VENTURER

Final Report

Providing insight on human responses to, and perceptions of, connected and autonomous vehicles and helping unlock their potential benefits

Executive summary

Since 2015, the **VENTURER** partners have been collaborating on connected and autonomous vehicle (CAV) research and development to help shape the future of mobility in the UK. The key values and successes of **VENTURER**, achieved through its holistic and multi-disciplinary approach, have been demonstrated through:

- The economic value to the West of England with new investment opportunities generated in the region. through a strengthened local supply chain, unlocking new opportunities for regional growth.
- The development of lasting relationships resulting in a regional cluster of CAV knowledge and expertise in the West of England.
- The emergence of an ecosystem of CAV innovation in the UK.
- Increased knowledge of the potential effects and requirements for the successful adoption of CAVs in the UK.
- The establishment of the West of England as a centre of excellence for the safe, user-led trialling of CAV technology.

As a result, **VENTURER**'s achievements and learnings are helping the government to fulfil the Future of Mobility Grand Challenge it established in its Industrial Strategy and supporting the delivery of its other three foci: Artificial Intelligence and data, Ageing society and Clean growth.

The **VENTURER** project's approach to enabling the deployment of CAVs onto UK roads included:

- Delivering pioneering and safe user and technology trials enabling partners to assess the responses of passengers, other road users and pedestrians to driverless cars.
- Developing connected and autonomous technologies to facilitate successful real-world and simulated participant trials.
- Conducting social research to develop insight into public acceptance challenges associated with CAV technology.
- Informing the development of future CAV insurance and legal requirements using the findings from participant experiments and investigations.

Key findings from the project include:

- Findings of the experiments in both the **VENTURER** simulator and the Wildcat revealed participant responses were comparable between both simulated and controlled road network environments.
- Planned handover between autonomous driving systems and the human driver, as would be required to achieve Level 3 vehicle autonomy, is achievable in optimum conditions, but not necessarily desirable in safety terms.
- Participants have greater trust in the behaviours of autonomous vehicles when they demonstrate more cautious vehicle behaviour than the average human driver.
- Participants did not show significant differences in trust ratings depending on whether they experienced the trial scenarios in the role of a cyclist, driver or pedestrian indicating that there is no particular need to differentiate messaging around CAVs for different audiences.
- Key insurance and legal recommendations for insurers, the CAV industry and regulators arising from the deep insight developed through **VENTURER** include considerations such as: encouragement of clarity around legal and insurance definitions of automated vehicles, and establishment of minimum standards for the capture, retention and sharing of CAV data for incident investigation and analysis.

We are pleased to present **VENTURER**'s achievements, findings and their potential applications in more detail in the following pages. We will also introduce the **VENTURER Alliance**, which will ensure the successes of the project are continued and built upon so that **VENTURER** continues to help shape the future of mobility.

Context

In 2014, Innovate UK launched its first competition for collaborative research and development projects for driverless cars (*'Introducing driverless cars to UK roads'*[1]) to be part-funded by industry and Innovate UK. **VENTURER** was successful in this competition and became the first of the Four Cities Trials[2] to launch in July 2015.

Based in Bristol and South Gloucestershire, **VENTURER** has been a three-year, £5 million collaborative research and development project investigating the barriers to the adoption of connected and autonomous vehicles (CAVs) in the UK. The project, led by Atkins, represents a rich partnership of universities, large and small businesses and local authorities, which has drawn on state-of-the-art technologies, industry expertise and world-class academic research to establish the West of England as a centre of excellence for the safe trialling of CAV technology, user behavioural response analysis and social research.

VENTURER has systematically assessed road users' responses to the introduction of driverless cars, using a series of increasingly complex scenarios. It has focused on developing a greater understanding of public acceptance and user behaviour, as well as the legal and insurance implications of increased vehicle autonomy.

Having adopted a holistic approach to the integration of CAVs, the findings of the **VENTURER** project mean we can identify recommendations for introducing driverless cars in the UK. Their implementation will help unlock the potential benefits of CAVs in everyday life, which could potentially include:

- **Improved safety** – human error is a factor in 90% of collisions and automated technologies which reduce and/or remove the need for human driver input will help reduce this safety risk[3].
- **Optimised use of travel time** – as driver attention is no longer needed for the driving task, the driver's time can be utilised on other tasks on their journey[3].
- **Improvements to transport network performance** – when the proportion of automated vehicles on the road is higher than the number of human-driven vehicles, driverless cars could offer potential benefits to traffic flow and help reduce delays and congestion[4]. Furthermore, improved network performance and evolving vehicle power technology could help contribute to environmental benefits, including improved air quality.
- **Increased mobility, enhanced quality of life and improved social inclusion** – for those who may not have access to a vehicle or do not have a driving license, automated technologies can provide journeys without the need for a driver[3].

The VENTURER consortium

VENTURER was delivered by a successful collaboration of universities, large and small businesses and local authorities.

Partner	Role in the project
SNC-Lavalin's Atkins business	• Programme management. • Trial development, planning and co-ordination. • Intelligent mobility expertise.
AXA UK Ltd	• Development of the scope of the trials. • Application of learnings from the trials to inform insurance requirements.
BAE Systems (Operations) Ltd	• Provision of the Wildcat autonomous vehicle and technical support to deliver the trials.
Bristol Robotics Laboratory (BRL)	• Development of the scope of trials. • Trial coordination and delivery. • Facilitation of technology integration activities. • Development of and testing the Decision-Making System (DMS).
Fusion Processing Ltd	• Development of and testing the situational awareness system.
First Bus Ltd	• Provision of a bus as a means for data collection and demonstration purposes.
Bristol City Council South Gloucestershire Council	• Facilitation of access to their road network to enable demonstrations. • Promotion of CAV capabilities in the West of England.
University of Bristol (UoB)	• Development of and testing the Decision-Making System (DMS). • Development of and testing vehicle communications technology.
University of the West of England (UWE) – Bristol	• Development of the scope of trials. • Trial coordination and delivery. • Analysis of participant responses to the trials. • Social and public acceptance research.
Williams Advanced Engineering	• Development of the simulator and provision of ongoing technical support during the trials.
Burges Salmon LLP	• Supporting partner, providing legal expertise. • Development of the scope of trials. • Application of learnings from the trials to inform legal analysis.

