UKAutodrive

Milton Keynes leading the way in partnership with Coventry and the motor industry

Final project report

May 2019

“The move to automated cars, vans and trucks could bring huge benefits to people across the UK. This country is in the early stages of an exciting and profound change and UK Autodrive is one of the organisations helping to put us at the forefront of that change.”

Jesse Norman, Future of Mobility Minister

“The success of the project was primarily down to the vast and varied expertise of the UK Autodrive consortium partners, and to the collaborative manner in which we worked from day one.”

Mission accomplished

When UK Autodrive got underway in October 2015, it was the largest trial of connected and self-driving vehicles ever to have taken place in the UK. Back then, the concept of autonomous cars would still have struck many people as the stuff of science fiction. And yet, in the space of just three years, we have gone from concept to reality – delivering on our promise to trial fully connected and self-driving vehicles on UK streets.

The success of the project was primarily down to the vast and varied expertise of the UK Autodrive consortium partners, and to the collaborative manner in which we worked from day one. For the vehicle manufacturers, in particular, this meant working with commercial rivals to identify a method of jointly trialling their separate technologies without compromising those commercial interests.

Ford, Jaguar Land Rover, Tata Motors European Technical Centre and RDM Group were ably supported in this by the safety, security and communications expertise of Thales and HORIBA MIRA as we embarked on our first closed road trials at HORIBA MIRA’s specialist proving ground. We then benefited enormously from the advice and experience of Milton Keynes and Coventry City Councils (as well as their road networks) as we started to move out on to the streets of the real world.

Trialling the technology was, however, just one element of UK Autodrive, with the programme also considering the wider ramifications of connected and autonomous vehicles via a series of white papers and research activities carried out by AXA, Gowling WLG and our academic partners at the Universities of Cambridge, Oxford and the Open University. As the project’s dissemination lead, the Connected Places Catapult was meanwhile instrumental in making sure that all of our research, our demonstrations and our results reached a truly global audience.

I would not go quite as far as to say that the role of Arup, as the project’s lead organisation, was an easy one – there were far too many technical and organisational challenges along the way for that to ever be the case with a project of this scale! But the persistent spirit of cooperation displayed by the project partners and the breadth of knowledge that was collectively brought to the table ensured that we more than met those challenges.

From the initial brief, which simply called for projects that would “introduce driverless cars to UK roads”, we have moved on to lay a significant foundation for the many projects that will now follow – delivering not just a new generation of vehicles, but also a body of work that will help define the future roads, regulations and safeguards needed to accommodate them.

Tim Armitage
UK Autodrive Project Director, Arup

UK Autodrive project overview

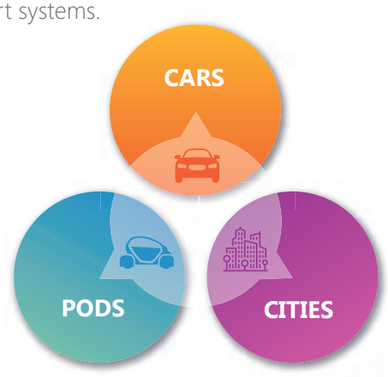
The UK Autodrive project was born in direct response to the "Introducing driverless cars to UK roads" competition that was announced by the UK's innovation agency, Innovate UK, in 2014. Forming part of the government's commitment to "advance the research and development, manufacture and use of driverless cars in the UK", the competition sought to attract towns or cities that could "host trials of driverless cars and other road vehicles in a real-world environment and carry out research that leads to greater levels of understanding and promotes integration and acceptance of such vehicles into daily operation".

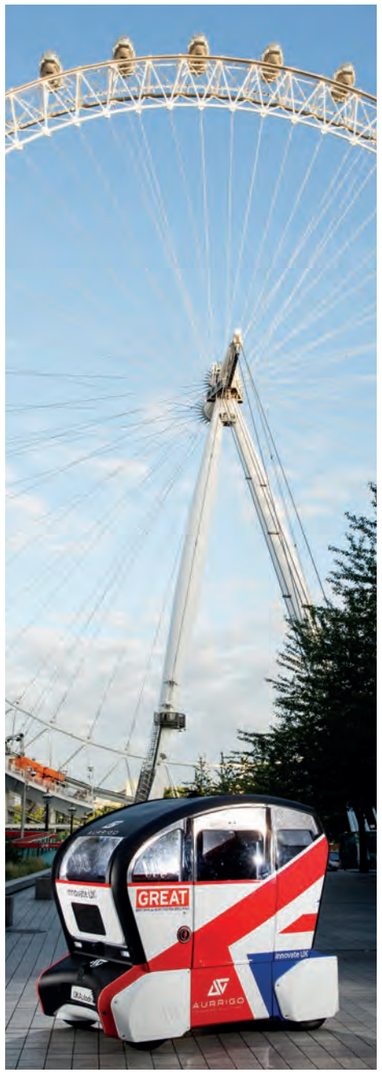
Under the project leadership of engineering and design consultants Arup, a consortium was formed that comprised automotive giants, world-leading universities, an autonomous vehicle start-up, renowned legal and insurance firms, experts in the fields of transport, safety and security, and two ambitious city councils (Milton Keynes and Coventry) that would host the dual-city trials (see full list of project members opposite).

In December 2014, UK Autodrive was named as the largest of three successful consortia to be selected – along with the Bristol-based VENTURER project and the GATEway project in Greenwich.

