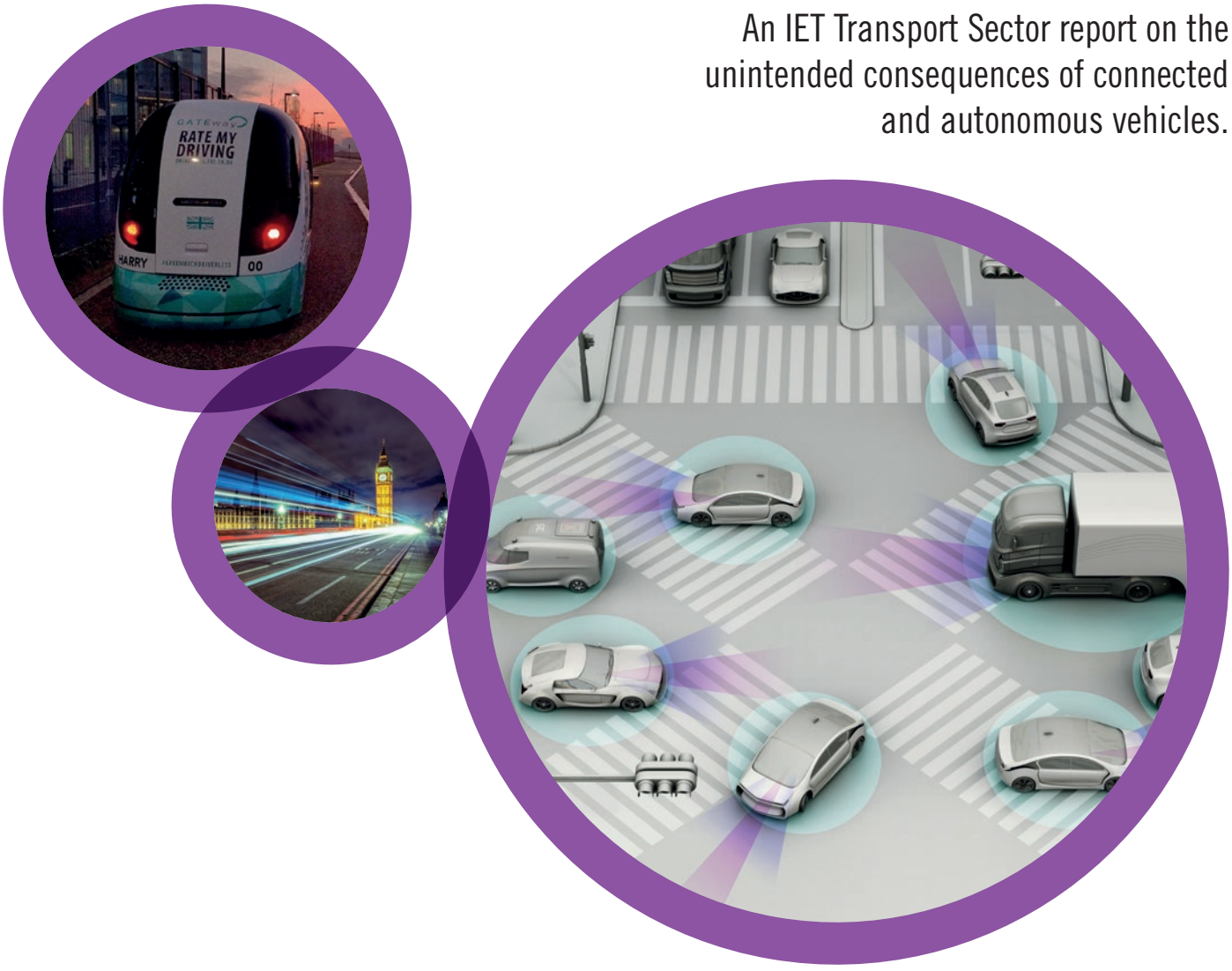
The Institution of Engineering and Technology

Expect the Unexpected

An IET Transport Sector report on the unintended consequences of connected and autonomous vehicles.



www.theiet.org/transport

REFERENCES

1 *Connected and Autonomous Vehicles – The UK Economic Opportunity* report by KPMG for The Society of Motor Manufacturers & Traders (SMMT), www.smmt.co.uk

2 *Automated Driving Levels* by SAE International, www.sae.org/misc/pdfs/automated_driving.pdf

ACKNOWLEDGEMENTS

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Front image of a GATEway public shuttle courtesy of Digital Greenwich.