	VENTURER project timeline	UK CAV landscape
2013–2014	**December 2013** – National Infrastructure Plan and Autumn Statement announced that UK Government would award £10m to cities to develop testing grounds for driverless cars to inform policy development and direction, and to understand public perception and the impact such cars would have on society. **July 2014** – First UK driverless cars competition ('Introducing driverless cars to UK roads') launched by Innovate UK.	
VENTURER Year 1 2015–2016	**February 2015** – Innovate UK awards funding to three consortia, including **VENTURER**. **July 2015** – **VENTURER** project launched. **July 2015 to June 2016** – **VENTURER** mobilisation and scoping: • Trial scoping, development and planning. • Simulator development. • Technology development and specifications. • Literature reviews and research design. **May 2016** – First **VENTURER** showcase event.	**February 2015** – The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies published by the Department for Transport. **July 2015** – The Pathway to Driverless Cars: Code of Practice for testing published by the Department for Transport. **July 2015** – Centre for Connected and Autonomous Vehicles (CCAV) established.
VENTURER Year 2 2016–2017	**July 2016** – First **VENTURER** insurance and legal report published. **July and August 2016** – **VENTURER** Trial 1: planned handover. **October 2016** – Commenced social research on public opinions and acceptance. **November 2016** – **VENTURER** technical lead provides evidence to House of Lords Inquiry: Connected and Autonomous Vehicles: The future? **June 2017** – **VENTURER** Trial 1 findings released.	**November 2016** – House of Lords Inquiry: Connected and Autonomous Vehicles: The future? **March 2017** – House of Lords, Science and Technology Select Committee publish Connected and Autonomous Vehicles: The future? **March 2017** – Government launches competition to establish UK CAV test bed. **September 2017** – Meridian Mobility launched. **October 2017** – first reading of Automated and Electric Vehicles Bill (AEV Bill) in Parliament. **October 2017** – UK CAV test bed competition winners announced. **November 2017** – Industrial Strategy White Paper published with 'Future of Mobility' one of four Grand Challenges.
VENTURER Year 3 2017–2018	**June and August 2017** – **VENTURER** Trial 2: interactions with other vehicles and at junctions. **August 2017** – **VENTURER** autonomous pod demonstration. **September 2017** – Second **VENTURER** showcase event. **November 2017** – Trial 2 findings release. **March and April 2018** – **VENTURER** Trial 3: interactions with pedestrians and cyclists. **April 2018** – Second insurance and legal report published. **June 2018:** • Trial 3 findings released. • Third insurance and legal report launched. • Final **VENTURER** showcase event.	**March 2018** – Government and Law Commission of England and Wales and the Scottish Law Commission launch a three-year review of driving laws in preparation for self-driving vehicles. **May 2018** – AEV Bill Committee stage: House of Lords.

Connected and Autonomous Vehicles (CAV) are autonomous vehicles that communicate with each other and other objects or infrastructure.

An Autonomous Vehicle (AV) is a vehicle which uses a range of advanced vehicle systems, enabling it to operate with no driver intervention in some or all driving situations.

The Wildcat and simulator were operated as Autonomous Vehicles (AV) with the exception of the Trial 3 bus demonstration where the Wildcat could be defined as a CAV.

The approach

In its three-year programme of successful collaborative research and development, **VENTURER** has:

- **Systematically assessed the responses of passengers, other road users and pedestrians to driverless cars** in a series of increasingly complex participant trials to derive the requirements for their acceptance by the public.
- **Developed several technologies to support CAV capabilities** – a systems interface, situational awareness software, decision-making systems, a connected and autonomous vehicle simulator and vehicle communications, all of which facilitated successful participant trials using a realistic simulation environment and a CAV in a controlled road network. The technologies developed have been tested on three autonomous vehicles (Wildcat, pod and Twizy).
- **Conducted social research** to develop insight into public acceptance challenges associated with CAV technology.
- Used findings from participant experiments and investigations to help **inform the development offuture insurance and legal requirements**.

Summer 2016

Trial 1 – planned handover of control between a vehicle and a driver in real-world and simulated environments.

Understanding the handover process is important for informing policy and decision-makers on some of the key issues surrounding Level 3 and 4 autonomy (SAE, 2014[5]) for autonomous vehicles, which would require the transfer of control between the human and autonomous system. These are the levels before Level 5 (full autonomy, which will not require the transfer of control between the human driver and the vehicle).

Conducted with participants of varying levels of driving experience, in environments and at speeds typical of day-to-day driving in urban areas.

58 participants took part in the simulator and the real-world experiments to gain a deeper understanding of:

- How long it took participants to engage with the driving controls (steering wheel, brake, and accelerator) after a planned handover request.
- Whether typical manual driving performance is achieved after planned handover.
- At what time during the handover period is typical manual driving performance achieved.
- For how long does the driver maintain typical manual driving performance during the handover period?

> Planned handover: the driver is aware that they might be alerted to take control of the vehicle at any moment, either due to decisions made by the driver, or the capabilities of the vehicle in particular situations.

Spring 2017

Trial 2 – autonomous vehicle interactions with conventional vehicles and at junctions.

VENTURER identified that some of the most complex driving situations occur in urban areas. These include requirements for safe interactions at junctions, on road links and often involve reacting to the decisions of other vehicles.

Demonstrating that AVs can safely navigate these scenarios, and that passengers are comfortable with the AV's manoeuvres will be a crucial aspect of ensuring that AVs are safe for deployment onto UK roads.

46 participants took part in Trial 2 which aimed to understand:

- Whether participants' trust varied depending on the type of AV scenario they experience.
- If there was a correlation between trust scores and measures such as participant age or driving experience.

Whether trust varied dependent on the real-world (Wildcat) or simulated environment (**VENTURER** simulator).

- Whether trust varied depending on whether the AV accepted or rejected the 'critical gap'.

