Connected & Autonomous Vehicles
Introducing the Future of Mobility
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Connected and Autonomous Vehicles (CAVs) are no longer a question of ‘if’ but rather of ‘when’.

There are significant economic and social benefits associated with their take up, including increased safety, reduced congestion and reduced emissions. From a user perspective, the deployment of CAVs will provide a time and space for other activities to take place from catching up on emails to watching TV.

Elements of automation and vehicle connectivity are already here. Self-parking, lane keep assistance systems and adaptive cruise control are all features of autonomy that give the driver added value and safety during their journey.

The challenge exists for cities, companies and road authorities to understand what the impact of CAV will be and how we maximise the opportunities that they will bring in order to better manage our networks today and in the future. There is also the need to position the UK at the forefront of CAV development and testing, creating long term sustainable economic growth and intellectual property (IP) creation.
Autonomous Vehicles

A fully autonomous vehicle, as described by the Department for Transport’s (DfT) Code of Practice, ‘is one in which a driver is not necessary’. That’s to say, there will be people in the vehicle but they are not responsible for the driving. The Code goes on to say, ‘The vehicle is designed to be capable of safely completing journeys without the need for a driver in all traffic, road and weather conditions that can be managed by a competent driver’.

The reality is that there will be elements of full and partial autonomy delivered into the market place at different rates. Vehicles with partial autonomy are already becoming available in the market place, such as self-parking, advanced driver assistance, lane control and autonomous emergency braking systems.

Connected Vehicles

Connected vehicle (CV) technologies allow vehicles to talk to each other and the wider world. Vehicles today are already more connected than many realise. Sat navs already include connected vehicle functionality, such as dynamic route guidance. ‘eCall’ (emergency call) is a CV capability that is currently being provided by several vehicle manufacturers, and which the EU plans to make a legal requirement in all new vehicles. When a car is involved in an accident, it will detect what has happened (such as air bag deployment) and set up an automatic voice call to a control centre. At the same time it will use GPS to send precise location details, so the emergency responders can set off faster and have more details of the situation.

Connected and autonomous vehicle technologies are not necessarily reliant on one another. However, the combining of CAV technologies within vehicles allows for the safer, quicker and more efficient movement. This is achieved by allowing computer driven vehicles to ‘know’ the conditions of the road network ahead, undertake rerouting based on new information (such as a lane closure) and warn vehicles behind of incidents – such as the need to avoid an obstacle.

Generally, the technologies being developed to support CVs include:

<table>
<thead>
<tr>
<th>Vehicle to vehicle (V2V) technology</th>
<th>Vehicle to infrastructure (V2I) technology</th>
<th>Vehicle to everything (V2X) technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowing vehicles to communicate with one another about for example, traffic conditions</td>
<td>Connectivity between vehicles and highway infrastructure, for example, vehicle to traffic signal communications to provide guidance on signal phasing</td>
<td>Connectivity between the vehicle and all appropriate technologies</td>
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</table>
Getting the fundamentals right

CAVs are a subject of huge interest both in the UK and internationally as companies and cities try to understand what the future holds when these vehicles are widely available. Much focus has been made on the future, the technical wizardry – from platooning and connected traffic lights to last mile automation – and the possible panacea of travel that may exist. But this has been at the expense of recognising the very basic building blocks that must be put in place for the technology to succeed, and the need for a fundamental plan of activity around this future deployment.

The drive towards CAV capability is underpinned by the opportunity to open up new business models and job creation and in doing so, provide services and connectivity between people and transport that are not available at present. Testing of autonomous capabilities is already underway across the US, Europe and Asia, in both closed and open road environments.

However, the focus of testing has been on the capabilities of the technology itself rather than on the use case and scenarios relating to people, vulnerable users, community impact and socio-economic growth potentials. Human factors and the influence between the behaviours and services that CAV can look to address for different individuals to meet their tailored needs have not been considered to date, though they remain a vital and fundamental part of any CAV deployment.

In essence, cities must understand the impact of CAVs on existing Intelligent Transport Systems (ITS) deployments as well as the investment needed around communications technologies, linked to strong policy development and strategic direction. Companies must look to understand how they can exploit the huge volumes of data that come with CAVs and how their existing operating models need to change to benefit fully from this new wave of intelligence.
This paper looks to take a different view on CAVs and take a step back from the plethora of research papers and hyperbole that exists in this developing market space. Instead, Atkins is focused on bringing things back to basics and helping people understand what the different levels of autonomy and connectivity can bring to them. From optimised freight delivery, such as platooning on motorways or last mile automation of delivery, to changes to public transportation and the new services that might be created, CAVs and their impact on our daily lives must be full considered.

Internationally there is huge interest around CAVs and multiple test sites are springing up offering a range of validation and testing services. This is where the UK has a key role to play and it is timely with this paper to highlight the key role of validation and benchmarking that UK Plc can play in this global space. This paper will tell a story around this new market space and explore new business opportunities that will exist. It also tries to address the questions that organisations struggle with, such as ‘what does it mean for us?’, ‘what do I need to do?’ and ‘why do I need to do it?’.

