes in insuring AVs are already in development and the government has been proposing changes to insurance law to ensure that motorists who have given control to their AV will be properly insured. Motor insurance will still be compulsory, but will be extended to cover product liability for automated vehicles. The government acknowledged that proving liability in the event of a collision could be complex and time consuming, which implies that insurance policies for AVs could prove to be costly even though the improved safety should theoretically reduce premiums. Many of the AV projects underway are already considering the insurance implications, because expensive premiums will dampen demand. In a new policy document “Pathway to driverless cars,” published in January, 2017, the government announced: “We now propose to supplement the compulsory motor insurance (Part VI of the Road Traffic Act 1988) to include the use of AVs, and establish a single insurer model, where an insurer covers both the driver’s use of the vehicle and the AV technology. This single insurer model would ensure that the driver is covered both when they are driving, and when they have activated the ADF (automated driving function). In the event of a collision while the ADF was active, the innocent victim (both inside and/or outside the vehicle) would be able to claim from the insurer”. 7

In the document, it was farther stated that the new AV regulation will not sway existing rules. The government has no immediate plans to relax any existing restrictions relating to driver distraction, such as eating or drinking at the wheel. Those will be considered “when vehicles are designed such that the driver no longer needs to remain alert and in the loop”. 7

**Initiatives**

In December 2014, the government announced £10 million of funding from Innovate UK for three projects with formal trials into automated vehicle technology, designed to provide a path to self-driving cars. Separate consortia had bid for the funding though the Introducing Driverless Cars competition. The projects are jointly funded by government and industry. The winning consortia, all of which include SMEs as well as larger companies and public sector organisations, were GATEway in Greenwich, UK Autodrive in Milton Keynes and Coventry, and VENTURER in Bristol. There is collaboration between the various projects which, along with other significant government-funded projects, are detailed on the following six pages.

The DRIVEN consortium has been awarded £8.9 million in funding from the government’s Centre for Connected and Autonomous Vehicles (CCAV), to stimulate the development of new autonomous vehicles. It is led by Oxford-based Oxbotica, with the UK Atomic Energy Authority’s RACE robotics technology centre at the Culham Science Centre in Oxfordshire, which incorporates 10km of roads and associated infrastructure for field testing, playing a key role. The other members of the consortium are Oxfordshire County Council, the Oxford Robotics Institute (part of Oxford University), IoT firm Nominet, insurer XL Catlin, Telefónica, Transport for London, Transport Research Laboratory and Westbourne Communications.

"DRIVERLESS VEHICLES WILL BE PART OF OUR SHARED FUTURE AND THE PUBLIC CLEARLY BELIEVES THERE ARE BENEFITS. BUT DEPLOYMENT IS GOING TO BE CHALLENGING. EXTENSIVE TESTING IS ESSENTIAL IN ORDER TO BUILD PUBLIC TRUST AND UNDERSTAND THE BENEFITS ON OFFER. THROUGH OUR WORK WITH DRIVEN WE ARE TAKING A BIG STEP TOWARDS ‘MOBILITY AS A SERVICE’ BY ADDRESSING A RANGE OF CHALLENGES FACING SELF-DRIVING VEHICLES. DRIVEN GOES BEYOND THE TECHNICAL CHALLENGES AND LOOKS ACROSS THE ENTIRE AUTONOMOUS VEHICLE ECOSYSTEM – INCLUDING INSURANCE, CYBER-SECURITY AND DATA PRIVACY. I’M NOT AWARE OF ANY CONNECTED AND AUTONOMOUS VEHICLE TRIAL WITH THIS LEVEL OF COMPLEXITY AND INTEGRATION BEING ATTEMPTED ANYWHERE IN THE WORLD." ROB BUCKINGHAM, DIRECTOR, RACE

DRIVEN unveiled its first three self-driving vehicles in September 2017, a 2014 Ford Fusion Titanium hybrid, a 2017 Ford Mondeo hybrid and a Range Rover Evoque, that will be used for autonomous driving trials. Testing of key manoeuvres was already underway at the RACE test facility, and the plan is to begin testing on selected roads around Oxford in early 2018. There are expected to be six vehicles by late summer 2018, when wide-area road testing is set to begin across urban roads as well as motorways. Multiple end-to-end journeys between London and Oxford should take place in 2019.