> Critical gap: defined as the minimum gap at which 50% of human drivers would decide to give way to an oncoming car ('reject the gap'), and the other 50% of drivers would pull out in front of the oncoming vehicle ('accept the gap').

Summer 2017

Public autonomous pod demonstration in Bristol city centre.

VENTURER hosted a public demonstration of its autonomous technology in Millennium Square, Bristol. The event showcased a pod vehicle, developed collaboratively with the GATEway project.

The public were invited to take a journey in the pod to experience autonomous technology first hand. The public were also able to get up close to the Wildcat AV and BRL Twizy adapted to Level 3 autonomy, including impressive demonstrations of the 'hands-free' BRL Twizy in the square.

The purpose of the event was to engage with a wide range of people on the issues and opportunities associated with autonomous mobility. **VENTURER** used it as an opportunity to engage the public, especially young people, in discussions on the science and ethics behind autonomous vehicles and new technologies that are being developed in the West of England and to encourage future study in these areas.

The demonstration also provided the opportunity to research public perceptions about these new technologies. Over 200 members of the public were engaged in UWE's social research at this event.

Spring 2018

Trial 3 – autonomous vehicle interactions with pedestrian and cyclists.

Trial 3 tested levels of public trust in the decisions of autonomous vehicles when they interact with pedestrians and cyclists at junctions and on road links.

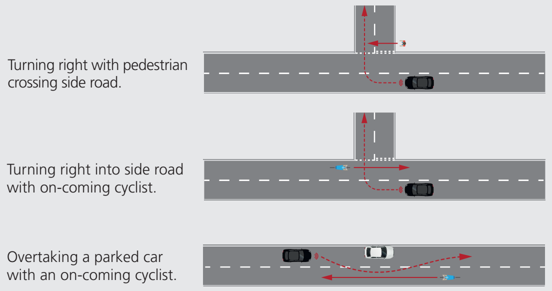
All of the scenarios being tested in Trial 3 were typical of those encountered by vehicles on the UK road network every day. If autonomous vehicles are to be successfully integrated into the transport network, they must first demonstrate the ability to cope safely with real-world traffic situations such as these.

Trial 3 assessed:

- How trust in the AV varied depending on the manoeuvre the AV was undertaking.
- Whether trust levels varied depending on whether the observer was a pedestrian, cyclist or passenger in the AV.

If the level of trust was different depending on whether the AV was the real-world Wildcat or the VENTURER simulator for the pedestrian, cyclist and the passenger in the vehicle.

- In the simulator environment, how the observing pedestrian and cyclist's trust levels varied when the vehicle was driven by a human compared with when the vehicle was in AV mode.



Demonstrated the interaction between an autonomous vehicle and a bus.

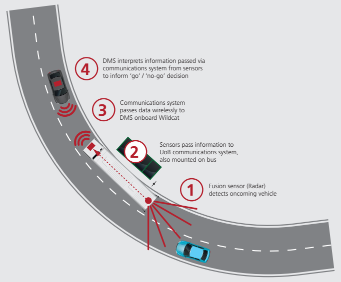
VENTURER tested and validated the Wildcat's autonomous system during a demonstration of a 'look-ahead' capability on a South Gloucestershire road.

The purpose of the bus demonstration was to test **VENTURER**'s autonomous technology in a typical highway scenario: overtaking a stopped bus on the highway.

This involved several firsts for the **VENTURER** project, including integrating a vehicle-to-vehicle communications system with the rest of the CAV system and planning and undertaking a demonstration on the road network outside the UWE campus.

The key challenges of the demonstration included:

- Ensuring the integrated CAV system was able to accept and act upon information communicated from another vehicle.
- Enabling the communications system to successfully share data in a real-world CAV situation.



How we did it

VENTURER has developed a successful methodology for the safe development and delivery of participant trials and the safe testing of technology in both simulated and controlled road network environments, using the **VENTURER** simulator and the Wildcat road vehicle.

This approach enabled **VENTURER** to successfully deliver participant trials and public demonstrations of CAV technology throughout the project and gather robust data on user experiences of the technology. Using the **VENTURER** simulator and Wildcat to conduct experiments, **VENTURER** has developed leading expertise in user behaviour analysis.

The **VENTURER** simulator was developed by Williams Advanced Engineering and programmed with simulated scenarios developed by BRL. The simulator replicated the scenarios presented in the Wildcat real-world experiments. The simulator operated in autonomous mode, enabling the participant to feel as though they were being driven autonomously.

The VENTURER Simulator

BAE Systems provided a bespoke Bowler Wildcat, which was already fitted with autonomous systems to enable autonomous driving in restricted environments, such as off-road driving. The Wildcat had never been used in urban environments or on public roads until the **VENTURER** project. The Wildcat provided **VENTURER** with the capability to test the decision-making system developed by BRL and UoB and the situational awareness systems developed by Fusion Processing.

The Wildcat road vehicle

The trials were conducted at the BRL Autonomous Driving Research Zone on the UWE campus. All testing and trials conducted by **VENTURER** comply with the Department for Transport Code of Practice[6].

Human factors experiments were planned, co-ordinated and conducted by a partnership of:

- Atkins.
- Members of the Centre for Transport & Society, UWE, Psychological Sciences Research Group, UWE and Psychology – Centre for Health and Clinical Research, UWE.
- Technology partners: BRL, BAE, Williams and Fusion.

VENTURER social research

The UWE Centre for Transport & Society conducted extensive social research for the **VENTURER** project and also undertook. literature reviews. The work supported design of the trials but also examined the wider context of CAV adoption. The social research was conducted using the following approaches and focused on engaging participants from Bristol and South Gloucestershire:

- Stakeholder interviews with professionals.
- Focus groups with residents.
- Online survey including a Stated Preference exercise following a Contingent Valuation Method with inferential statistical and cluster analysis of data.
- Online debates with a citizen panel on five topics relating to CAVs.
- Engagement with the public at science and technology events and the autonomous pod demonstration.