With a total budget of just over £19 million jointly funded by government and industry, UK Autodrive would set out not only to trial a new generation of connected and autonomous vehicles, but also to explore wider issues relating to their potential future deployment – ranging from the possible business models that could encourage the mainstream adoption of self-driving vehicles to the legal, ethical and public acceptance issues that might form a challenge to the technology's success.

The project could be considered as having three main interlinked elements: a 'Cars' programme, focused on the development and trialling of connected and autonomous passenger cars; a 'Pods' programme, focused on the development and trialling of a new form of 'last-mile' electric-powered pod vehicle; and a 'Cities' programme, aimed at helping cities to understand how they could best facilitate and benefit from automated transport systems.



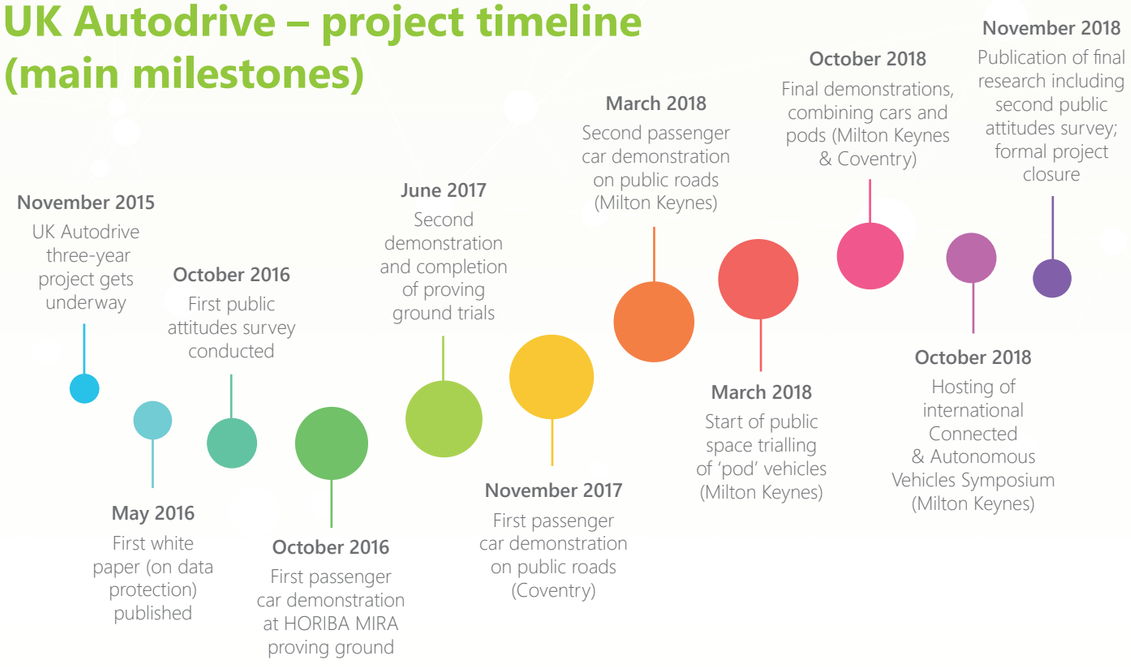


Running throughout the timeline of the project would be a series of high-profile technology demonstrations aimed at the media, industry stakeholders and eventually the general public as UK Autodrive moved from the closed roads of the proving ground and private test facilities and out onto open roads *(see project timeline).*

UK Autodrive – project members and their main role

- **Arup –** programme leader and technical co-ordinator
- **Milton Keynes Council –** programme host
- **Coventry City Council –** programme co-host
- **Ford Motor Company –** provided M1 (passenger car) vehicles capable of car-to-x communication
- **Jaguar Land Rover –** provided M1 vehicles capable of car-to-x communication as well as cars equipped with autonomous technologies
- **Tata Motors European Technical Centre –** provided M1 vehicles capable of car-to-x communication as well as cars equipped with autonomous technologies
- **RDM Group –** provided low-speed autonomous transport systems (L-SATS) 'pods' for trialling on the pavements of Milton Keynes
- **HORIBA MIRA –** provided proving ground facilities and project lead on safety case developments
- **Connected Places Catapult –** project lead for dissemination of programme results
- **Thales –** provided expertise on infrastructure systems and cyber-security
- **AXA –** provided expertise on insurance matters relating to the introduction of autonomous vehicles
- **Gowling WLG –** provided expertise on legal matters relating to the introduction of autonomous vehicles
- **University of Cambridge –** undertook research on the large-scale impact of autonomous vehicles
- **University of Oxford –** undertook research in regard to the future scalability of autonomous vehicle technology
- **Open University –** provided a link to the MK:SMART programme

UK Autodrive – project timeline (main milestones)



Driving into the future – UK Autodrive's connected and autonomous cars

The road-based cars element of the UK Autodrive project involved two distinct aspects of automotive research and development: firstly, connected cars (i.e. cars that are able to communicate with other vehicles as well as surrounding infrastructure) and, secondly, autonomous or self-driving cars.

A standout-feature of UK Autodrive was the collaboration between three separate car manufacturers, with Ford, Jaguar Land Rover and Tata Motors European Technical Centre all working together to demonstrate the compatibility of their individual connected car technologies (see pages 8-11). In addition, Jaguar Land Rover and Tata Motors European Technical Centre used the project to stage simultaneous demonstrations of their self-driving vehicles in action (see pages 12-14).

