An exploration of where we are going on our way to autonomous vehicles and how soon we will get there
The UK is facing serious road safety and congestion issues.

1,810 people died on the UK’s roads in the year ending September 2016. This figure has remained around this level since 2009. In 2016 the direct and indirect costs of congestion to UK motorists was estimated to be at least £30.8 billion.

These issues of road safety and congestion certainly aren’t new, but what is new is the increasing optimism that congestion, deaths and serious injuries on the road don’t have to be a fact of life and we are on the cusp of significant change.

In this white paper, we will explore what recent technological advances are improving our roads now and what changes lie ahead on the road to efficient, safe and sustainable car journeys.
Many of us are already benefitting from the addition of sensor technology to the cars we drive. Parking sensors are probably the most common example, which many of us have come to rely on. Motorists fortunate enough to have a newer, higher-end car can enjoy the benefits of parking cameras that make it even easier to avoid scrapes and bumps when parking. Another step up is to use parking assist, which combines cameras and sensors to allow the car to steer itself into the space.

Other sensor technology already making our cars safer comes in the form of lane departure warning systems. These vary in how much control they have of the vehicle from simply alerting a driver to their departure from a lane, to the car actively keeping itself in the centre of the lane. These generally work via a camera on the windshield that detects the lane markings and acts to keep the vehicle in lane until the driver indicates to move lane. If you have a vehicle with both lane centering assist and forward collision warning, you are already some way to an autonomous driving experience using technology that is readily available. Adaptive cruise control, whereby the vehicle can sense how close it is to the vehicle ahead and adapt its speed accordingly, is another feature that is becoming more commonplace as new vehicles come to market.

The next step up is of course a car with autopilot. For example, Tesla cars now come with sensor coverage made up of cameras, radar, and ultrasonics that enable you to use autopilot on motorways and single-lane roads providing the road markings are good quality.

Looking beyond the car, there is an increasing proliferation of technology being employed to reduce congestion and increase safety. Smart motorways use traffic management technology to increase capacity and reduce congestion. For example, Hard Shoulder Running schemes allow the hard shoulder to be opened during busy periods, and on controlled motorways the speed limit will be varied to control the flow of traffic. These changes are made in response to the traffic on the road at the time, thus rely on sensing technology to monitor the flow of traffic before making instructions clear to drivers.
Inductive loops, wireless magnetometers and other sensing technology currently being trialled are used to monitor this traffic flow and feed it into a MIDAS outstation. MIDAS (Motorway Incident Detection and Automatic Signalling) systems detect vehicles every 500m on the network to calculate volume, speed, and occupancy of each lane. Alerts for congestion and queuing traffic are created from this data using algorithms that calculate road occupancy levels.

The very same sensing technology is used in urban environments to optimise the flow of traffic at lights through adaptive traffic control (ATC). With ATC the traffic lights respond to where traffic is building so drivers aren’t kept waiting unnecessarily. This technology can be used at single junction level to improve pain points or city wide to optimise flow right across an urban network. Road safety can also be improved with this technology by detecting vehicles waiting to turn or travelling too fast and activating warning signs.

Smart parking is another area where sensors are already improving congestion. Here, the sensing technology can provide data that varies in granularity. Simple in/out counts can tell you whether there is a space in the car park or not. In multi-storey car parks the same technology can determine how many spaces there are on each level of the car park. The most granular data can be gained through sensors placed either in or above each individual space. This data is of use to retail and facilities managers, but can also help drivers when made available via Variable Message Signs (VMS) and mobile apps. Knowing where spaces are saves drivers queueing and endlessly circling car parks that are already full.

This kind of technology is beginning to be widely used across towns and cities as part of connected and smart city concepts. Clearly there are many benefits to deploying sensors to monitor the presence and movement of vehicles, but there is some debate over the invasiveness of this technology.
Invasive or non-invasive technology

The above examples all represent invasive technology. Inductive loops used to detect traffic flow on smart motorways or to provide in/out counts for car parks need to be dug into the road. Wireless technology such as that used to detect cars for MIDAS, ATC or monitor parking bay occupancy is easier to install, but still requires the road to be closed—if only for a short while.