The DRIVEN vehicles are designated as ‘Level 4’, meaning that they have the capability to drive themselves most of the time without any human input. During testing, specially trained drivers will be in the vehicles so they can take over the driving as necessary. They incorporate Oxbotica’s Selenium autonomy software, Lidar (Light Detection and Ranging) sensors, on-board computers and cameras. An important factor in the look of the vehicles was the use of high visibility branding to make them easily recognisable by drivers and pedestrians when trials move out to streets, so they don’t cause panic or confusion.

LUTZ Pathfinder

The UK’s first driverless cars projects were announced in May 2014 when Coventry-based RDM Group and Oxford University’s Mobile Robotics Group (MRG) were selected to develop a self-driving vehicle under the Low Carbon Urban Transport Zone (LUTZ) Pathfinder project. RDM Group would develop the vehicle and the autonomous control software. MRG is now known as Oxford Robotics Institute (ORI), which in 2014 launched a spin-out company Oxbotica to drive the commercialisation of its work. Oxbotica’s technology is also being used in other UK AV projects.

The LUTZ Pathfinder project received £1.5 million in Innovate UK funding along with similar levels of investment from the Transport Systems Catapult (TSC), which co-ordinated the project, and investment in kind (including time and expertise) from industry.
The two-seater prototype pod developed by RDM was revealed in February 2015 when testing began. In October 2016 a vehicle travelled 1.25 miles through pedestrianised areas in Milton Keynes at speeds up to 15mph. It used an array of 19 sensors, cameras, radar and Lidar scanners as well as virtual maps for navigation. It was the first time a driverless vehicle had been tested on UK streets, although a person remained in the car for safety reasons and in line with government regulations. The trial marked the conclusion of the project, which has fed into the UK Autodrive project. The vehicles operated as expected and the project has therefore been deemed a success.

GATEway

Greenwich Automated Transport Environment (GATEway) is an £8 million research project that launched in February 2015. It aims to trial and validate different use cases for AVs for last-mile mobility, to explore the legal and technical changes required for their introduction, but the main focus is to understand the human response to and acceptance of AVs. It is led by Transport Research Laboratory (TRL), which was set up in 1933 and privatised in 1996. Other key partners include the Royal Borough of Greenwich, the University of Greenwich, which will look at the human angle, and insurer RSA. Agility3 contributed a 3D virtual environment of Greenwich Peninsula for TRL to use in its DigiCar simulator.

The first trials of a prototype GATEway shuttle began in April 2017 on a 2km route around the Greenwich Peninsula. It is a true driverless vehicle with no steering wheel or typical drive controls, although a “safety steward” remains on board to comply with the UK’s code of practice on AV testing. The shuttle carried passengers, over 100 in total, who were interviewed in detail both before and after their journey. It is modelled on the pods in use at Heathrow Airport and was manufactured by Westfield Sportscars, with Heathrow Enterprises responsible for vehicle software engineering and Oxbotica contributing its Selenium autonomy software.

In June GATEway completed the UK’s first trials of grocery deliveries via a self-driving delivery vehicle in partnership with Ocado Technology. The CargoPod is able to carry a 128kg load and delivered orders to 100 customers. It used Oxbotica’s Caesium cloud-based fleet management system to schedule and co-ordinate deliveries.

The open public trial of GATEway shuttles was set to begin in autumn 2017, with Fusion Processing providing sensing and control equipment on the fleet of new pods. Gobotix will provide a remote teleoperation service to help passengers with reduced mobility.

Over an eight-hour period of operation, a single GATEway shuttle collects a staggering 4TB of data, equivalent to 2,000 hours of film or 1.2 million photographs.