" Enabling cars to communicate not only with other vehicles but also with their surrounding infrastructure is expected to bring a number of major benefits "

Connected cars

While self-driving cars have tended to hog the limelight when it comes to future vehicle technologies, many in the industry believe that connected cars could have just as big an impact, particularly in the near- to mid-term. Enabling cars to communicate not only with other vehicles but also with their surrounding infrastructure is expected to bring a number of major benefits – in terms of safety, traffic flow, productivity and the environment.

Of course, it will make little sense if these connected cars can only "talk" to cars of the same brand, so an important aspect of UK Autodrive was to demonstrate connected car features that could be sent, received and understood by any of the vehicles taking part in the project – regardless of brand.

A total of seven connected car features (see 'Connect Seven' box opposite) were chosen by project partners Ford, Jaguar Land Rover and Tata Motors European Technical Centre, with the first demonstrations (connected traffic lights and emergency braking warnings) taking place in October 2016 at the HORIBA MIRA proving ground in Warwickshire.

Two years later, as the UK Autodrive programme reached its grand finale, all seven features were successfully demonstrated on public roads across the two host cities of Coventry and Milton Keynes (see pages 18-19).

Connect Seven – the UK Autodrive connected car features

- **Electronic Emergency Brake Light (EEBL)** – Alerts the driver when a vehicle in front suddenly brakes, providing advanced warning, especially when the driver is unable to see the lights of the braking vehicle due to weather conditions, road layout or other vehicles in between.
- **Green Light Optimal Speed Advisory (GLOSA)** – Sends traffic light information to the connected car which is able to calculate the optimal speed for approaching the lights, potentially minimising the number of red light stops, improving traffic flow and reducing emission levels.
- **Emergency Vehicle Warning (EVW)** – Sends a signal directly from the emergency vehicle (e.g. ambulance, fire engine, police vehicle) to nearby connected cars. Driver is informed that the emergency vehicle is approaching and advised to make way for it.
- **Intersection Movement Assist (IWC)** – Warns the driver when it is unsafe to enter an intersection, due to a high probability of collision with other vehicles.
- **Intersection Priority Management (IPM)** – Assigns priority when two or more connected vehicles come to an intersection without priority signs or traffic lights.
- **In-Vehicle Signage (IVS)** – Sends information about road conditions, congestion or other incidents directly to the in-car display, rather than having to rely on expensive gantry systems.
- **Collaborative Parking** – Provides real-time information about free parking spaces either in the vicinity or close to the driver's final destination

Connected car demonstrations

October 2016	June 2017	November 2017	April 2018	October 2018
HORIBA MIRA	HORIBA MIRA	COVENTRY	MILTON KEYNES	MILTON KEYNES & COVENTRY
EEBL, GLOSA	EVW, ICW, IVS	EVW, IVS	COP, EVW, EEBL	All Seven Features

Key findings

During the course of UK Autodrive, the project partners were able to test, develop and refine all seven connected car features to the point that they could be successfully showcased in the two host cities of Milton Keynes and Coventry as part of the project's final demonstrations in October 2018.

Several of the connected car use cases, including the Emergency Vehicle Warning and Collaborative Parking features, were judged to have worked particularly effectively, and could be seen as offering real-world benefits in the near future once sufficiently developed for use in production vehicles.

The Electronic Emergency Brake Light feature was also considered as having strong potential to reduce road accidents, although further refinement will be needed – for example, in defining the timing of driver alerts and determining whether and how the braking vehicle should continue to send warning signals once it has come to a stop.

When it comes to the Green Light Optimal Speed Advisory use case, the project partners concluded that further work would be needed on the development of the infrastructure, including the phasing and signalling of the connected traffic lights themselves, before this feature could reach its full potential. While the In-Vehicle Signage trials went well from a technical point of view, it was felt here too that more work would be needed in terms of standardising the signals that are sent to drivers, and also ensuring that drivers are not "overloaded" with information.

The Intersection Collision Warning feature worked well within the parameters of the project trials (which focused on the avoidance of T-junction collisions) but the project team recognised that most real-world collisions arise in situations that are more complex than those simulated during the UK Autodrive demonstrations. Much more work (and a greater number of connected vehicles on the roads) will therefore be necessary before this use case can achieve maturity.

Similarly, the Intersection Priority Management system trialled by the project partners worked well within the scope of the trials but was identified as "the most futuristic" of the project's seven connected car features because of its reliance on 100% of cars being connected, as well as a massive change in the road infrastructure and how cars deal with this infrastructure. The project team concluded that this was a feature that "might appear after automated cars have been well integrated in the world".

Self-driving cars

As well as participating in the connected car demonstrations, UK Autodrive partners Jaguar Land Rover and Tata Motors European Technical Centre used the project to develop and demonstrate their respective advances in highly automated vehicle technology.

Following the same methodology as for the connected cars, both manufacturers began their trials on the closed-off roads of the HORIBA MIRA proving ground, before moving out into fully open public roads in the host cities of Coventry and Milton Keynes.

The increased complexity of the environment was matched by gradual increases to the complexity of the vehicles' self-driving systems. This began with a relatively simple drive around an oval track at the proving ground in October 2016. By November 2017, the two manufacturers had completed sufficient testing to stage a demonstration in Coventry city centre, where the cars were required (at a maximum speed of 20 mph) to navigate through a busy "mixed use" area – taking account of buses, cyclists and pedestrians as well as other cars.

