SWINBURNE UNIVERSITY OF TECHNOLOGY

24 March 2017

Committee Secretary
Standing Committee on Industry, Innovation, Science and Resources
PO Box 6021
Parliament House
Canberra ACT 2600

Subject: Inquiry into the social issues relating to land-based driverless vehicles in Australia

Thank you for the opportunity to provide a submission to the above inquiry.

The inquiry comes at an important time and acknowledges the challenges facing our societies, governments, policymakers and regulators in planning ahead for self-driving vehicles to capitalise on their social benefits and minimise their adverse impacts. This task is particularly challenging amidst the fast-moving innovations and relentless breakthroughs in new technologies and scientific advances which continue to unfold on many fronts related to autonomous driving.

This submission provides some insights on the changing landscape of urban mobility and how self-driving vehicles can be turned into a positive influence if they are planned for as part of a shared mobility or new form of public transport. The submission also touches on safety, regulations, liability, privacy, access and equity issues.

Thank you for your time in considering this submission and I would be available to meet with you and provide further details or clarify any issues in the submission.

Yours sincerely

[redacted]

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Inquiry into the social issues relating to land-based driverless vehicles in Australia

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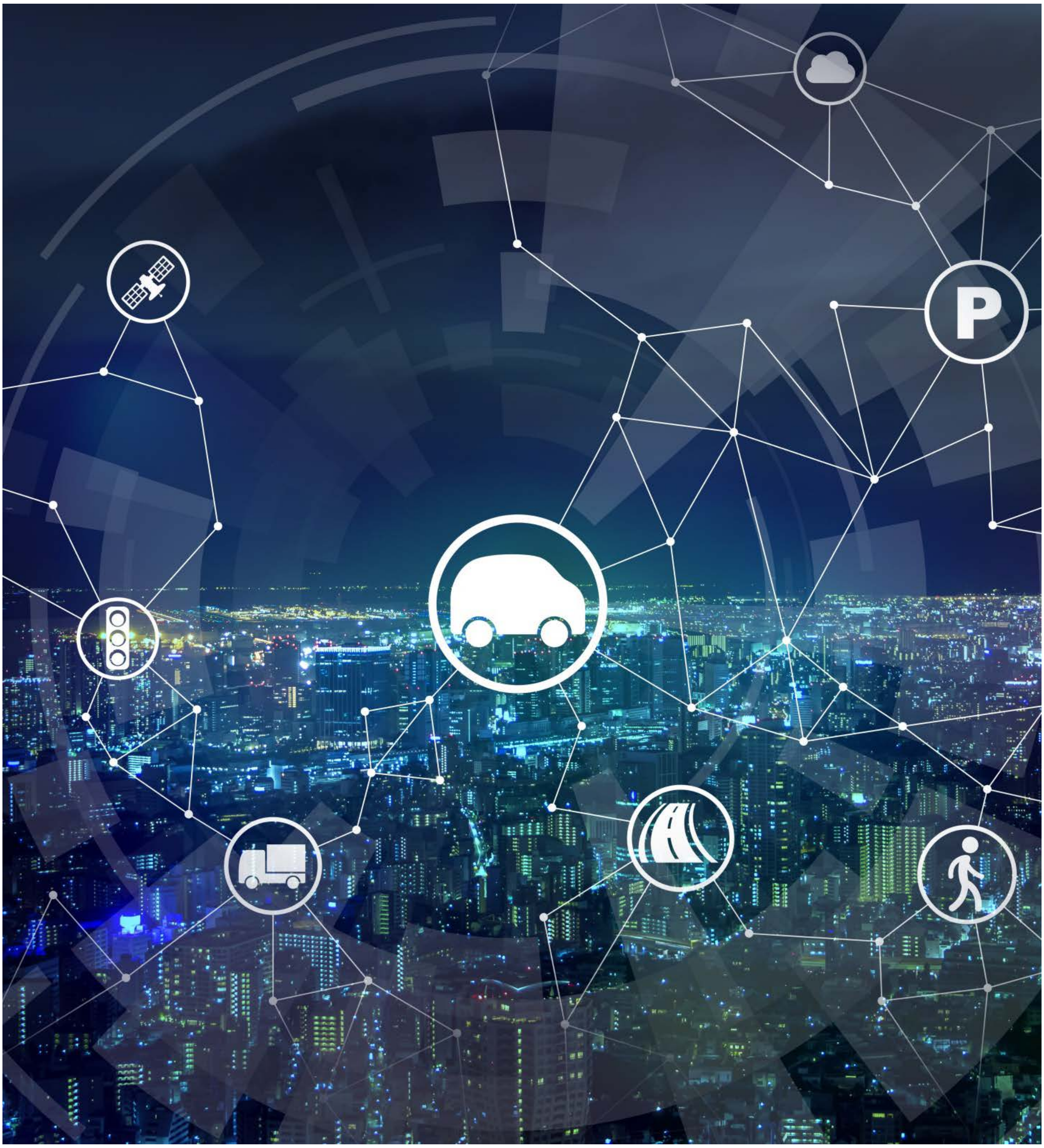
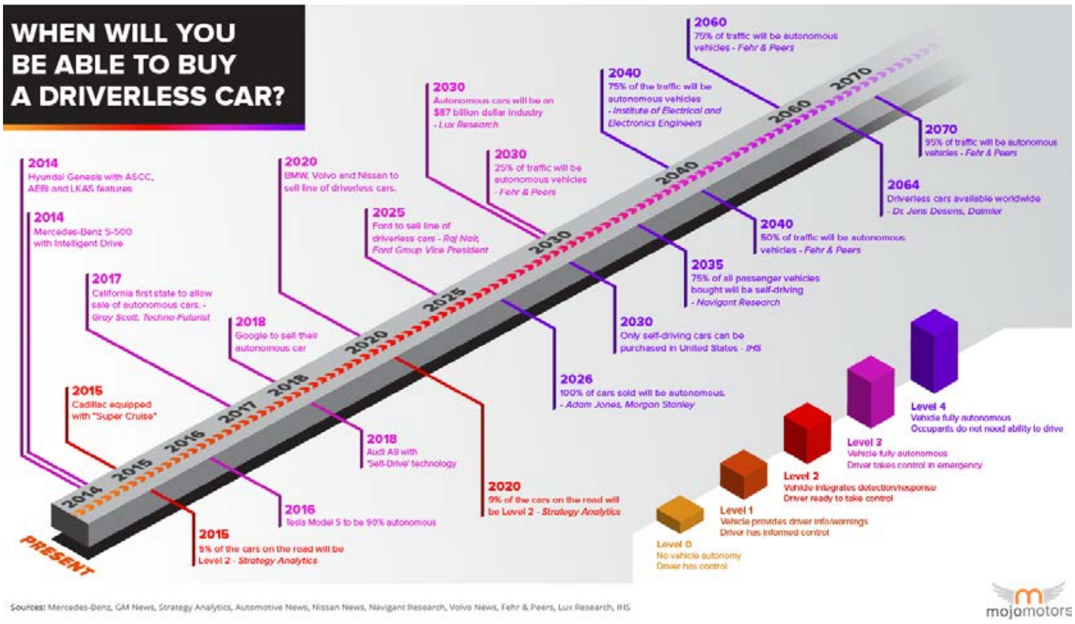


Background

Vehicles which drive themselves may very well be on our roads within 5 years. Vehicles with varying levels of self-driving capabilities are already available to consumers today, and the transition to full autonomous operation and widespread adoption is expected to be gradual taking up to 20-30 years. The pace of change will depend in part on acceptance by consumers, regulators and the wider industries which may be disrupted by the changes.