With contributions from the public, private and academic sectors, this paper reflects both the level of change that the introduction of CAVs will bring and the variety of considerations needed in order to maximise the opportunities we will be presented with.

CAVs are not somewhere in the future, they are a growing reality that must be considered in the present. CAVs have the ability to optimise network capacity, reduce congestion, make people’s journey’s stress free and increase safety. This is why this paper is needed, to encourage dialogue and engagement with national and local government, network operators, the automotive industry, technology providers, the logistics sector etc– as well as all the different stakeholders for who the road network is fundamental to connecting people and places.

Why this paper and why now?

This paper looks to take a different view on CAVs and take a step back from the plethora of research papers and hyperbole that exists in this developing market space. Instead, Atkins is focused on bringing things back to basics and helping people understand what the different levels of autonomy and connectivity can bring to them. From optimised freight delivery, such as platooning on motorways or last mile automation of delivery, to changes to public transportation and the new services that might be created, CAVs and their impact on our daily lives must be full considered.

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Levels of automation

With various levels of autonomous vehicle technology – from driver assist through to fully automated driverless vehicles – we must be clear about the terminology used. For this purpose, SAE International Standard J3016 sets out the taxonomy used when discussing the levels of autonomy, as outlined here.
The benefits of CAVs

Safety
Over 90% of accidents involve driver error and we know that machines could drive more reliably than humans. By greatly reducing the opportunity for human error, AV technologies have the potential to significantly reduce the number of crashes.

Reduced congestion
Through connected and automated technologies, vehicles could drive closer together, which would increase roadway capacity without impacting safety since machines can help maintain much shorter minimum distances between vehicles compared to human drivers and still be safe. We cannot keep building roads and adding lanes to meet demand, so CAV will be the vital next big step for increasing capacity.

Improved emissions
Vehicle platooning reduces air resistance for following vehicles, and traffic signal information could lead to more optimised speeds, two examples of ways in which emissions can be reduced.

Time
If drivers aren’t driving they can be working or reading or watching television!

Equity
Anyone can use a self-driving car. Disabled, younger or older people would all have increased mobility, surely one of the greatest potential benefits of CAVs. Of course this could greatly increase demand, and potentially change our relationship with cars.

Improved road design
The improved safety could remove the need for crash barriers, which when combined with the replacement of signs with in-vehicle information could lead to our roads becoming less cluttered and more attractive.
The GOOD

THE BAD

AND THE

BRILLIANT

1,700+ people died in vehicle collisions in the UK in 2013

£16bn annual cost to GB economy

90% of all accidents are caused by driver error
The average driver in England can save up to 6 working weeks a year driving time

10 million people in the UK are over 65 years old

30% of traffic congestion in urban centres is the result of drivers’ looking for parking

CAVs could create 320,000 additional jobs in the UK by 2030

Road traffic injuries are the leading cause of death among young people, aged 15–29 years

CAVs will generate £51bn benefit per year by 2030

Emissions fall by 20% with smooth travel
What must we do to prepare for CAVs?

Cities, local authorities, network operators, companies etc must all prepare now for the coming technologies that will fundamentally change how people move and interact with their surroundings. The actions that cities can take to prepare for CAVs include providing the digital infrastructure required, considering systems for data capture and exploitation, preparing existing infrastructure for CAVs, consider cyber security requirements and taking on a governance and regulatory role.

1. Digital infrastructure

Many of the benefits to be delivered by CAVs will be enhanced through connectivity between the vehicles and wider infrastructure. Wireless connectivity networks within urban areas will allow vehicles to communicate with traffic management systems in real time, sharing information such as signal phasing and timing and live traffic conditions. With this knowledge, CAVs will be able to optimise their speed and routing to minimise journey times and overall congestion.

Cities and road transport authorities play a critical role in delivering this by putting in place the required digital infrastructure networks, such as 802.11p, allowing fast and secure connections between vehicles and traffic management systems. Beyond the base networks, cities must consider the systems and technological standards that will ensure that the opportunities provided by connected vehicles are fully realised. Liaising with CAV developers on this is a good starting point – as the city of Berlin has done with Audi with real world testing of vehicle-traffic signal communications.

2. Data capture and exploitation

CAVs will generate extensive data on how and when people move about cities, as well as transport networks and congestion. The value in this data is significant, with cities already trying to tap data reserves from human driven vehicles – shown by Uber’s agreement to open up its trip data to the city of Boston. CAVs provide cities with the opportunity to capture and exploit this valuable data in order to improve transport networks and understand how people interact with the city.

Data brokerage is key in this – ensuring cities have access to appropriate datasets and can make sense of it. Related questions touch on how you store the data, how you strip the valuable data from the useless, and how you link mobile and virtual data sets as in CAVs and mobile phones, to fixed geographical areas.