The research was designed to gauge public perceptions and views of CAVs in relation to:

- Willingness to use (exclusively or sharing with unfamiliar others).
- Willingness to pay.
- Social variance (age/gender/primary mode of travel).
- Inclusion and disability.
- Spatial variation.
- Trust (system safety).
- Connectivity (tracking, hacking).
- Interactions between CAVs and other road users.

VENTURER human factors research

Trial 1 – sought to understand driver performance before, during and after the planned handover of control from the autonomous vehicle to the participant. Driving measures recorded include: average speed, acceleration, lane position of the vehicle, movement of the steering wheel and the amount of pressure being applied to accelerator and brake.

Trial 2 – sought to collect data on human reactions and to test participants' trust in the decisions of the AV. Different phases of experiment were included to establish whether trust ratings varied dependent on the type of AV scenario experienced, if trust scores were significantly different depending on the platform and how trust scores correlated with relevant validated psychometric test scores.

Trial 3 – sought to collect data on participant trust in AV behaviour, behaviour modelled during carefully constructed scenarios where the AV must consider other moving and static road users on straight roads, roads with bends, roads with obscured forward visibility and at T-junctions. In particular the objective of these experiments was to test the perceptions of cyclists, pedestrians and drivers in the role of observers of the interactions by asking them to rate their trust in an AV as they watched it interact with a pedestrian and cyclist in a number of typical highway scenarios.

VENTURER insurance and legal analysis

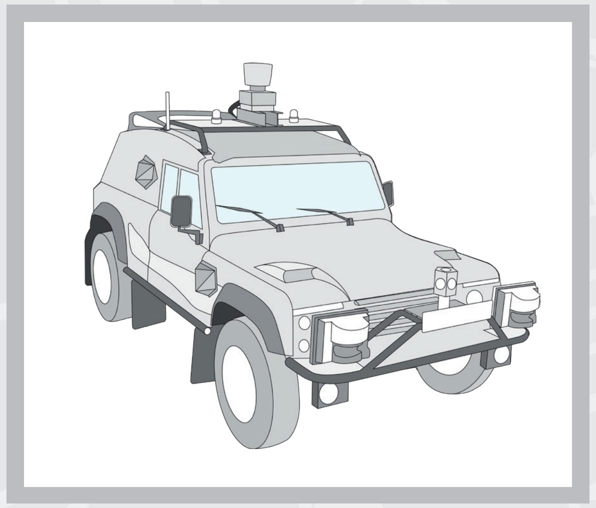
AXA and Burges Salmon used the insight gained from **VENTURER** and the findings from the trials to:

- Consider how insurance business models may evolve.
- Consider a more user-led approach to insurance.
- Consider liability issues arising from CAV own-fault incidents.
- Consider the current legal constraints preventing the deployment of CAVs.
- Understand the legal framework for CAV deployment and the required future changes to legislation.
- Shape the emerging Automated and Electric Vehicles Bill.

How the different elements of VENTURER work together and their impact on the wider CAV ecosystem

VENTURER has demonstrated the importance of the inter-dependencies between human factors research, social research, insurance and legal requirements and technology development for deepening our understanding of how driverless cars could be introduced safely onto UK roads.

Communications development and understanding human interaction with CAVs and the integration of CAVs into the wider transport network will help develop smart cities of the future.

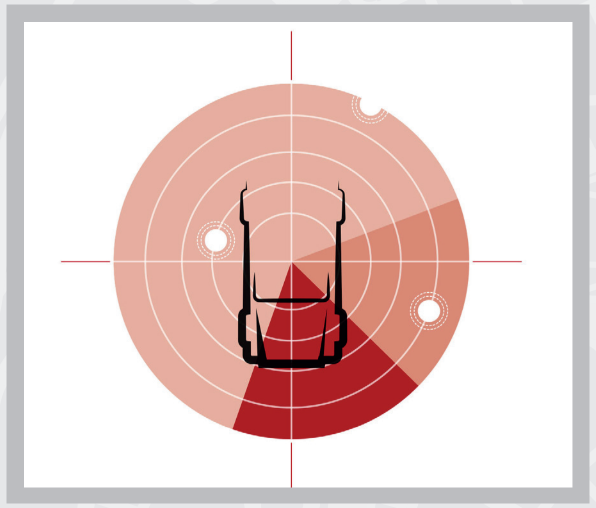


Learning from public acceptance and human factors research can shape insurance and legal frameworks.

Insurance and legal requirements can influence the design of human-machine interface (HMI), connected and autonomous systems and processes and how data is collected and stored.

The testing and design of connected and autonomous systems and processes is influenced by human factors research and insurance and legal requirements.

This will help build user confidence and assure safe and trusted connected and autonomous vehicle technology.



Understanding public views on how we will travel in the future and willingness to use CAVs is derived from social research.

This helps inform technology development and testing and those planning for how we travel in the future.

Key learnings

VENTURER has developed a greater insight into how driverless cars could be deployed onto UK roads – the following are key learnings from the VENTURER project.

1. Safe testing using both simulated and controlled road network environments

VENTURER delivered three successful trials safely, securing robust data for analysis.

Overall, nearly 200 participants took part in the **VENTURER** trials in both the **VENTURER** simulator and the Wildcat. All testing and trials conducted by **VENTURER** complied with guidance contained in The Pathway to Driverless Cars: Code of Practice for testing[6].

2. Robust and comparable results from testing in both simulated and controlled road network environments

The findings of the experiments from both the **VENTURER** simulator and the Wildcat revealed participant responses were comparable between both simulated and controlled road network environments.

This demonstrates the validity of using simulated environments for future CAV testing to assess user responses to CAV technology in a range of scenarios. This is significant for future CAV testing as **VENTURER** has demonstrated the validity of using simulators for testing human responses to CAV technology in addition to conducting more resource intensive real-world experiments.

While there are caveats associated with the findings, the VENTUER trials have provided valid data which has been published in peer-reviewed academic journals and **demonstrated the feasibility of undertaking further comparative research. This is needed before industry standards and production prototypes for connected and autonomous vehicles can be produced.**

3. Safe and user-centric design

Trial 1 – planned handover between autonomous driving systems and the human driver, as would be required to achieve Level 3 vehicle autonomy, is achievable in optimum conditions, but not necessarily desirable in safety terms.

