MOTT MACDONALD

# Planning for connected autonomous vehicles

Jannat Alkhanizi, Ed Forrester,
Glenn Lyons and Kate Mackay

**January 2019**

# Summary


Connected autonomous vehicles (CAVs) are increasingly in the news, and speculation about their role in a future mobility system is widespread. Transport authorities face the task of determining what part they should play in this unfolding story.

This will involve addressing governance, and supply- and demand-side developments. There are challenges arising from divergent views and values between stakeholders, technical, social and economic uncertainty, lack of evidence, and complex interrelations with wider developments.

To help our clients in considering and addressing these challenges, we have crowdsourced the key problems and questions and set out responses. This report is the product of connected thinking from nearly 90 professionals across the Mott MacDonald business globally.

The report highlights the multiple dimensions of uncertainty relating not only to what a CAV-based future of mobility could look like but how to achieve it. The need for strong planning is paramount. Transport authorities need to play an active part in shaping the future for the communities they serve. They should ask what CAVs can do for their own higher-level vision for the future regarding economic prosperity, wellbeing and social equity, and environmental sustainability.

Our towns and cities need to continue to evolve in ways that place the needs of their populations at the heart – pursuing developments centred on people and placemaking rather than vehicles.  Addressing such needs calls for a participatory approach in order to identify how to achieve an equitable and inclusive outcome from what CAVs could offer.

People's behaviours are changing and there is a significant prospect for society's dependence on the private car to diminish as a new mobility regime emerges. To what extent this materialises is unclear because the breadth and depth of private car ownership and utility is significant. There are serious concerns that CAVs could pose a threat to public transport patronage and discourage walking and cycling, so exacerbating rather than relieving traffic problems.

Transport authorities need to guide the focus of CAV trials and developments so that they orientate CAVs towards acting in a complementary rather than competitive way to the modes that are key to urban vitality and sustainability. Transport infrastructure changes need to be flexible, allowing the opportunity to adapt over time in tandem with the uncertain nature of the transitional decades ahead.

There is a need for ongoing monitoring and horizon-scanning regarding people's behaviours and lifestyles and also technological development. When the progression from technology readiness to CAV adoption and effects on system operation and performance takes place, there is a need to anticipate the consequences and take steps to avoid those that are undesirable. In a highly connected world, the scope for hype is considerable and we see it as essential to help our clients hear through the noise and identify the signals of importance.




# Introduction

The transport sector faces an uncertain future which makes forward planning a challenge. This report addresses the topic of Connected Autonomous Vehicles (CAVs). The focus is on vehicles that use the highway and is not limited to cars. Although vehicles can be connected without being autonomous, it is likely that those with higher levels of autonomy would have the technological capability to connect and communicate with other vehicles and/or transport infrastructure.

In this report we do not set out to provide an encyclopaedic description of what CAVs are in their different guises but it is helpful to be aware of the different levels of automation – in particular 4 and 5. Level 4 reflects a vehicle that has the option of being run in fully autonomous mode where the road environment allows and when the human driver chooses to activate this mode. Level 5 is fully autonomous in that no manual driving of the vehicle is required (or possible) at all.

CAVs could play a transformative part in shaping future mobility. They are part of a wider agenda now being referred to as 'CASE' (Connected, Autonomous, Shared/Services and Electric) that depicts what may be some of the key ingredients in a new mobility regime. As such they matter to our clients, who will need to account for them in their strategic and business planning cycles. This involves coming to terms with how far, how fast and in what direction CAV developments go. It involves considering how to influence this and the steps that may need to be taken to evolve the transport system.

Mott MacDonald recognises the importance and power of connected thinking – especially when dealing with complex or even 'wicked' problems. Accordingly, we have addressed the matter of planning for CAVs through an open, Group-wide debate within the company. Using the social media platform Yammer, the four report authors launched a five-week discussion allowing a diversity of views to be expressed and challenged – views from professionals with different backgrounds and with insights from experience in various countries and contexts. Nearly 90 people participated (see the acknowledgements section at the end of this report).

Planning for CAVs is a wicked problem in that it involves:

- a divergence of views and values across different stakeholders;
- uncertainty and a lack of empirical evidence (inherent in being future-facing); and
- complex interrelations with other developments (such as demographic trends, changing travel behaviours and technological innovations).

This is why we considered a connected thinking approach was necessary. We wanted to crowdsource views on the issues our clients should be aware of, and examine responses to the key questions that arise.

The report is divided into three main parts:

- setting the ground rules – with an emphasis on the governance of CAV developments and the importance of transport authorities shaping the unfolding innovations
- shaping and supporting performance in a CAV future – with elaboration on what supply- and demand-side issues need to be considered; and
- forward planning – with attention to how we consider transport authorities in particular can engage with this agenda

Across the three parts there are 10 sections, reflective of the themes that have emerged as important from the Mott MacDonald Group-wide debate. The themes are not mutually exclusive as will become apparent. For each we outline the position and problem and in turn identify key questions that arise and the responses to them. In each section quotes from the debate itself are included.

Part 1

# Setting the ground rules

Ensuring safe and acceptable rules of the road

Shaping network efficiency

Guarding against adverse consequences for public/ sustainable transport

Ensuring CAV developments enhance mobility for all

# 1

## How to ensure safe and acceptable rules of the road

**Situation**
Today's CAVs are still at the research, development and testing phase but technology developers are aiming to show that they can operate under all conditions and unlock the challenge of societal adoption. Transport regulators and municipal authorities can feel inspired or compelled to join the race and find their place in preparing themselves to maximise the potential benefits that the technology could provide.