3. Infrastructure

Cities should consider how their infrastructure – from traffic signals and lamp posts to roads and bridges – is prepared to accommodate CAVs. Can current infrastructure support the wireless connectivity required by connected vehicle technologies – particularly traffic signals. This is particularly important as infrastructure is replaced or renewed through maintenance and improvement. Rather than replacing like-for-like, cities should consider how infrastructure can be upgraded in preparation for CAV adoption.

More widely, cities should consider the implications of CAVs on new transport schemes. For example, the congestion benefits realised by CAVs may negate the need for new road building in certain areas, or the need for new car parks. Are existing traffic modelling approaches used by cities capable of considering the impact of CAVs?
4. Cyber security

Public acceptance of CAV technology and the safety and security of the vehicles rely on secure cyber ecosystems. Data and information must be protected from external and internal attacks that will occur. Large global companies must both ensure and protect the flow of data across their organisation – the need for this is evidenced by Land Rover’s recall of 65,000 vehicles due to issues with software security. Given this, it is vital that organisations maintain a real time understanding of the security of their network, and the threats, mitigations and weaknesses that exist 24/7.

5. Leadership

The future relationship between the city and CAVs is as yet unclear. Who will make decisions on technological readiness, regulation and data ownership? How will the transition from human to machine driven vehicles be managed? Will cities have to mandate CAV use in order to deliver road safety improvements and protect their citizens and will cities develop urban transit systems based on autonomous vehicles?

Cities must consider their role in leading on CAV development from an operational perspective, challenging themselves to take the right technical and strategic view across their organisation. New roles, such as chief digital officer or emerging technical directorates, which are becoming common in the private sector, must also be considered of relevance, ensuring leadership and direction. Los Angeles has recognised this, appointing a transportation technology advisor position within the city’s department of transportation, with a remit to consider the impact of new car and rideshare services, as well as planning for the arrival of CAV.

6. Partnerships

Cities should consider positioning themselves in order to maximise the potential for CAV technology at an early stage. One approach would be to partner with car manufacturers and other companies developing CAVs to provide opportunities for testing and development. Already cities such as San Francisco, Gothenburg and Las Vegas are becoming known for their relationship with CAV developers, giving them competitive advantages.
The impact of CAVs on KPIs

As adoption occurs, CAVs will have an increasing impact on a range of Key Performance Indicators (KPIs) measured by cities and road authorities. Below we present a summary of how CAVs may impact some of the common KPIs used by road authorities.

<table>
<thead>
<tr>
<th>KPI</th>
<th>CAV impact on KPI</th>
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<tbody>
<tr>
<td>Journey time reliability</td>
<td>Positive. With increasing adoption of CAVs, journey time reliability will be expected to increase as incidents that cause delay (such as collisions) will reduce. Impacts caused by congestion will be reduced as CAVs will be able to drive closer together, increasing roadway capacity without impeding safety since machines can keep minimum distances and still drive safely when compared with a human driver.</td>
</tr>
<tr>
<td>Traffic volume</td>
<td>Unknown. The impact that CAVs will have on traffic volumes is unknown. A common line of thought is that CAVs will lead to a notable reduction in the number of vehicles on the road network (as people share vehicles) but could lead to an overall increase in traffic on the roads (in terms of vehicle kilometres travelled) as CAVs provide equal opportunity for use by those that currently cannot drive (children, the elderly and those with disabilities).</td>
</tr>
<tr>
<td>Road safety</td>
<td>Positive. By greatly reducing the opportunity for human error, CAV technologies have the potential to significantly reduce the number of crashes. Where collisions do occur, their severity rate is expected to fall as CAVs will be able to brake and take evasive action quicker than a human driver, thus mitigating the severity of the collision.</td>
</tr>
<tr>
<td>Safety of the most vulnerable road users</td>
<td>Positive. As with road safety in general, CAVs will improve the safety of the most vulnerable road users.</td>
</tr>
<tr>
<td>Ensuring the road network supports economic growth potential</td>
<td>Positive. By reducing congestion on the road network and improving journey time reliability, the road network will support the economic growth potential of an area by allowing efficient and reliable mobility.</td>
</tr>
<tr>
<td>Topic</td>
<td>Summary</td>
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<tr>
<td>Reduce carbon emissions associated with road traffic</td>
<td>On a per vehicle basis, carbon emissions will be expected to fall as CAVs are adopted as the technology will improve driving efficiency (for example reducing stop/start driving conditions). However, if there is an overall increase in traffic on roads then aggregated carbon emissions may remain static or increase.</td>
</tr>
<tr>
<td>Reduce the negative impact of road traffic on local air quality</td>
<td>As with carbon emissions, on a per vehicle basis, local air quality conditions will be expected to improve. As Connected and Autonomous Vehicles are adopted, the technology will improve driving efficiency. However, if there is an overall increase in traffic on roads then local air quality conditions may remain static or worsen.</td>
</tr>
<tr>
<td>An accessible and integrated road network that provides equal opportunity for use</td>
<td>CAVs will open up the road network for equal opportunity use. This will increase mobility options and travel horizons for large sections of the population, resulting in increased economic, social and well-being opportunities.</td>
</tr>
<tr>
<td>Freight optimisation</td>
<td>From connected platooning to automated and predictable last mile deliveries, CAVs will have a role to play in optimising and streamlining logistic movements. This in turn will help to improve the ability to both schedule and meet reduced delivery times, helping improve customer loyalty and satisfaction.</td>
</tr>
<tr>
<td>Increase the number and proportion of people using active modes of travel (walking and cycling)</td>
<td>The impact of CAVs on the number of people using active modes of travel is unknown. Persons currently using active travel modes because they cannot drive or do not have access to a vehicle may be able to use CAVs, thus reducing the proportion of people using active travel modes. Conversely, the improvements in road safety resulting from CAVs may lead to more people cycling or walking.</td>
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What would deployment look like for a city?