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The Institution of Engineering and Technology

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INTRODUCTION

The UK is taking further steps towards the realisation of fully connected and autonomous vehicles (CAVs) to fulfil public and commercial transport needs. The idea of CAVs is far from new but there are good reasons why they have not made meaningful progress beyond concept or prototype in the last 50 years.

Part of this is down to the technological constraints which have rendered the deployment of any mass-scale CAV fleets impractical until now. The introduction of CAVs also needs transport policy support from local and central government – something which has only emerged in recent years.

Today however, the move to fully connected and automated vehicles is inevitable.

Public trials for the use of automated vehicles for public transport and haulage are already live and will pave the way for a new generation of transport. In terms of personal transport, research commissioned by The Society of Motor Manufacturers & Traders (SMMT) and conducted by KPMG[1] suggests that all new UK cars will be connected by 2026. Cars capable of fully automated urban driving are forecast to be with us as soon as 2021 or even earlier.

A GUIDE TO LEVELS OF AUTONOMY

Levels of driving automation are typically defined using the following levels (based on the Automated Driving Levels by SAE International[2]):

Level		
0	Driver only	Relies on humans to continuously fulfil all tasks.
1	Assisted	Driver continuously performs the majority of tasks with some assistance from a computer.
2	Partial automation	Driver monitors driving tasks which are undertaken by a computer at all times.
3	Conditional automation	Computer is responsible for driving, monitoring and adapting to road conditions. Driver must be ready to intervene as needed.
4	High automation	No driver required for specific tasks such as urban driving, deliveries or shuttling. Computer manages all aspects of defined task.
5	Full automation	No driver required in any instance; computer manages all tasks and all situations encountered in the journey.

TOWARDS AUTONOMOUS VEHICLES ON UK ROADS - A TIMELINE

2011
Ultra (**U**rban **L**ight **Tra**nsit) personal rapid transit pod system open at Heathrow Airport.

2015
Trials of CAVs start in Greenwich (London), Milton Keynes, Coventry and Bristol. UK's international leadership in CAV development and testing bolstered by creation of CCAV – Centre for Connected and Autonomous Vehicles.

2016
Public street tests of driverless pods in Milton Keynes.

A three-year trial of an autonomous 'Venturer' Jeep begins in Bristol and South Gloucestershire.

Image courtesy of the Venturer Consortium

2017
Public tests of driverless shuttles in Greenwich.

Trials of automated milk floats delivering shopping in Woolwich.

Legislation in the Queen's Speech provides policy framework to support CAV development covering insurance and infrastructure for electric vehicles.

Further testing of connective vehicle technology due in Coventry

2018
Trials of automated trucks travelling in convoy due.

2019
Demonstrator on the UK's motorways between Oxford and London planned, following completion of test track trials.

2020
Major motor manufacturers target production of partly automated cars followed by full automation within a five-year period.

Image courtesy of Digital Greenwich

THE BENEFITS OF CAVS

There is no doubt that the introduction of CAVs can benefit individuals and communities.

The perceived benefits of CAVs include:

- Improved road safety.
- Increased mobility (particularly for those sections of the community whose mobility is restricted).
- Greater efficiency in terms of both time and physical resources.

But this change also has the potential to bring about profound and unintended consequences which will have an impact on the way we must consider the technology, design and deployment of CAVs.

IET EXPERT WORKSHOP

To explore some of these potential issues, the Institution of Engineering and Technology (IET) brought together experts from transport, local government, academia, telecoms and technology to think through the implications of five everyday scenarios for the different stakeholders involved in the design and introduction of CAVs. These were:

- Rural to urban travel: moving from a rural setting to a town.
- Commute from the town centre: travelling from a centrally located workplace.
- Suburb to hospital visit: travel to a town centre hospital from the edge of a city.
- Town centre delivery: fulfilling the shipment of a parcel in an urban environment.
- Town centre journey for an older traveller.

