Connected & Autonomous Vehicles

Introducing the Future of Mobility

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Contents

Connected & Autonomous Vehicles

Connected and Autonomous Vehicles (CAVs) are no long a question of 'if' but rather of 'when'.

There are significant economic and social benefits associated with their adoption, including increased safety, reduced congestion and reduced emissions.

The challenge exists for transportation agencies, cities, and companies to understand what the impact of CAV will be and how we maximize the opportunities that they will bring in order to better manage our networks today and in the future.

Connected and Autonomous—what's the difference?

Suzanne Murtha, Atkins, North America

Connected

Simply stated, connected vehicle (CV) technologies allow vehicles to communicate with each other and the world around them. Your vehicle is likely already more connected than you realize. Navigation systems already include connected vehicle functionality, such as dynamic route guidance. Your GPS-based system receives information on congestion in the road ahead through cellular signals (4G LTE or 3G) and suggests an alternative route.

The connected vehicle concept is about supplying useful information to a driver or a vehicle to help the driver make safer or more informed decisions. Use of a "connected vehicle" doesn't imply that the vehicle is making any choices for the driver. Rather, it supplies information to the driver, including potentially dangerous situations to avoid.

The United States Department of Transportation (USDOT) has been working on a CV program that communicates within a radio spectrum specifically allocated by the Federal Communications Commission in 1999 for this purpose. And by the end of this year, the National Highway Transportation Safety Administration will propose a rule mandating inclusion of 5.9 GHz-based equipment in all new vehicles to make them CV-ready. This technology has the potential to eliminate 80 percent of unimpaired crash scenarios that could save tens of thousands of lives each year.

Without compromising personal information, this technology will also enable transportation agencies to access vehicle data related to speed, location and trajectory—enabling better management of traffic flow. So in addition to sending information to the driver, CVs will send information to transportation agencies to enhance their knowledge of real-time road conditions, as well as generate historic data that will help agencies better plan and allocate future resources (which are typically stretched far too thin). By deploying roadside equipment, which reads and sends signals to and from these vehicles, transportation agencies can fully participate in the nationwide deployment of the connected vehicle system.

Autonomous

Some vehicles are already being deployed with autonomous functionality, such as self-parking or auto-collision avoidance features. But, until a vehicle can drive itself independently, it is not a true autonomous vehicle (AV). A fully autonomous vehicle does not require a human driver—rather, they are computer-driven. Most manufacturers will phase in various levels of autonomy until fully autonomous vehicles are widely tested and accepted by the general public.

Unlike connected vehicles, transportation agencies have little control over the deployment of these autonomous vehicles or the technology they use—this is controlled by the private sector companies who are building them, and responding to market forces. However, there are some actions agencies can do now to help encourage deployment of autonomous vehicles. For example, some agencies are already working to improve road striping and signage that will aid autonomous vehicles' recognition of the road. Agencies can also encourage and support policies that will further AV deployment, such as certification policies, licensing rules, and following distance standards.

Autonomous vehicles do not need connected vehicle technology to function since they must be able to independently navigate the road network. However, CV technologies provide valuable information about the road ahead—allowing rerouting based on new information such as a lane closures or obstacles on the road. By incorporating CV technology, AVs will be safer, faster, and more efficient.

Furthermore, virtually all autonomous vehicles will require some form of connectivity to ensure software and data sets are current. As autonomous vehicles rely on knowing the roadway they are traveling on, changes to the roadside such as new development or construction will require the type of real-time exchange of information that CV technology provides.

While a complex task, transportation agencies need to be ready to support both connected and autonomous vehicles. By making the best use of technology, setting specific time frames for deployments, and addressing specific regional/geographic needs, we're working to help our clients bring both connected and autonomous vehicles to the road.

Getting the fundamentals right

CAVs are a subject of huge interest both in the US and internationally as transportation agencies 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 recognizing 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 behaviors 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, agencies 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.

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 optimized freight delivery, such as platooning on highways 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 fully considered.

Internationally, there is huge interest around CAVs and multiple deployments are springing up offering a range of validation and testing services. This paper will present a story around this new market space and explore new business opportunities. It also tries to address the questions that organizations 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 expected to emerge.

CAVs are not somewhere in the future, they are a growing reality that must be considered in the present. CAVs have the ability to optimize 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, as well as all the different stakeholders for who the road network is fundamental to connecting people and places.