UK Autodrive

UK Autodrive encompasses Milton Keynes and Coventry. The project got underway in November 2015 and will run for three years. Ford, Jaguar Land Rover and Tata Motors are providing cars and the first vehicle trials took place in October 2016. Having successfully completed proving ground trials, in June 2017, UK Autodrive got the green light to move trials onto city streets. The first trials will be on segregated sections of roads, before moving to open road trials and demonstrations before the end of the project. UK Autodrive will test seven connected car features: emergency vehicle warning, intersection collision warning, in-vehicle signage, electronic emergency brake light, green light optimal speed advisory, intersection priority management and collaborative parking.

The project is also trialling lightweight electric-powered self-driving pods for use on pedestrianised areas, which are being designed and built by RDM Group. The initial trials will begin in Milton Keynes in late 2017 and up to 40 pods are set to be deployed across the town centre by the time the project ends.

VENTURER

Bristol City Council, South Gloucestershire Council, the University of Bristol, University of the West of England (UWE) are partners in the VENTURER consortium, which completed its first trial in August 2016 at Bristol Robotics Laboratory and on roads at UWE campus. The trial used the Wildcat autonomous ground vehicle, a 4x4 off-road production car from Bowler Motorsports that was modified by BAE Systems and has now been handed to Oxford University for further research. An area of focus for VENTURER is on-road autonomy issues including handover of control.

CAV Testing

The government has sought to make the UK an attractive option for testing CAVs, for UK as well as international firms. It is one of only a few countries which has enacted legislation allowing the testing of CAVs on public roads – a vital step in the development process.

The Industrial Strategy outlined in the 2016 Autumn Statement included a four-year £100 million investment
programme (to be match funded by industry) to support the development of world-class CAV testing infrastructure. The plan is to use some existing CAV test centres to develop a cluster of excellence in CAV testing along the M40 corridor between London and Birmingham, including Coventry, Milton Keynes and Oxford. By coordinating testbeds at the national level, the programme aims to accelerate the development of CAV technology in the UK, grow intellectual capital, attract overseas investment and create a national ecosystem that covers all testing requirements for CAV technology, from software design to on-road testing.

The first competition for access to funding was launched in March 2017, to support a number of projects in areas including:

- Public test facilities in a complex, real-world urban or city environment
- A controlled test environment representative of driving in a city
- A realistic and controlled high-speed, test environment

**Intelligent Roads**

There are multiple smart motorways in the UK which have been implemented to increase road capacity without widening the road, but they are by no means widespread or even intelligent. The RAC describes a smart motorway as “A section of motorway that deploys traffic management methods to increase capacity and reduce congestion in particularly busy areas”. In essence, these motorways use the hard shoulder as a running lane for traffic, either permanently or at busy times, and may also incorporate variable speed limits. The technology side comes from messages on gantries telling drivers which lanes to use and what the speed limit is.

Although it is slowly beginning to deploy more advanced, automated technologies, Highways England still relies extensively on CCTV cameras that are manually monitored. In June 2017 it adopted an open standards approach to video technology for the continued expansion and management of its CCTV and traffic system. This will enable it to support existing cameras while providing a pathway for adding new ones to the system.

But the future is for far greater automation and the collection of far more data than can be captured by CCTV, which will be interrogated through analytics and artificial intelligence to a far greater degree than can be achieved manually. UK road infrastructure providers are taking early steps down this path. Infrastructure-mounted sensors and radar are already being used to collect information on road conditions to proactively alert about potential issues, and the use of drones is starting to take off. In future data collection sources may be embedded in the road surface itself as well as the vehicles travelling over it.

As in the connected vehicle space, the early use cases are around improving safety but the potential goes far beyond that to optimise traffic flows so.