Although there is yet no consensus on the commercial maturity of vehicle automation, some manufacturers have announced the arrival of highly automated and possibly fully automated vehicles by as early as 2019. Others have proposed different timelines extending to 2030, with Japan's motor industry represented by Toyota and Nissan having pegged 2020 as the year they hope to release fully autonomous cars to the public. Some of the technologies are here today, some may be distant, and some will depend on specific technical innovations or particular policy choices**.**



Source: http://www.mojomotors.com/blog/when-will-you-be-able-to-buy-a-driverless-car/
Timescale of Introduction of Autonomous Vehicles – mojomotors

Although fully autonomous vehicles are still a few years away, they have already started to shape some visions for a mobility transformation driven by four key converging forces: Vehicle electrification, automated self-driving, mobile computing and on-demand car and ride sharing. The coming together of these powerful trends is shaping a different urban mobility future inspired by a vision of reduced road injuries, reduced car ownership and low carbon living. The introduction of these vehicles, however, presents some big challenges to our societies and their potential impacts are still not fully understood. There remains many questions, for example:

- Will they ultimately improve road safety, and by how much?
- Will they reduce congestion or are they likely to induce more demand for travel?
- How will they impact the vehicle kilometres of travel per capita?
- Will they increase or decrease urban sprawl?
- How will the automation of driving impact employment for truck drivers, couriers and taxi drivers?
- How will they impact urban form, parking and public spaces?
- What impact will they have on public transport?
- Will they reduce or increase emissions?
- How will they impact car ownership?

This submission discusses some of the key social and economic impacts surrounding autonomous vehicles, and how they are likely to influence the transport and mobility industries and marketplace now and into the future. The submission first presents the changing landscape of urban mobility, the opportunities afforded through smart vehicle technologies, the current state of play, potential future impacts, and how we can plan today to ensure that their negative impacts are minimised and that they are used to support rather than hinder urban mobility.

The changing landscape of urban mobility

Conventional approaches	Emerging approaches
Supply and capacity	Demand management and resilience
Focus on mobility	Accessibility
Street as road for vehicles	Shared between all modes
Physical dimensions	Social dimensions
Vehicle-oriented	People-oriented and customer-focused
Motorised transport	Hierarchy of modes
Travel as a derived demand	Travel also a valued activity
Minimisation of travel times	Reliability of travel times
Petrol taxes/vehicle registration fees	User-pay models
Private car ownership	Car-sharing and ride-sharing

Source: Dia, H. (2017). Low Carbon Mobility for Future Cities: Principles and Applications

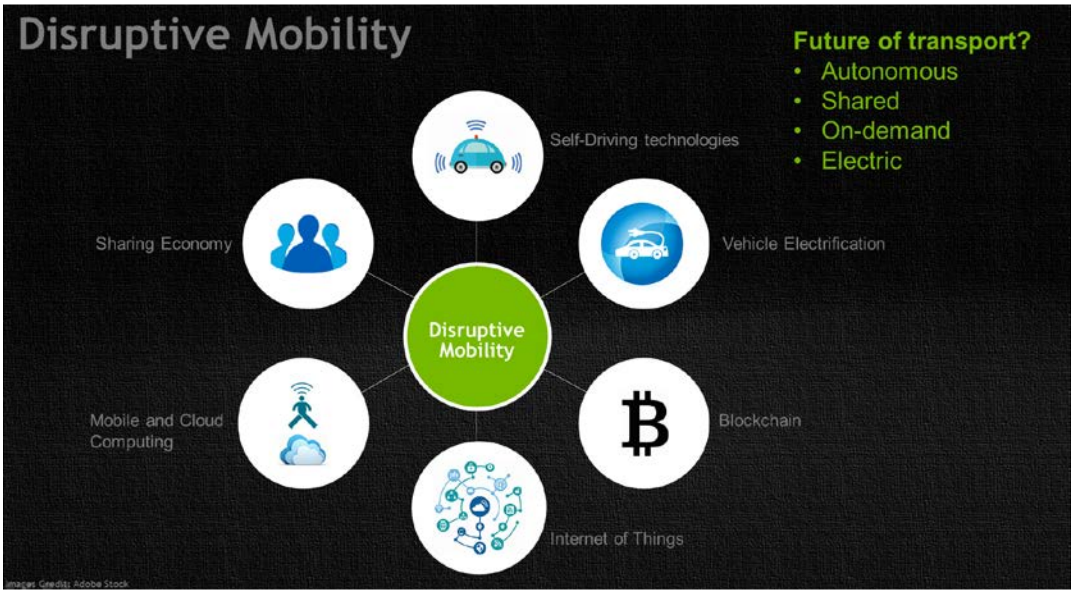
There's been some renewed thinking in recent years about how we provide mobility and access to jobs and economic opportunities in our cities. Some of these trends are likely to help with the introduction of automated vehicles, while others may actually hinder their deployment. Some of these emerging trends and approaches to urban mobility have been partly due to a recognition that past practices have met with limited success and that new approaches are needed. And some of it is due to the widespread use of technology and innovations, and through the changing context of how we should plan and build future cities – smart, healthy and low carbon.

These encouraging trends recognise that the ultimate goal of mobility is to enhance access to jobs, places, services and goods. The narrative is changing – the focus is shifting from 'transport' to 'mobility', and more emphasis is given to 'accessibility'. Rather than focusing on the infrastructure required to move people and goods, the focus is on providing the mobility needed to access economic opportunities. And instead of giving priority to building additional infrastructure, the focus is shifting to understanding and managing the demand for travel, maximising efficiency of existing assets, and improving their reliability and resilience.

These trends are also increasing the focus on the social dimensions of transport to ensure that mobility benefits are equally and fairly distributed for all income groups. Probably one of the most significant trends in recent times has been the challenge to car ownership models, and in particular car sharing and ride-sharing initiatives that have been made easier and more popular worldwide through mobile technology platforms.

Another megatrend that will have a profound impact on mobility is the rapid urban population growth. Today, our cities make up only 2% of the earth surface, yet they accommodate around 54% of the world's population, account for 75% of the energy consumption and are responsible for around 80% of the emissions and pollution. And the percentages are growing. By 2050, two thirds of the world population will be living in urban areas. Transport energy consumption is also forecast to double to meet the travel demand in the world's future cities. As more people move into cities, we need to think of new solutions to make transport more sustainable.

The opportunities



Technology and innovations continue to surprise us with their fast pace of breakthroughs and advances which continue to unfold on many fronts. There are at least six forces which will probably have big impacts on urban mobility over the next 5-20 years. From self-driving vehicles and the sharing economy, through to vehicle electrification, mobile computing and blockchain technologies, each of these trends is quite significant on its own. But the convergence and the coming together of their disruptive forces is what will create real value and provide innovations. Once converged, they are expected to enhance the travel experience for millions of people and businesses every day.