As CAVs are being developed, cities have a leading role to play in the testing and roll out of the technology. Already cities including Bristol, Milton Keynes and Coventry are welcoming localised testing of autonomous vehicle technologies on their roads.

But if a city wanted to go further and develop a full proof of concept for CAVs, what would this look like?

Wireless connectivity between CAVs and urban traffic management systems would allow a continual, real time dialogue between vehicles and the city, sharing information such as traffic conditions, incidents and signal phasing/timing. This would involve a wireless network, such as 802.11p to allow real time, secure connections between vehicles and the city.

A full proof of concept would require multiple CAVs being tested in a variety of conditions – from congested streets to residential areas and urban highways. The vehicles would interact with each other and traditional human driven vehicles, as well as pedestrians, cyclists and other road users.
City authorities would capture the valuable data created by CAVs to be used for optimising transport networks, enhancing the operation of transport systems and improving the planning process.

The impact of CAVs would be assessed against a pre-defined success criteria with a particular focus on the city’s key KPIs – road safety, journey time reliability and environmental impacts.
1. You tell your phone to get the CAV car ready for the school run.

2. You get in and catch up on emails as your kids finish their homework.

3. Your vehicle joins others on the school run and a green light is given to let you get there on time.

4. You all get out at the door and the autonomous vehicle goes to the closest available parking spot.
You want to finish your presentation for a meeting so you book a slot for your CAV on the network at this time.

You head to your office and you are conference called into a meeting in order to get updates on how the work is going.

Later that day you are running late so you prebook a car with safety features to pick up your kids and set it to meet you at the train station where you will join them.

You get to their car and after passing the safety tests, the doors open and you head home together.
Changing business models

The CAV market opens up opportunities and challenges for a range of different sectors, challenging existing business models and creating new ones. CAV offers a new piece to the connectivity puzzle, offering opportunities to improve mobility, from bridging the first mile/last mile connectivity gap to improving independence for the elderly and increasing access to employment.

We are living in a changing world. People’s expectations are constantly growing and evolving, driven by new technologies, sustainability, changing demographics and urbanisation. Many people are re-thinking their relationship with vehicles, with a move towards access over ownership - particularly among young urbanites.

The wider automotive sector recognises this and have been very active in developing connected and autonomous solutions that offer a different lifestyle choice. People’s behaviours, and their relationship with transport and the different solutions that can be provided, such as CAV, represent a challenge and opportunity to the supply side. The future is unknown but what is certain is that solutions for the present will not fit the needs of the future.

The different business effected by the introduction of CAV will include:

- Government
  - Policy and regulation
  - Traffic management systems
  - Parking

- Suppliers
  - Freight
  - Vehicle manufacturers

- Technology
  - Shared mobility platforms
  - Data analytics

- Finance
  - Car insurance
  - Good-to-Driver payments

- Healthcare
  - Emergency service response
  - Mobility for the elderly
  - Patient centric care

- Transportation
  - Travel to/from and within airports
  - Taxis
  - Public Transportation

So far this paper has taken a high level view of the impacts that CAVs will cause on society and how cities and organisations can respond.

The following pages take a closer look at some of the issues raised, including:

- The impact CAVs may have on business models
- The insurance implications of CAVs
- The human side to CAV technology deployment
- Cyber security considerations
- Communication requirements
- Virtual and physical testing
Insurance

Insurance is a fundamental piece of the puzzle and key to enabling these cars to reach the roads. Compulsory car insurance in the UK was first introduced with the Road Traffic Act (RTA) 1930 and there is no reason at all to suggest that the advent of driverless technology will alter that particular status quo. However, the integration of semi-autonomous, highly autonomous and fully autonomous vehicles into the UK motor market has the potential to disrupt and fundamentally alter the current motor insurance model. In a nutshell, there will be insurance but not as we know it.

The sheer scale of the motor insurance market means that there will be huge ramifications for insurers, individuals and businesses alike.

From an insurer’s perspective the fundamental question will be to determine whether the driver or the car was at fault at the time of a collision i.e. who was in control of the vehicle at the time? The issue of ownership will be critical to determining whether any personal cover is still warranted and we will need to carefully consider whether the vehicle manufacturer or software manufacturer will be liable in the event of an accident. The solution, especially in the short term, may well involve a combination of the above in conjunction with necessary legal changes to, for example, the definition of “driving” and “without due care and attention” as contained in the updated RTA 1988.