There are three primary types of CAV trials in operation which need reflecting on as we try to understand how to integrate CAVs into the built environment.

1. Trials on existing and dedicated infrastructure that has been repurposed and closed to most other forms of mobility to ensure the safety of all users.
2. End-to-end autonomous taxi services operating in mixed environments (with a human driver on board to take over the controls under particular conditions).
3. Simulated trials.

The trials on dedicated infrastructure are typically with autonomous personal rapid transit (PRT) or guided rapid transit (GRT) vehicles. These operate at low speeds offering first and last mile solutions connecting residential and commercial areas to transport hubs. The vehicles are 'cautious', operating at a maximum speed of 15km/h. Nevertheless, there have been incidents resulting in injury and property damage.

The autonomous taxi services in the United States operate in mixed environments with cyclists, pedestrians and motor vehicles. Yet trials of this type have resulted in fatalities (albeit a very small number) as the limitations of the technology are exposed. The risks are mitigated or managed through a licensing process where CAV solution providers must demonstrate the vehicle's performance in off road conditions similar to those of the live environment.

The possibility of accidents highlights the importance of simulated trials to understand how the technology will perform in the real world.

"Do we (re)design infrastructure to help accommodate CAVs in a way that overcomes potential problems of interaction and ultimately safety? Or should we place the onus on CAVs to be developed in a way that accommodates our existing socio-technical environments?"

"Will rules of the road for non-car users need to change? Cyclists and pedestrians *may* be pleasantly surprised by how CAVs respond to their presence when compared to current experiences with human drivers."

"The responsibility of solving these issues should lie with a collective group of professionals and not just with software developers."

**Problem**
CAV developments necessarily require a 'learning by doing' approach whether in real world or simulated settings. This is a long and complicated process. As city authorities engage in live running of CAVs, there are substantial challenges in ensuring road safety. One incident can be seen as one too many. This is especially true at this embryonic stage when public acceptance of a CAV future can be considered fragile. Steps to ensure safety could result in a heavily constrained form of CAV operation and performance or could result in changes to highway design and operation that seek to limit interaction of the vehicles with other transport users. A key challenge then is to establish safe and acceptable rules of the road. The challenge is even greater given:

- the inherent lack of a steady state environment through the transitional period ahead towards a CAV-based mobility system;
- deep uncertainty over what form a future CAV-based mobility system could or should take; and
- differences in existing cultures, norms and regulations for road use across different cities, regions an d countries.

**Questions**
How will safety on our roads be ensured, accounting for the system envisaged, with the mass adoption of CAVs?

Will CAVs always require separate, potentially expensive infrastructure?

Will they be capable of safely operating in a mixed environment with human drivers (and other road users) or will fully autonomous highway environments be needed?

Regardless of the type of mobility system, a key consideration is how we transition to it, which raises several questions.

While the technology is evolving, what impact could there be on the safety of all other forms of mobility, particularly pedestrians and cyclists?

Who is responsible for determining the new 'rules of the road'?

Should some accidents be accepted as an inevitable consequence of the CAV development journey in pursuit of the longer-term goal of enhanced road safety?

Who determines the tolerance of any such accidents?

Can a failsafe, fully autonomous environment ever be achieved in the face of potential cyber attack or technology failure? If not, will a requirement for human intervention and manual driving remain as an important back-up?

**Response**
Given the embryonic state of the technology, consistent standards and regulations relating to infrastructure provisions and implementation to ensure safety in dedicated or mixed environments have yet to be developed. CAV original equipment manufacturers (OEMs) have a challenge to establish common global standards.

Some cities have developed codes of practice and other forms of governance to guide CAV trials and help to provide a safe, consistent approach. These should be reviewed regularly and updated when the technology upgrades. They should also be developed through a participatory and consultative approach.

Before any trial starts, all possible risks should be identified and practicable steps taken to mitigate them. The measures can be removed over time as the technology proves itself in different scenarios of increasing complexity. Simulations and scenario planning, policy and regulation will be key to enabling a safe environment for CAVs and other forms of mobility to coexist.

# 2

## Shaping network efficiency

**Situation**
Today's transport ecosystems in high income countries tend to be based on single or low occupancy internal combustion engine vehicles. Although this mode of transport forms the backbone of people movement, it is widely considered to be inefficient in terms of land use, cost, use of materials and productivity. It also brings with it adverse environmental consequences.

CAVs could help to tackle those issues. There is the prospect of increased network efficiency in terms of people movement. For example, CAVs may drive closer together and attract higher occupancy.

However, it is also possible that CAVs assume different forms of operation and use that could have a negative impact on the transport network by creating more journeys or zero-occupancy journeys.

CAV developments are focused mainly on technology and the nature and effective capacity of transport supply. However, it is the prospect of shared mobility on which the greatest hopes rest for substantial efficiency gains. Moving from single-occupancy vehicles to multi-occupancy will reduce the number of vehicles on the roads per unit of people movement and use existing infrastructure more efficiently.

Since Uber started to offer ride-hailing services in 2009 options for shared mobility have increased and are becoming more mainstream. There are now several such services, including Careem, Moia, Chariot and Lyft, presenting the opportunity to reduce reliance on private vehicle ownership. There is evidence to suggest that ride hailing journeys have increased markedly, albeit from a small base. However, it seems less apparent that this is contributing to improved transport network efficiency, not least because some public transport patronage is migrating to the more convenient offer of ride hailing. A further influencer, however, remains the inclination of humans towards self-interest – in this instance a desire for secure space, ownership, perceived convenience and social esteem. Emotions are relevant because many people, quite simply, like their cars and many like to drive. The choice to drive is often about values far beyond mobility, such as independence, status and self-image (fast, loud, slow, sure).