Vehicle technologies and autonomous driving functions

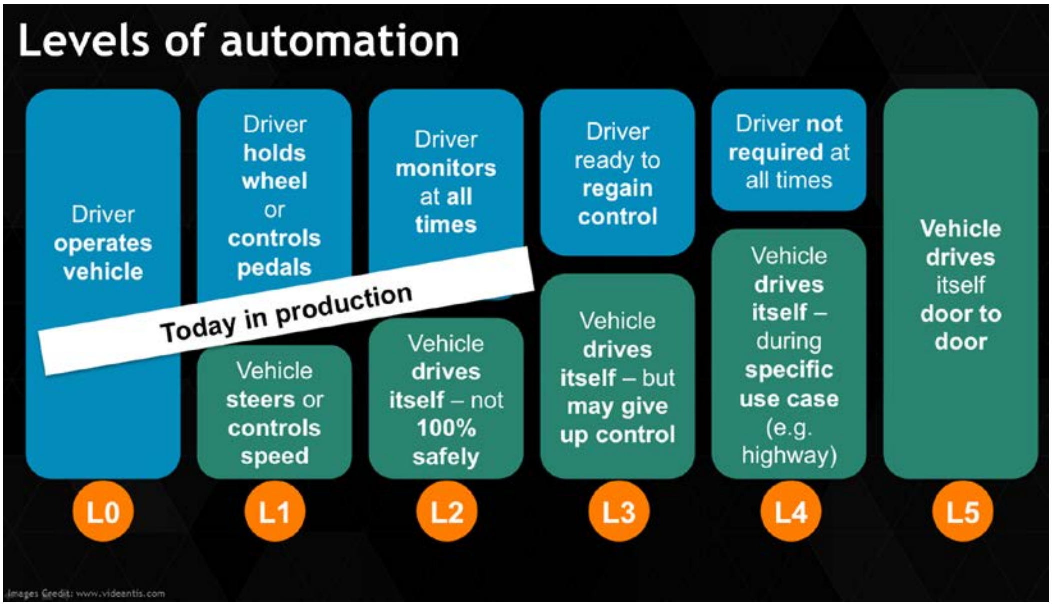
Vehicle automation is part of a much larger disruption in automation and connectivity. Autonomous vehicles include a range of sensors, radars and cameras which work together to provide emergency braking, lane departure warning, cross traffic warning, pedestrian detection, collision avoidance, blind spot detection, rear collision, surround views and traffic signal recognition in addition to other functions.

The technology for automated driving is quite mature. Currently available prototypes of automated vehicles apply state-of-the-art sensors to gather information about the world and surroundings. Combined with high accuracy maps, they allow on-board systems to identify appropriate navigation paths, as well as obstacles and relevant signage. The vehicles also include increasingly sophisticated Artificial Intelligence (AI) algorithms to process sensor data and control the vehicle.

Car manufacturers and technology companies are working towards a vision of fully autonomous vehicles, and that vision includes taking the human driver out of the loop. They have already made huge advancements in this space. For example, the self-driving software that has been developed, based on “deep neural networks”, includes millions of virtual neurons that mimic the brain. The on-board computers have impressive supercomputing power packed inside hardware the size of a lunchbox.

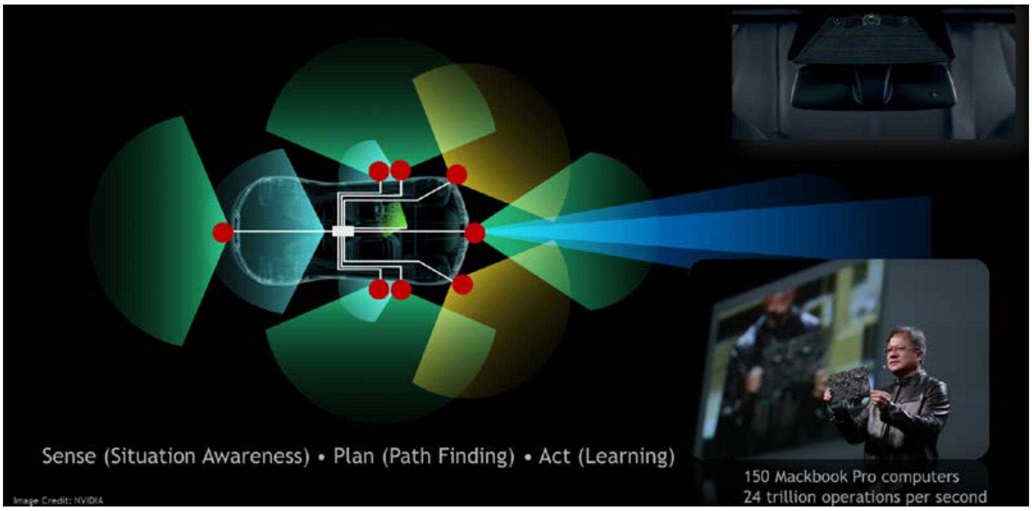
The neural nets do not include any explicit programming to detect objects in the world. Rather, they are trained to recognise and classify objects using millions of images and examples from data sets representing real-world driving situations. The computational power of on-board computers and processors have permitted this level of development and allow for the processing to be run and acted upon in real time.

The road to full autonomy



There are 5 levels of automation that are now widely accepted in the industry. It is widely speculated that we will soon have Level 2, but the real disruption that will totally remove the driver and transform the economics of mobility, comes at Level 5. The journey to Level 5 is a long one that has only just begun. Full automation is difficult because it requires solving problems beyond technology. A fully automated vehicle needs to handle all situations including its own equipment failure. In commercial aircrafts, for example, equipment failure is handled through multiple redundant systems which makes the aircraft systems very complex and also very expensive. No one knows yet how to scale an aircraft's level of redundancy to an affordable mass-market vehicle. It is also often argued that the biggest barrier to Level 5 automation is Level 3. The prospects for L3 are probably in doubt today because of the problem of recapturing the attention, in an emergency, of a driver who has zoned out or who has fallen asleep. It is important that governments monitor these developments because they would impact the speed with which these vehicles could be introduced in our cities.

The technology today



Today, the sensing technologies and devices are quite mature. Last year, Tesla announced that every car shipping from its factory will have the hardware needed to fully drive itself. A total of 8 video cameras that give the vehicle 360 degree peripheral vision up to 250 metres range. One radar, 12 ultrasound sensors; and a liquid-cooled supercomputer the size of a lunchbox. The on-board computer can perform more than 24 trillion operations per second, which is equivalent to 150 MacBook pro computers put together! But still no mention of redundancy. If any of these critical components fails at L4 or L5, what would the vehicle do? For Telsa drivers, this also doesn't mean they can flick a switch and turn self-driving on yet. Two things are not ready yet: First, the self-driving software still has to be validated before the new features can be enabled, and second, the regulators will have to approve the system. Even if consumers buy the technology today, it is not clear when they will be able to use it.

The sensor technology on its own has no value without the self-driving software which will become a key differentiator for self-driving vehicles. The software is based on artificial intelligence and machine learning algorithms. It is calibrated by showing an artificial neural network examples of hundreds of thousands, or even millions, of videos and images from real-life conditions so that it can recognise and respond to different situations.

Potential impacts

Over the past few years, self-driving vehicles have captured people's imaginations and have also inspired some visions of a different future, as well as a great deal of hype. Considerable research still needs to be done to distinguish between the hype and reality, particularly their likely impacts on road safety, urban mobility, congestion, public transport, insurance and car ownership. There is also a wide range of social, economic and cyber security issues that must be addressed to ensure that barriers are removed; the benefits are maximised and any negative impacts are reduced. This submission addresses some of these impacts including:

Road safety	**Road users**
Mobility	**Infrastructure upgrade**
Congestion	**Infrastructure investment**
Public transport	**Regulations**
parking	**Ethics**
Active transport	**Cyber security and privacy**
Freight	**Jobs and labour**
Insurance	**Pollution and emissions**
Liability	**Urban planning and land-use**
Car ownership	**City finances**
Vehicle sales	**New business models**

Impact on road safety – the moral imperative

There is general agreement in the literature that vehicle automation can have a positive impact on road safety. Nearly 1.2 million people die in road traffic crashes worldwide annually. That is the equivalent of 15 wide-body aircrafts, each with a capacity of 200 passengers, falling out of the sky every single day and killing everyone on board. This wouldn't be accepted in air travel and it is disturbing that it continues on our roads today. In addition to the pain, suffering and unnecessary loss of life, these crashes are estimated to cost countries between 1%-3% of their gross national product - more than $500 billion each year globally. Staggeringly, some 70%-90% of motor vehicle crashes are caused at least in part by human error.