To some extent we are in unknown territory but there are already statistics and data that evidence why driverless cars should be a goal rather than a fantasy. There are many cars that include autonomous emergency breaking, active parking assistance, distance controls and lane discipline. Some cars have cameras and sonar fitted. Adding lidar, radar and other sensor technologies does not, therefore, require an active leap of imagination. It will be how we harness and access the data that those sensors generate that will be crucial to developing a holistic insurance solution.

As the technology advances and we gather more information, insurers like AXA will be in a position to enable driverless cars to be on the roads sooner rather than later. It is no secret that a large part of motor insurance premiums is based on the frequency of claims and ratio (cost) of those claims so the reality is that if automated technologies deliver fewer accidents with lower associated costs, motor insurance premiums will go down.

David Williams Managing Director
Underwriting AXA Commercial Lines and Personal Intermediary

Great Britain in 2013

35 million vehicles licensed on the road

This figure has increased every year since the end of the Second World War (except 1991)

£2,767 average cost claimed for car insurance

£11,292 average cost claimed for bodily injury

£17.1m paid out per day in private car claims by motor insurers

3 million total claims
It’s not just about cars

For me, CAV’s will be a success when they have helped to create a greener and more sustainable urban mobility system. What we are aiming for are fewer single occupancy cars, less congestion, less pollution and a better, safer, more inclusive and hassle-free travel experience for pedestrians and cyclists as well as those travelling in CAV’s. What we really aspire to is a whole system approach that will radically shift the way people move around in cities - building intelligence in to vehicles is just the start.

Stephen Hilton
Director Bristol Futures, Bristol City Council
People and behaviours

Yes, technology is a critical part of the connected and autonomous vehicle evolution, but it is people, and their behaviours towards this new offering and the services it can provide, which will play a huge part in its adoption and roll out.

It is vital that we understand the emotional responses that the deployment of CAVs will cause. It is also hugely important we fully consider the attitude and changes of behaviour that may exist between different generations, and how CAVs can offer a solution that provides value and meaning to all, from the elderly to the Y generation.

CAVs must address a need or a problem that current transport solutions do not provide. For the elderly, independent and assisted living can be enabled but only in a way that CAVs makes lives easier rather than more complicated. CAVs can open up new economic opportunities for those that do not drive or cannot afford to, it can proactively engage with the next generation who do not see car ownership as a necessity. It can facilitate stress free journeys and make driving a safer and more secure way of travelling. However, to make sure this comes to pass it should go without saying that those working on CAVs must link the technical solutions to the needs of the population; reaching out to all aspects of the community in order to understand their response, both theoretical and practical, in the new world of connected and autonomous vehicles.
Public acceptance of CAV technology and the safety and security of the vehicles rely on secure cyber ecosystems. Data and information must be protected from external and internal attacks that will occur. Large companies must both ensure and protect the flow of data across their organisation - the need for this is evidenced by Land Rover’s recall of 65,000 vehicles due to issues with software security. Given this, it is vital that organisations maintain a real time understanding of their network, and the threats, mitigations and weaknesses that exist 24/7.
Understand the importance of cyber security and how their organisation addresses it.

Define the ‘ideals’ behind their day to day security, such as ‘always protected/always monitored’ etc.

Create the capability to deliver a ‘snap shot’ assessment of all parts of their digital chain, from devices, to communication, to information feeds etc and the impact factor associated with a breach.

Deliver a range of counter strategies that factor in the operational and brand impact for the organisation and their customers.

Operate a secure and resilient monitoring system for real time integration of all steps outlined as well as a reporting mechanism and chain of command structure for decision making.

A cyber framework model will help deliver this. It is a tool that will quantify the cyber effectiveness of the digital ecosystem within an organisation. It focuses on the overall system as well as identifying the strengths and weaknesses relating to cyber for each sector within the organisation itself. It can be used to drill down into the deployed systems, assets and architectures etc. in place for effective measurement of safety and vulnerability.

In order to address cyber security issues, companies must:
Communication requirements

To maximise the benefit that connected vehicles can bring, fast, secure and reliable wireless communications are required.

Various vehicular communication standards have been proposed over the years with the dominant standard known as IEEE 802.11p. IEEE 802.11p defines only the lower layers of the communication system. The upper layers are defined in separate standards: in the US this is IEEE 1609 while in Europe this is ITS-G5. Together the upper and lower layer standards define a wireless access in vehicular environments (WAVE) system. The term WAVE is becoming synonymous with V2X Capability.

CAVs will benefit from this wireless connectivity by allowing instant, secure communications between vehicles and roadside infrastructure, such as signals. The current signalling infrastructure was designed for the human driver and therefore the entire system is based of visual signals. Despite tremendous progress in computer vision, humans are still much better than machines in the perception of visual information. The only 100% reliable way of communicating signalling information to machines is via robust, secure and low latency wireless networks. Infrastructure based on wireless connectivity is inherently low cost, and offers unparalleled flexibility.