"Local authorities, regulators, developers, providers, planners and designers all have an important role in encouraging a sharing culture."

"CAVs through convenience and widened access could exacerbate dependence on cars and an individualised approach to mobility at the expense of public transport and sustainability."

"There is evidence from many countries around the world that shows a lower willingness to share vehicles."

**Problem**
It is important to distinguish between shared access to a vehicle and shared use of a vehicle on a given trip. Although growing digital connectivity offers the prospect of people sharing rides – and services such as Uber Pool are now available – in the mobility system generally this practice is not popular in high-income countries. Alongside those who are using public transport services through choice or necessity, more remain drawn to the comfort and convenience of their own cars or an individually hailed ride. The introduction of CAVs may not change this.

Price is a big factor in determining modal split. If left unregulated, CAVs used as door-to-door taxi fleets could, depending on pricing, increase congestion. Indeed, the very convenience of hailing a CAV for which the operating costs are lower could encourage usage patterns that are even less efficient than the private car as vehicles run empty between customers.

**Questions**
Will the introduction of CAVs increase our dependency on cars and increase congestion at the expense of public transport and sustainability?

Can they instead be used to address the current transport challenges and improve network efficiency?

Will sharing or private ownership of vehicles predominate in future?

What can be done to encourage vehicle sharing both in asynchronous and synchronous terms? And what are the roles of local authorities, regulators, developers, providers, planners and designers?

How can CAVs complement public transport rather than detract from its use?

**Response**
City authorities must distinguish between what they can do to enable technological innovation and what technological innovation can do to help achieve their goals. The latter must surely have priority, though the two need not be mutually exclusive. Some planners are at risk of being drawn into the race for their cities to be at the forefront of the introduction and adoption of technological innovation. This is why it is so important to have a clear vision with stakeholder buy-in that is revisited and updated regularly as the primary focus for development. This then sets the framework conditions within which innovation must operate.

Designing cities around people rather than vehicles is likely to make sense economically, socially and environmentally. Making it less attractive for people to travel by car and more difficult for them to park will encourage a shift to different modes of transport. Copenhagen consistently sits at the top of the UN's happiness index and is one of the healthiest cities in the world, according to the World Health Organization. The Danish National Travel Survey showed that 62% of people cycle to work, partly because towns and cities are designed for cycling. Thus at the very time CAVs are seen by some to offer so much potential for improving our mobility system, the need for strong planning has never been greater. If CAVs are to be invited into our towns and cities this should be on the understanding that they are used efficiently.

# 3

## Guarding against adverse consequences for public and sustainable transport

**Situation**
Among the modes of transport, private vehicles have continued to account for the largest share of trips made. Factors including convenience, availability and frequency have deterred travellers from switching to public, more sustainable modes.

The emergence of CAVs will allow these factors to be addressed in ways that could substantially move preferences away from private vehicles. Imagine a future in which CAVs offer an affordable, efficient, on-demand service that renders private car ownership pointless.

However, imagine instead a future in which CAVs – either owned or hailed – offer a door-to-door personal mobility service that drives public transport to all but extinction and whose convenience in people's busy lives erodes rather than supports use of active travel modes. Or a vision in which CAVs are seen as exclusive and not for 'everyday folk'.

If we are to set a direction of travel towards CAVs helping to make future urban mobility more sustainable and efficient, regulators and service providers must play an influential part in ensuring responsible innovation.

**Problem**
There is concern over whether the provision of services with no control measures could lead to travellers being deterred from using public transport as they are drawn by the benefits CAVs have to offer. Indeed, some city authorities have considered withdrawing investment for public transport on the basis that a new era of ride-hailing is on offer. CAVs could promote even more vehicle-based door-to-door mobility, which may lead to reductions in walking and cycling, a potential increase in obesity rates and a return of segregated road space (hindering placemaking of shared spaces in the public realm).

"It will depend on the balance, but there is a danger that CAVs don't replace private cars, but public transport, making traffic worse, not better."

"We could also see an increase in the number of vehicles/ trips on the network if access to transport/AVs is left unrestrained and inexpensive."

"If we consider the 'connected' more than the 'autonomous' part of CAV technology, there may be potential for traffic to be directly managed/controlled at the network level to minimise congestion and maximise efficiency …. connections at the city network level could allow direct matching of demand to capacity without TDM or behaviour change measures."

**Questions**
To design a network of complementary transport services, agencies need to ask the following questions:

Where are the gaps in the mobility system beyond the private car that CAVs could help to fill?

What control measures or behavioural influences should be in place to chart a course for CAV use that enhances rather than erodes sustainable mobility?

What is the role of transport agencies in regulating the uptake of CAVs while supporting public and sustainable modes?

These questions must be addressed if a coherent, complementary and comprehensive mobility system is to be developed rather than an environment of competition and fragmentation.

**Response**
CAVs need to be provided as an accompaniment and enhancement to public transport rather than a personal transport mode that dominates the future of mobility.

Transport agencies need to be supported in addressing these issues by analysing their networks. Identifying and understanding service gaps should be the first step in determining the types of complementary CAV provision and the development of trials. The trials should form the basis for developing and fostering a regulatory framework and public acceptance. Then the stage can be set to scale up CAV service deployment.

Service development will need to involve appropriate pricing measures and incorporation of a mobility as a service (MaaS) approach to supporting the user.