A large proportion of these crashes could potentially be avoided through vehicle automation and there is considerable logic in removing humans - the key source of distraction and collisions- from the driving equation. Driven by AI algorithms, these vehicles may ultimately reach a level where they do not make errors of judgement the way a human driver does, and they won't take as long to make crucial split-second decisions. They will not drive drunk. They will not get distracted by SMS and smart phones. And they will not fall asleep behind the wheel. In addition, cars' sensors will be able to see objects from very far, in every direction, in the most unforeseeable scenarios even using radars, and always calculating the best course of action in milliseconds. If vehicle automation delivers on the promise to eliminate the vast majority of fatal traffic accidents, the technology will potentially rank among the most transformative public-health initiatives in recent times.

Impact on car ownership

A number of research studies show that car ownership is increasingly making less sense to many people, especially in urban areas. These studies show that a car is an expensive proposition. Beyond the cost of buying one, there are many costs of ownership, including fuel, maintenance, insurance, and such. Autonomous technology will no doubt make new cars more expensive, but some of that expense can be mitigated by reducing the need for each family to own small fleets of them. This is already happening in some countries - in the US, for example, the rates of motor-vehicle licensing are already plummeting among young Americans.

Other studies have reported that consumers are finding it difficult to justify tying up capital in an under-utilised asset that stays idle for 20-22 hours every day. Morgan Stanley's research shows that vehicles in the US are driven just 4% of the year – a considerable expense considering that the average cost of car ownership is nearly $9,000 per year. These studies have argued that autonomous on-demand vehicle sharing may provide a sensible option to a second car for many people and as the trend becomes more widespread, they may also begin to challenge the 'first' car.

Results from a recent study by the International Transport Forum which modelled the impacts of shared driverless vehicle fleets for the city of Lisbon in Portugal demonstrate the impacts on car ownership. The results showed that the city's mobility needs can be delivered with only 35% of vehicles during peak hours, when using shared driverless vehicles complementing high capacity rail. Over 24 hours, the city would need only 10% of the existing cars to meet its transportation needs. Other studies have shown that dynamic ridesharing using driverless vehicles will increase vehicle utilisation up to eight hours per day.

Impact on road users

In addition to reducing driver stress, advocates of driverless vehicles argue that it would free passengers from the task of driving and would provide a personal mobility option to people unable or unwilling to drive. A study by McKinsey estimates that Autonomous Vehicles could free as much as 50 minutes a day for users, who will be able to spend their travel time working, relaxing, or accessing entertainment. But there are also much wider impacts such as providing mobility options for the aged and younger people. Shared autonomous mobility is likely to change the number of passengers that pass through every vehicle—including a vast untapped market that doesn't drive today. For example, the higher levels of autonomy, when the vehicle does not require a human driver, would enable transport and mobility for the blind, disabled or those too young to drive. The benefits for these groups would include independence, reduction in social isolation, and access to essential services and opportunities. These same benefits would return mobility to millions on the margins.

Impact on infrastructure

The Google cars are an example of self-driving technology that does not require any special instrumentation of infrastructure for successfully operating the vehicles. Cameras in the vehicle leverage image recognition to help the car read signs, traffic signs and other elements in the driving environment. Other automobile manufacturers are making efforts in the same direction and focusing efforts on modification and expansion of vehicle systems to assist the automated driving. However, the foreseen step-wise introduction of automated vehicles in traffic will face a transition period where the coexistence of conventional and highly automated vehicles will have to be managed in order to ensure uninterrupted levels of safety and efficiency. Instrumentation of road infrastructure will still play a major role in managing this transition period.

Impact on infrastructure investment

At the international level, there have been large investments in the Cooperative ITS (C-ITS) space. This includes vehicle-to-vehicle and vehicle-to-infrastructure communications and associated technologies. These investments will continue to be made over the next 15-20 years and will remain a priority until the market approaches full autonomy and very high autonomous driving market penetration rates. As long as there is a mix of human-driven and autonomous vehicles, C-ITS investments will remain important to ensure safety of the travelling public. It is premature at this stage to speculate what might happen nearing full autonomy as the enabling technologies are developing very fast.

Impact on intersection control and congestion on urban arterials

A team of researchers at the University of Texas in Austin are investigating how road authorities can manage autonomous vehicle traffic at intersections. Their project, Autonomous Intersection Management or "AIM", is developing a multi-agent framework for managing autonomous vehicles at intersections. The researchers argue that in the long-term, it will make more sense to have intersection control mechanisms that offer more precise control, better sensors, and quicker reaction times. The researchers claim that intersections of the future will not need traffic lights or stop signs. Instead, the autonomous vehicles' movement around intersections will be managed by a virtual traffic controller. The research team proposed an intersection control system using sensor technologies, a standardised communication protocol, and the ability to deploy gradually over time to safely accommodate a mix of autonomous and human-driven vehicles in changing proportions. The researchers demonstrated that their system can decrease traffic delay when most vehicles are semi-autonomous, even when few (if any) are fully autonomous. Their incremental deployment study showed that traffic delay keeps decreasing as more vehicles employ features of autonomy.

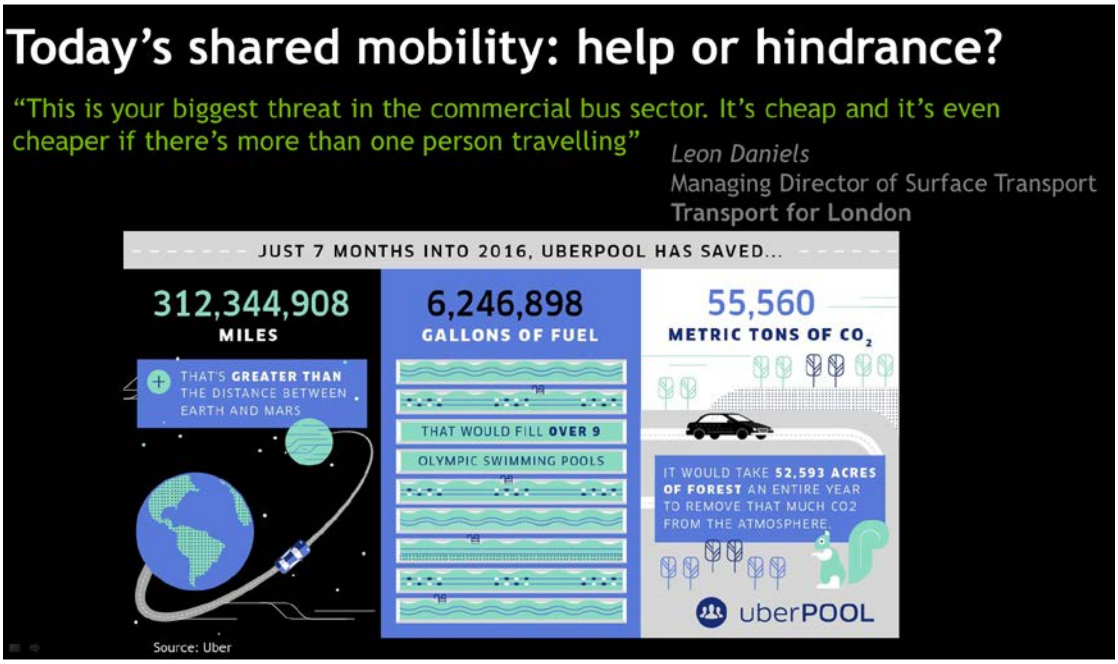
Impact on mobility, parking, public spaces and congestion

Shareable autonomous appear like a promising proposition for decreasing the overall number of private cars. This would potentially also address the problems of oil dependency, pollution, promote higher utilisation rates and reduce parking lot sprawls.