In the final year of the project, the two teams demonstrated their systems in a higher speed suburban area of Milton Keynes (in April 2018) before coming together to stage the project's final multi-vehicle demonstrations across both Milton Keynes and Coventry in October 2018, with both sets of cars now able to successfully negotiate mapped stop signs, traffic lights, roundabouts, intersections and pedestrian crossings (see 'The Grand Finale' on pages 18-19).

Public safety was paramount during all three years of the project, with trained drivers present in all vehicles at all times, ready to take back control if required.

Self-driving car demonstrations

Why autonomous? The benefits of ditching the steering wheel

Self-driving vehicles are expected to revolutionise the way people and goods are moved around, with major benefits expected in terms of safety, accessibility and traffic flow.

When it comes to safety, human error is generally regarded as the biggest single contributor to road traffic accidents – with some official reports estimating that it is a factor in more than 90% of serious accidents. Self-driving cars still have to prove that they can achieve the same high mileage that human drivers currently attain on average *without* incident, but once they have passed that milestone it is expected that their more regulated, less erratic style of driving and interacting with other road users will lead to far fewer accidents.

As well as making our roads safer, self-driving vehicles should make them more accessible for those who are unable or unwilling to drive – due to age, frailty or disability – opening up new mobility options for people who currently need to rely on others for their transport needs.

It is hard to fully calculate the effect that self-driving vehicles will have on traffic congestion, particularly since they are expected to radically alter the nature of driving. The aforementioned 'new journeys' that could be made by people who are currently unable to drive may lead to an increase in total journeys made, as could the possibility of cars driving without any people on board at all – for example, when driving to pick up passengers. However, many experts believe this will be offset by the increased efficiency of self-driving vehicles, the potential ability of autonomous vehicles to drive closer to each other and the time savings brought about by the anticipated reduction in the number of accidents. Research carried out as part of UK Autodrive concluded that traffic delays could be reduced by as much as 30% if all of the vehicles on our roads were replaced by fully self-driving vehicles – although this research did not consider the net effect of the potential new journeys (see pages 20-21).

Besides helping more people to move around more efficiently and more safely, self-driving vehicles should also improve the road transport experience, with autonomous vehicle passengers no longer having to take care of the driving. As a result, those who currently drive should be able to work, rest or play while getting from A to B.

> **"Self-driving vehicles are expected to revolutionise the way people and goods are moved around"**

During the three years of the UK Autodrive project, both Jaguar Land Rover and Tata Motors European Technical Centre were able to significantly develop their autonomous vehicle capabilities – in both cases, taking their technologies through successful trialling at the HORIBA MIRA proving ground and then out onto the open roads of Milton Keynes and Coventry.

The following capabilities were successfully showcased during the UK Autodrive final demonstrations in the two host cities:

- Dynamic Longitudinal & Lateral Control
- Stopping at Give Way signs and traversing simple traffic lights
- Complex traffic light traverse
- Simple roundabout traverse
- Complex roundabout traverse
- Lane changing in city environments
- Merging in Traffic
- Lane changing and overtaking on highway environments
- Cross roads & right turns
- Highway junction recognition & exit
- Valet parking (single storey)

Key findings

It was evident by the end of the project that both manufacturers had made major progress in terms of their respective autonomous vehicle capabilities. The project was also useful in highlighting a number of remaining challenges that will need to be addressed in future development of autonomous vehicle technology, including:

- what levels of integration are necessary with road infrastructure, including traffic signals (particularly during future technology trials);
- minimising any issues related to time synchronisation between system components, with a key project learning being that distributed systems are highly reliant on their networking;
- the handling of pedestrians, with restrictions on areas where pedestrians cross roads recommended during future trials, and as long as in-vehicle pedestrian prediction models remain in a relatively immature state;
- the need to correct for three-dimensional 'imperfections' on real road surfaces compared to two-dimensional mapping software (e.g. potholes, speed bumps);
- the current unsuitability of GPS as the sole source of traffic lane-level localisation (Jaguar Land Rover and Tata Motors European Technical Centre both monitored for GPS variance during the UK Autodrive trials and demonstrations, as well as developing separate 'back up' localisation systems, with both teams confirming that GPS localisation was not sufficiently precise without these additional systems.).

A whole new mode of transport – UK Autodrive's driverless pods

Self-driving vehicle technology offers an opportunity not only to modify our approach to cars, taxis, trucks and buses – but also to invent entirely new forms of transport.

A major strand of the UK Autodrive project focused on the development and demonstration of pavement-based, electric-powered, driverless 'pods' – paving the way for a possible fleet of on-demand vehicles that could be used for 'last mile' journeys, for example taking a train passenger from the station to their final destination, or transporting a car driver from an out-of-town car park to a location of their choice in the city centre.

Potentially blurring the lines between public and private transport (by offering an on-demand vehicle which can pick you up and drop you off wherever you choose), the UK Autodrive pods were designed and manufactured by Coventry-based automotive firm RDM Group.

Just as with UK Autodrive's connected and self-driving cars, RDM initially developed the pods' autonomous systems in a closed environment (in their case within a purpose-built 'Urban Development Laboratory' adjacent to the company's headquarters) before setting up a test facility in central Milton Keynes which was then used as the base for 'real world' trials and demonstrations on the city's pavements and other pedestrianised areas.