Even at speeds as low as 20 mph, the planned handover task from the vehicle to the driver at Level 3 brings new kinds of road safety risk due to a driver performance deficit following the resumption of control. Where the handover practice cannot be avoided, it will need careful management.

While these risks are present at all speeds, the potential consequences are greater at higher speeds and might be mitigated by a CAV reducing speed prior to initiating a handover event. A lengthier, more structured handover process is likely to be necessary, especially in the early stages of adoption, in order for drivers to regain control safely and in a manner which does not expose them to unfair liability consequences.

Further research is required from a broader variety of participants, assessed across a wider range of driving scenarios and driving conditions using both the simulated and controlled on-road platforms, before more definitive conclusions can be drawn. This will enable the future technical specification and production of these vehicles.

Trial 2 – participants had greater trust in the AV when it demonstrated more cautious vehicle behaviour than some human drivers.

Trust ratings were lower for all events when the AV accepted the gap that 50% of drivers would accept (accept the gaps – N') as compared with when the AV rejected the gap that 50% of drivers would accept (reject the gaps – N).

These results could have significant implications for the future UK roads. For example, if connected and autonomous vehicles were to drive more cautiously than the average human driver they may create a traffic-calming effect on the network, resulting in safety benefits in conditions with mixed AV and manually driven vehicles. There might also be congestion-reducing benefits in certain traffic flow conditions, as a result of smoother traffic flow from the greater level of consistency in gap acceptance behaviour.

To fully understand the implications of the use of different CAV modes on user acceptance, road safety, congestion and manufacturing standards, further research and development will be required focusing on variable headways and critical gaps. VENTURER supports this and anticipates working with government and industry to develop standards around CAV operating modes to underpin a robust legal and insurance model for the production and operation of CAVs and their safe deployment onto UK roads.

Trial 3 – participants did not show significant differences in trust ratings depending on whether they experienced the trial scenarios in the role of a cyclist, driver or pedestrian indicating that there is no particular need to differentiate messaging around CAVs for different audiences.

As for Trial 2, on average the trust ratings given by participants in Trial 3 experiments were consistently high. A possible implication of this high level of trust given to AVs operating in test environments is that members of the public might be too trusting of CAVs in their early stages of development.

This becomes particularly problematic when considered against the backdrop of on-going debates around liability at different SAE levels of autonomy. The distinctions between the SAE levels can be small and the potential for confusion in terms of a vehicle's capabilities will be more acute during the early stages of CAV development and deployment. As a means of mitigating this, CAVs may need to be clearly identifiable to other road users, such as pedestrians and cyclists, particularly in their early stages of deployment.

The consistency in findings between Trials 2 and 3 gives further confidence in the experimental design used in these **VENTURER** trials. The reliability and consistency of the trust measures obtained both trials are also supported by the correlation between participants' trust in automation and their trust ratings, with people who reported high levels of trust in general automation providing high trust scores.

Identified through Trial 3, some other factors that may influence participant trust in AVs include external factors, such as the presence of other road users and the appearance of a very 'safe' environment (i.e. through obvious presence of safety marshals) and the movement and noise of the vehicle. Therefore, while it is crucial that CAVs continue to be thoroughly tested in safe and controlled environments, future research should consider how the use of incrementally complex trials akin to real world situations and mimicking the smooth, safe driving behaviours of manually-driven cars can be used to increase understanding of road users' trust in CAVs.

More complex trials should involve introducing multiple pedestrians, cyclists and motorised vehicles, and allow for scenarios involving closer proximity between CAVs and road users. It is also crucial that trust ratings generated when participants are interacting with the CAVs themselves are gathered and analysed, including in scenarios where participants are blind to whether a vehicle they are being asked to rate is an AV or not. Future research should also examine how trials can appear to be less closely-managed, whilst retaining the high levels of safety. This could involve marshals wearing more discrete clothing or being more physically removed towards the boundary of the testing area.

Key learnings

4. Appropriate insurance and legal frameworks

The **VENTURER** project has provided AXA and Burges Salmon with new and deeper insights into the insurance and legal factors which will influence the adoption of CAVs. The insight gained from **VENTURER** has highlighted that the early input of the insurance and legal industry is essential for the adoption of CAVs within an appropriate and timely regulatory framework, which adapts as CAV technology and uptake develops.

Insights have fed into the motor insurance reforms contained in the Automated and Electric Vehicles Bill which is currently progressing through Parliament. The Bill has begun to address some key insurance questions by extending the compulsory motor insurance regime to automated vehicles driving themselves. This outcome gives third parties greater certainty in the event of any incidents caused by automated vehicles.

Key insurance and legal recommendations for insurers, the CAV industry and regulators arising from the deep insight developed through three separate reports delivered during the **VENTURER** project include considerations such as:

- Encouragement of clarity around legal and insurance definitions of automated vehicles.
- Establishment of minimum standards for the capture, retention and sharing of CAV data for incident investigation and analysis.
- The need for greater clarity on the regulatory and industry approach to deployment of SAE Level 3 vehicles including appropriate focus on the requirements for safe handover from machine to human.
- The need for consultation and engagement on how the UK will implement, test and verify standards and regulate automated vehicles (including investigation of safety reports and incidents) with due regard to learning from other transport systems such as aviation and rail.
- Mandating and prioritising safety and consumer experience into design and over asset lifetimes in a manner which recognises the complexity of CAVs and CAV ecosystems, the safety-critical nature of their operation and the reasonable expectations of variable external factors such as highway condition or connectivity.
- Approaches to reform of the civil and criminal law to take into account CAVs, feeding into the Law Commission review.

As the industry begins to consider the emergence of CAV standards, we would recommend that a parallel process of dialogue should take place with government to develop safety standards regulation and management.

5. Microsimulation modelling of planned handover

When simulated in a virtual representation of planned handover events, vehicles were subject to additional delay (as much as 20%) as a result of planned handover.