To date, few studies have dealt with the implications of shared autonomous mobility systems. A study for the city of Lisbon, for example, showed that shared self-driving fleets can deliver the same mobility as today with significantly fewer cars. When serviced by ride-sharing TaxiBots and a high capacity public transport underground system, 90% of cars could be removed from the city. Even in the scenario that least reduces the number of cars (AutoVots without underground), nearly half of all cars could be removed without impacting the level of service. Even at peak hours, only about one third of today's cars would be needed on the roads (TaxiBots with underground), without reducing overall mobility. On-street parking could be almost removed with a fleet of shared self-driving cars, allowing cities the size of Lisbon to reallocate 1.5 million square metres to other public uses. This equates to almost 20% of the surface of kerb-to-kerb street area (or 210 football pitches).

A study currently being undertaken by researchers at Swinburne University of Technology has shown similar results for a case study in Melbourne. The study area had around 3,000 single-occupant private vehicle trips during the AM peak. The results showed that this would lead to 88% reduction in the fleet size, 83% reduction in the space required for parking but at an increase of 10% in total vehicle kilometres travelled (VKT). It should be pointed out that these results can be achieved today if we can get people to car-pool (we don't need to wait for self-driving vehicles). The key difference with autonomous vehicles when they arrive, however, is that they will lower the cost substantially because there will be no driver cost. This will create other issues and concerns about the loss of jobs for drivers and this is something that we need to discuss as a community to determine the kind of future we want, and how to address the negative impacts of automated technologies. The key, then, in the case of self-driving vehicles, is that they will need to be shared - otherwise we risk a dystopia scenario where these vehicles would simply reinforce existing norms and make congestion worse.

Impact on public transport



So what does all of this mean for public transport?

Consider first the situation today with ride sharing and in particular UberPool, a service available in a number of cities around the world. Transport for London believes it is a big threat to the commercial bus sector. Uber claims that more than 700,000 driving miles were saved by UberPool in London just in 6 months. The appeal of the service is that it is affordable, on-demand, and available any time of the day. If these numbers are true (they cannot be verified because the data is proprietary), they represent big savings and can potentially compete with bus services in the outer suburbs particularly during off-peak periods. And we are seeing this already. In the U.S., local governments are partnering with ridesharing companies to provide first and last mile services to take travellers from their homes to nearby transport hubs. Some of these local governments have since cancelled fixed bus line services altogether. One local government has reported savings of $40,000 per month using this approach.

But with full autonomy, the situation could be different. Full automation of buses, for example, could be much easier to achieve than for private vehicles. When the situations in which autonomous vehicles must operate on shared road space are limited, this would greatly increase their feasibility. Fixed route buses with high ridership are perfect examples of this possibility. They run on pre-set paths in a narrow range of situations and in some cases they have their own exclusive lanes. Unlike vehicles that could go anywhere, fixed route buses don't need a map of absolutely everywhere.

It should also be pointed out here that the findings from the Lisbon study suggested that the largest benefits for autonomous mobility-on-demand systems are achieved in the presence of high-capacity public transport system. This was a significant finding which reinforces the need for on-going investment in both traditional and innovative types of public transport.

Potential changes in the role of public transport

The new mobility options to could become available through autonomous driving may provide an important complement to existing public transport systems. Some related evidence may be drawn from some of today's cities where technology-based car-sharing and ride-sharing (e.g. Uber) is very popular. It is suggested that the prices being charged for these taxi-like services maybe too high to attract most people out of public transport for their daily trips. Autonomous driving, however, may very well challenge this given that that prices may become much cheaper because there is no human driver labour involved. It is still too early to draw conclusions on this but the research shows that in terms of city-wide impacts on mobility, public transport – particularly high-capacity for longer distances - will still have a strong role to play in urban mobility. Low-capacity public transport modes like buses, shuttles, mini-vans and school buses may however be impacted and potentially be replaced with autonomous vehicles particularly for those trips that are too long to walk and too short to drive (especially during off-peak hours when travel demand is low). It should be noted, however, that eliminating bus lines altogether may disassemble the public transport grid which makes the network work in most places. Autonomous vehicles could fill some of that gap (e.g. first and last kilometre), but it's unclear if they would replace public transport bus routes entirely. The evidence so far suggests that for dense urban neighbourhoods and major job centres, public transport will likely remain a big component of mobility options in cities.

Impact on active transport

Instead of having to create separate spaces for different types of street-users because they are incompatible in terms of safety or some other ways, self-driving technology may present an opportunity for safe, low stress shared spaces. There are many planning advantages to this including more friendly-feeling streets and making more efficient use of space.

There are also increasing calls for vehicle technology developers and urban planners to design transport systems involving automated vehicles such that pedestrians intuitively understand how such vehicles operate. The presence of automated vehicles should in no way discourage pedestrians from completing their journey on foot but the vehicles should integrate seamlessly with other modes, particularly walking and cycling. There will be human factors work required to ensure automated vehicles communicate with pedestrians in a highly intuitive manner and ultimately standards will need to be developed to address this topic. The public would have to trust the technology and this will take some time.

Impact on freight

Similar to the previous discussion about public transport, any advances in technology that provide for automated vehicles could also result in automated freight delivery, potentially saving significantly on the cost of operations because of labour cost reductions when the system reaches full autonomous operations.

In the U.S., Nevada was the first state to legislate the use of autonomous trucks on its highways. Nevada granted a Daimler-built autonomous truck a license for road use in the state, making it the first of its kind to navigate public roads in the US. The truck had to undergo rigorous testing before it was granted a license and had to drive over 10,000 miles on a circuit in Germany. A number of other companies are also reported to be investigating the use of autonomous vehicles for freight delivery. Uber, for example, is reported to be conducting research to enable its future fleet of autonomous vehicles to deliver small parcels around the city and suburbs. Other companies are also working in this last-kilometre delivery space. London-based Starship proposes to use a secure robot on wheels to deliver goods within 30 minutes. The robot has six wheels and an integrated array of sensors, and can make autonomous deliveries within a 3-mile radius. The storage compartment of the robot can hold about two grocery bags, and deliveries can come from retail outlets or dedicated Starship hubs .

Impact on jobs and labour

It has been suggested in some literature that the fallout from vehicle automation and self-driving capability will likely eliminate some 10 million jobs in the US alone within 10-15 years of the rollout of self-driving vehicles. This speculation was based on a report by PwC which predicted that the number of vehicles on the road will be reduced by 99%, and that the fleet will fall from 245 million to just 2.4 million vehicles. It was also based on statistics from the Bureau of Labour which listed that 884,000 people are currently employed in motor vehicles and parts manufacturing, and an additional 3.02 million in the dealer and maintenance network. According to the Bureau, truck, bus, delivery, and taxi drivers account for nearly 6 million professional driving jobs in the US. These 10 million jobs have been speculated to be in danger of elimination within 10-15 years. But the same literature also speculates that despite the job losses, eliminating the needs for car ownership will yield over $1 trillion in additional disposable income – and that is likely to usher in an era of unprecedented efficiency, innovation, and job creation.