Non-invasive technology, as the name suggests, doesn’t require the technology to be installed directly into the road. Instead sensors (in the form of cameras or radars) are installed above the area to be monitored. Video analytics of camera feeds is increasingly being used to detect and classify cars using computer vision and is slowly entering the market. The same applies to the parking sector with solutions that can recognise parking space occupancy with cameras mounted high above the car park.

Cameras and radars undoubtedly cause less disruption when being installed. They also detect vehicles in a larger area. However, they may fail to distinguish vehicles in heavy traffic and depend on line of sight, so are less accurate if obstructed or in low visibility conditions.

Alternatives to car ownership

In considering where we are now, it is worth casting the net wider to include alternatives to travelling in a car you own and drive (or autopilot). With cities becoming more geared towards cyclists and pedestrians and car owners facing congestion charges and parking that is increasingly difficult and expensive, it may be that the car features much less prominently on our roads of the future.

In the UK, both Milton Keynes and Greenwich have trialled driverless pods. In 2016 the Transport Systems Catapult demonstrated the capabilities of a self-driving pod on pedestrian areas around Milton Keynes train station. In early 2017, Greenwich introduced the first driverless pods to London to travel set routes as part of a trial. With plans to take payment for fares by 2019, such pods may become commonplace in cities very soon.

Alternatively, people may continue using cars, but without owning them, either through ride-sourcing companies such as Uber and Lyft or through car sharing schemes. Manufacturers including Ford and BMW are now offering car share schemes and researchers at the University of California, Berkeley found an increase in car sharing memberships across all continents from 2006 to 2014.
Despite our road safety and congestion issues, it is hard to imagine us falling out of love with the car any time soon. The most recent statistics from the Department for Transport (DfT) released for July to September 2016 show the highest number of new car registrants ever recorded at 893,000 and total of 37.4 million vehicles were licenced for use on Great Britain's roads at the end of September 2016.

Autonomous vehicles seem the perfect solution; we can still take a personalised route in our own space, while benefitting from the promised improvements in road safety and congestion. Less obvious is the level of autonomy we will go to.

The widely accepted levels of driving automation published by SAE International defines six levels of automation where each level requires less and less driver intervention:

**Level 0: No Driving Automation**
The driver is responsible for all aspects of the vehicle.

**Level 1: Driver Assistance**
The vehicle has functions that work with the driver. For example, lane drift assistance.

**Level 2: Partial Driving Automation**
The vehicle can perform some autonomous functions. For example, parking without any intervention from the driver.

**Level 3: Conditional Driving Automation**
The driver is expected to take back control, but the vehicle can control all necessary functions to travel safely, provided the environmental is appropriate.

**Level 4: High Driving Automation**
This covers a self-driving vehicle. It is capable of navigating without human intervention, but the driver can still take back control of the vehicle.

**Level 5: Full Driving Automation**
This vehicle cannot be controlled by a driver—no steering wheel is fitted. Instead the vehicle operates completely autonomously.

**Where are we going?**
Non-autonomous cars (level 0)

This is where we are and arguably won’t be for much longer. At the present time, non-autonomous vehicles still represent the lion’s share of vehicular traffic on the roads. However most new vehicles sold within the last five years tend to offer features on SAE levels 1-3. Given the life cycle of most vehicles is generally thought to be between 10-12 years, it is easy to see how within the next five years a level 3 partially automated vehicle may become the dominant class of vehicle on our roads.

Autonomous cars (levels 1, 2 and 3)

It could be that the higher levels of automation never reach mass adoption and we stay in a more familiar place with autonomous vehicles. Autonomous vehicles look a lot like our existing cars and allow the driver to switch autopilot on and off. In such a vehicle, you may choose to drive for pleasure at the weekend, but enable autopilot while commuting to allow you to work in your car. The autonomous car market is likely to work like our current car market where individuals own their cars and leave them parked at their destination when not in use.