Data from **VENTURER** Trial 1: planned handover was used to calibrate a traffic microsimulation model. Microsimulation is used to model the behaviour of individual vehicles, and of different vehicle types. It has been used extensively for testing the impacts of CAVs, considering shorter headways, different levels of gap acceptance, and a variety of other behaviours. For **VENTURER**, the impact of planned handover on vehicle speed and trajectory was analysed and used to simulate a vehicle during a planned handover event.

The microsimulation modelling of planned handover highlights the potential to incorporate data from CAV trials and experiments into traditional traffic modelling and simulation tools – allowing the impact of events such as planned handover to be considered in the design of future transport infrastructure and traffic management measures.

6. Smart cities and digital infrastructure

In March 2018, **VENTURER** conducted the bus demonstration which was one of the first explorations of the interaction between connectivity and vehicle autonomy, with many other trials in the UK focusing on either connectivity for driver advisory systems or autonomy for self-contained automated driving.

V2X[7] communications were utilised by **VENTURER** to facilitate the interaction between a bus and CAV on a controlled road network. While successfully demonstrating the capabilities of the University of Bristol's communications technology, the demonstration also highlights the importance of V2X communications and digital infrastructure for successfully integrating CAVs into the wider transport network and effectively managing the interactions between CAVs and other users of the transport network.

V2X – vehicle-to-everything communications

"Technology that allows vehicles to communicate with other objects, including moving parts of the traffic system around them; V2X encompasses vehicle-to-vehicle and vehicle-to-infrastructure."[7]

The successful deployment of CAVs will not only require vehicles to be equipped with connected technology, but also necessitate the provision of a supporting digital infrastructure, which in urban areas could be part of a wider smart cities system. This will be integral to the successful deployment of CAVs and their integration into our daily lives. Secondary benefits of a fully integrated connected and autonomous transport system could include reducing the need for road signage and markings, which would contribute to maintenance savings and limit street clutter.

Further testing and design of connected and autonomous vehicle technology is needed to consider the use of V2X communications functionality to enable the integration of CAVs into existing infrastructure assets. These include vehicle fleets and the wider transport network to maintain and optimise the performance of the transport network.

Key learnings

7. Willing to Use and Pay for different CAV modes

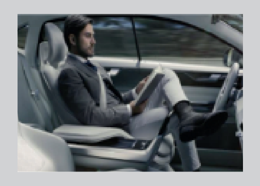
Overall public acceptance of high levels of automation had a strong emotional basis for some, but for others was about practical benefit. In the survey, responses were polarised into two main groups.

People who would use fully autonomous vehicles. They would be motivated by being able to use in-vehicle time for things other than driving and they were comfortable not being in direct control of the vehicle. Different people were particularly interested in AVs for long journeys or for urban travel.

People who would not use fully autonomous vehicles have a preference for a human driver as they are perceived as safer. Some participants who valued driving themselves as an activity might nonetheless be interested in optional full automation, for times when they did not feel like, or should not be, driving (drinking alcohol, long trips).

It is notable that, although women were more likely to raise concerns in the focus groups about both sharing with strangers and hacking, there were no statistically-significant differences in the principal survey responses.

Willingness to Use (WTU) and Willingness to Pay (WTP)



Autonomous car

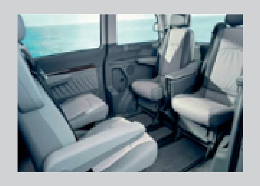
WTU YES 49.3% → WTP 0.66 £/mile

Bus users, with provisional UK driving licence or no driving license, mainly females and younger people, students and less affluent urban young families, **willing to pay more than the other group (mean value=£1.61/mile).** 85 of participants.

Car users and cyclists, who hold driving licence and enjoy driving, mainly males and older people, less affluent older sceptics, affluent empty nesters, educated suburban families and town and rural heavy car users, **willing to pay less than the previous group (mean value £0.72/mile).** 299 of participants.

On average (excluding outliers) 359 users would pay **0.66 £/mile**.

55.1% would pay more than for a non-autonomous car
(cost presented to respondents 0.59£/mile).



Autonomous taxi

WTU YES 47.5% → WTP 0.97 £/mile

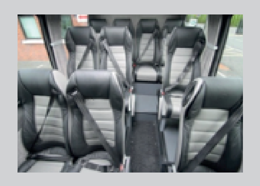
Car users (47.6%). **Bus users** (58.7%). **Pedestrians** (47.6%), **Cyclists** (32.9%).

Purpose of the journey:
YES when travel for personal business (63.6%)
NO when travel for business (59.1%)

Age:
YES 21-29 years old (60.0%) & 30-39 years old (56.5%)
NO 70+ years old (65.2%)

On average (excluding outliers) 359 users would pay **0.97 £/mile**.

1% would **pay more** than for a non-autonomous taxi
(cost presented to respondents 2.88£/mile).



Shared autonomous vehicle

WTU YES 38.9% → WTP 0.59 £/mile

Car users (37.6%). **Bus users** (49.3%). **Cyclists** would not use Shared-DV (70.9% No).

Purpose of the journey:
YES when travel for business reasons (43.2%)
NO when travel for educational reasons (70.5%)

Age:
YES 21-29 years old (56.7%)
NO 16-20+ years old (61.6%) & 70+ years old (60%)

On average (excluding outliers) 293 users would pay **0.59 £/mile**.

In general **"sociable"** people would pay more than people who prefer not to interact with people they do not know.

Autonomous bus

WTU YES 48.9% → WTP 0.47 £/mile

WTU DV bus **does not depend** on **gender** or **purpose** of the journey.

Age:
YES 21-29 years old
NO 40-50+ years old & 70+ years old

On average (excluding outliers) 372 users would pay 0.47 £/mile.

37.2% would pay more than for a non-autonomous car
(cost presented to respondents 0.53£/mile).

8. Public understanding of and opinions about CAVs

The public has a growing understanding of the potential benefits and risks of the adoption of CAVs.

The public proved unusually motivated to engage with the project. Awareness of CAVs as an idea was high amongst the online survey respondents. Understanding of the different levels of automation and the timeline for possible adoption was generally low at the point of first engagement with the research. The online survey focused on four different kinds of fully automated vehicle: car, taxi, shared car and bus. The focus groups, and online debates conducted also considered partial automation.