By the time the project came to a close in November 2018, the pods had gone from individual prototype vehicles that could navigate within a closed test track environment to a fleet of ten self-driving vehicles that could successfully negotiate public spaces and link up with the projects' road-based connected and autonomous cars (see 'The Grand Finale' on pages 18-19).

The Grand Finale

The UK Autodrive project concluded its three years of trialling in spectacular fashion with three days of complex demonstrations spread across the two host cities of Coventry and Milton Keynes. In keeping with the collaborative, multi-vehicle nature of UK Autodrive itself, the final demonstrations included a potential future journey demonstration in which the project's connected and autonomous cars were able to link up with the self-driving pavement-based pods.

Fully connected

During the three days of the final demonstrations, all seven connected car features were successfully showcased (see pages 8-11 for more details on the connected car use cases), showing the benefits that could be realised in the future if cars are enabled to "talk" to each other. This included a number of potential safety features (including Emergency Vehicle Warning and Intersection Collision Warning) as well as features that could improve traffic flow and reduce congestion (such as connected traffic lights and collaborative parking notifications).

Autonomy everywhere

The final demonstrations were also used to showcase the ability of the project's self-driving vehicles to function successfully in a diverse range of settings – from high-speed dual carriageways in Milton Keynes to more complex built up areas within Coventry city centre, and even out onto Coventry's notoriously challenging ring road. As well as showing off their ability to negotiate all sorts of road configurations and other road users, the self-driving cars also demonstrated their ability to end their journeys with a successful autonomous 'valet parking' manoeuvre.

Of cars and pods

As the demonstration days (and the project as a whole) reached their climax, there was time for a final showcase involving the project's two separate vehicle types i.e. the connected/autonomous passenger cars and the pavement-based self-driving 'pods'.

Providing a vision of how the pods could in future act as a form of 'last mile' transport – by enabling people to make the last leg of their journey via an on-demand door-to-door service – the demonstration saw participants arriving at a car park in a connected or autonomous car before transferring into a pre-ordered pod to complete their journey (in the case of the demonstration, by being taken to Milton Keynes train station).

Bringing together the entire UK Autodrive vehicle fleet and showing how pods, cars and existing public transport services could be brought together in future to offer a safer, greener, more accessible and more customer-orientated method of transport, it was a fitting note for the three-year programme to end on.

As well as trialling the self-driving pods on the pavements of Milton Keynes, the UK Autodrive project carried out research focusing on how the pods would interact with people and how best to build trust and acceptance when it comes to autonomous vehicles.

To investigate the interaction between people and pods, at a time when pods are not yet widely encountered in public spaces, Jaguar Land Rover's Research Team worked with visualisation experts at the Connected Places Catapult (CPC), using the CPC's state-of-the-art 360 degree virtual reality 'Omnideck' to simulate a fully walkable virtual reality version of central Milton Keynes.

Participants in the trial were then able to walk around the virtual city, encountering pods in a number of situations, including at pedestrian crossings or when walking down the pavement while being approached by pods up ahead or behind them. In each instance, the virtual pedestrians were shown different ways in which the pods could indicate their 'intentions' (for example, to give way or to overtake). The participants were asked, both during and after the simulated experience, which indications had been clearest to them.

It is planned that the findings from the research project will be used to help the continuing development of the Human Machine Interfaces (HMIs) installed within the pods, as further real world trials continue.

The research into people's trust levels in relation to autonomous vehicles was carried out by Jaguar Land Rover's Research Team at a purpose-built Urban Development Lab (UDL) next door to the self-driving pod manufacturer's Coventry headquarters.

The UDL consists of a 20m x 35m warehouse designed to simulate a town centre, using temporary walls and projections of shopfront designs to create the impression of buildings, roads and pedestrian crossings. Pedestrian 'actors' were also employed as the trial participants took rides around the 'town' in a self-driving pod – with more than 650 participants eventually experiencing 20 different experimental scenarios.

The project team examined different methods of measuring people's trust in autonomous vehicles and then tested how they could influence trust levels – including by simulating system failures that appeared genuine to the participants but had, in reality, been well rehearsed during the study's preparation stages.

As with the virtual reality HMI study in Milton Keynes, the findings from the UDL trust studies will be used in future projects with the aim of further bolstering public confidence in autonomous vehicles and how they interact with people.

“ As well as trialling the self-driving pods on the pavements of Milton Keynes, the UK Autodrive project carried out research focusing on how the pods would interact with people and how best to build trust and acceptance when it comes to autonomous vehicles. ”

All of the research papers carried out for UK Autodrive can be accessed free of charge via the downloads section of the project website, **www.ukautodrive.com**

Cities Research

As well as demonstrating the potential benefits of connected and autonomous vehicles using its own small fleet of cars and pods, the UK Autodrive project sought to explore the 'wider picture' issues that could hamper or accelerate the mainstream adoption of self-driving vehicle technology.

With the support of project partners the University of Cambridge and the University of Oxford, UK Autodrive carried out a wide range of research activities, including nationwide surveys to assess different aspects of the public's attitude to self-driving cars, an examination of the potential business models that could help finance the roll-out of the technology, an investigation into the possible effects (both positive and negative) that autonomous vehicles could have on traffic flow and an exploration of the future scalability of the technology that underpins autonomous cars.

Key findings from all of the research activities are set out below.

Public still open minded about self-driving vehicle technology

Researchers at the University of Cambridge carried out two detailed national surveys on behalf of the UK Autodrive programme to examine the UK public's attitude towards self-driving vehicles and to see if attitudes shifted at all during the course of the project.