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.

Human driver monitors driving environment

SAE International LEVEL 0 – No Automation

Human driver controls all aspects of driving

SAE International LEVEL 1 – Driver Assistance

Human driver is assisted with either steering or acceleration/deceleration by the driver assistance system

E.g. adaptive cruise control

SAE International LEVEL 2 – Partial Automation

Driver assistance system undertakes steering and acceleration/deceleration using information about the driving environment, with the human driver performing all other tasks

E.g. more advanced levels of Driver Assistance expected in vehicles from 2015/16

Automated driving system monitors driving environment

SAE International LEVEL 3 – Conditional Automation

Automated driving system undertakes all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene

SAE International LEVEL 4 – High Automation

Automated driving system undertakes all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene

SAE International LEVEL 5 – Full Automation

Automated driving system undertakes all aspects of the dynamic driving tasks in all roadway and environmental conditions

SAE International Standard J3016 www.sae.org/misc/pdfs/automated_driving.pdf

The Benefits of CAVs

Safety

Over 90% of accidents involve driver error. The ability of AVs to perform repetitive tasks reliably (such as those encountered in stop and go traffic), without experiencing fatigue, makes them superior to human drivers for certain functions. 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 following 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 optimized speeds, two examples of ways in which emissions can be reduced.

Time

In many situations, humans have other tasks to manage: work, kids, school. 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

Improved safety could eliminate the need for crash barriers, and roadway signs could be replaced with in-vehicle information – making our roads less cluttered and more attractive. In addition, lane sizes could be reduced while allowing greater through-put of traffic and less space would be needed for parking lots and spaces.

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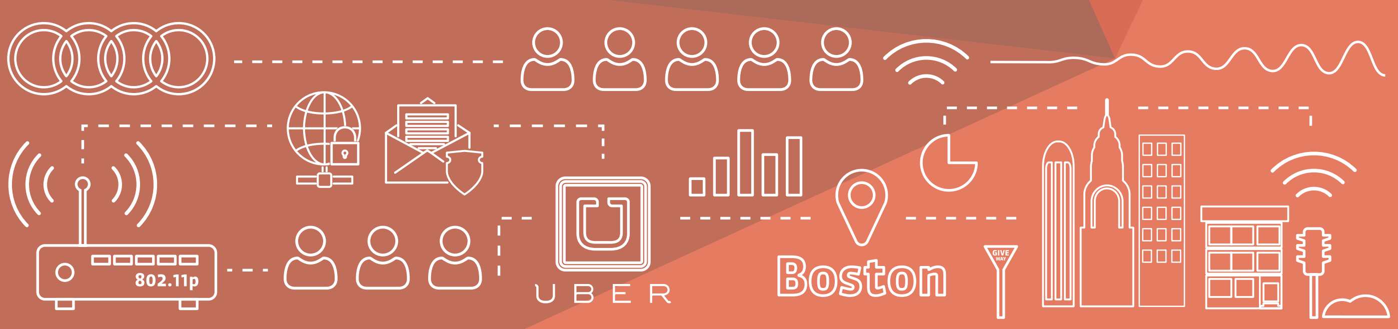
What must we do to prepare for CAVs?

Transportation agencies, local authorities, network operators and private companies 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 optimize their speed and routing to minimize journey times and overall congestion.

Transportation agencies and local 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, they must consider the systems and technological standards that will ensure that the opportunities provided by connected vehicles are fully realized. Liaising with CAV developers on this is a good starting point.

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 transportation agencies 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 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 agencies 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

Local agencies 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, agencies should consider how infrastructure can be upgraded in preparation for CAV adoption.

More widely, transportation agencies should consider the implications of CAVs on new transport schemes. For example, the congestion benefits realized by CAVs may negate the need for new road building in certain areas, or the need for new car parks.

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 organization. Given this, it is vital that organizations maintain a real time understanding of the security of their network, and the threats, mitigations and weaknesses that exist 24/7.

5. Leadership

Transportation agencies must consider their role in leading CAV development from an operational perspective – challenging themselves to take the right technical and strategic view across their organization. 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. Los Angeles has recognized 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

Transportation agencies should consider positioning themselves in order to maximize 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 transportation authorities. Below we present a summary of how CAVs may impact some of the common KPIs used by road authorities.