“**THE MORE YOU KNOW ABOUT HOW THE ROAD NETWORK IS GOING TO BEHAVE, THE BETTER YOU CAN CONTROL IT TO OPTIMISE TRAFFIC FLOW, FOR EXAMPLE TO ALLEVIATE CONGESTION. EXTRAPOLATING AND LEARNING FROM THOSE BIG DATA SETS ENABLES YOU TO CONSIDER DIFFERENT HYPOTHETICAL CHANGES TO THE NETWORK, FOR EXAMPLE TO STOP QUEUES INTERACTING WITH EACH OTHER.**”

Shaun Howell, Data Scientist/Machine Learning Researcher, Vivacity Labs

**Knowledge Transfer Network**

The Knowledge Transfer Network (KTN) is the network partner of Innovate UK, linking new ideas and opportunities with expertise, markets and finance through a network of businesses, universities, funders and investors. It has a number of intelligent transport initiatives underway across its infrastructure and transport teams, and others are at the discussion stage.

**Infrastructure Innovation Platform**

The Infrastructure Innovation Platform (I3P) was developed by KTN in partnership with Crossrail and Tideway and launched in October 2016. It now has 25 members across major infrastructure providers and their supply chains. To date, Highways England is the only transport provider on board, but the intention is to broaden the membership to others. Early conversations have been held with Transport for London and Transport Scotland, but the programme is still in the early stages and KTN wants to focus initially on consolidating what it has already achieved in order to ensure it is providing a valuable service.

The idea is to bring together the large customers and suppliers across the infrastructure industry in order to facilitate and enable the sharing of ideas, innovation and experience. One of the goals is to pull innovation into the supply chain by opening up what continues to be a difficult nut for SMEs to crack.
OXFORDSHIRE-BASED SME NAVTECH RADAR is proof that not all innovation is done by start-ups. Founded in 1999, as its name suggests the company uses radar technology, starting out with industrial automation applications before branching out into security and, more recently, traffic applications. The ClearWay radars can be mounted on existing road infrastructure and provide 360° views for up to 500m in both directions, enabling it to scan up to a 1km stretch of road. One radar mounted at the side of the road will identify all objects in all lanes on both sides of the carriageway and detect those that are stationary and those that are moving. The moving objects are tracked as they travel down the road and the system is set up to monitor whatever the user wants to know, such as traffic flow data, stopped or slow vehicles, or pedestrians or debris on the road.

Unlike a traditional radar system (or indeed CCTV), Navtech is fully automatic so that users do not need to see the raw data or picture. An alert is sent out as soon as an incident is detected – and Navtech can identify a stopped vehicle within 12 seconds or less. At present, the system is primarily used for incident detection to improve road safety, but it has traffic optimisation applications both for infrastructure providers and, as cars become more connected and automated, road users. The ability to automatically monitor and relay live traffic information in real time would enable the infrastructure provider to quickly divert traffic away from an area where an accident had just taken place. Machine learning and data analytics could be applied to predict an accident waiting to happen by using data on weather and road conditions, vehicle volumes and driving speeds, so that preventative measures such as a lower speed limit or traffic diversion could be put in place. Ultimately, when data is streamed direct to the autonomous vehicle and accidents should be a thing of the past, the vehicle’s speed would automatically be adjusted to best meet the specific road conditions or the route altered to avoid any traffic buildup.

Navtech Radar has been deployed in the UK’s three largest tunnels, but the company’s biggest markets for transport are international. It has exported to over 10 countries globally and has had particular success in Sweden and Norway, where long nights and poor weather conditions require an all-weather solution such as radar.

Highways England trialled Navtech Radar as early as 2010, and trials are now underway on the M25 and elsewhere. Interest is definitely growing because the benefits are so compelling. Says Avery, “Unlike CCTV, ClearWay works in all weather conditions and is extremely reliable. It has a very high detection rate and very low false alarm rate, plus it’s automatic.”

While i3P wants to broaden engagement with SMEs as well as the academic and research communities, its membership is currently limited to major infrastructure providers and their supply chains. It is not intended to be a mechanism for companies to pitch their services, but to enable engagement with innovative and agile SMEs that can bring something new to the table.

The first exercise in direct engagement with SMEs was held in October 2017 at Digital Construction Week. Working in partnership with Immerse UK, a KTN-led project focused on immersive technology (i.e. augmented and virtual reality, or AR and VR), with three i3P members set a number of high level challenges. Some 50 SMEs, AR and VR rather than infrastructure companies, responded and 12 were invited to present their solutions. Further such programmes will be held, including around road transport.