The first survey, carried out in 2016, suggested that the technology had not been around long enough for hard-line attitudes to set in. Responses revealed a remarkably open mind to the arrival of self-driving vehicles, with 35% of those surveyed saying they would use a fully self-driving vehicle, while only 33% expressed opposition to the idea.

In general terms, the subsequent 2018 survey matched the initial survey's results closely, with no major shifts in attitudes discerned – though a detailed analysis suggested a slight polarisation of opinions had taken place, along with a mild 'hardening' of opinions in response to the main question concerning the desire to use self-driving vehicles – with 33% now saying they would use one, compared to 37% who said they would not.

Taken together, the two surveys were seen to represent a valuable starting point for what could become a regular national survey in future, as self-driving vehicles come closer to mainstream reality. The research team suggested that a 'Self-Driving Vehicle Index' for the UK could be developed, in order to monitor any changes in public perception and, potentially, to make comparisons between attitudes in the UK and in other countries.

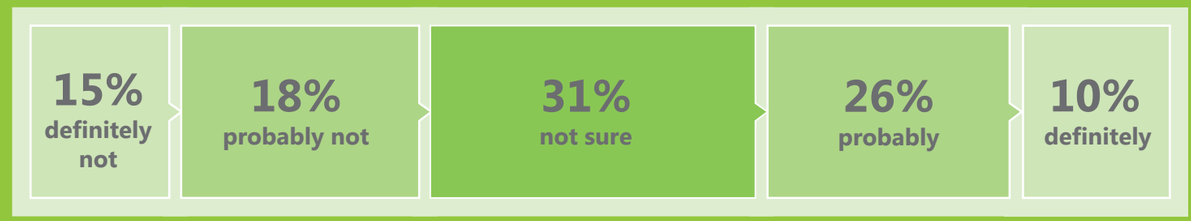
A marked reduction in traffic congestion?

The mainstream adoption of fully automated vehicles could lead to a significant decrease in traffic congestion, according to modelling work carried out for the UK Autodrive project by the University of Cambridge's Department of Engineering. Combining a city-wide 'macro-simulation' (using Milton Keynes as the study's 'base city') with a highly complex series of 'micro-simulations' at the level of individual roundabouts and junctions, the research team created one of the largest and most complex traffic simulation models reported to date, and used this to observe the likely effect of introducing self-driving vehicles (based on market penetration levels of between 0 and 100%).

It was concluded that self-driving vehicles could have a markedly beneficial effect on traffic flows, mainly as a result of these vehicles having a much better driving discipline (and less variability) than conventional human-driven cars. The study found that congestion levels (as measured by journey delay times) could be reduced by as much as 25-30% if all of the vehicles on our roads were replaced by fully self-driving vehicles.

Would you use a fully driverless vehicle?

(UK Autodrive 2016 survey results)



It should be noted that the study did not take into account the 'additional journeys' that could be made possible by self-driving vehicles, including empty cars travelling without any humans on board (for example, to pick up passengers) or the use of self-driving cars to transport children or people who may not currently drive due to old age or disability.

Stating the business case for self-driving pods

The University of Cambridge also carried out research into the possible business models and associated costs (to operators and customers) that could help accelerate a city-wide adoption of the self-driving pod vehicles which were trialled within the UK Autodrive programme.

Since the pavement-based pods represent an essentially new form of urban transport, the researchers had very little historical data to rely on – for example, when it came to calculating the likely speed and journey time of the vehicles in crowded environments. By using the MASSMOTION software of UK Autodrive lead partners Arup, however, they were able to estimate a rough average speed and journey times for the pods within a range of different pedestrian densities, and use this information to calculate the number of pods, and overall associated costs, required to service a given city.

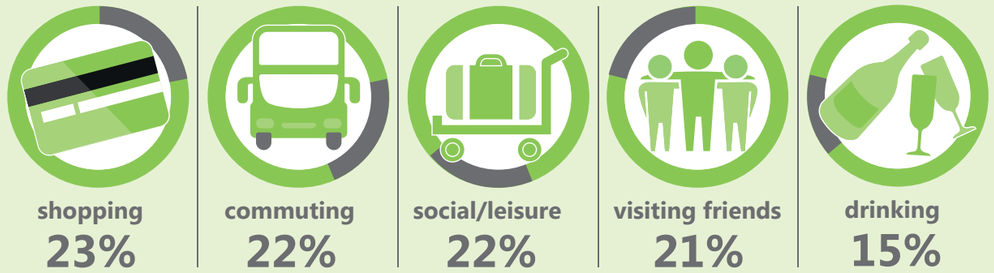
Applying the model to anonymised population data derived from central Milton Keynes, the researchers calculated demand for up to 80,000 pod trips within the city centre during an average 'good weather' week, and more than five million trips for the year as a whole. Taking the capital and operating costs of a future pod operator into account, however, the research suggested that the best conditions would be met by offering a fleet of around 380 pods that could provide around 2.5 million trips per year at a cost per ride of £3 – with the operator able to start generating a profit within the third year of operating.

Cutting the costs of sensor technology

With the cost of onboard sensors forming a major part of the capital outlay required to run a self-driving vehicle fleet, UK Autodrive also commissioned the Oxford Robotics Institute (ORI) to carry out detailed research into the scalability of this technology – and whether it can reach affordable levels, while remaining safe and reliable.