Formula 1 is an example of where pioneering technology in the connected infrastructure space is already occurring. For the 2015 F1 season, a virtual safety car was introduced to provide a means of instantaneous race neutralisation. Should a dangerous situation occur on the track, all cars receive an instantaneous speed limit message and speed guidance for different parts of the track. This type of signalling could be rolled out on all public roads. Time and location specific electronic speed limits, road works / accidents diversions, engine emission/remap instructions, emergency vehicle passage etc. could be transmitted directly to all vehicles on the roads and actioned upon.

There is little doubt that future vehicles will have a mixture of wireless connectivity options including LTE, Wi-Fi and also perhaps WiGig and IEEE 802.15.4. But it also certain that future vehicles, especially CAV, will have WAVE on board - a system specifically designed to meet the requirements and constraints of vehicular communications.

Dr. Robert J. Piechocki
University of Bristol
Physical and virtual testing

Why VALIDATION is so important

The testing, certification and validation of CAVs play a fundamental role in the adoption and usability of CAV based technology. At the heart of any deployment will be validation, ensuring elements of CAVs are fit for purpose and that the services developed will operate as expected under all conditions. Both within the UK and globally a number of test tracks are or will be in operation but according to a report from the Institute of Engineering and Technology (2014):

Issues such as safety, hand over mechanisms, cyber protection and usability will all have to be rigorously validated and understood, from a manufacturer, regulator, country and user perspective. Validation is not just technology driven. Companies will have to ensure that people, the end users, engage with CAV as expected and understand the benefits and usability of solutions on offer.

Testing and the facilities needed to perform the validation and verification needed, are very much seen as a global opportunity. Testing opens up avenues for job growth and IP creation.

In the UK, the DfT have drafted a ‘Code of Practice’ that outlines a practical approach to the testing of autonomous vehicles. This will allow real-world testing of automated technologies to take place in the UK today, providing a test driver is present and takes responsibility for the safe operation of the vehicle, and that the vehicle can be used compatibly with road traffic law.

From a testing perspective both physical and virtual testing should be jointly considered, and not in isolation. The physical should help optimise the virtual which in turn will be fed back to optimise the sensors and algorithms deployed on-street.

Traditional off-road testing facilities may not be appropriate for the testing of some aspects of highly automated systems. The UK’s dedicated test-track facilities do not have facilities that are configured in an urban layout with blocked sight-lines that may be important in testing how automated vehicles behave at busy junctions where it is not possible to have a direct preview of approaching traffic.
With roads becoming increasingly ‘smarter’ and new types of vehicles with increasing autonomy joining daily traffic, advanced testing is recommended. Behaviour of such vehicles cannot always be predicted and the risk of testing in a real world environment is high - significantly higher than for manual vehicles. The use of simulators is crucial - not dissimilar to in-lab testing of medication before actual consumption by humans.

An automotive simulator provides an opportunity to reproduce the attributes of an actual vehicle, but in a virtual environment. External factors and conditions are replicated to such extent that the passenger – or, in the case of autonomous vehicles, the computer – has the impression the vehicle is operating in a real world environment. Simulator software can replicate real life events and situations with extreme accuracy to create a fully immersive experience. This has a multitude of advantages, such as driver safety, reduced risk (no real damage to the car in case of a collision), cost reduction (e.g. fuel savings, reduced maintenance costs), and environmental advantages (reduced emissions) to name a few.

The ability to safely replicate dangerous or rare situations gives simulators a unique ability in training or assessing drivers or users of (semi-)autonomous vehicles. This is equally important when assessing how the roads of the future will deal with emergency services such as police and fire - where vehicles navigate chaotic environments at high speed. If some of the surrounding vehicles are autonomous, they will not behave in the same way a human would.

In the case of an autonomous vehicle, a virtual vehicle model is required that will dynamically behave in the simulation exactly as the robot vehicle does in reality; replicating parameters like acceleration, braking distances, cornering speed limits and suspension behaviour.

Especially for autonomous vehicles, reliability and precision are of the utmost importance.

Katrien Hermans
Business Development Manager at Williams Advanced Engineering
Atkins as part of the VENTURER consortium is trialling autonomous vehicles in the Bristol and South Gloucestershire areas to explore the feasibility of driverless cars in the UK. VENTURER will help the UK develop a market leading capability and independent test site for autonomous vehicles. We will follow a requirements based approach in order to overcome the key barriers to widespread autonomous vehicle adoption enabled by state of the art technologies, industry expertise and leading academic research.

The technology for cars to drive themselves in simple scenarios is proven. The barriers to adoption are how they respond to the real events that happen on real roads, e.g. cyclists and pedestrians. Dense cities are the most challenging scenarios. VENTURER will systematically assess the responses of passengers, other road users and pedestrians to driverless cars in a series of increasingly complex scenarios; and derive requirements for their acceptance by the public. In addition to road trials of a driverless car and a Pathfinder pod in Bristol city and the surrounding region, VENTURER will investigate the technical challenges and attitudes to a bus equipped with our innovative sensing technology.