KPI	CAV Impact on KPI	
Travel time reliability	**Positive**	With increasing adoption of CAVs, travel time reliability will be expected to increase as incidents that cause delay (such as collisions) decline. 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.
Traffic volume	**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 miles traveled) as CAVs provide equal opportunity for use by those that currently cannot drive (children, the elderly and those with disabilities).
Road safety	**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.
Safety of the most vulnerable road users	**Positive**	As with road safety in general, CAVs will improve the safety of the most vulnerable road users.
Ensuring the road network supports economic growth potential	**Positive**	By reducing congestion on the road network and improving travel time reliability, the road network will support the economic growth potential of an area by allowing efficient and reliable mobility.

Reduce carbon emissions associated with road traffic	Unknown	On a per vehicle basis, carbon emissions will be expected to fall as CAVs are adopted and the technology improves 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 worsen.
Reduce the negative impact of road traffic on local air quality	Unknown	As with carbon emissions, on a per vehicle basis, local air quality conditions will be expected to improve. As CAVs 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.
An accessible and integrated road network that provides equal opportunity for use	Positive	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.
Freight Optimization	Positive	From connected platooning to automated and predictable last mile deliveries, CAVs will have a role to play in optimizing 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.
Increase the number and proportion of people using active modes of travel (walking and cycling)	Unknown	The impact of CAVs on the number of people using active modes of travel is unknown. People 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.

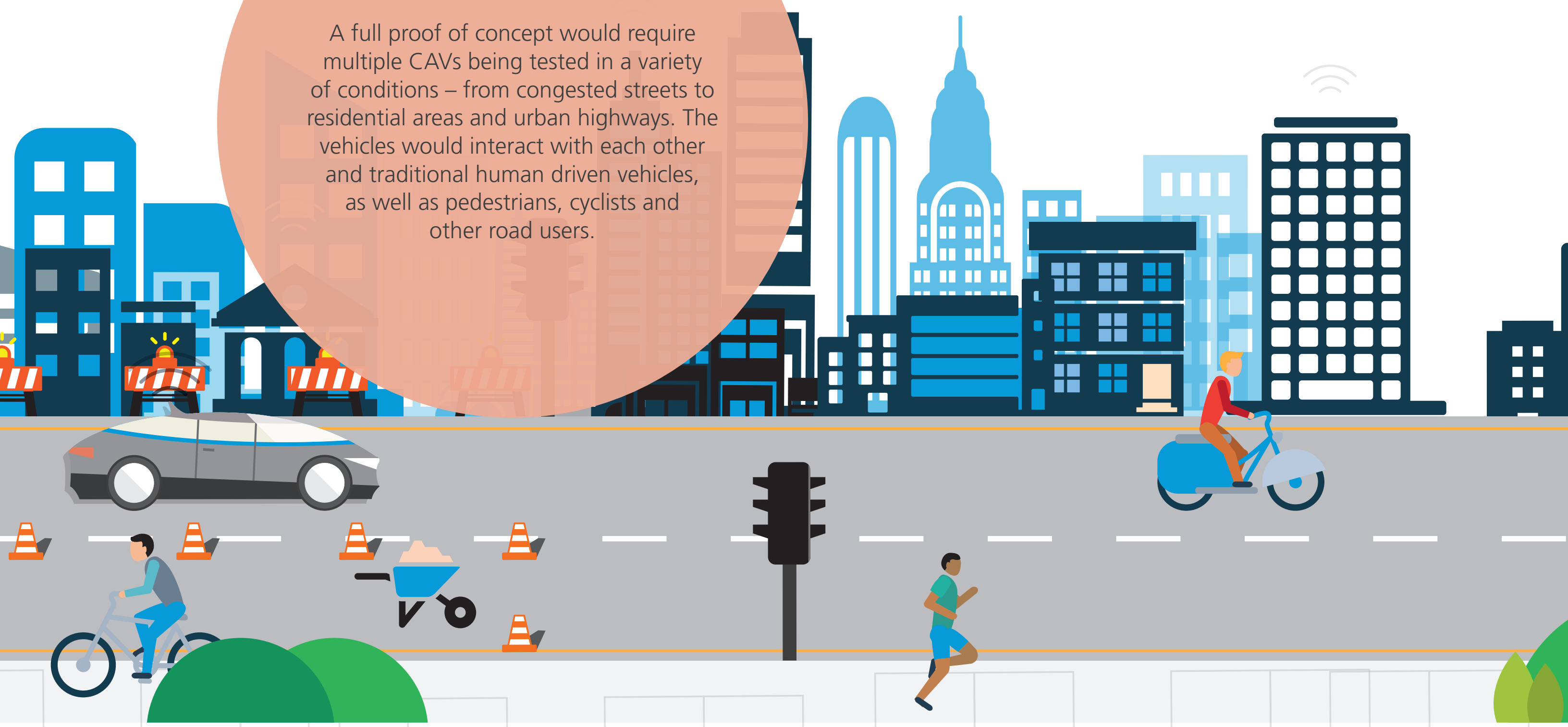
What would deployment look like for a city?