"As a Londoner with access to a car and good public transport at all reasonable times of day I have only used a taxi a few times in the last few decades – why then would a CAV service increase my use of this … I worry that a shared vehicle would not be available at peak times without some forward planning…"

"An alternative viable use of CAVs is for long-distance motorway journeys. Again in Europe why would you not use a train? This appears to be sensible for the low traffic long routes in America and Australia"

# 4

## Ensuring CAV developments enhance mobility for all

**Situation**
Current transport systems cater best for the needs of people near high-quality public transport services or those with access to private vehicles.

The technological advances embodied in CAVs introduce an opportunity for 'non-drivers' currently excluded from the transport network to gain access to mobility.

The benefits of CAVs are expected to reach various categories of 'non-drivers', including those unable to drive because they are not qualified to do so, are physically or mentally unable to or cannot afford to. However, this is likely to depend on them being sufficiently technology-savvy to use smartphone-based services to access CAVs.

**Problem**
There are many people in society who do not have direct or affordable access to usable and convenient mobility options. CAVs could represent a cost-efficient and convenient service to connect those in need of mobility to the people, goods, services and opportunities that help to ensure their economic and social wellbeing. However, it will be especially important that new barriers created unintentionally by CAV developments do not become an impediment to parts of society at risk of being marginalised.

**Questions**
To provide an inclusive CAV service that benefits everyone, authorities and policymakers should consider four questions:

What steps need to be taken to ensure people can engage with the information services that provide the gateway to CAV access, and ensure that some are not excluded if they are unable to do so?

"Access depends upon whether you can afford to use such a vehicle (including whether or not you are happy to share use of one with others). Access depends upon whether you are physically able to get in and out of such a vehicle and get to your final destination."

"If level 5 CAVs were to become mainstream, those who fall short because of one or more of the points above could be MORE excluded in a society growing dependent on CAVs."

"Will 'drivers' of CAVs below level 5 still need full driving licences? If the answer is no, then they would provide some increase in accessibility for those currently barred from getting a driving licence on medical grounds."

If marginalised users do not have the means to access a device to use the service, how can transport authorities eliminate this technological barrier?

How could urban and rural contexts for CAV access and use differ in terms of the characteristics of users and their mobility needs?

What might be the impediments to getting into and out of the vehicle that some individuals may face, how can these be overcome, and who should take responsibility for addressing this?

**Response**
Ongoing evaluation and understanding of the impacts of transport trends on the short- and longer-term social and economic development of communities is needed. CAV developments should be encouraged and perhaps obliged to incorporate user-centred participatory design to cater for the range of needs for a heterogeneous travelling public.

Efforts are needed to strengthen local institutions that represent community interests as part of fostering an inclusive approach to building long-term solutions. Specific approaches to ensuring the development of an inclusive CAV-based mobility system include: undertaking evidence reviews and data analysis for existing transport modes and assessing community needs to identify gaps; preparing economic and socio-economic impact assessments; and undertaking stakeholder interviews and engagement with users.

Part 2

# Shaping and supporting performance in a CAV future

Identifying infrastructure implications and rethinking asset management

Understanding and influencing acceptability and adoption

Managing demand through changing travel behaviour

# 5

## Identifying infrastructure implications and rethinking asset management

**Situation**
Most global CAV trials are operated on existing infrastructure (that has been adapted from its original function). It is not yet as common for new, bespoke infrastructure to be constructed for autonomous vehicles. However, there are a few examples, such as the Bluewaters development in Dubai, where bespoke infrastructure has been installed to complement existing modes of public transport and address congestion challenges. This infrastructure has been built using design standards developed through research into vehicle specifications and human drivers.

It is premature for consistent standards and regulations on infrastructure design and construction to exist for CAVs. However, using existing infrastructure and technology to complement key public transport services is logical for public authorities in terms of reducing capital expenditure and improving transport efficiency.

Purpose-built infrastructure for CAVs would need to be justified in terms of return on investment. But it may be that trailblazer investments will set a lead from which others can learn in terms of integrating technology into our existing environment.

**Problem**
There is much uncertainty when trying to determine the best course of action for CAV infrastructure provision, in particular during the transition period. When the technology is fully developed, it is assumed that the potential benefits will include reduced congestion, a smaller infrastructure footprint and less parking. Any purpose-built infrastructure or new infrastructure construction should be future-proofed for advances in new transport technologies and designed flexibly in order to maximise the potential benefits within the context of an unknown future. The inherent problem is that this is easier said than done. There are no accurate timescales for the development of the technology, despite manufacturers claiming that level 5 autonomy is close. Many in the transport sector question this in terms of technology readiness, let alone adoption.

> "The connected nature of CAVs, the repetitive nature of some operations, could lead to concentrated wear and tear on the road surface."

> "Research indicates that car sharing apps are leading to increase in vehicle trips and may replace PT rather than private vehicles. This begs the question, will autonomous vehicles reduce congestion or increase it?"

> "Fundamental changes will be required, which will have big cost and time implications."

**Questions**
Several infrastructure questions come to light, illustrating the extent of the unknowns:

How should we deal with the transition period from the current level of autonomy to level 5? Should we adopt a wait-and-see approach (forcing the CAV technology to cope with existing infrastructure), repurpose the infrastructure or build new, dedicated infrastructure?

If custom infrastructure is to be constructed during the transition period, how can it be future-proofed for advances in technology?

The repetitive and machine precision of autonomous vehicles could lead to channelised flow and increased wear and tear on road pavements – how should they be adapted for CAVs?

What implications from CAV uptake can be expected in terms of car parks and on-street parking?

'Connected' suggests digital infrastructure investment, such as signalling and kerbside data transmission, is required. Who benefits, who pays?

Will lane widths be reduced, or can they be?

Will visibility requirements be irrelevant with advances in vehicle-to-vehicle and vehicle-to-infrastructure connectivity?