These trials will go hand in hand with developing the understanding of the insurance and legal implications of increased vehicle autonomy. VENTURER will also establish a realistic simulation environment of the same roads used in trials as a test bed for our own and other’s driverless car technologies, and for public acceptance studies.

VENTURER will leverage the ground breaking “Bristol is Open” (BIO) network. BIO is an open programmable city wide network (fixed and wireless) and represents a £75m investment from UK government to create a unique smart city platform and enabler for Internet of Things technologies. Our CAVs will benefit from additional sensory data which will improve their decision making capability and safety, and reduce congestion.

Other trials are also being conducted by other consortium in Coventry, Milton Keynes and Greenwich.
CAVs are a disruptor that offer huge potential to users and network operators alike. By utilising road space more efficiently, reducing emissions and saving people’s lives, CAVs can change the way we engage with transport and allow us to question the fundamentals around car ownership and usage. In addition, the UK is in a prime position to capitalise on the global interest in CAVs by providing world class test and validation facilities, creating sustainable economic growth and investment.

Through this paper we have shown that getting the fundamentals right is key. We have sought to cut through the confusion and grand rhetoric, instead focusing on aiding organisations and cities in understanding how CAVs may impact upon them – from challenging existing business models and creating new ones, to fundamentally changing how we move within and interact with our cities. We have also identified how cities and organisations should be preparing for CAVs – from preparing digital and physical infrastructure to understanding how business models may change. Preparation now will place our cities and organisations in good stead to capitalise on this emerging technology for the benefit of the economy.

To conclude, we have summarised our thoughts into four areas of focus for the future that we believe cities and organisations should keep in mind when considering how to respond to the emergence of CAVs. We call them The 4 Ts: Testing, Trust, Transport and Time as presented on the following page. With a focus on The 4 Ts, we believe society will be well placed to exploit the opportunities CAV technology presents.
Testing

Independent validation is fundamental to emphasise the capability and safety of any solution in the CAV space. It is vital that appropriate and audited testing takes place in a controlled environment before any deployment takes place. As the software and hardware components come from multiple vendors and integrate in numerous ways, the various levels of testing required must be fully understood and integration with primary and secondary parts must be considered. The communications backbone must be robust and secure with a realistic urban backdrop. This is necessary to fully understand real life deployment issues.

Transport

The deployment of CAV capability has considerable ramifications on the wider transport sector and cities/communities in general. Key questions that must be addressed relate to the infrastructure investment needed, the data intelligence that can be garnered for a transport operator, and how CAV is one piece of the Smart City puzzle.
Trust

People must believe and trust the technology they are using. They must feel safe and want to use/buy new services that CAV open up to them rather than being sold solutions that are not fit for purpose or for person. CAV must be safe, secure and valued by the consumer and understanding the behaviour and emotions around CAV is an important step towards deployment.

Time

CAV deployment is a question of ‘when’ rather than ‘if’. For the UK to create a competitive advantage it is necessary to continue to invest in this area. Significant growth potential exists as well as growing global competition. The UK must maximise the opportunities that regulation currently provides and aggressively target market growth in the areas of testing and validation.
Various bodies are currently developing technologies to develop the level of vehicle automation up the SAE scale, including vehicle manufacturers, technology providers, academics and collaborative groups. These technologies are being tested in a variety of settings, from private testing grounds to university campuses and public roads. Page 33 shows examples of where vehicles of various levels of autonomy have been, or are due to be, deployed in real-world trials.

Deployment of CV technology has been slower than that for CAVs. The cause appears to be driven less by the technology and more by the need for multiple parties to work together – particularly local highway authorities. There has been some testing by OEMs – namely Audi – but otherwise deployment testing has been driven by academics and government programmes.
TLRT is a form of V2I connectivity, providing drivers with information about signal time phases on the approach to a signalised junction. The system informs the driver the speed they need to take to pass through the junction on a green signal - or whether they should slow down as they cannot safely arrive at the junction before the signal turns red. A countdown is also provided when a driver is waiting at a red light.

The system reduces fuel consumption and emissions whilst saving the driver time.

TLRT requires close working with local highway authorities, and is currently deployed in Berlin (including public users) where the system works at 1,000 different signalised junctions. It is also being trialled in Las Vegas and Verona.

The University of Michigan’s M City site opened in July 2015, providing a 32 acre testing ground for connected vehicles, covering both V2V and V2I technologies.

The closed testing ground is the first step in a plan to open up the University’s home city of Ann Arbor for V2V and V2I testing over the coming years.

The SARTRE project, which commenced in 2009, successfully trialled the use of platooning technology on a public highway in Spain.

The work is funded by the European Commission under the Framework 7 programme, and is led by Ricardo UK Ltd with the involvement of Volvo. The project aims to develop platooning technology for deployment.