The workshop involved playing out how the everyday scenarios would work in a real UK city, using maps of an actual road network.

The issues and unintended consequences presented by each journey were collected and collated into common themes. After the event, expert feedback from members of the IET's Transport Sector Steering Group, representatives from local and central government, transport research and industry provided additional insight.

This report explores some of the unintended consequences that emerged and provides a number of recommendations which may help to mitigate the impact of such consequences.

Image courtesy of the DRIVEN Consortium

UNINTENDED CONSEQUENCE

PUBLIC MISTRUST COULD LEAD TO THE UK MISSING OUT ON THE OPPORTUNITY THAT CAVS PRESENT TO SOCIETY AND THE ECONOMY

"One real issue we have to be aware of is the potential that a lack of public understanding around CAVs may have to derail their adoption.

There is an increasing amount of consumer research and expert comment around the introduction of CAVs, but in many instances this is not based on experience or first-hand knowledge. Research which claims to reflect public attitudes is frequently based on perceptions of CAVs taken from sci-fi movies.

Equally, while the ethics of how vehicles will deal with potential collisions are important, this is another area where debate is skewed, focusing on marginal or theoretical problems rather than talking about the fact that removing the opportunity for human error will lead to improved vehicle safety. Even the recent coverage of the trial of automated lorry platooning with drivers was misreported as automated lorries arriving on our roads.

Communication is important in any new technology and we need to ensure that misconceptions don't take hold in the public mind, as was the case with other technologies such as GM foods. Experience is a key factor here because what the public trials have shown is that once they get accustomed to CAVs, any anxiety quickly disappears. So current trials in UK towns and cities have a key role to play here."

Nick Reed, Head of Mobility R&D, Bosch.

The stakes around the deployment of CAVs in the UK are high. At a local level, dealing with congestion and improving accessibility to transport will deliver quality-of-life benefits to communities. According to the Department for Transport, the potential value of preventing road accidents alone is £15bn, to say nothing of the human cost.

For the UK economy, KPMG estimates CAVs are worth £51bn of benefit or an additional 1% of GDP. On a global stage, the UK is currently one of the countries in the lead and maintaining leadership in this area is critical to ensuring the UK is a beneficiary of the shift to CAVs.

GAINING AND MAINTAINING PUBLIC CONFIDENCE

RECOMMENDATION

Create a more nuanced public understanding of CAVs and the benefits they may bring.

For all but those who are most interested in technology or transport, the introduction of CAVs still equates to the arrival of self-driving cars on our roads and parked on our drives – at least this is the picture painted by all but the specialist media.

In our workshop, as our five future scenarios played out, it was clear that while self-driving cars will continue to feature as a common form of transport both in the near and distant future, the rise of these vehicles will be accompanied by a new wider range of CAVs which will fundamentally change our relationship with transport.

In crowded urban centres like London, we are already seeing a move away from car ownership to buying 'transport-as-a-service' solutions, such as short-term car hire or Uber-type services.

Due to the expected high costs of CAVs they are unlikely to be personally owned and their arrival will trigger a more formal model of mobility-as-a-service, where transport is bought when needed, either paid for 'on-demand' or as part of a subscription – much like a mobile phone contract where you pay for a specific amount of travel at a specific time and it is priced accordingly.

To realise the benefits of CAVs, these new vehicles will behave very differently from the way traffic flows today. For commuting, lift sharing and the platooning of vehicles in convoy it will be necessary to make best use of road space.

Equally, the availability and cost of transport may lead to pick-up and drop-off hubs where CAVs can be accessed as a last mile solution.

The arrival of CAVs will also change the mix of traffic on the road; automated delivery vehicles are likely to feature either as pods or vans carrying goods in and out of town.

There will be a long period where unautomated vehicles, pedestrians and cyclists will have to share the roads with these CAVs until fully automated vehicles become the norm in the 2030s – something that both CAVs and traditional road users will have to adapt to.

Our workshop also suggested that CAVs may hasten the demise of the personal car and driving as a skill, which is hard to imagine standing by a town centre road in rush hour today.