Alternatively, will sight distances and horizontal offsets for human operation need to be maintained as a redundancy system?

Will changes need to be made to the design and standards of non-motorised vehicles to ensure the safety of all forms of mobility?

**Response**
It is uncertain how the mass adoption of CAVs would affect society, which highlights the importance of scenario planning and flexibility for infrastructure design as well as other areas of the CAV agenda.

It may become more common for dedicated guided rapid transit (GRT) systems with higher capacities to be implemented on dedicated infrastructure during the CAV transition period because they operate in a similar way to light railway systems but without the expensive infrastructure costs. However, since dedicated infrastructure may be required in the short to medium term only, it should be designed with the flexibility to be adapted or even repurposed as the technology evolves.

Existing closed environments, such as airports, are increasingly discussed as potential test beds for the technology. A recent publication by Aberdeen airport in Scotland explored the possibility of deploying autonomous technology in airside scenarios using the existing infrastructure to explore the efficiencies that might be gained from removing human drivers. Hamburg airport in Germany is considering autonomous parking using the existing infrastructure but with the addition of vehicle-to-infrastructure equipment to guide vehicles into predefined parking spaces.

# 6

## Understanding and influencing acceptability and adoption

**Situation**
Only an embryonic understanding exists of what people's use of CAVs might be in the future. The appetite for adoption is unclear – in part because people appear undecided on whether they need or want CAVs in place of manually driven vehicles.

The emerging body of data suggests that young people may be more likely than older people to use automated vehicles and to share vehicles. But in some jurisdictions, there is considerable resistance to sharing. Evidence also continues to point to people valuing the control and freedom of driving themselves.

People's early experience of encountering CAVs, their understanding of the technology and their attitudes and perceptions will influence their propensity to use them. Safety and security concerns are likely to be paramount, as will liability issues. There is a danger that proponents of a CAV future are assuming it is a certainty and in turn that the challenge becomes how to encourage people to accept and adopt the vehicles. This risks overlooking any tendency towards resistance and inertia.

**Problem**
Public authorities, vehicle providers, and operators face a challenging journey ahead to show that the hypothetical benefits from CAVs for society can be realised and in a way that is deemed attractive while fostering acceptance and adoption.

Demonstrating the potential benefits from fewer accidents will be critical – yet the very course towards technology readiness is set to be accompanied by CAV-related incidents making headline news and denting confidence and public appetite or interest. Indeed, realising demonstrable safety benefits from CAVs of the sort and scale often quoted is likely to require substantial CAV penetration into the fleet. Attaining this will require consumer confidence to grow at the very time the take-up phase may encounter instances of deterioration in safety conditions as road network usage and behaviours adapt. Concerns have already been raised with the potential safety issues of level 2 and 3 CAVs, caused by the inability of human operators to step in and retake control when necessary and to fully understand how to use the semi-autonomous features. Many manufacturers are now intending to bypass level 3 altogether as a result of these concerns.

Clarity on liability issues will be another prerequisite to build public confidence and propensity to adopt. Yet, arguably, until level 5 automation is reached, drivers could still be found liable under some circumstances.

**Questions**
The issues of vision, risk and promotion need addressing:

What future are we seeking to shape for CAVs into which to encourage transport users?

Should CAV technology become a complement to, rather than a substitute for, current forms of car use?

Should it be promoted to particular markets for particular types of trips?

How should road space be shared between CAVs and conventional vehicles?

How vigorously should a 'Vision Zero' safety approach for CAVs be pursued and what risks are deemed acceptable both on the road to CAV availability and on into the adoption phase?

What should be done to encourage and support uptake of CAVs?

How can uptake of a form that is equitable and where the (dis)benefits of CAVs are equally distributed across society be achieved?

How should the insurance industry adapt and will primary legislation be required on liability for CAV road incidents?

**Response**
Developing an understanding of the market for CAVs is essential. Expertise in behavioural analysis and research, and knowledge of human capabilities allied to technological understanding could deliver insights into how people may respond to new technologies. This concerns technology and user trials with an array of quantitative and qualitative methodologies that consider CAV prospects from a user perspective. This should be in both functional and experiential terms in the context of people's lives and lifestyles.

Alongside this, policymakers and planners need to embrace scenario testing to evaluate the potential futures for CAVs that account for uncertainties concerning technological possibility and consumer demand. This would allow the development of well-considered and stress-tested roadmaps for CAV technology readiness, user adoption, behavioural consequences and system performance.

The biggest and perhaps least considered barrier for CAV remains the rules and regulations of the road. The driver is liable for incidents – so what if there is no driver? Insurance costs are unlikely to fall because the extra connectivity and 'kit' CAVs require will push up the costs of repair (a current UK trend). It is possible that, for privately owned CAVs, insurance will be included in the purchase price.

"As the technology develops, it will also be important to remember that, for a lot of people, the freedom to be able to drive yourself where you want, when you want, in whatever you want, and enjoy the experience of 'switching to manual' and driving the car is still of prime importance… one of modern life's great freedoms."

"Of course public views on driving are diverse and there are generational issues to deal with. I've suggested that the car may be moving from being a foreground symbolic entity to a background functional entity. While I wouldn't suggest that (some) younger people might not like to own and use a flash new car if it was given to them, there is also a need to recognise that new generations are finding other ways to signal their status and to 'get their kicks' – not least the online world and social media."

"The transition from level 1 to level 5 automation [is] perhaps the most difficult part of reaching the utopia or dystopia of full automation. I believe there is a lot we can do to better understand the immediate impacts of real-life trials, sketching out through systems dynamic thinking to ensure that unwanted consequences are recognised early, monitored and dealt with. In that way our understanding will only improve and some of the hype will become less relevant and visible."