Differences were identified both in the levels of understanding between people, and the diversity of views shared, which reinforced the importance of ongoing information sharing and debate on the CAV subject. The key results from three of the more controversial research topics were:

1. **Trust and road safety** were important and related concepts with some apparent contradictions. Survey respondents on balance preferred human drivers for cars (just, at 51%), taxis (55%) and buses (61%) but safety could be a motivation for favouring either automated or human driving. Similarly, in the qualitative research the public safety benefits of automated driving could be recognised, although the autonomous systems were also seen by some as untried and fallible.

2. **Sharing vehicles**, too was a controversial topic. The traffic efficiency and environmental benefits were seen as essential by some, and sharing was seen as a force for social inclusion, extending the mobility options of those unable to drive or afford a personal car. Using a collectively-owned vehicle was seen by some as 'less hassle' than owning a car, but there were also clear motivations for continuing to own a vehicle (e.g. wanting to personalise the interior or the risk of finding the vehicle left in a poor state by previous users). Some respondents would want exclusive use of an automated taxi, due to concerns about sharing with unfamiliar people and the extent of detours away from shortest route. From the survey, business travellers, bus users and adults aged 21-39 were more likely to use shared autonomous vehicles. Those aged 16-20, people aged over 70, those travelling for education reasons and users of private modes were less likely.

   These results suggest that confidence as a traveller and experience of shared road transport are underlying relevant factors. Given the potential for changes in travel demand associated with the adoption of CAVs, this will be an important topic for further research.

3. **Privacy and system security** related closely to the 'connected' aspect of CAVs. The focus group participants had a greater polarisation of existing knowledge in relation to connectivity than for automation, but were able to grasp and debate the issues effectively. In the online debates, attitudes were also polarised: responses ranged between people having "nothing to hide" and great concern for privacy. A distinction could be made between data collection essential for system operation and other purposes. Benefits from connectivity were recognised, such as the possibility to clear a path for an emergency ambulance, but cybersecurity was a deep concern, in the context of terrorists being innovative and vehicle manufacturers constrained by commercial viability in their countermeasures. Open-source software and data sharing was identified as a possible better way to address such problems than proprietary systems, beyond scrutiny.

The findings demonstrate that information sharing on the subject and the profile of CAV projects is providing the public with information on CAVs and that the public is aware and has interest in the topic. Sharing of this information and regular updates on the development of technology and findings from research will help further public understanding of the potential benefits and risks of adopting CAVs.

These findings will help shape further research and to develop a greater understanding of how CAVs could be integrated into the wider transport network and help shape how future CAV operating and business models develop.

VENTURER achievements

In its three-year programme **VENTURER** has successfully:

- Delivered safe trials to systematically assess the responses of passengers, other road users and pedestrians to driverless cars.
- Developed several technologies to support CAV capabilities – a systems interface, situational awareness software, decision-making systems, a connected and autonomous vehicle simulator and vehicle communications, all of which facilitated successful participant trials using a realistic simulation environment and a CAV in a controlled road network. The echnologies developed have been tested on three autonomous vehicles (Wildcat, pod and Twizy).
- Conducted social research to develop insight into public acceptance challenges associated with CAV technology.
- Used findings from participant experiments and investigations to help inform the development of future insurance and legal requirements.

In addition to these VENTURER achieved wider impacts for both industry and the public, influencing policy and regulations and with impacts at both regional and national levels.

Industry and public profile

VENTURER achieved a high profile within industry and in public.

27 – Innovate UK CAV project roles secured by partners as a result of VENTURER

100+ – Events and conferences attended by partners on behalf of VENTURER

135+ – References to VENTURER in the media (newspapers, radio and TV)

13 – Publications produced and disseminated by VENTURER partners

33+ – Jobs created or safeguarded because of VENTURER

20,000+ – Members of the public engaged with during VENTURER

670 – Twitter followers from academia, industry, Government and the public

250+ – Businesses engaged with during VENTURER

198 – Participants in the VENTURER trials

VENTURER has helped to advance the UK's ambition to be a world leader in CAV development and deployment, by:

Influencing policy and regulation

Our experts are respected and influential with regulator s and policy makers and will continue to work with industry and government to inform the development of policies and regulations, **VENTURER** has:

- Further informed the debate on the safety and feasibility of deploying CAVs on the UK road network, in particular SAE Level 3 and 4.
- Provided evidence to inform how future policy and regulation should consider the design of autonomous vehicle systems.
- Enabled the development of a more appropriate and timely regulatory framework beginning with the Automated and Electric Vehicles Bill.
- Played a leading role in analysis of necessary changes to the insurance and legal landscape.

Achieving regional and national impacts

VENTURER has not only helped inform development of policy and regulation, but has also had a regional and national impact. It has:

- Developed and demonstrated CAV expertise in the West of England region.
- Created opportunities for investment in the region and strengthened the local supply chain, unlocking new opportunities for regional growth.
- Established lasting relationships resulting in a regional cluster of CAV knowledge and expertise in the West of England.
- Helped to further build an ecosystem of innovation in the UK.
- Engaged hundreds of children in the region through STEM activities to help them understand the potential benefits and challenges of CAVs and encourage them to explore future career opportunities in this evolving sector.
- **VENTURER** has increased knowledge of the potential effects and requirements for the successful adoption of CAVs in the UK.
- As a consequence **VENTURER** is helping the government deliver the Industrial Strategy.

VENTURER Alliance

From July 2018 the **VENTURER** partners will continue to work together as the **VENTURER** Alliance.

The **VENTURER** Alliance aims to continue the vision of the original project, helping shape the future of mobility. Working together, the VENTURER Alliance partners will offer a suite of services related to CAV testing and development.