UNINTENDED CONSEQUENCE

COMPETITION STYMIES THE DEPLOYMENT OF CAVS

A striking feature of the current development environment of CAVs is the range of commercial organisations positioning themselves to succeed in the roll-out of a new transport infrastructure. This is bringing traditional and new vehicle makers into competition with technology giants and new-to-market start-ups.

Given the scale of the opportunity, the reward for developing a technology or class of CAV that can win significant market share will be substantial.

The consequence of this 'race to win' is the development of parallel or conflicting technologies which prevent the kind of integration necessary for CAVs to succeed.

To avoid this, the consensus from our workshop was that open standards and collaboration – even among competitors – is critical.

The UK government's Centre for Connected Autonomous Vehicles (CCAV) is currently playing a key role in tracking evidence, ensuring early testing focuses on issues such as road safety, transport network effectiveness and accessibility.

CCAV recognises that there is a definite need for codes of practice which are developed as needs emerge. It's important that Original Equipment Manufacturers (OEMs), local government and other stakeholders have their say and share their perspective on the issues that matter to them. Collaboration will be key to finding solutions which solve the more complex problems in CAVs such as the safety of software-based systems.

SECURING COOPERATION

RECOMMENDATION

Make it an imperative for all stakeholders to collaborate in the development of new rules and standards for CAVs.

One of the biggest challenges that will impact on the success or otherwise of CAVs comes from the question: how will CAVs be governed as they operate on the road? Getting this right is not only important from a perspective of safety and public confidence in CAVs; it is also critical to removing barriers which can slow their adoption.

Our scenarios found that this was a particularly complex issue with a response needed on six new areas:

NEW RULES OF THE ROAD

One of the most immediate challenges to resolve are the rules which will need to govern a transport network with mixed levels of autonomy. Here the issue of balancing the priority for CAVs against other traffic emerged as particularly problematic. How, for instance, can you ensure that other users – pedestrians, non-automated vehicles and cyclists – don't take advantage of the safety-oriented CAVs by pulling out or cutting in front of them, leading to travel disruption for CAV users? The answer is managing mixed levels of autonomy in a way which is acceptable to all groups of road users and may lead to CAV-only lanes and zones with exclusions or penalties for non-automated vehicles.

CAR BEHAVIOUR AND ATTITUDES

A second area emerging from our workshop was the potential requirement for standards around the attitude and behaviour of CAVs towards similar vehicles, other road users and in different road settings. This goes beyond decisions identifying when and where to swerve if presented by an obstruction such as floods, children and animals. A lack of consistency in the basic behaviour has the potential to lead to chaos when confronted by bad weather, accidents or other obstacles.

CYBER SAFETY STANDARDS

A cornerstone for the safety of vehicles, which rely on connectivity and automation safety, will be standards for the control systems, software development and security and reliability of communications systems – none of these are in place yet and there is a clear need for leadership on this issue.

VEHICLE-TO-VEHICLE AND VEHICLE-TO-NETWORK COMMUNICATION

For CAVs to work effectively from Level 3 and above and deliver benefits such as congestion reduction through platooning, as well as better safety through avoiding accidents or managing network loads, they will need to seamlessly communicate with other vehicles and the road network itself. An unintended consequence of the rush to win in this emerging market may be the development of different protocols or walled garden technology among equipment manufacturers.

NETWORK-TO-NETWORK COMMUNICATION

While the rise of combined authorities will allow for area-wide, rather than city-wide, traffic planning, there will still be a need for different area networks – particularly the strategic road network – to talk to other networks to manage traffic and reduce congestion.

UNIVERSAL ACCESSIBILITY

One of the key goals for CAVs is to provide greater mobility choices for those who are marginalised or poorly served by 'traditional' transport. Without focusing on a design principle of accessibility for all, these groups will continue to be poorly serviced as CAVs are rolled out, particularly in rural communities.

UNINTENDED CONSEQUENCE

UNCERTAINTY PARALYSES INFRASTRUCTURE INVESTMENT

With their role co-ordinating transport, public service delivery and the development of the right infrastructure in towns and cities, local authorities must get to grips with the huge agenda which lies in store for them.