As CAVs are being developed, cities and transportation agencies have a leading role to play in the testing and roll out of the technology. Already cities are welcoming localized 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.

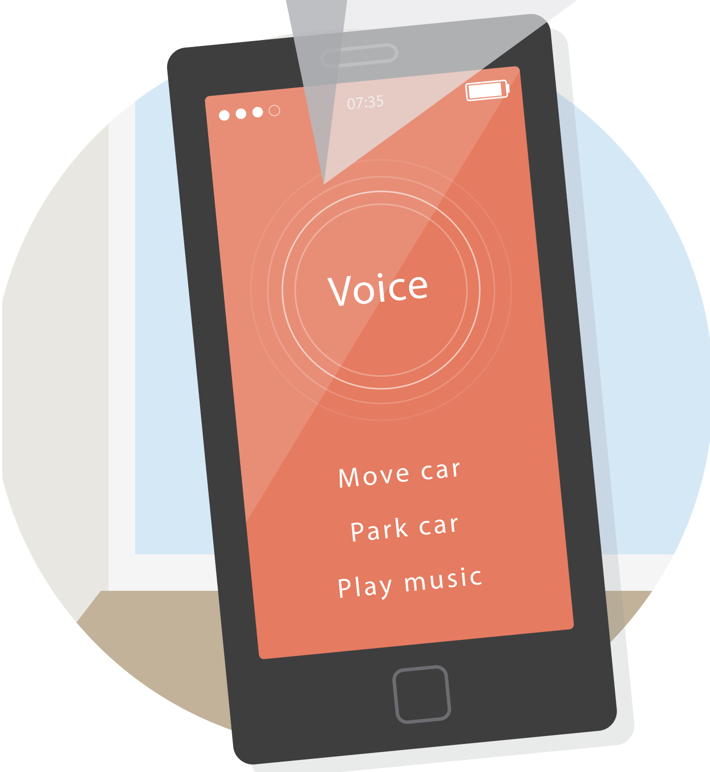
A full proof of concept would require multiple CAVs being tested in a variety of conditions – from congested streets to residential areas and urban highways. The vehicles would interact with each other and traditional human driven vehicles, as well as pedestrians, cyclists and other road users.

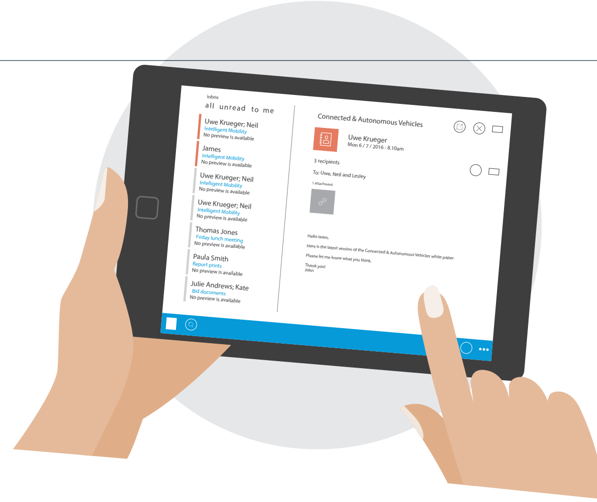


The impact of CAVs would by assessed against a pre-defined success criteria with a particular focus on the city's KPIs – road safety, travel time reliability and environmental impacts.

Transportation authorities would capture the valuable data created by CAVs to be used for optimizing transport networks, enhancing the operation of transport systems and improving the planning process.