# 7

## Managing demand through changing travel behaviour

**Situation**
CAVs are set to create an unprecedented convenience in driving (or rather being driven), eliminating most of the 'hassles' of driving, such as manual parking, and physical and cognitive effort.

Half the UK population has a driving licence, although fewer young people are acquiring one. CAVs will expand the opportunity to 'drive' to many more people: to adults without licences, to children, to people with visual and physical impairments.

The pool of potential car owners and independent car travellers could widen significantly. The distance travelled may also increase as issues such as driver fatigue become irrelevant. This may be positive for the direct users but could exacerbate congestion on our already busy road networks.

**Problem**
To share or not to share…? There is little indication of how people will adapt. But if they are unwilling to car share, the number of vehicles on our roads and the kilometres travelled could both increase dramatically.

Confounding the situation, one of the most effective tools for managing demand for car travel is set to become redundant: parking controls. No longer will car users need to park near their destination. They can be dropped off and the car could park somewhere else, return 'home', or continue on to service the needs of other passengers.

**Questions**
Attention turns from the enabling capacity of a CAV future to managing demand. Key questions include:

How do we shape a shared future when this is arguably more central to any transformational effects from CAVs than their technological realisation?

What tools should we be looking to use to manage demand for car travel in future?

"I like to call it TDM 2.0. There is a huge opportunity for TDM to provide much more sophisticated carrots and sticks using real time big data to set the pricing and incentives, as well as working in conjunction with newer communication methods via smartphones and social media channels."

"When discussing future mobility let us consider 'trip behaviour' as the focal point rather than taking it for granted and remember that, as in any market, success of future transport solutions is dependent on the willingness of people to pay for those services."

"Airports offer a great 'test case' for CAVs, essentially being a mini-city driven by a need to balance mobility and revenue. As already suggested, park and rides will just offer a transfer point from dispersed mobility to autonomous HOV."

How can mobility as a service (MaaS) applications be integrated into future CAV models of operation and how must MaaS be shaped to ensure sustainable mobility patterns?

How should we be redesigning for pick up and drop off? How should we be reallocating parking spaces to other uses? And where should we put our parking spaces?

**Response**
The best time to change behaviour is before it has become habituated and normalised.

Evidence of young adults' travel patterns in many high income countries suggests a trend towards owning and using cars less. People are learning to drive later and then driving less. If this indeed signals a reduction in car dependence this is surely something to be further nurtured rather than countered through CAVs.

Efforts need to be directed towards minimising the extra kilometres travelled in a CAV mobility future and minimising the demand for situations involving zero-occupant vehicles.

Multiple occupancy vehicles – public transport – should continue to be prioritised. Shared CAVs must become the mode of choice. CAVs to support the public transport system should be prioritised.

Fiscal mechanisms must be part of the demand management approach to establish fair and efficient pricing based on marginal social cost and using real-time data on use and occupancy.

"The opportunity of change theory offers a great chance to influence travel behaviour on a grand scale. We could also see an increase in the number of vehicles/trips on the network if access to CAVs is left unrestrained and inexpensive. For example, parents sending children to school in a separate car, or people sending small items to each other using CAVs. We may also need TDM to influence people to use/adopt CAVs as they may perceive them as unsafe or may consider ownership as a prerequisite"

"It's the connectivity that offers the opportunity for management and change. As we will know at any point in time where a vehicle is and who is in it, we can at last begin to charge in line with economic theory, not only determining the exact marginal costs that the vehicle incurs and should pay, but also who should pay. In some respect, CAVs will be easier to 'manage' than the current fleet."

Part 3

# Forward planning

Managing the transitional period to a CAV-rich future

Handling uncertainty in forward planning mobility

Tracking developments through knowledge exchange

# 8

# Managing the transitional period to a CAV-rich future

**Situation**
Optimistic scenarios for CAV-rich futures have their protagonists and opponents. We are uncertain about whether, when and how we will have a mobility system that is CAV-rich. We are also uncertain about what such a future might look like. Added to this is the realisation that such a future requires a transitional period that itself could take a number of forms and is a source of uncertainty.

The current mobility system, in which the manually driven internal combustion engine vehicle is dominant, has taken decades to evolve. Yet where we are today is a consequence of multiple concurrent and inter-dependent developments in vehicle technology, infrastructure provision, consumer behaviours, traffic management and demand management. Over several decades the overall vehicle fleet has grown, the infrastructure has expanded and consumer demand has changed, alongside changing land-use patterns, regulations and expectations.

It may be tempting to see CAVs as rapidly replacing manually controlled vehicles in a like-for-like substitution. However, the reality may be more convoluted and protracted, involving recognition of changes in demand for travel and competing ideas on how to meet that demand.

**Problem**
A notional end state for a CAV-rich future is not clear. Are we transitioning towards a future mobility system in which all vehicles are fully autonomous? Or will it be one in which some parts of the infrastructure allow or require automated control of vehicles while other parts require the occupant to maintain some continued engagement in the driving task?

Parts of our public road network could be dedicated to CAV-use only. However, public and political acceptability of this would require a prior degree of initial penetration of CAVs into the vehicle fleet. Inevitably, during the transition there will be mixed flows of manually controlled vehicles, CAVs and (in some instances) interaction with other road users. Mixed use of infrastructure raises questions over the implications for efficiency, reliability and safety.

"Having manually operated vehicles sharing the roadspace will slow down the decision-making process for the CAVs as they need to consider what these vehicles are doing (or might do) rather than being able to communicate with them and agree a road share, and this will lead to slower vehicle traffic."