But the biggest immediate difficulty they face is that of dealing with the uncertainty presented by CAVs as they plan transport investment today.

"This is undoubtedly the biggest challenge for local authorities. As councils struggle to cope with the changes which lie ahead, the risk is that they fail to make the right investments in order to combat short and long-term transport issues.

I have seen how uncertainty about CAVs is already undermining plans for infrastructure investment based on current technology. If you are Transport for London (TfL) looking at what will happen to buses or a council looking at a new kind of transport system, the changes to the investment model and the time horizons are enough to make you stand back.

This is understandable but as we move away from a way of planning which has been fixed for about 50 years and relatively straightforward, what is needed going forward is a two-pronged attack. We must invest in existing transport and use exploration of the future of CAVs to get as much resilience in transport systems as we can, reducing redundancy as far as possible so they can stand up to change. CAVs are not the whole answer right now, but they are already part of the answer.

So if you are going to build a new bus system, make the investment but understand the future transport scenarios which lie ahead and make it more applicable so elements of the system can be reused. We can be sure that CAVs will arrive but it is important to remember that most predictions suggest a mixed fleet of road vehicles for at least 20 years."

Paul Zanelli, Director, Engineering and Technology, TRL.

PREPARING FOR AN AUTONOMOUS FUTURE

RECOMMENDATION

Plan new infrastructure to accommodate changes in the communities where we live and work.

One of the more visible consequences resulting from the deployment of CAVs will be in the road infrastructure designed over the last 100 years for non-autonomous road vehicles, which we take for granted today.

But the outputs from our workshop suggest that the possible disappearance of roundabouts and the reimagining of our road infrastructure is just the start of the change to infrastructure we will need to accommodate CAVs, with the following issues emerging from our groups:

LAND USE PLANNING

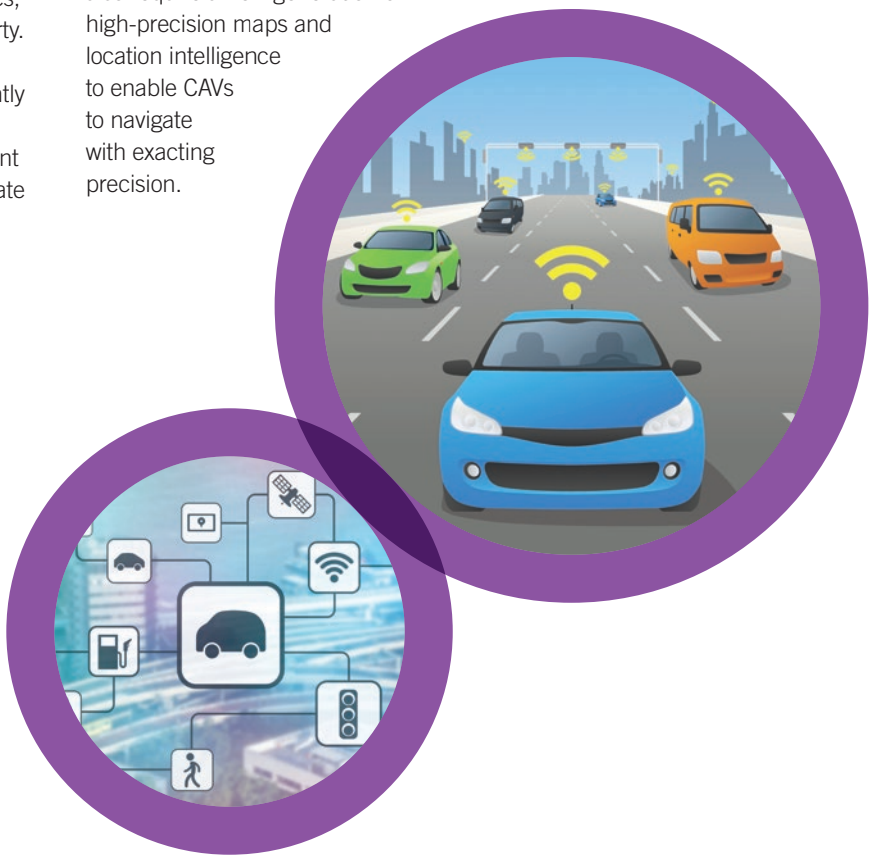
With driverless pods providing fulfilment of goods and transit of people in future urban areas, planners working on strategic plans reaching into the next decade will need to consider the impact on land use in city centres, where parking can currently take up to 25% of property. This is important because if CAVs are not owned they will be in use more frequently than the cars we currently have at home, and therefore will not take up valuable parking space, except when charging. The requirement for parking could be offset by the need to accommodate large numbers of CAVs idling between 'jobs'. They will also need to consider how housing developments, transport hubs and the location of workplaces will be affected. An unintended consequence here is unmanaged change, which could have a negative impact on our town and city centres.