It is still unclear at this stage how autonomous driving and the rise of robots may threaten the jobs of the future in Australia. It is certainly a possibility that as some jobs are eliminated, more will be created to deal with the innovations of a new era. There is also a counter possibility. As technology continues to accelerate and vehicles become smarter, fewer labour may be necessary especially drivers. Some speculation in the industry is that AI may impact the wider economy beyond autonomous vehicles and is already well on its way and making "good jobs" obsolete with many blue and white collar jobs poised to be replaced by robots and smart software over the next 20 years. This would clearly result in job inequality and economic insecurity for some segments of the labour market. It is still unclear, however, whether past solutions to technological disruptions, such as more training and education, will work. The World Economic Forum has made calls in recent times to consider a universal basic income to counteract the negative impacts of automation, while others have also called for a tax to be imposed on future robots which replace humans. This is ultimately a societal issue that must be debated and decided on publicly to ensure that the future will see broad-based prosperity levels as automation becomes more common and widespread.

Impact on the environment and pollutants emissions

Research shows that outdoor air pollution contributes to more than 2.5 million deaths worldwide each year. In some countries, transport is estimated as the source of nearly 30% of all emissions responsible for global warming. In Australia, transport activity is one of the major sources of emissions related to the combustion of fossil fuels. In 2010, transport contributed 83.2 Mt CO2 or 15.3% of Australia's net emissions with road transport accounting for 71.5 Mt CO2 or 86% of national transport emissions.

Modelling results from a number of studies show that the overall volume of car travel would likely increase with autonomous shared driving because the vehicles will need to re-position after they drop off passengers. Autonomous vehicles could still be turned into a major positive in the fight against air pollution if they were all-electric (or other type of renewable energy), and would have the potential to curb transport emissions and reduce our dependence on fossil fuels. Google has announced plans to roll out a handful of cordless charging prototype autonomous electric vehicles in California and it is very likely that most autonomous cars in the future will also be electric.

A study by the Lawrence Berkeley National Laboratory in the US also found that self-driving electric taxis – battery powered and driven without human intervention - could reduce greenhouse gas emissions by around 94% by 2030. The reductions in Greenhouse gas emissions would be achieved by running the vehicles from the electricity grid, which by 2030 will use a greater proportion of renewable power. The researchers report that human drivers are responsible for between 20% and 30% of inefficiencies in vehicles, so the shift to autonomy has the ability to use the car in a more efficient manner.

The energy and carbon impact of highly automated vehicles

In another study by researchers at the University of Leeds, the research team argued that vehicle automation may affect road vehicle energy consumption and greenhouse gas (GHG) emissions in a host of ways, positive and negative, by causing changes in travel demand, vehicle design, vehicle operating profiles, and choices of fuels. In their research, the authors identify specific mechanisms through which automation may affect travel and energy demand and resulting GHG emissions and bring them together using a coherent energy framework. The researchers reviewed the literature for estimates of the energy impacts of each mechanism and, where the literature is lacking, developed their own estimates using engineering and economic analysis. They also considered how widely applicable each mechanism is, and quantified the potential impact of each mechanism on a common basis

Impact on car insurance

As autonomous driving technology advances, perhaps the most notable benefit is the promise of a striking reduction in accidents. But what impact will this have on the insurance industry? Some estimates put the potential reduction in accidents due to introduction of autonomous vehicles at higher than 90%. If automation will make crashes far less likely, then why buy vehicle insurance? Some studies have speculated that premiums could be reduced by 75%, especially if drivers are no longer required to get coverage, and liability is shifted from drivers to product liability, manufacturers and technology companies. Under this scenario, insurers might move away from covering private customers from risk tied to 'human error' to covering manufacturers and mobility providers against technical failure.

A Rand Corporation report also predicts that drivers might end up covering themselves with health insurance instead of vehicle insurance. According to a similar report by KPMG, the insurance industry could contract by as much as 60% by 2040 as accident damage payouts and premiums fall. Warren Buffett, whose Berkshire Hathaway conglomerate owns Geico, has said that widespread adoption of autonomous technology poses "a real threat" to the industry. Insurance companies have been examining potential changes to the current business model. KPMG's report envisions a future in which insurers will depend more on commercial accounts for revenue as companies offering ride-sharing and mobility on demand become more prevalent. It is likely that the number of individual policyholders will decline as households get by with one car, or no car at all. And as the cost of covering losses declines, so will the premiums insurers collect. As driverless cars are set to take to the road between 2020 and 2025 and mass adoption to reach its peak by 2040, auto insurers might shift the core of their business model, focusing mainly on insuring car manufacturers from liabilities from technical failure of their autonomous vehicle. The change could transform the insurance industry from its current focus on millions of private consumers to one that involves a few OEMs and infrastructure operators, similar to insurance for cruise lines and shipping companies.

Impact on urban planning and land use

Self-driving cars are not just about a hands-free driving experience. Their emergence could point to an urban transformation that will change the way people navigate, access information, and interact with one another. The emergence and broad adoption of autonomous vehicles could have a profound, if paradoxical, impact on prevailing land-use patterns. In weighing the trade-offs between land values and transport costs, this should increase the willingness of households, and possibly some firms, to locate farther away from the urban core. Just as the rise of the automobile in the 20th century led to the emergence of suburbs by reducing transport costs relative to earlier modes of travel, the introduction of autonomous vehicles could negatively strengthen a trend towards even more dispersed and low-density land-use patterns surrounding metropolitan regions. In contrast, and somewhat paradoxically, the technology could also lead to greater density in core urban areas. Here the main issue relates to parking supply and demand. The emergence of autonomous vehicles could sharply reduce the amount of parking needed in core urban areas which in turn could lead to denser urban cores, increasing the amount of land and building space dedicated to human occupancy or some use other than parked cars. At the same time, they could support even greater dispersion of low-density development along the outskirts of major metropolitan areas given the ability of owners to engage in other activities as vehicles pilot themselves. These effects on land use are likely to occur over the long term and require the development of high levels of automation.

Some researchers have argued that this may help in easing the affordable housing problem. If city governments can be persuaded to ease parking requirements for developers as a result of shifting to driverless vehicles, the cost of erecting buildings could also be reduced by more than 20%, according to the research.

Will autonomous vehicles cost or benefit cities?

Autonomous vehicles could have deleterious consequences for cities. For example, automated vehicle technology – unlike humans – abides by the law and that can spell bad news for local government revenues. Deep revenue sources acquired from driving-related violations, such as speeding tickets and other violations, will decrease sharply. But others disagree and argue that revenue from traffic violations is not a significant source of revenue for local councils. So will the introduction of autonomous vehicles bring financial benefits or costs to cities, on balance?

A paper published in 2014 by Brooking and Purdue scholars shows that driverless car technologies are quite likely to effectively leapfrog most of the existing technologies that the public sector could but has failed to implement to improve travel. The leapfrog effect will have numerous positive impacts. Driverless systems and centralised traffic control will expand roadway capacity and reduce congestion by efficiently routing vehicles dynamically through traffic jams. Unlike human-driven vehicles, where the driver may not be influenced to change routes, self-driving vehicles will be optimally diverted to least congested or polluted routes to their destinations. For example, when congestion occurs, computerised systems will divert a certain percentage of vehicles off the highways and onto surface streets. The system will then recalculate congestion measures and dynamically route vehicles to their destinations according to an optimal strategy. This will cut travel times, reduce fuel wasted while sitting in traffic, and improve productivity. Moreover, autonomous driving systems will likely adjust routing patterns for trucks and other heavy vehicles to avoid vulnerable infrastructure, thereby cutting costs and preserving the lifespan of critical roadways, and bridges.