1 You tell your phone to get the CAV car ready for the school run

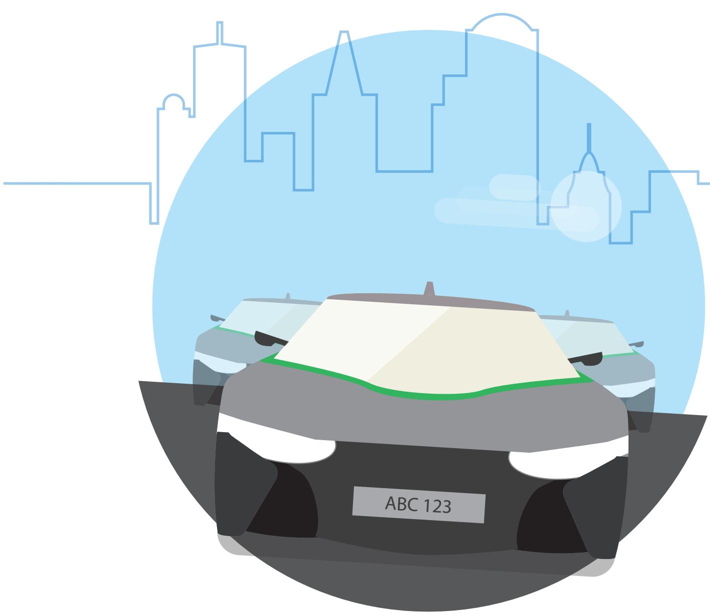


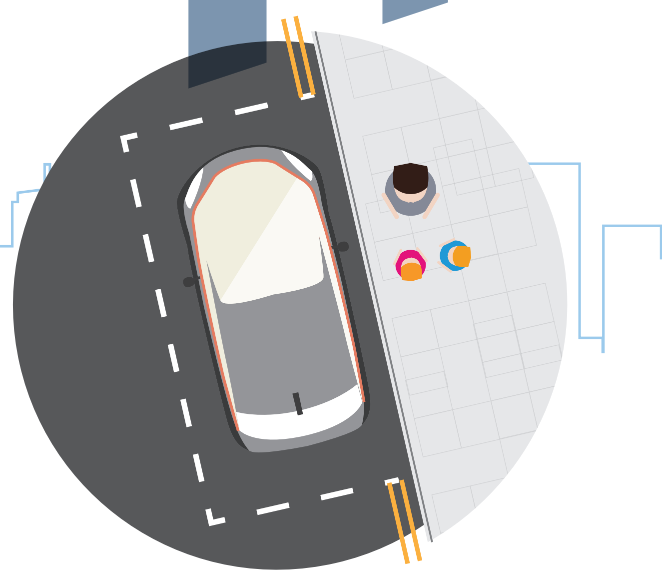


2 You get in and catch up on emails as your kids finish their homework

A DAY
TH

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





4 You and your kids are dropped off at the door, and the vehicle then parks itself at the closest available spot

5

You need to meet a colleague for lunch, so you book a slot for your CAV on the network to get you there on time

6

While on your way, you conference into a meeting for updates on a current project

7

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

8

You meet their car at the station, and after passing the security tests, the doors open and you all head home together

So far this paper has taken a high level view of the impacts that CAVs will cause on society and how cities and organizations 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 human side to CAV technology deployment
- Cyber security considerations
- Communication requirements
- Virtual and physical testing

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 urbanization. Many people are re-thinking their relationship with vehicles, with a move towards access over ownership – particularly among young urbanites.

The wider automotive sector recognizes this and have been very active in developing connected and autonomous solutions that offer a different lifestyle choice. People's behaviors, 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:

People and behaviors

Yes, technology is a critical part of the CAV evolution, but it is people, and their behaviors 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 behavior that may exist between different generations, and how CAVs can offer a solution that provides value and meaning to all, from the elderly to Millennials.

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, and they can proactively engage with the next generation who do not see car ownership as a necessity. They can facilitate stress free journeys and make driving a safer and more secure way of traveling. 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 – this requires 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.

Cyber Security

Public acceptance of CAV technology and the safety and security of the vehicles rely on secure cyber systems. 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 organization. It is vital that organizations maintain a real time understanding of their network, and the threats, mitigations and weaknesses that exist 24/7.