Other KTN Initiatives

The transport and infrastructure teams also aim to replicate elements of i3P with KTN smart city colleagues to provide a joined up way for local authorities to share experience and best practice. Bringing together local authorities and other road infrastructure providers should improve interaction between the various parties and, hopefully, provide greater clarity regarding ownership of infrastructure and encourage the development of common procurement policies.
SenSat was established in February 2015 and has grown rapidly in 2017, from just five employees at the start of the year to an anticipated 20 by the end of the year. It will open a Silicon Valley office in January 2018 to add to its London HQ, and expects to have a workforce of around 30 at the end of 2018. SenSat uses mapping drones to automatically collect engineering-grade survey data, with road projects accounting for around 90% of revenues. It has supported £2.2 billion in road infrastructure projects and, by November 2017, had clocked up 9,000km over live highways in the UK since the start of the year.

SenSat has been granted unique Civil Aviation Authority (CAA) permission to fly over live highways in the UK as well as Beyond Visual Line of Sight (BVLOS), as part of the government’s Pathfinders programme into drone research. SenSat’s remit is to prove the economic case for drone data within infrastructure, with CEO James Dean publicly announcing in 2017 that SenSat planned to cut the cost of drone data by over 90% by the end of 2018.

A SenSat drone can fly around 300km in a day, taking millions of ground measurements to build a digital replica of up to 30km of road at a time that is accurate to 25mm. SenSat is then able to perform complex calculations on the data and overlay live information to create a ‘digital twin’ running in real time. Over and above the obvious benefits in the design and planning stage, it helps project managers keep track of progress during construction and identify any issues before they become costly mistakes. But the digital twin is not static, it can be measured over time to see how it has changed and it can also ingest data from a variety of sources like sensors on lamp posts. Once the asset has been built, this capability will enable predictive maintenance and potentially other services.

SenSat was commissioned by Costain Galliford Try to provide a topographical 3D survey of the work in progress on an upgrade to the M1, to be used for asset modelling and stakeholder communication. SenSat has also worked with Highways England on its Rapid Engineering Model project, which aims to significantly reduce design time (and therefore costs) by automating the design of rules-based features, such as lamp posts placed at regular intervals. Initial testing of the software built by Highways England has taken the design time from nine months to a single day. SenSat has fed in digital drone data to the project.
Vivacity Labs was founded in late 2015. Vivacity has designed a smart street sensor that can be installed on existing infrastructure such as street lamp columns in order to make large-scale deployments financially viable. Peter Mildon, Vivacity’s Co-founder and COO, explains that traditional computer vision methods do not tolerate movement, such as when street lamps vibrate during high winds, but the Vivacity sensors have been designed to cope with such issues. The Vivacity system uses machine learning to detect and classify different road users, and then to gain insight from the data to learn how traffic is flowing. The company has been using various forms of neural networks in order to try to predict what will happen in the network in the future, whether that is in five minutes or later in the day. The aim is to help infrastructure providers predict where and when congestion might build up or an accident happen, so they can pre-empt the incident.

Vivacity has deployed over 40 sensors in Milton Keynes for the UK Autodrive AV project (See Connected and Autonomous Vehicles). Along the route the pods will travel. It also has another project underway in the town, under the aegis of an Innovate UK First of a Kind contract, to deploy a city-wide smart transport sensor network in order to gather data at scale and provide insight from that data. As of November 2017 the system was detecting and classifying five million vehicle movements per day across the 420 traffic sensor network. By February 2017 Vivacity will have added a further 1,800 similar sensors to provide live occupancy data on around 12,000 parking spaces in the city centre.