Regulations

Regulations will play a key role in the emergence and development of autonomous vehicle technologies. They are also likely to be the biggest hurdle for their deployment beyond the testing and trial periods. Several jurisdictions around the world have passed or are considering regulations that would enable the research and development testing of autonomous vehicles. Most of these regulations address safety-related issues to operation of these vehicles on public roads. More jurisdictions are now moving beyond regulations for testing and focusing their efforts on implications for large-scale deployment and the new business models that are likely to emerge as a result of their deployment. The regulators are adapting and rethinking their approaches to regulating these activities in order to avoid conflicts without stifling the innovative uses of these technologies.

Regulation under uncertainty is difficult. Effective responses would require an early and on-going dialogue between regulators, developers and the public in which regulators would actively plan to minimise future risks and create legal frameworks that are flexible but robust. An important role for the regulators will be to limit physical risks especially those that might be posed during interim years when legacy fleets of vehicles would interact with autonomous vehicles.

A number of studies reported in the literature provide some guidance for policymakers around the types of regulation, regulatory approaches, and policy choices. The response from regulators would vary according to the frameworks within which they operate in their individual countries. Overall, the guiding principle for policymakers has been that they should permit this technology if and when it is superior to average human drivers**.** However, others argue that some risks will have to be accepted. They argue that these vehicles have much opportunity to do good, and while the technology will never be perfect, the opportunity to reduce accidents and tragedies remains the key motivation for their quick deployment.

Clearly autonomous vehicles have considerable promise for improving social welfare but will require careful policymaking at both the state and commonwealth levels to maximise their promise. Policymaker intervention to align the private and public expenditure may be justified once the costs and benefits are better known. Further research and experience can help regulators better understand these uncertainties. Some studies have argued that at this point, aggressive policymaker interventions are premature and would probably do more harm than good.

Cyber security and privacy

There are a number of privacy and security concerns about connected and autonomous vehicles that pose few challenges to automakers. These include concerns related to hacking into the connected vehicle's infotainment and computer systems to gain control of the vehicle and concerns about gathering too much information about drivers and travellers inside a connected and automated vehicle.

The vulnerability of connected vehicles to 'cyber attacks' was highlighted in two separate cases in the US and the UK which occurred in 2015. In the first case, a leading UK-based software security system company demonstrated how car infotainment systems can be vulnerable to hacking and could put lives at risk by seizing control of a vehicle's brakes and other critical systems. This case coincided with a similar flaw discovered by two security researchers in the US where they demonstrated that they could take control of a Jeep Cherokee travelling along one of the Interstate highways, by sending data to its internet-connected entertainment and navigation system over a mobile phone network. The researchers managed to take full control of the vehicle while it was in a vacant parking lot, altering the engine speed, braking sharply and disabling the brakes completely.

Connected vehicles comprise a large number of sensors and detectors which report on safety-related issues (for example how hard the driver brakes and accelerates). To help identify faults or plan maintenance, manufacturers are also able to gather performance data from connected cars such as the total distance travelled, or the length and number of trips made.

But some of the new sensors inside vehicles also allow manufacturers to gather other data about drivers and occupants. According to a study conducted by the German motorists organization ADAC, on behalf of the FIA (Federation Internationale de L'Automobile), it was found that the vehicles also transmitted the latest destinations entered into the car's navigation system, and personal information such as contacts synchronised from mobile phones. The FIA study recommended that car manufacturers publish an easily understandable list for each model of all the data collected, processed, stored and transmitted externally so that the public are aware of what data is being transmitted from the vehicles they travel in. With the risk that the data might be intercepted or the car hacked and the data taken, ADAC recommended that carmakers secure the data, and make it possible for drivers to block the processing or transmission of non-essential data. The FIA has since launched a campaign to promote motorists privacy rights through the My Car, My Data initiative. The FIA has also recommended a number of consumer principles be adopted including data protection (legislation to ensure informed consent to a car's data); free choice to use service providers and fair competition (ensuring an open and secure telematics platform)

Opportunities for new business models

Today's wave of disruptive mobility has been driven by innovations and new solutions to optimise "excess capacity" of assets: namely ridesharing and car sharing. For example, Silicon Valley is extending its reach into the auto industry, and vice versa. Uber is testing self-driving vehicles on the streets of Pittsburgh in the US, and Google is investigating a ridesharing model. Meanwhile, Tesla also announced that its vehicles will become part of a network of autonomous car-sharing service to give owners a way to generate revenue from their electric vehicles.

The kilometre as a utility: the merging worlds of technology, vehicles and shared mobility

In 2016, investments worth more than $US 9 billion were poured into ride sharing services. The biggest investors have been the auto manufacturers and technology companies. The world's most powerful companies, including auto manufacturers, are no longer interested in making a one-off transaction with consumers through the sale of a vehicle. Instead, they are targeting a new business model in which they would offer consumers seamless mobility services in which the kilometre of travel will become the main utility. These developments show there's more to the connected and autonomous vehicle than technology and infotainment, and may also signal the beginning of inventions and creation of entire new shared economy businesses. These opportunities have potential to tap into new markets that could see smart mobility seamlessly integrated in people's lives.

Today, the average cost of passenger-kilometre of travel using a privately owned vehicle is still much lower and more appealing than ridesharing. But huge investments have already been made in automation. When self-driving vehicles arrive, the return on investment will be substantial and could reduce the cost of on-demand point-to-point mobility services to nearly the same cost of owning and driving a car. This assumes no carpooling. With successful carpooling, the cost per passenger per kilometre is going to put car ownership even under greater threat.

Collaborative Mobility

Probably the biggest anticipated impact of driverless vehicles will be around the collaborative mobility space. To date, the transport sector is the most funded industry in the Collaborative Economy. This is manifested by one of the most promising trends within the disruptive mobility space: 'Mobility-as-a-Service' or (MaaS). The key concept behind MaaS is to place the road users at the core of transport services, offering them mobility solutions based on their individual needs. This can be achieved by providing a single platform for combining all mobility options and presenting them to the customer in a simple and completely integrated manner.

This means that easy access to the most appropriate transport mode or service will be included in a bundle of flexible travel service options for end users. MaaS has the potential to fundamentally change the behaviour of people and reduce reliance on car ownership by providing easy on-demand access to the mobility services they need. The trend is therefore gradually shifting, particularly in the context of smart cities, from the provision of urban transport networks i.e. buses, trams and trains, to a focus on what people require, and how a more considered and integrated approach could produce far better outcomes.

Ethical challenges

Autonomy in general, and autonomous vehicles in particular, pose a number of ethical challenges. The most important ethics hurdle is related to safety and the fact that driving and mobility can never be perfectly safe, which raises some difficult issues. How should the car be trained to act in the event of an unavoidable accident? Should it minimise the loss of life, even if it means sacrificing the occupants, or should it protect the occupants at all costs? Should it choose between these extremes?

One way to approach this kind of problem is to act in a way that minimises the loss of life. By this way of thinking, killing one person is better than killing 10. But that approach may have other consequences. If fewer people buy self-driving cars because they are trained to sacrifice their owners, then more people are likely to die because ordinary cars are involved in so many more accidents. This result can be counter-productive.