Using cameras, radar and lasers, the project deployed three Volvo cars and a truck in a platooning trial. The cars followed the truck for 124 miles across public highway in Spain, with the lead truck communicating with the following vehicles on how they should accelerate, decelerate and navigate along the route.
Autonomous Vehicles

Google Chaffeur

Google has been publically trialling its AV technology on the streets of California for several years. Over 1 million miles of autonomous driving have been clocked up by several AVs, all powered by the Google Chauffeur software.

The AVs use a variety of lasers and sensors to monitor the wider environment, relying on pre-programmed route data for knowledge of road infrastructure - including traffic signals.

Google is in the process of constructing 100 electrically powered AVs to be deployed for public use.

Rio Tinto’s Autonomous Haulage Systems (AHS)

Since 2008, Rio Tinto, a mining and metals company, has been using AHS on its mines in Australia. It currently has in excess of 50 of the AVs operating, with plans for a continued rollout.

The AHS, which are designed by Japanese firm Komastu Limited, are used to move materials around sites. Through their use, fuel consumption and maintenance costs have fallen, whilst operations have sped up.

The trucks are operated and controlled by a computer system which monitors their location through GPS, navigating with the use of sensors and radar.

VENTURER

The VENTURER consortium will deploy an autonomous BAE Systems Wildcat on the streets of Bristol from 2016, investigating the legal and insurance aspects of driverless cars and exploring how the public react to such vehicles.

An independent test site will be created in order to understand both in a real and virtual environment, the behaviour of people and technology for CAV.
Daimler

Whilst also working on autonomous cars, Daimler is one of few OEMs working on autonomous HGVs. Original work by its subsidiary Mercedes on its ‘Future Truck 2025’ concept was deployed on one of Daimler’s Freightliner Inspiration Trucks during trials on public roads in Nevada.

For now, the adapted trucks use radar and cameras to test advanced versions of adaptive cruise control - including acceleration/deceleration and lane departure warning - but in future take on greater autonomous capabilities.

CityMobil2

CityMobil2, which commenced in 2012, is a European Commission funded programme to pilot AV systems across Europe. The focus of the programme is test AVs as supplements to public transport systems, helping bridge ‘first mile and last mile’ connections. In addition, the project will consider the technical specifications and communications required for AVs, how other road users react to AVs and subsequently help inform future European legislation on their use.

Alongside smaller scale trials, three large public tests are being conducted in Milan, La Rochelle and the Commune of St-Sulpice.

The trial in La Rochelle began in December 2014 with an AV developed by Robosoft deployed within the city. The vehicles, which are open for public use, carry up to eight passengers with no driver.

Shared Computer Operated Transport (SCOT)

SCOT is a low cost AV which has been jointly developed by the National University of Singapore and the Massachusetts Institute of Technology, being funded by the Singapore Research Foundation.

SCOT was originally deployed on the campus of NUS since 2011, with the early prototype being an adapted golf buggy. The results of this early deployment have led to the latest version of SCOT, an adapted Mitsubishi i-MiEV, which uses LADAR sensors to navigate through an environment. The vehicle is not equipped with GPS, allowing it to drive through tunnels and places where a GPS signal would be hindered.

A public deployment of SCOT (in golf buggy form) was undertaken in November of 2014, with two AVs transporting members of the public around public gardens in Jurong Lake District, Singapore.

As with the NAVYS, SCOT’S designers see the vehicle as a solution to the ‘first mile, last mile’ mobility issue. During the deployment, the AVs, which can communicate with each other through CV technologies, carried 500 people over 400 kilometres.

Volvo

Volvo has been behind a number of the technological advancements seen in vehicles in recent years, progressing towards its Vision 2020 – for no fatalities or serious injuries in a new Volvo from 2020. Given this, it is not surprising the Volvo is driving research in the AV market. Whilst already offering lane assistance systems and autonomous emergency breaking, the car marker is now working towards higher levels of automation.

Under its Drive Me programme, Volvo is working with various levels of Swedish government to place 100 AVs on the streets of Gothenburg by 2017, all being driven by real customers. It is as yet unclear exactly what AV features will be available, though lane following, speed adaptation and traffic merging are expected. Pilot vehicles have already been deployed by Volvo to test the technologies ahead of the 2017 roll out.
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Atkins and Intelligent Mobility

At Atkins we are passionate about the role intelligent mobility can play in supporting a wide range of positive social, economic and environmental outcomes.

Intelligent Mobility is a new way of thinking about how to connect people, places and goods across all transport modes. It is about how we utilise a combination of systems thinking, technology and data across the transport network to inform decision making and enable behavioural change. Intelligent Mobility combines a strong focus on putting the customer at the heart of the service offering with the requirement of integrating all transport opportunities into a whole system.

Our team brings together a wide range of experience and knowledge from across the industry and covers four broad, strategic themes:

- Mobility as a Service – focusing on the customer-centric approach to mobility and how to deliver an integrated transport system;
- Journey Management – looking at ways to deliver a more seamless customer experience across the whole journey;
- Data Exploitation – understanding how new technology can help us to analyse data to generate new insights and uses;
- Roads of the Future – at the forefront of how autonomous vehicles and smart infrastructure will look and develop in the near future.

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