Tesla are an example of a car brand with autopilot features available now. Currently, the system is in beta and constrained by the quality of the road markings where the car is driving. But as a concept it works and some early adopters are benefitting from driving without the need for such intense concentration when on the motorway, supposedly allowing them to be more alert and ‘fresh’ when they reach the point of exiting the motorway and need to take full control again.

Self-driving cars (levels 4 and 5)

A self-driving car differs from an autonomous car by being able to complete a whole journey without the need to switch between self-drive and autopilot modes. In theory, you’ll be able to summon your car to your door, tell it where you want to travel to (or have the car synchronise with your calendar), the car will select the most efficient route and take you to your destination before parking itself (or in a car sharing scenario, go and collect the next passenger). According to Waymo, the Google self-driving car project “you’ll be able to get where you want to go at the push of a button—without the need for a person at the wheel”.10

Road traffic incidents will decrease by removing the possibility for human error. Congestion is also likely to reduce. Without the requirements for reaction times, stopping distances will decrease and cars will travel closer together. Vehicles will be able to sense what is happening on the roads much further ahead and communicate with other vehicles on the road to know what is coming. Junctions will also operate more efficiently as cars will be able to travel closer together and won’t be limited by one human anticipating the actions of another—vehicles will communicate directly with one another.

However, these gains could be negated by more people using cars if it becomes an even more popular mode of transport without the need to watch the road while travelling.
Are we nearly there yet?

Some would argue we are already there; the technology to achieve what has been described above is already on the road. Since Google started the Waymo project, their vehicles have driven more than 2 million miles\(^1\). Back in 2015, Chris Urmson, former CTO of Self-Driving Cars at Google, joked that his son wouldn’t be needing a driving licence in 2019\(^2\).

And the technology isn’t just available for those who live in California; travellers to Heathrow Terminal 5 have been able to get from the car park to the terminal in a self-driving, electric pod since 2011. The artificial intelligence from these pods is expected to operate a self-drive vehicle all the way from London to Oxford as soon as 2019\(^3\).

Other trials are being run by car manufacturers with the likes of Nissan testing their prototype autonomous Leaf in London and Volvo now seeking volunteers to trial their autonomous vehicles in London as well as Gothenburg\(^4\). The UK government is committing to these future scenarios with permissive regulations to allow such trials and investment of over £100million\(^5\) available for driverless and low carbon projects.

Is our destination further away than we think?

We would argue that we are still a long way from self-driving cars and the journey there is going to be a bumpy one. It’s easy to get carried away in our ITS echo chamber and believe Chris Urmson when he says his son won’t need a driving licence in two years’ time. But in reality, it’s going to be decades before people scrap their non-autonomous cars and start travelling regularly in self-driving cars. Here are some of the reasons why:

1. **The number of vehicles to replace**
   The average age of a car in the UK is 8 years and those who buy a different car every year tend to buy used cars, so any change in vehicle technology takes years to penetrate the market. As always with new technology the initial costs are high—a certain level of adoption needs to be reached before manufacturers can benefit from economies of scale and pass these savings on to consumers. Therefore, we expect the high price associated with the most autonomous cars available today to be maintained for decades to come and so the average household in the UK simply won’t be able to afford one.

2. **Public perception of autonomous vehicles**
   In a recent survey, 70% of motorists reported concern over the reliability of the software autonomous vehicles will use and 66% of motorists reported fearing that the computer system controlling the car could be hacked\(^6\). We also need to consider that people outside the industry are simply less interested than we are. A 2017 report by Deloitte found that, despite interest in self-drive technology increasing, only 43% of US consumers are interested in even limited self-drive features\(^7\).
3. **Willingness to share the network**

In addition to concerns over being in an autonomous vehicle, some drivers may be hesitant to share the network with these vehicles if they perceive them as less safe. Vice versa, those who invest in a high level of autonomy may not want to share the network with vehicles driven by humans.