Noting recent and ongoing falls in the cost of laser sensors, while also exploring the potential to replace laser-based systems with less costly alternatives (such as radar and audio), the researchers concluded that a £10,000 target for an entire sensor array would be achievable in the near future, with new low-level light technologies (such as event cameras) already offering potential ways of accelerating cost reductions.

What would you use a self-driving vehicle for?



From morality to future motorways – the UK Autodrive white papers

UK Autodrive's body of research also included a series of white papers that examined potential legal, ethical and practical matters arising from the introduction of autonomous vehicles. Produced by international law firm and UK Autodrive project members Gowling WLG, the white papers covered topics as diverse as data privacy, cyber-security, infrastructure requirements and the 'moral algorithm' question which asks whether self-driving cars might one day be programmed to make moral decisions.

The UK Autodrive white papers can be downloaded in full and free of charge from **www.ukautodrive.com/downloads** or from the Connected and Autonomous Vehicles section of the Gowling WLG website.

> **"The moral algorithm is a term that is good for tabloid newspapers. There is no such thing in the software that will tell the car to hit the 80-year-old in order not to hit the group of kids."**
>
> **Dr Heiko Schilling**
> TomTom ('The Moral Algorithm', December 2016)

Report highlights

In the first of the white papers, **'Are You Data Driven?'**, Gowling WLG warned that vehicle manufacturers would have to get their head around international data protection rules if self-driving cars were to enter mass production. Published two years before Europe's General Data Protection Regulation (GDPR) came into force, the paper also considered ways in which data protection rules could help or hinder the advent of fully automated cars.

In **'The Moral Algorithm'** white paper, Gowling WLG examined concerns over the so-called 'trolley problem' – where a vehicle is unable to avoid a collision and is asked to make a choice over which defined individuals it hits – but the report suggested that such concerns were exaggerated, with most experts agreeing that autonomous vehicles would never be programmed to make such decisions.

Nevertheless, the paper argued that harmonised safety regulations would be needed for other 'decisions', such as when it is permissible for a car to break the rules of the road, or when determining the suitable levels of 'assertiveness' that a vehicle can deploy when interacting with other road users.

In **'Connected and Autonomous Vehicles: A Hacker's Delight?'**, Gowling WLG called for more regulation and collaboration in the field of cyber-security, arguing that the motor industry and law-makers needed to work much more closely on "all things cyber". In particular, the report suggested that new laws would be welcome in relation to the issuing of updates, data storage and sharing, penetration testing and accident investigation.

'Paving the Way' looked at the future road infrastructure that might be needed for connected and autonomous vehicles. Considering both physical and digital infrastructure requirements, the report concluded that connected and autonomous vehicles would only reach their full potential if they were supported by the correct levels of infrastructure (including infrastructure to enable effective digital connectivity). It also warned that technology developed behind closed doors was unlikely to work well with similarly developed rival technologies, and called for central government investment and changes to legislation in order to ensure that developments are coordinated and able to meet the demands of society as a whole.

UK Autodrive in the global spotlight

As well as actually trialling connected and autonomous vehicles, the UK Autodrive consortium had an important obligation to ensure that as many people as possible heard about the project.

Dissemination of the project's main findings, reports, announcements and demonstrations was overseen by the Connected Places Catapult, which also hosted an International Connected and Autonomous Vehicles Symposium at its Milton Keynes headquarters in October 2018 at which the UK Autodrive partners were able to present some of their main learnings from the project.

By the time the three-year project was completed, UK Autodrive had made headlines all around the world, with more than 5,500 individual news items being published, posted or broadcast – corresponding to a potential global reach (the cumulative number of potential readers, listeners and viewers) of 13 billion people during the lifetime of the project.

Besides supporting the world's media with their coverage of the project, the Connected Places Catapult also created the project website **www.ukautodrive.com** and commissioned a series of project films (available on the **UK Autodrive YouTube page**), both of which will be kept online as a lasting record of the project's achievements.

World view – UK Autodrive's global coverage by numbers

5,636
TOTAL NUMBER OF NEWS ITEMS COVERING UKAutodrive

13 billion
POTENTIAL AUDIENCE REACH (cumulative)

69
NUMBER OF COUNTRIES where news items ran

£121 million
ADVERTISING VALUE EQUIVALENT (what equivalent coverage would have cost in advertising)

28 million
Potential audience reach on social media

1,000+
BROADCAST (TV & RADIO) News/features

£260,000
ADVERTISING VALUE EQUIVALENT ON SOCIAL MEDIA

View from the finish line – the UK Autodrive International CAV Conference

One day after the successful completion of the final UK Autodrive demonstrations, many of the consortium members were back in Milton Keynes to present some of their initial project findings at the UK Autodrive International CAV Conference.

Hosted by the Connected Places Catapult and welcoming more than 200 delegates from the worlds of vehicle manufacturing, wider industry, government, academia and the media, the event was compered by BBC Science and Technology Correspondent Richard Westcott. The morning section included presentations on the project's testing and safety measures, the vehicle technology behind the connected and autonomous cars, the self-driving pods programme and the potential impact for cities and communities, followed by a panel debate and a questions and answers session.

The afternoon then saw an International Cities Programme Seminar, focusing on the research papers published by UK Autodrive's academic partners in the areas of public attitudes, autonomous cars and their impact on congestion, potential business models for self-driving pods and the scalability of the related technology (see pages 20-21).