These services are based on the capabilities and technologies developed during the VENTURER project and will include CAV trial services, technology and advisory capabilities:

Trial services to enable the safe testing of CAVs:

- Access to an independent controlled urban test environment, equipped with technology to enable vehicle-to-infrastructure communications and a fully programmable vehicle-to-everything platform.
- Public road test support, facilitated alongside and with experience and knowledge from local highway authorities, in accordance with the Department for Transport's Code of Practice for CAV testing, utilising our significant experience and knowledge of the safe trialling of CAV technology on controlled road networks.
- Access to SAE Level 3+ CAVs to facilitate complex CAV trial services.
- Technology to support the testing and development of CAVs in digitally simulated and real-world scenarios:
- A CAV simulator to complement the urban test environment, allowing both virtual and physical testing and validation.
- SAE Level 3+ CAVs to support testing/demonstration of technology and/or user/behavioural analysis
- Intelligent sensing and situational awareness technology for CAVs, to enable vehicles to be partially or fully autonomous.
- A complete Autonomous Vehicle Control System.
- Sensor integration services for connected and autonomous vehicles.

Advisory capabilities to support and enable the deployment of CAVs:

- Consultancy services related to CAVs, including CAV modelling and advice on the integration of CAVs within the wider transport system.
- User behavioural response analysis and social research.
- Insurance expertise, including CAV liability and data ownership issues.
- Legal expertise to support the establishment of robust laws to enable the safe integration of CAVs.
- Facilitation of access to local authority support for inward investment and to the local CAV cluster.

Further details and contact

Further details, including the technical reports, are available on the **VENTURER** website: www.venturer-cars.com

You can follow us for updates on Twitter: @Venturer_cars.

You can also contact us: Enquiries@VENTURER-cars.com

Industry context

"*We're going to end up with complete autonomy [Level 4], and I think we will have complete autonomy in approximately two years. [2019]*"
Elon Musk, Tesla/Space X CEO (2017)

2016 – VENTURER Trial 1

Supports the industry direction and findings that Level 3 connected and autonomous vehicles could be hazardous and unsafe due to issues with the planned handover process when switching from autonomous driving to human driving and vice versa.

Highlights the need for the further testing of Level 4/5 autonomous systems and discourages the use of Level 3.

On level 3 autonomous vehicles – "*We abandoned the stepping-stone approach*"
Mark Fields, Ford Motor Company CEO (2016)

2017 – VENTURER Trial 2

Supports the testing and design of user-centric safety and design principles being carried thoughout the industry, examples of this include the DfT The Pathway to Driverless Cars: Code of Practice for testing, Waymo's Safe by Design initiative and the US DoT Vision for safety.

Demonstrates the need for multiple redundant safety systems and creating user friendly interfaces.

"*No more than four years [2021] to have fully autonomous cars on the road*"
Jensen Huang, NVIDIA CEO (2017)

2018 – VENTURER Trial 3

Supports testing the integration of CAV technology with the wider transport network and the interaction of CAV technology with other network users in both simulated and controlled road network environments.

Indicates the needs for the continued testing of connected and autonomous systems and processes to enhance the future research and development of CAVs.

"*I expect the first self-driving cars to reach the market, and to be on UK roads, by 2021*"
Chris Grayling, UK Transport Secretary (2017)

Levels of autonomy

Levels of autonomy	Year	
1	2010 to 2011	The race for autonomy is in full swing. Leading car manufacturers and technology companies like Ford, GM, Uber, and Google pursue a range of Level 2/3 automation tests, studies and products.
2	2012	Google completes 300,000 autonomous-driving miles accident free. Initially exploring vehicle to human handover at Level 3 of automation. The company decided from its findings that Level 3 of automation holds far too many risks and hazards associated with the handover process. Google decides to explore full automation with no driver input going forward.
	2014	• Tesla releases 'Autopilot' in its Model S and X vehicles – an advanced driver assistance system (ADAS) as the first example of a Level 2 to 3 automated system available to consumers. • Google revealed prototype 'Firefly' – the first autonomous vehicle without a steering wheel, gas or brake pedal.
2/3	2015	Ride-sharing company Uber opens its own autonomous vehicle lab in Pittsburgh, with announcements to partner with manufacturers to create its own fleet of self driving vehicles for its taxi/ride sharing services.
	2016	• Tesla announces in October 2016 that all its vehicles are built with hardware capable of full self-driving functionality, but would not be functional due to the legal, regulatory, and software validation requirements. • Additionally, a few high profile crashes involving Tesla's further highlight the difficulty of non-fully automated systems and issues associated with vehicles that rely on both the automated system and human drivers.
3/4	2017	• Google transitions its research and findings into a new subsidiary Waymo. Waymo has introduced a fleet of fully autonomous vehicles for passenger use in its designated areas – including the 'early rider 2' program in Phoenix, Arizona. • Navya introduces self driving shuttles/buses capable of carrying up to 15 passengers.
	2018	• Waymo currently building 20,000 self-driving vehicles with partner Jaguar, enabling about one million autonomous trips to take place per day. • Tesla announced that by the end of 2018, a fully self-driving vehicle will be available. • Fully autonomous system available for selected public to use in designated areas of Waymo's trials. • Tesla to include option for traditional driving/steering mechanisms in any environment.
	2021+	Technology and car manufacturing CEOs/companies promising the rollout and availability of fully automated vehicles as a part of their product lines.
4/5	2040	Transition of traditional human-driven vehicles to fully autonomous vehicles on the road. Transition from steering wheels and control mechanisms to systems with no driver input. Mix of autonomous vehicles to human-driven vehicles to begin shifting substantially, to as much as 75% autonomous vehicles by 2040.

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The diversity of the partner organisations enabled **VENTURER** to balance important interdependent topics and collaborate to deliver the successful project outcomes described in this report. The project couldn't have been delivered without the time and expertise of wide range of team members, however the following people in particular have been instrumental to the project's successful completion:

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- **Ed Barratt**, **Chris Jackson** and **Brian Wong** – Burges Salmon.
- **Tim Bainbridge**, **Jim Hutchinson** and **Amanda Richardson** – Fusion Processing.
- **Abdul Choudhury** – South Gloucestershire Council.
- **Dr Rob Piechocki** and **Dr Andrea Tassi** – University of Bristol.
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