It has been suggested that vehicles operating at level 4 and 5 autonomy may need designated lanes or whole roads to separate them from levels 0-2 autonomy\(^1\). That additional roads would be built just for autonomous vehicles is hard to imagine in the UK; even if there were the necessary funding, there simply isn’t space.

One reason for not wanting to share the network is ambiguity around who is responsible if a self-driving vehicle crashes. This will become clearer as the level of automation increases and the vehicle manufacturer becomes responsible, but while vehicles require the human driver to pay attention, the issue of where responsibility lies remains ambiguous\(^2\).

The UK government introduced legislation earlier this year to clarify the issue of insurance of autonomous vehicles. Per the Vehicle Technology and Aviation Bill (HC Bill 143)\(^3\) insurers are liable for accidents caused by an autonomous vehicle that is driving itself, but the insurer can then try to recover the cost from the manufacturers.

4. **Lack of consistent protocols**

For self-drive cars to achieve the potential safety and congestion benefits they need to communicate with each other and the external environment. This will only work if they use consistent communications protocols.

Smart city initiatives around the world are still using a variety of communication protocols: 4G, Wi-Fi, LoRaWAN, NFC, Bluetooth... adopting a primary protocol will
allow sensors and devices to be developed and integrated more efficiently, but we are still waiting for one to win out. It’s the VHS vs Betamax of this decade and needs to be resolved before self-drive cars enter the mass market.

5. **Data sharing and privacy**
   We already have considerable data on traffic flow, journey times and planned roadworks. As experts in vehicle detection and transforming vehicle detection data into actionable intelligence we understand the huge volume of data available on what traffic is where at any given point. However, this data has remained siloed due to issues of ownership, consent, and privacy.

   Autonomous vehicles will need access to this data as they communicate with other vehicles, navigate roadworks, and plan journeys. For this to happen drivers need to consent to sharing personal data and organisations and transport authorities need to protect privacy while sharing data sets with each other.

6. **The need for maps**
   For self-driving cars to be used routinely, they’ll need to work every day—not just in good visibility. A self-driving car that cannot sense the road in rain, fog, or snow will not provide a true alternative to non-autonomous cars. The solution could be in 3D maps that provide additional intelligence on the environment the car is operating in as well as providing satellite navigation. However, creating these detailed, 3D maps represents a monumental challenge.

7. **The state of the roads**
   Remember Heathrow’s driverless pods? They rely on high curbs to guide them between the car park and the terminal. Current autonomous cars are similarly reliant on road markings to navigate safely; their cameras need to be able to sense white lines to remain in lane or move from one to the other. As a supplier of Active and Intelligent Road Studs we understand the challenges Local Authorities and Highways Agencies are facing in trying to keep road markings in good condition. Without substantial changes in funding, we cannot see how the entire network can be maintained in a condition that is readable for autonomous vehicles.
Where will we go along the way?

While it is possible that we will leap straight into self-driving cars, we would suggest the more likely route will include adoption of increasing levels of autonomy en route to self-driving cars. This route will take longer, we suggest at least 20-30 years, but we think it is much more likely. While those developing self-driving cars are quick to point out the issues in human behaviour that lead to the high numbers of people killed or seriously injured on the road, they forget the human decision making biases that will slow the adoption of this new technology.

People are naturally resistant to change and hesitant to adopt new technology. It may have felt relatively fast, but it took more than 10 years for both mobile phones and the internet to exceed 40% penetration in the United States. These examples are comparable to self-driving cars in their reliance on upgrading infrastructure to enable people to use the technology and the huge impact they have had on people’s day-to-day lives. However, both are significantly lower cost to the consumer and had to overcome a lower level of perceived risk to personal safety.

This is why we think adoption will be slow and that organisations and industry will adopt this technology first.

Shared mobility

While people could be reluctant to buy this technology, we believe people will be willing to use it on a pay-as-you-go basis. Mobility as a Service (MaaS) is the idea that you use a single app to plan and pay for your entire journey, regardless of the modes of transport utilised. This could include taking a self-driving car or pod as part of a larger journey.

