FUTURE AGENDA

Open Foresight

THE FUTURE OF AUTONOMOUS VEHICLES

An Interim Report based on Multiple Expert Discussions

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Glossary

Abbreviation	Definition
ACC	Adaptive Cruise Control - Adjusts vehicle speed to maintain safe distance from vehicle ahead
ADAS	Advanced Driver Assistance System - Safety technologies such as lane departure warning
AEB	Autonomous Emergency Braking – Detects traffic situations and ensures optimal braking
AUV	Autonomous Underwater Vehicle – Submarine or underwater robot not requiring operator input
AV	Autonomous Vehicle - vehicle capable of sensing and navigating without human input
CAAC	Cooperative Adaptive Cruise Control – ACC with information sharing with other vehicles and infrastructure
CAV	Connected and Autonomous Vehicles – Grouping of both wirelessly connected and autonomous vehicles
DARPA	US Defense Advanced Research Projects Agency - Responsible for the development of emerging technologies
EV	Electric Vehicle – Vehicle that used one or more electric motors for propulsion
GVA	Gross Value Added - The value of goods / services produced in an area or industry of an economy
HGV	Heavy Goods Vehicle – EU term for any truck with a gross combination mass over 3,500kg (same as US LGV)
HMI	Human Machine Interface – User interface between a vehicle and the driver / passenger
IATA	International Air Transport Association - Trade association of the world's airlines
LIDAR	Light Detection and Ranging - Laser-based 3D scanning and sensing
MaaS	Mobility as a Service - Mobility solutions that are consumed as a service rather than purchased as a product
ODD	Operational Design Domain - Definition of where and when a vehicle is designed to operate
OEM	Original Equipment Manufacturer - The original producer of a vehicle or its components
ROI	Return on Investment - Performance measure used to evaluate the efficiency of an investment
SAE	Society of Automotive Engineers – US based professional association and standards developing organization
TNC	Transportation Network Company – also known as a mobility service provider (MSP) matches passengers with vehicles
UAV	Unmanned Aerial Vehicle - An aircraft piloted by remote control or onboard computers
V2V	Vehicle to Vehicle – Wireless exchange of data between nearby vehicles
V2X	Vehicle to External Environment - Wireless exchange between a vehicle and its surroundings

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Contents

Introduction

Why This Topic?

There are great expectations around the future of autonomous vehicles (AVs) and equally, much uncertainty. For example, some believe that AV's will transform safety and efficiency, and are making significant investments in new technologies in this area. At the same time, others are concerned that the technological developments are outpacing society's ability to adapt, and there is an urgent requirement to develop better regulation before there is widespread deployment. Moreover, there are questions in some cities of how far first-deployment trials by, say 2025, will evolve to scale by 2030. It is clear that there are multiple views and that these can be conflicting and contradictory. Given the speed of change in this area, the need to unravel fact from speculation and identify which are the real areas of innovation and opportunity, is growing.

Beyond this, having ideas, even building prototypes, is comparatively easy, but ensuring they are adopted in the wider community is much more challenging, particularly when it involves changing the status quo and dealing with human interactions. Some suggest, for example, that for AV to get real traction, it may be necessary to turn transport planning on its head, and rather than follow the traditional approach of first predicting transport needs, to adopt a more flexible approach. To do this, the key will be to understand what the varied ambitions of manufacturers, technologists, and governments are, how they intersect and align, and so what can be delivered. This is why a global rather than a local conversation is important. Uncovering the bigger picture and recognising different perspectives from multiple regions and companies will provide a richer outlook that can then help guide some of the pivotal decisions that lie ahead.

Finally, while it is easy to get distracted by current trends and short-term needs, if we look ahead, beyond the immediate transportation problems, and consider the 20 to 30-year horizon, we may see a significant alternative future, in which the AV ambition has delivered change across many areas, not just on land, but also on and under the sea, as well as in the skies.