Researchers are seeking to find a way through this ethical dilemma by gauging public opinion. The premise is that the public would be more likely to go along with a scenario that aligns with their own views. Researchers in France posed these kinds of ethical dilemmas to a sample of several hundred people to find out what they thought. The results showed that in general, people are comfortable with the idea that self-driving vehicles should be programmed to minimise the death toll. This utilitarian approach is certainly laudable but the participants were willing to go only so far. They were not as confident that autonomous vehicles would be programmed that way in reality—and for a good reason: they actually wished others to cruise in utilitarian autonomous vehicles, more than they wanted to buy utilitarian autonomous vehicles themselves, according to the research team. And therein lies the paradox. People are in favour of cars that sacrifice the occupant to save other lives—as long they don't have to drive one themselves. The research team also points out that their work represents the first few steps into what is likely to be a complex moral maze. Other issues that will need to be factored into future thinking are the nature of uncertainty and the assignment of blame.

Who controls the AI software?

Should there be a single software code that all vehicle manufactures use to program how the autonomous vehicle behaves when faced with these decisions? And who gets access to the code that determines these decisions?

Consider, for example, if the autonomous vehicle is designed to intentionally murder its driver under certain circumstances. How would we make sure that the driver never alters its programming so that they could be assured that their property would never intentionally murder them? Should the car be designed to only accept software that's been verified and signed by the relevant transport authorities (or the manufacturer), and make it a felony to teach people how to override the lock?

Safe versus legal

Should autonomous vehicles be trained to break the law in cases where safety is compromised? Take the double-yellow line problem. An road crew or other objects suddenly appear on a road and the autonomous vehicle does not have enough time to stop and has to make a decision: Obey the law against crossing the double-yellow line and hit the object, or break the law and spare the road crew? It may be clear that the car should cross it to avoid the road crew. Less clear is how to go about training a machine to break the law or to make still more complex ethical calls. Although researchers working in this field agree that these may not even be the right questions to ask, they argue that societies need to start thinking about traffic codes reflecting actual behaviour to avoid putting the developer in a situation of deciding what is safe versus what is legal.

Industry and public engagement

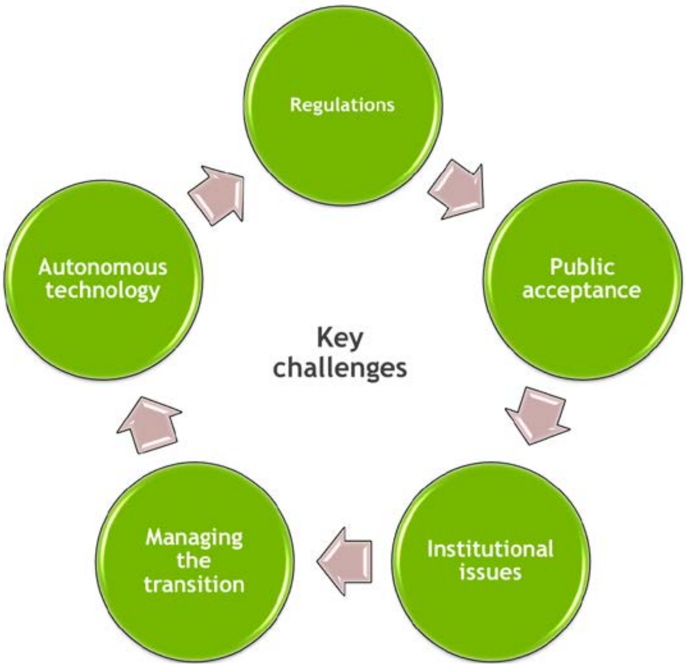
As with other fast-moving innovations, policymakers and regulators have a major role to play and need to engage developers and the public to ensure that a comprehensive testing and legal framework is available to verify compliance. The trials and demonstration projects offer great opportunities to facilitate such an engagement.

Public acceptance

One of the most comprehensive studies of public acceptance was undertaken by the University of Michigan. It examined public opinion regarding self-driving vehicles in three major English-speaking countries—the US, the

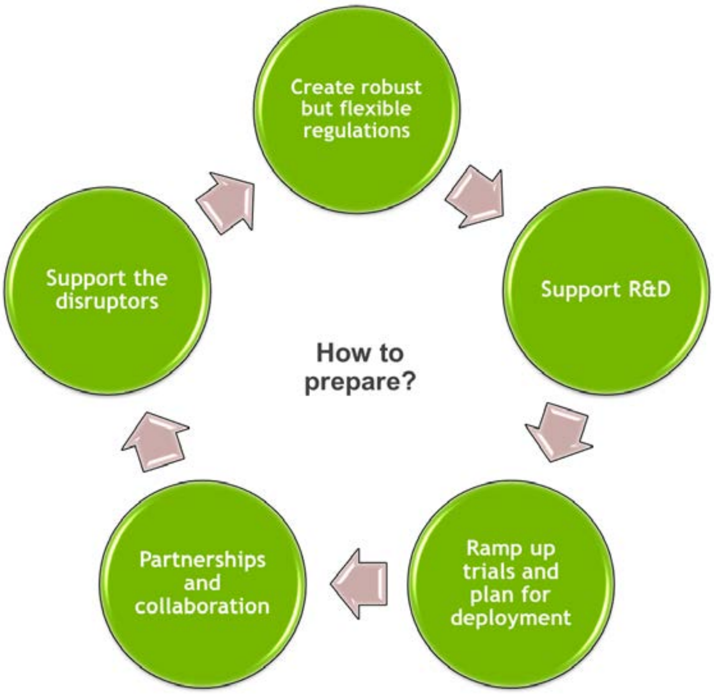
UK, and Australia. The survey yielded useable responses from 1,533 persons 18 years and older. The main findings from the survey showed that motorists and the public generally feel positive about self-driving vehicles; have optimistic expectations of the benefits; and generally desire self-driving-vehicle technology when it becomes available. Some respondents in the Michigan survey, however, also expressed high levels of concern about riding in vehicles equipped with this technology, and the majority was not willing to pay extra for such technology at this time.

Key challenges



Policy and regulations remain the last major hurdles. But there is also public acceptance, managing the transition period during which fleets of autonomous and human-driven vehicles will share the road, and further refinement of the technology.

How do we prepare for their arrival?



There is already strong momentum around development of regulations and the challenge here is to ensure that these regulations are robust yet flexible and are outcome-focused. Trials and demonstrations will also go a long way to demystify the technology and increase public acceptance. Similarly, more support for research and development and forming partnerships and collaborations between the public and private sectors will also help

Conclusions and future directions

In conclusion, not everyone will be excited by the vision of autonomous driving, and many would be sceptical and disagree that we are at the cusp of a transformation in mobility. Others still want to drive and not everyone is likely to want to rideshare or carpool on a daily basis. Many might also argue that better investment in public transport would achieve similar outcomes. Whether we embrace or object to these scenarios, the reality is self-driving vehicles are coming and they will have socio-economic impacts and other effects on our society – some good and some bad. They need to be viewed as part of the solution to solving our urban transport problems – not the only solution. They could have a big role to play in delivering new public-transport-like mobility solutions as part of a holistic approach to improve road safety and promote low carbon mobility. The real challenge will be to ensure that they don't simply reinforce existing norms. This will require a shift in attitude in travel behaviour and encouraging commuters to share excess capacity in vehicles of all types.

This is too important to be left only to market conditions and commercial interests. The time is now to think about the kind of future we want to have in a highly automated world, and ramp up the work today to shape the future directions of urban mobility.