In this scenario, self-driving vehicles replace car ownership and people use the shared resource as and when they need to. This future scenario presents a considerable risk to car manufacturers if personal car ownership falls, but an opportunity to be the manufacturer of choice for delivering self-driving vehicles. General Motors, for example, plans to deploy thousands of self-driving cars in 2018, exclusively for use by the ride-sharing company, Lyft.

Similarly, fleet operators will likely offer higher levels of autonomy sooner. This means you will be able to hire an autonomous car sooner than buying one. With long or short-term car hire, the fleet managers will be better placed to deal with insurance and maintenance requirements of autonomous vehicles and will benefit from economies of scale.
The mining industry has already adopted autonomous vehicles. RioTinto are already using vehicles that combine information from sensors, GPS, and control from remote operators in their mining operation. They don’t have to overcome the issue of getting autonomous vehicles allowed and insured on public roads and so they already have two mines where all iron ore is moved using driverless trucks.\textsuperscript{24}

The freight industry may also be an earlier adopter. Platooning is the term used to describe multiple vehicles connected in a convoy, travelling as one. The lead vehicle sets the speed and the vehicles following have their braking and acceleration controlled by the lead. They still have a driver who is responsible for steering, but the vehicles can travel nose-to-tail, so take up less space on the road and benefit from reduced aerodynamic drag. This will reduce the fuel costs for freight companies and could provide wider road safety and congestion benefits. However, some suggest it could attract more freight onto the road, thus increasing congestion.\textsuperscript{25}
We will need to wait and see how much of what we have discussed here becomes a reality and how soon this happens.

Self-driving cars seem like the most likely solution to our road safety issues, and perhaps we’ll be wrong and they won’t take as long as we think to develop or reach market saturation. But what if we’re right? Can we wait 20-30 years for this revolution? With current road safety statistics that’s 36,200-54,300 deaths in the UK alone.

We need to continue to be excited about self-driving cars and lobby for the investment in their research and development, but we also need to address the present issues on our roads with the technology we have available now.

Road safety

There are technologies available that can help us address our road safety record right now. For example, Clearview Intelligence provide:

- **Junction safety solutions** that alert drivers to vehicles waiting to turn, travelling too fast, or reduce lane transgression. Junctions are the areas of the network where accidents are most likely to happen. Our junction safety solutions alert drivers to vehicles turning ahead or that they are travelling too fast, which drastically reduce the number of incidents at junctions. Similarly, our multi-award winning installation of Intelligent Road Studs on the A720 Sheriffhall roundabout has been proven to reduce transgression by >50%.26.

- **Solar powered active road studs** that provide all-weather lane marking and increase visibility of the road ahead to 900m can also significantly improve road safety. A recent installation on the A1 in Scotland has been described as “improving night-time visibility beyond all recognition” by Councillor Michael Veitch.

- **Vehicle detection technology** that facilitates advanced warning of an incident on the road ahead through MIDAS. Knowing there is an accident or queue ahead is vital to ensuring they can avoid the incident safely.
Congestion

We already understand what traffic is flowing where, what we need to do is make this intelligence available to drivers and share data across companies and authorities. Clearview are working to reduce congestion through:

- **Monitoring journey times** and sharing this intelligence with drivers via variable message signs. This allows drivers to find an alternative route and minimises frustration if they know how long they will be held up for.

- Maximising traffic flow at signalised junctions with wireless vehicle detection to enable MOVA, SCOOT, and ramp metering. Having the traffic signal respond to where the traffic is waiting or building around traffic lights means that people aren’t kept waiting unnecessarily and traffic flows as freely as possible.

- Monitoring **traffic flow** on the strategic road network to enable operators to address any problem areas.

- Facilitating dynamic lane marking so that contraflows can be invoked or lanes added as required when congestion is building minimises congestion and allows traffic to be diverted around blockages in the road ahead.

These are some solutions that Clearview Intelligence already offer to combat present road safety and congestion problems.

At the same time as we are working to revolutionise the driving experience of tomorrow, we must make journeys work today.

The journey starts here
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