Vivacity has already tested its technology outside of urban areas to ensure it gets similar accuracy from fast-moving traffic, for example on a motorway, and is in discussions with Highways England regarding how the agency could use Vivacity’s sensors and the resulting data to improve its traffic management. The higher street lighting and gantries on motorways allow the sensors to be placed higher than in urban scenarios, giving the wider field of vision needed to capture vehicles at speed, while it can actually be easier to capture traffic moving in lanes in a single direction, rather than a cyclist weaving through traffic in a city. Further down the line, Vivacity expects its technology will play into the CAV market as it will give vehicles predictions beyond their line of sight to provide better route guidance.

Use case

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Facilities

TS Catapult opened its Innovation Centre in June 2014 as a world-class facility designed to develop smarter ways of transporting people and goods. It features IT infrastructure, simulation and modelling rooms, technology and collaborative areas.

The CAVLab enables the testing of CAV technologies for UK businesses and research organisations. It is centred around the LUTZ Pod vehicles and provides access to a CAV with a modular software platform, as well as to a real world test environment, CAV engineers, and safety and legal frameworks for testing.

TSC’s Visualisation Lab is equipped with 3D, VR, visualisation and simulation technologies to help transport planning, infrastructure, engineering and design professionals build their VR capability.

TSC developed the IM Data Hub (IMDH), a platform for the storage, analysis and processing of large volumes of transport-related data that can be used by third-parties to analyse their own data or to collaborate with the IM community. TSC has negotiated licences to data sets which can be combined for the first time, including detailed mapping grids, traffic movement patterns and vehicle emissions among others.

Conclusion

Vehicles and roads are starting to be connected and gradually moving towards fully autonomous vehicles and truly intelligent road infrastructure. There are plenty of challenges ahead, although some of these are not related to technology. Proponents of EVs believe it is far more convenient to be able to charge the car when it is parked than go to a filling station to refuel, but it is a huge shift in mindset from generations of drivers used to the latter. Moving to a self-driving vehicle will be another big step up, and the market will ultimately move away from car ownership altogether. Then there are the legal implications around AVs, particularly around insurance.

As a major auto manufacturer the UK has an important role to play in this revolution and, as the featured technologies in this report prove, there are significant opportunities for SMEs to contribute technology and services to the movement, creating innovation, jobs and wealth in the process.
Opinion piece: The Importance of End-to-End Considerations in IoT Systems

BY PROFESSOR NIGEL DAVIES, LANCASTER UNIVERSITY

The Internet of Things (IoT) is often described as the glue that binds together a wide range of heterogeneous sensors and actuators - creating a complex web of devices that can be used to support applications in areas as diverse as healthcare, smart cities, entertainment and transport. As such, the IoT is typically perceived as a purely technical system, differentiated from traditional web systems by its focus on connecting together “things” rather than people. As a result, much of the IoT research and development focuses on issues such as the creation of new sensor, actuator and communications technologies. While such work is clearly valuable, it often fails to recognise that the IoT is inherently an embedded technology - situated in a specific context of use and typically part of a complex socio-technic system in which people form a critical component. This situated nature of the IoT brings both new challenges and opportunities. For example, within the PETRAS RoadMAPP project we have been exploring the new security issues that arise when deploying the IoT to support highways maintenance.

Highways maintenance refers to the process of keeping roads and all of the associated assets (such as bridges, tunnels, street furniture) in working order. Estimates suggest that in the UK alone, £1 billion was spent on maintaining the highways network in 2016 with a further £1.1 billion on capital improvements. IoT technology is increasingly being deployed in this domain to support maintenance functions in the face of increasing demands on the road network and financial pressures to reduce maintenance costs.

THE FUTURE INTEGRATION OF REAL-TIME MAINTENANCE DATA WITH INTELLIGENT TRANSPORT SYSTEMS SUCH AS CONNECTED AND AUTONOMOUS VEHICLES (CAVs) WILL SIGNIFICANTLY INCREASE THE OPPORTUNITIES FOR MALICIOUS ATTACKERS TO COMPROMISE SAFETY CRITICAL SYSTEMS ON THE NETWORK.