"The focus for consumer uptake will be level 4. Whether or not the move to level 5 takes place is more debatable. Yet it's really only at level 5 that some of the suggested changes to the mobility paradigm could truly start to come about."

"I don't think we should anticipate a world where level 5 never happens, but we may well find ourselves stuck at level 4 for a very long time. From a personal perspective I think that the hype about level 5 is probably stirring up opposition and may well lead to a slower transition period."

**Questions**
What elements of the transition will need managing?

Who will have responsibilities in managing them?

Should CAV design be able to accommodate the existing transport systems globally?

Should existing transport systems change to accommodate standardised CAV designs?

Should it be some combination of the two with iterations over time?

**Response**
There is the prospect of a growing public policy view that enabling the introduction of CAVs into our mobility system is beneficial, notwithstanding the need to set some framework conditions.

CAV manufacturers can create a viable market for their product only if the prevailing transport system conditions can be accommodated. This suggests that for the immediate future the onus will be on manufacturers to design their vehicles to accommodate existing infrastructure and built environments rather than rely on their adaptation which may not consistently take place in different locations.

Key to managing the transition will be a need to:

- monitor and understand how mobility supply and demand are being changed by the penetration of semi- and perhaps fully autonomous vehicles;
- horizon scan to detect indications of wider trends and developments that can inform the nature and extent of transition in the medium term;
- incorporate insights from the points above to ensure that unwanted consequences are recognised early, monitored and dealt with; and
- use these steps to inform planning and investment decisions that will shape the longer-term nature of the land use and transport systems in a way that aligns with higher-level policy goals and the trajectory of the transition.

# 9

# Handling uncertainty in forward planning mobility

**Situation**
Multiple scenarios are emerging in literature on the prospects for our mobility system, including the place of CAVs. These involve assumptions both regarding the pathway to their existence and the consequences. There is widely recognised deep uncertainty concerning future mobility.

The future is ours to shape. However, any stakeholder may have some agency and power to shape but will also be beholden to external drivers.

Such drivers of change can be defined as STEEP – social, technological, economic, environmental and political. For CAV innovation, it can be tempting to centre on technological drivers. However, the full breadth of potentially important drivers of change must be considered. For instance, climate change and energy markets could act as an environmental driver. This could amplify concerns regarding innovations that promote lifestyle profligacy which in turn affect CAV adoption models. Social drivers include changing demand for travel over time and changing attitudes and behaviours of people.

**Problem**
Uncertainty surrounding CAVs and how to respond can be considered a wicked problem. There are multiple actors offering different perspectives based on different values and with different objectives. If particular perspectives are given greater attention than others a risk of group think reinforced by confirmation bias arises. Perspectives from those specialising in understanding the technological system may differ significantly from those specialising in understanding the social system. This in turn may differ from those who adopt a 'socio-technical' perspective that considers more closely the interaction and inter-dependency between the social and technical systems.

The problem is wicked also because it has a complex relationship with other developments – for CAVs this includes how electrification of the fleet and mobility as a service (MaaS) are co-evolving as other mobility innovations.

"The uncertainties around CAVs are enormous – will values of time plummet or not? Will CAVs abstract from public transport? Will CAVs create new options for the young and elderly? Will we see parking decimated, but replaced by taxi 'dead mileage'? There's lots of ongoing research on this, but it's all highly speculative, and much of it is still contained within academia."

"We shouldn't underrate humans and overrate robots. This is especially so in terms of cultural preferences, interactions with our surroundings and how we engender a sense of place."

"I remain convinced that, given other areas of the economy where buying services rather than products is becoming the accepted norm, buying transport or mobility will become more and more acceptable. That's not to say that some will not continue to own a vehicle, bike, bus pass, just like me still buying DVDs."

Timescale is another predicament. To look to the long-term prospect of a mobility system that may be CAV-rich is fraught with uncertainty. Yet to be able to look to the nearer term in terms of policy action is also important – if there is confidence in the direction of travel.

**Questions**
How to handle such a wicked problem?

How can uncertainty be suitably exposed and embraced such that it is not concealed by assumption-laden conviction about the future but does not lead to decision-making paralysis?

**Response**
It is important to recognise that uncertainty can be turned into opportunity. It is plausible to develop a vision-led approach to shaping the future rather than a 'predict and provide' approach. However, the opportunity is constrained by the drivers of change that are beyond the control of those pursuing the vision.

Accordingly, the need to expose, embrace and respond to uncertainty becomes unavoidable. Key elements in addressing this are:

- A scenario planning exercise with key stakeholders should seek to illuminate current socio-technical trends and, in turn, the drivers of change affecting the future of interest. It should draw out those drivers that are most important but also most uncertain – illuminating the 'critical uncertainties'.
- Such an exercise should ensure a diversity of stakeholder perspectives to bring constructive challenge to collective thinking and insights.
- A broader scenario planning process can be considered in which multiple 'without policy' scenarios are drawn up to reflect the diversity of plausible future contexts for policy action. Policy options can then be tested against these scenarios for compatibility. Modelling tools are important enablers for examining multiple future combinations. However, the wider process relies heavily on human dialogue and judgement in setting a course for policymaking and investment that is adaptive to future uncertainty.

# 10

## Tracking developments through knowledge exchange

**Situation**
Signal versus noise is sometimes used as a metaphor for distinguishing between useful and questionable information.