With much of the day focused on the tangible benefits that connected and autonomous vehicles can deliver to city authorities, it was particularly interesting to hear the final thoughts of the representatives from UK Autodrive's two host cities.

"The challenges that we set were the challenges that the project met," Coventry City Council Transport Innovation Manager Sunhil Budhdeo told the conference. "We have statutory obligations to improve congestion, reduce emissions and improve safety – and working through this project has shown us how new technologies can support that."

"As a city, it's increasingly clear that we need to orchestrate these systems in a holistic way," agreed Geoff Snelson, Director of Strategy and Futures at MK Council. "We can't keep managing on less and less without thinking about the longer-term strategies. So we need these vehicles to be integrated and able to speak to each other, so as to provide that support environment."

Presentation slides from the UK Autodrive International CAV Conference can be accessed via the downloads section of the **www.ukautodrive.com** website.

READ ALL ABOUT IT

What the media said about UK Autodrive

The Guardian, 25th March 2018

The Guardian

"The autonomous car unveiled in Milton Keynes last week is bleeding-edge engineering, Britain's entry in a global race to get the first driverless car on the road. The converted Range Rover Sport can steer itself, speed up and slow down, stop at red lights and move off when they turn green. The five operators are there to examine every nuance of the car's reaction to the ever-changing conditions – cyclists, pedestrians and other drivers, and the weather, to name a few."

Leicester Mercury, 23rd October 2016

Leicester Mercury

"Cruising at a steady 51mph, the car made easy work of the test track at the MIRA research facility … One of the next big steps – and one of the big points of media days like this and the future real world trials – is getting the message out there that the technology is safe. If the cars on display at this … test track were anything to go by, that might not be half as difficult as you might imagine."

Daily Mail, 10th October 2018

Daily Mail

It's one of the most notoriously tricky highways in Britain to master, but an autonomous car has successfully completed a self-driving lap of Coventry's infamous inner-city ring road. A prototype driverless Range Rover Sport made a complete circuit of the complex Coventry Ring Road – with its complicated and often confusing succession of exits and entrances – successfully changing lanes, merging with traffic and exiting junctions at the speed limit of 40mph. The feat by Britain's biggest car-maker Jaguar Land Rover was the climax of a £20million government-funded project called UK Autodrive which ends this month after a three-year programme.

DAILY EXPRESS

The autonomous Range Rover signals to overtake, moves out, passes the other car, signals again and returns to the nearside lane. Amy's hands remain on her lap. It should have felt alarming but it felt perfectly normal … Driving home (140 miles) in the dark in heavy traffic I was tired. My reactions would have been slow in an emergency and I don't suppose I was any different from all those thousands of other drivers on the road with me. I reflected as I rubbed my tired eyes that I'd expected to write a scornful, dismissive piece about driverless cars. But I'd changed my mind completely... I have seen the future and it works.

Daily Express, 29th October 2018

SKY NEWS

Autonomous vehicles have successfully completed trials on the public highway in Britain. The project in Coventry saw major manufacturers Jaguar Land Rover, Ford and Tata Motors collaborate with UK Autodrive to road test the technology in real-life situations. The trials explored the possibilities of … cars that communicate with one another as well as their surroundings – including connected traffic lights, emergency warnings and emergency braking alerts."

Sky News, 17th November 2017

Thank you to all our partners and supporters

Centre for Connected and Autonomous Vehicles
Coventry Transport Museum
Department for International Trade
Department for Transport
Elder House, Milton Keynes
Government Office for Science
Innovate UK
Milton Keynes Development Partnership
Parks Trust
Ringway
South Central Ambulance Service
Thames Valley Police
The Guide Dogs for the Blind Association
West Midlands Fire Service

> “ ...the persistent spirit of cooperation displayed by the project partners and the breadth of knowledge that was collectively brought to the table ensured that we more than met those challenges. ”
>
> **Tim Armitage,** UK Autodrive Project Director, Arup

UK Autodrive

Milton Keynes leading the way in partnership with Coventry and the motor industry

> **“Taking place in Milton Keynes, Coventry, and on the Horiba MIRA test track, UK Autodrive carried out a series of trials of increasing complexity which have demonstrated the functionality and potential of connected and self-driving cars, as well as the fleet of lightweight, autonomous ‘pods’ which have been designed to operate last-mile services in an urban environment. The real advances that the UK Autodrive partners have developed and which we have demonstrated will be shaping the next generation of vehicles, the roads, regulations and safeguards needed to accommodate them, and the people using them.”**
>
> **Tim Armitage,** UK Autodrive Project Director, Arup

> **“Our involvement in the UK Autodrive project was a steep learning curve for RDM and has culminated in a well-trained team who have a good amount of experience in dealing with the pods and with members of the public. This team will become cornerstone of operations as RDM expands and will be involved in delivering training, maintenance, setting up commercial deployments and assisting with trade shows and exhibitions. UK Autodrive has equipped the consortium with the knowledge and skills necessary to continue the development of this technology.”**
>
> **Richard Fairchild,** Autonomous Vehicles Programmes Director, RDM Group

> **“The work we’ve been doing through UK Autodrive has been absolutely fundamental in helping us understand how we can create a future mobility strategy for the city, and shared mobility using autonomous vehicles seems to be absolutely at the heart of that.”**
>
> **Geoff Snelson,** Director of Strategy & Futures, MK Council

To find out more about UK Autodrive, please visit the project website: **www.ukautodrive.com**