However, as IoT usage increases within the highways maintenance sector, failure to secure such systems from malicious activity could leave both physical and digital transport assets open to attacks, with significant cost and safety implications. Consider, for example, the case of a simple cyber-physical system that collects data from roadside drainage assets to inform cleaning schedules. Potential attacks could result in serious surface water flooding incidents, long term damage to valuable highways assets (tarmac damage), increased risk of accidents and impaired journey time reliability with corresponding economic impact. The future integration of real-time maintenance data with intelligent transport systems such as connected and autonomous vehicles (CAVs) will significantly increase the opportunities for malicious attackers to compromise safety critical systems on the network, such as reporting incorrect road conditions to vehicles. Addressing these security concerns...

SmartClean

Managing urban surface water is a critical element in maintaining a resilient transport infrastructure. In the SmartClean project, funded by Innovate UK and NERC (Natural Environment Research Council) a multidisciplinary consortium including data scientists (Lancaster University), highways maintainers (Carillion, Balfour Beatty Mott MacDonald), technology providers (InTouch Ltd) and transport experts (The Transport Systems Catapult) have developed a next-generation highways drainage management system. The system leverages new pervasive data science techniques and IoT technologies to enable more proactive, effective management of drainage cleansing activities to mitigate the risk of flooding and minimise the impact of road-side contaminants entering the surrounding watercourse. The system includes custom IoT sensors for deployment in highways environments, a wireless communications infrastructure for connecting these sensors to the cloud, and new models of how gullies and contaminants behave in real world scenarios. The system has been trialled in a range of locations across the UK, demonstrating how the IoT can be used to reduce the cost and improve the effectiveness of drainage maintenance.
requires not just “standard” IoT solutions to issues such as network security, but rather a deep understanding of the context in which the system must operate because many of the potential threats are domain specific, relating, for example, to the physical environment in which the IoT is deployed.

Indeed, a key part of the context within which any IoT system must operate are the people that interact with the system. Within the highways maintenance domain we have found numerous examples of how IoT technology can be used to enhance existing working practices. For example, through the use of shared views onto IoT data sets we were able to help build trust between complex networks of stakeholders including the public, local authorities and maintenance contractors.

ENSURING THAT USERS ARE ABLE TO TRUST THE VERACITY OF THE DATA AND THE DECISIONS IT DRIVES IS CRITICAL TO SUCCESSFUL IOT DEPLOYMENTS

Of course IoT systems for connected infrastructure are not just about sensors, networks and people - equally important is the associated data processing infrastructure that is typically required to process the data produced by the IoT in order to deliver actionable insights - for example determining appropriate maintenance schedules for highways assets. Once again, we note that these insights are typically not used to directly drive IoT actuators but are instead used to inform human decision-making. Ensuring that users are able to trust the veracity of the data and the decisions it drives is critical to successful IoT deployments.

In reflecting on the use of the IoT to support infrastructure maintenance it is clear there is enormous potential for real innovation within the sector. The situated nature of IoT technology raises new security concerns but initiatives such as PETRAS are beginning to address these. However, what is equally clear is that the complex nature of the socio-technic systems within which the IoT is embedded dictates that IoT researchers consider the end-to-end nature of the systems they are creating - recognizing in particular the importance of people in all aspects of the IoT - from the field workers who install sensors through those who will be subject to changes in working practices to those who must make critical decisions based on data from systems they may not understand. By fully understanding the end-to-end nature of IoT systems we can ensure that we are able to benefit from the widespread deployment of this innovative technology and create systems that users embrace and trust.

About the Author

Nigel Davies is a Professor of Computer Science at Lancaster University, UK, and co-director of Lancaster’s Data Science Institute. His research is in the area of pervasive computing including systems support for new forms of data capture and interaction and is characterized by an experimental approach involving large-scale deployments of novel systems with end-users. He is particularly interested in the use of the IoT to support transport infrastructure maintenance and for information provision and sensing in the built environment. He leads the PETRAS RoadMaPP and DiSCC projects as well as multiple EPSRC, Innovate UK and EU projects. Contact Nigel at contacted at n.a.davies@lancaster.ac.uk.