We live in a highly connected society with more information at our fingertips than ever. However, just as 'big data' does not translate inevitably to 'greater knowledge', access to vast quantities of information does not immediately or automatically furnish us with better insight. In 2016, Oxford English Dictionaries' Word of the Year was 'post-truth', illustrated as: "In this era of post-truth politics, it's easy to cherry-pick data and come to whatever conclusion you desire."

In little time, a burgeoning volume of information and commentary has become available about CAVs. Understanding the messenger becomes important in judging the message offered. There are formal public policy documents, journalistic coverage, academic literature, commissioned industry reporting, advocacy and opposition commentary and more besides.

**Problem**
The key problem is how to keep abreast of the latest thinking.

Rapid spread of news can accentuate the phenomenon of hype – the inflation of expectations about a particular invention or innovation and how rapidly and dramatically it is set to 'revolutionise' society and, in the case of CAVs, the mobility system. Hype is a distortion of realistic expectation.

Different sources of information can have contrasting perspectives and selective representations of the state of developments and future prospects.

Multiple sources may overlap and duplicate the knowledge they impart. It can be hard with some sources to pass on the most useful information but also to have confidence in its robustness.

"Speaking of unknown hazards in the road, while on a recent holiday in Spain, I had to pass a herd of goats on an unbarriered mountain road. How would a CAV cope with this?"

"There is a Siemens Optiguide system in use in Rouen, Nimes and Castellón de la Plana (Spain) – this is a form of CAV bus using optical guidance on the approach to bus stops and to help with docking."

"There is an optically guided bus in advanced development for Tokyo 2020 Olympics."

"When do you know you've read a 'must read' article on CAV that should go on the list of key sources to recommend to others? The challenge of spotting 'new' news on CAVs and getting closer to really knowing 'how far and how fast'."

**Questions**
A central question becomes:

How can the strongest signals about CAVs be detected while filtering out the background noise?

Other questions follow:

Is it possible to synthesise 'state-of-the-art' thinking about CAVs over time in a way that maintains an up-to-date level of insight and confidence?

Can this synthesis guide transport planning and decision-making associated with, or affected by, the prospects of a CAV-based mobility system?

**Response**
We believe connected thinking lies at the heart of addressing this with and for our clients. Mott MacDonald uses its internal social networking platform to create and evolve peer-to-peer networks of knowledge sharing across its global business, centred on key themes and territories of shared interest such as future mobility. A five-week internal Yammer debate involving some 90 active contributors elicited networked knowledge to triangulate or challenge perspectives, and advance understanding and assertions about CAVs. It could be described as 'crowdsourced insight' – something to be called upon as needs require. It has formed the foundations for this report and gives rise to these points:

- The appeal of this approach is that it is agile and has the capacity for diverse engagement – diverse in terms of geographic settings, background skills, experiences and personal characteristics and perspectives of colleagues across the company.
- Crowdsourced insight is part of the response. Rapid evidence assessments are another important technique in which a finite selection of most relevant academic and 'grey' literature for the matters in question is identified, reviewed, synthesised and interpreted. This approach can avoid the need for costly bespoke research or can help to tailor research to address knowledge or evidence gaps.
- It is possible for a rapid evidence assessment to be refreshed periodically in order to update state-of-art understanding. The stage of selecting which articles to include is an important first filter on quality and relevance. Shortlisted articles can then be assembled into a library of key sources.
- Correspondence with a wider pool of experts can be an important accompaniment to the approaches above, particularly if they have 'gatekeeper' status in relation to their own networks of other commentators and information sources.
- Tracking developments through knowledge exchange in these ways can then be used with other techniques, such as SWOT analyses and scenario planning, to identify the most important considerations in forward planning.

## The crowd – acknowledgements

As noted in Section 10, this report is the product of a global debate across Mott MacDonald enabled through a digital platform. In this sense the report has been crowdsourced. The crowd comprised these contributors:

Richard Adamfi
Ali Albalushi
Balal Ali
Kawthar Aljufairi
Jannat Alkhanizi
Ammar Alkhatib
Jo Baker
Siamak Baradaran
Mike Barron
James Beard
James Bishop
Ian Bowman
Marion Carter
Martyn Case
Horace Chan
Paul Chase
Laurence Chittock
Alex Clewett
Kathryn Close
Ian Cornwall
Colum Crawford
Alex Crow
Clive Davies
Simon Davies
Qiyang Deng
Marion Derochet
Roy Desouza
Adrian Douglas
Andrew Eagle
Sean Finney
Jeannie Foo
Ed Forrester
Tom Godsmark
Andrew Gordon
James Griffiths
Clint Grove
Paul Hammond
Rana Hamwi
Simon Harrison
Matthew Hinton
Alan Holcroft
Paul Holden
Bharathkumar Jeppu Shekar
Alan Johnston
Jamie Kennedy
Ann Kerr
Cameron Lepper
Tim Lester
Joanne Leung
Steve Longman
Florian Longstraat
Stephen Luke
Glenn Lyons
Kate Mackay
Julian Malins
David Manfredi
Marcel Mario Van Zijdverld
Stephen Marsh
Andy McCallum
Edward Mellor
Sarath Nathoran
Kieran Nelson
Martina Olley
Ian Owen
Marco Picardi
Stephen Pike
Gareth Pullen
Andrew Radford
Philippe Rapin
Nick Richardson
Tom Roberts
Christopher Robertson
Chris Rosenberg
Dan Rouse
Tom Ruff
Anni Sander
Stuart Scott
David Sears
Mark Sellin
Helen Smith
Mark Staniland
Elain Thomson
Zlatko Tomevski
Roy Turland
Robert Urbanski
Tom Van Vuren
Dominic Westwood
Clare Wildfire
Jie Zhu

Opening opportunities with connected thinking.