NETWORK CONNECTIVITY

CAVs will rely on readily available and reliable telecommunication networks in order for them to operate. If unaddressed, the current gaps in coverage and quality will potentially limit penetration of connected vehicles. An alternative unintended consequence may be that the need for high quality connectivity accelerates investment in improving data coverage.

DATA MANAGEMENT, MAPPING AND MACHINE LEARNING

The operation of CAVs will require investment in systems which control traffic by artificial intelligence, creating and adjusting algorithms. It will also require a new generation of high-precision maps and location intelligence to enable CAVs to navigate with exacting precision.



UNINTENDED CONSEQUENCE

LOCAL TRANSPORT CHANGES RAPIDLY IN WAYS WHICH CANNOT BE EASILY PREDICTED

The public sector is critical to the future roll-out of CAVs in our towns and cities.

Councils and transport authorities need to be at the forefront of decision making to ensure the private sector is able to provide the services the public will demand.

"In both planning new infrastructure investment and day-to-day operation of our road transport systems, local authorities have a pivotal role to play.

The problem is that very few councils understand this right now and even fewer are engaging with an agenda which they will have to confront very soon. We are about to see a change potentially as great as the move from reliance on horses to the internal combustion engine.

One of the greatest changes to transport planning is likely to be a move from the situation where the local authority sits at the centre of transport delivery, to one where it is just one part of an ecosystem of many equally important providers and consumers of data, most of whom will be private sector commercial bodies. Learning how to discharge their legal obligations and deliver efficient and meaningful public services in this environment will be a major challenge.

We also need to challenge other areas of the council such as land use planning, where courageous decisions to abandon the long-held principles of designing for private car use will be needed. It is likely that the developments of the future will need to support very different models of private and commercial vehicle use from today and assumptions of what this will look like need to be built into the planning process.

Of course, that's all in addition to making sure that public transport services, in whatever form they evolve, are afforded the right priority in the design and management of new transport networks."

Darren Capes, Transport Systems Manager, City of York Council.

DRIVING NEW OPPORTUNITIES

RECOMMENDATION

Encourage new ways of working in the private and public sector.

While the arrival of CAVs is most easily understood from the perspective of a user who is substituting car, taxi or bus travel for a journey in a pod, with all the convenience that brings, this new generation of transport will bring much wider change to the way we consume and pay for mobility services across the public and private sector.

COUNCIL REVENUES FROM PARKING AND ROAD COMPLIANCE

The arrival of CAVs is likely to reduce parking and road compliance revenues for local authorities. However, the rise of transport based on mobility-as-a-service will create new opportunities for councils to charge for road use and generate income based on time of usage or journey lengths or destinations.

CAVS FOR PUBLIC SERVICE

A major opportunity for CAVs will be to improve access to public services – particularly health services – for those who normally have difficulty travelling from home to the point of service. While this may boost mobility and cut the cost of public service delivery, our hospital transport scenario identified a number of potential risks for this type of usage. These ranged from the need for emergency distress buttons in vehicles for people who fall ill, for example, to the ability to proceed with priority in emergencies ahead of other traffic, and functionality which can inform a destination of the impending arrival of someone in distress.

NEW TRANSPORT NETWORKS

CAVs will be able to bridge the gap between fixed public transport such as coaches, buses and trains. Whether this changes the role of, and demand for buses, or not, remains to be seen. It may require competitive pricing and road prioritisation to ensure that buses remain viable and valued.