In order to address Cyber Security issues, companies must:

1. Understand the importance of cyber security and how their organization addresses it.
2. Define the 'ideals' behind their day to day security, such as 'always protected/always monitored' etc.
3. 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.
4. Deliver a range of counter strategies that factor in the operational and brand impact for the organization and their customers.
5. 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 system within an organization. It focuses on the overall system as well as identifying the strengths and weaknesses relating to cyber for each sector within the organization itself. It can be used to drill down into the deployed systems, assets and architectures in place for effective measurement of safety and vulnerability.

Communication requirements

Fast, secure, and reliable wireless communications are required to maximize the benefits of connected vehicles..

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.

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 on 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 signaling 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.

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. A number of test facilities are or will be in operation in 2015/2016:

> Closed track testing is valuable for testing in an ideal, clean environment. These facilities are especially important to understand how to improve autonomous (or driverless) vehicles. Meanwhile for connected technologies, real-world pilot programs provide the opportunity to test in less-than-ideal situations, which is key to understanding how to improve functionality. Testing is not always about working within a clean, ideal environment—most need to involve challenging environments that must be conquered.
>
> **Suzanne Murtha, Atkins**

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 CAVs 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.

On September 14, 2015 the United States Department of Transportation (US DOT) announced awards for connected vehicle pilot deployment programs in New York City, NY; Tampa, FL; and WY. These cities and regions will receive up to $42 million to pilot next-gen technology in infrastructure and connected vehicles. The US DOT is also planning to support deployments in other cities and regions throughout the country, which will lead to even more successful larger-scale deployments.

Conclusions and Next Steps

CAVs are a disrupter that offer huge potential to users and network operators alike. By utilizing 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.

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 agencies, organizations and cities in understanding how CAVs may impact 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 agencies and cities 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 in good position to capitalize on this emerging technology for the benefit of the economy.

To conclude, we have summarized our thoughts into four areas of focus for the future that we believe should be kept 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 pages. With a focus on The 4 Ts, we believe society will be well placed to exploit the opportunities CAV technology presents.

Testing

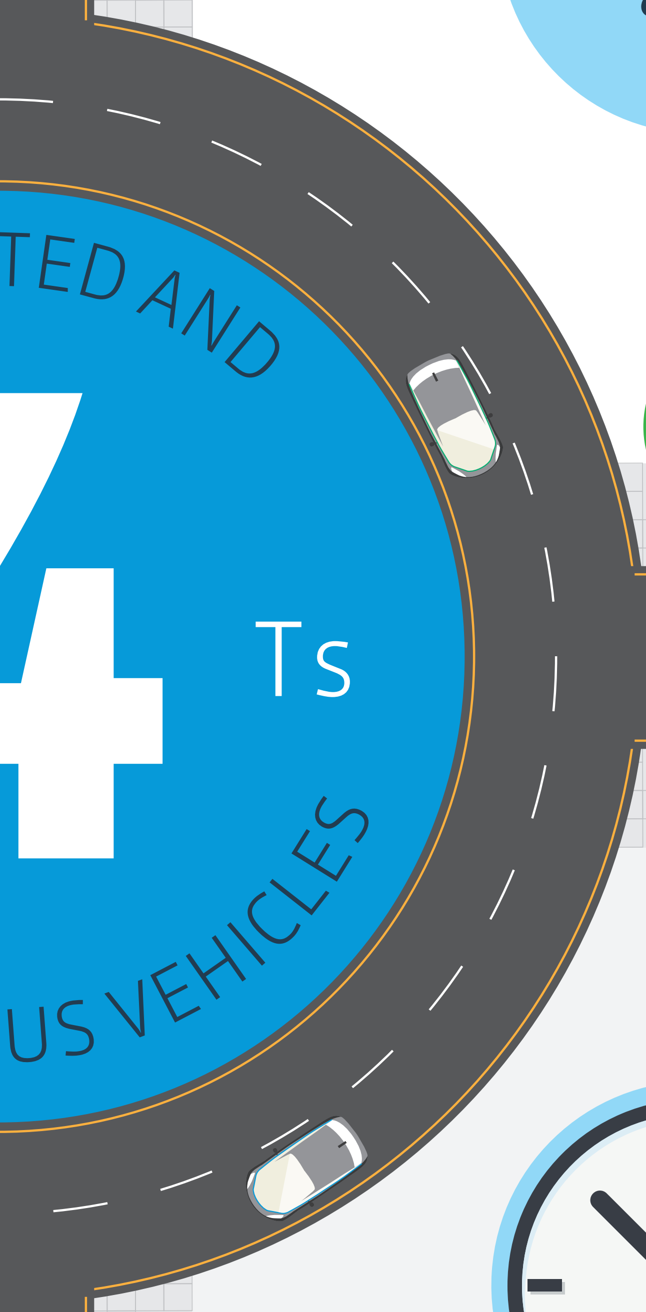
Independent validation is fundamental to emphasise the capability and safety of any solution in the CAV space. It is vital that appropriate and audited testing takes place in a controlled environment before deployments take place. As the software and hardware components come from multiple vendors and 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 CAVs open up to them rather than being sold solutions that are not fit for purpose or for person. CAVs must be safe, secure and valued by the consumer. Understanding the behavior and emotions around CAVs is an important step towards deployment.