An unintended consequence will be the creation of new capacity which allows for new transport networks to emerge, increasing mobility and the integration of public and commercial transport. This will support wider transport accessibility to different sections of the community and real-time information from transport networks would allow individuals to reduce time wasted on delayed or disrupted journeys by picking the best connections.

INSURANCE

Vehicle automation and connectivity promises to reduce accident rates and improve information where incidents occur. With plans in place for new insurance products for CAVs with clear liabilities, the cost element attributable to insurance in transport should fall, reducing one area of mobility costs.

LAST MILE FULFILMENT AND LOGISTICS

Our workshop scenario looking at town centre deliveries identified a profound change in store for the way this sector operates. The automation of last mile fulfilment will create the challenges of co-ordinating vehicles from different logistics companies and ensuring their presence in shared spaces with other road users and pedestrians is not disruptive.

The opportunity to tell logistics firms your whereabouts may create ‘delivery-on-the-move’ services which come to consumers away from usual work or home addresses.

EMPLOYMENT

One final theme associated with the changes to business and public service, and more broadly with the each of the themes in the report, is the impact of CAVs on employment. While it is clear that some jobs and transport activities will cease to exist it is also evident that CAVs will create a new generation of jobs with different skills to support their deployment, management and maintenance.

CASE STUDY

Milton Keynes Council is one of the first local authorities to test and trial autonomous vehicles. One of its current projects focuses on understanding how driverless pods can deliver a number of priorities for the town: offering greater mobility to more people, reducing congestion and improving safety.

"As a council we know that if Milton Keynes continues to grow, we will face some very serious challenges with regard to transport. We've looked at traditional solutions to issues like congestion, safety and accessibility of transport but they only get you so far.

As is the case for us, local authorities need to start to be involved in the planning for the deployment of autonomous vehicles and understanding where they may or may not help with their priorities. Given the constraints on funding and other resources, the future role for a local authority is likely to be a commissioning body or facilitator – to do that you need to know what you want to achieve.

We're now two years into a three-year project, actively planning live demonstrations in the city. Following the autonomous system testing we will deploy 40 vehicles, running on pavements providing a door-to-door transport service.

The OEMs we are collaborating with understand that they need to share data. We're also involved with academic partners in Cambridge on data modelling and reporting back to central government on the implications for a code of practice for CAVs which will be updated in time.

There's still a lot more work to do around areas like city centre design, people's attitudes and what happens to connected cars which don't need to park when they're empty. It's clear that working together outside of organisational silos – particularly with CCAV – we're able to share ideas and potential problems and collectively work on the solutions."

Image of the GENI driverless vehicle pictured in Milton Keynes courtesy of Oxbotica.

Brian Matthews, Head of Transport Innovation, Milton Keynes Council.

CONCLUSION

As we can see from the issues covered in this report around the introduction of CAVs, the challenges facing industry, the public sector and other stakeholders are clearly multi-layered and complex.

In this report we have highlighted some of the unintended consequences. However, as the name suggests, there are likely to be many other consequences of CAVs, some of which we may not be able to consider in advance of the technology being introduced.

But while the technology and its application may be new, we believe the IET and its members have the knowledge, expertise and understand what it will take to support the deployment of CAVs and help ensure they emerge as a successful technology within our communities and for the UK on a global stage.

It is critical that experts from all areas involved and impacted by CAVs continue to come together in a collaborative environment to share ideas, concerns and opportunities. Through this knowledge exchange it will be possible to maintain an insight of the impact of CAVs – both positive and negative – mitigate any risks and take advantage of the opportunities that arise.

In the coming years we will be focusing in greater detail on the issues we face in the development of CAVs, facilitating debate and knowledge exchange so we can identify specific areas where the IET can lead and support industry and the public sector.

It will take many years before CAVs are the majority occupiers of the roads. Until then a carefully honed transport strategy is required not only to ensure that CAVs and current road users exist in harmony, but that any transport planning must always look to the end game of a CAV-enabled infrastructure, so decisions support rather than preclude the move to a majority CAV road occupation.

Image courtesy of UK Autodrive

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