Time

CAV deployment is a question of 'when' rather than 'if'. 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. We must maximize the opportunities and aggressively target market growth in the areas of testing and validation.

Case Studies

Autonomous Vehicles

Various organizations are currently developing vehicle automation technologies 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.

Connected Vehicles

Deployment of CV technology has been slower than that for autonomous vehicles. 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 Original Equipment Manufacturers (OEMs) – namely Audi – but otherwise deployment testing has been driven by academics and government programs.

Connected Vehicles

Audi's Traffic Light Recognition Technology (TLRT)

TLRT is a form of Vehicle-to-Infrastructure (V2I) connectivity, providing drivers with information about signal time phases on the approach to a signalized intersection. 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 intersection 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 while 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 signalized intersections. It is also being trialed in Las Vegas and Verona.

Safe Road Trains for the Environment (SARTRE)

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

The work is funded by the European Commission under the Framework 7 program, 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.

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M City

The University of Michigan's M City site opened in July 2015, providing a 32 acre testing ground for connected vehicles, covering both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (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.

Autonomous Vehicles

Google Chaffeur

Google has been publically trialing 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 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, while 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

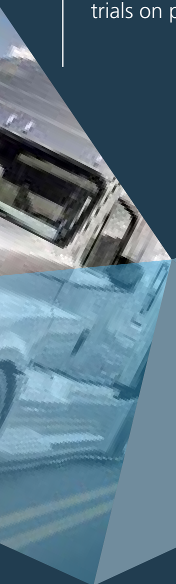
The VENTURER consortium will deploy an autonomous BAE Systems Wildcat on the streets of Bristol in 2016, investigating the legal and insurance aspects of driverless cars and exploring how the public reacts to such vehicles.

An independent test site will be created in order to understand the behavior of people and CAV technology in both real and virtual environments.

Daimler

While also working on autonomous cars, Daimler is one of few OEMs working on autonomous commercial vehicles. 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 the future they will take on greater autonomous capabilities.



Shared Computer Operated Transport (SCOT)

SCOT is a low cost AV that 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 in 2011, with the early prototype being an adapted golf cart. The results of this early deployment have led to the latest version of SCOT, an adapted Mitsubishi i-MiEV, which uses LIDAR 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 cart form) was undertaken in November of 2014, with two AVs transporting members of the public around public gardens in Jurong Lake District, Singapore.

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 kilometers.

Volvo

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

Under its Drive Me program, 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.

CityMobil2

CityMobil2, which commenced in 2012, is a European Commission funded program to pilot AV systems across Europe. The focus of the program is to 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.

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 utilize a combination of systems thinking, technology and data across the transport network to inform decision making and enable behavioral 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:

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

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Mr. D'Angelo, vice president and division manager with Atkins in North America, is responsible for ITS and traffic engineering contracts in the Eastern US and provides strategic counsel to multiple state departments of transportation (DOTs) and toll clients with complex program management initiatives. He also offers guidance on emerging solutions, such as early deployment strategies to leverage connected vehicles to support safety, mobility, and environmental objectives.

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Dr. McCarthy has more than 18 years of experience working across a variety of sectors and industries, delivering leading edge technical solutions for public, private and academic bodies. He is part of the successful Innovate UK 'Venturer' consortium, an autonomous vehicles trial taking place in South West UK, looking at technology, customer requirements and impact on insurance and legal issues. John previously worked in Transport for London for over 7 years, responsible for delivering the Smart City agenda internally through a number of innovative technology programs.

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