Summary of Findings to Date

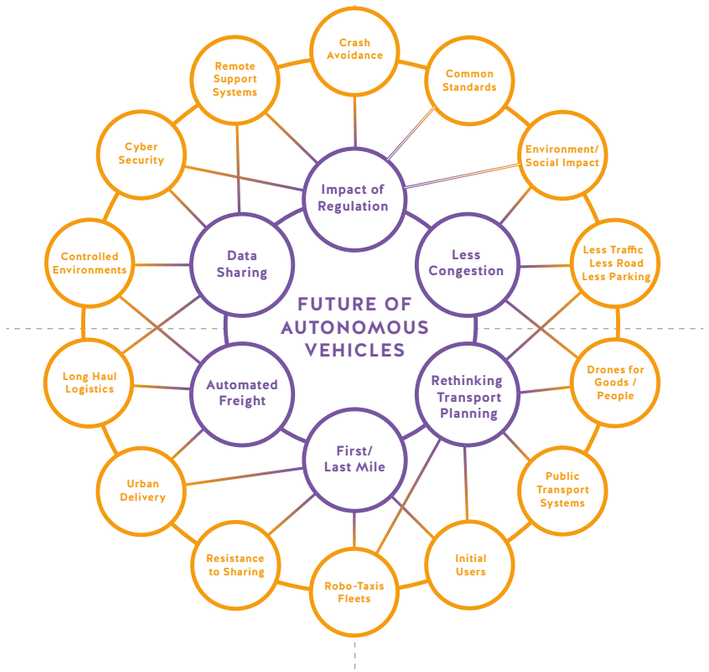
This is an interim summary based the insights gained from a global open foresight project exploring the future of autonomous vehicles that is being undertaken throughout 2019. It combines an analysis of existing research with opinion gained from multiple interviews and a series of 5 workshops held in Los Angeles, Frankfurt, Singapore, Wellington and Melbourne during Q2 of 2019. Ahead of further discussions, its aim is to share the different expert perspectives on how the future of autonomous vehicles will evolve over the next decade, and highlight some of the key issues that will drive change.

Our ambition is to set the scene for debate, highlight the insights gained from our initial discussions, and then consider some key implications and associated questions for further exploration in the second half of the programme. The views contained within this document are those of both the authors who have organised, facilitated, and captured the research dialogue, as well as those who have kindly given up their time to contribute.

There are many perspectives of how, where, and why autonomous vehicles may have impact. In particular, looking at the next decade, from the discussions in the first batch of workshops, a number of key issues were prioritised, debated, and explored in depth – most in multiple locations. Within these, there are six pivotal high-level macro drivers of change that can be considered to be the focus of greatest debate. These are:

- Impact of Regulation;
- Less Congestion;
- Rethinking Transport Planning;
- First/Last Mile;
- Automated Freight;
- Data Sharing.

Underlying and connected to these, there are also fourteen additional priority topics of focus. These are related to the macro drivers and can be mapped as shown in the diagram below.



Collectively, these twenty areas cover a broad range of the autonomous vehicle landscape, and the comments and feedback gained from the initial workshops provide both detail on how they are being considered, and the level of alignment in the various locations. In summary they are driving multiple changes.

Impact of Regulation: The regions that gain most initially will be those where there is advanced regulation to act as a catalyst for AV deployment. Addressing information sharing, collaboration, and liability are critical.

Crash Avoidance: Reducing accidents and road deaths caused by humans is a political priority behind support for AV. While benefits can be gained from ADAS, the promise of significant safety improvements is pivotal.

Common Standards: International standards and commonly-shared technologies may be essential for driving global rather than regional AV adoption. Without them, a more fragmented approach will be taken.

Environmental and Social Impact: Ensuring that autonomous vehicles are cleaner than alternative options may be a pre-requisite in many cities, while the benefit of AVs for wider society is a crucial issue for wider endorsement.

Less Congestion: Decreasing congestion on the roads is a core ambition for AV advocates, but many recognise that with mixed fleets operating for several years, we may initially see an increase in urban traffic.

Less Traffic – Less Road – Less Parking: Effective deployment of AVs as part of integrated public transport systems may mean not only fewer vehicles on the roads, but also parking spaces can be removed and roads can become narrower.

Drones for Goods and People: Investment in timely drone delivery services accelerates deployment in several locations, but the roll-out of air-taxis may not be as widespread as many hope. Large scale impact is limited.

Rethinking Transport Planning: For AV to have impact, it may be necessary to rethink a more flexible approach to planning. Poor coordination between transit systems, urban planning, and future solutions, may delay the benefits.

Public Transport Systems: As autonomous buses are introduced, other mobility solutions will also have to be used to fill transportation gaps. Security, flexibility, reach, and interconnectivity are primary criteria.

First/Last Mile: Improving the inefficient first/last mile is a major opportunity with health, energy, and efficiency benefits. Scooters, bikes, and small autonomous robots in urban environments, all play a part.

Initial Users: Although AVs may have significant benefit for those without access to affordable mobility – especially the young, elderly, and disabled – from the start, autonomy has to be attractive for all users.

Robo-Taxi Fleets: Robo-taxis are increasingly seen as the way forward for passenger vehicles and could change both travel patterns and car ownership decisions. They are a core part of ‘Mobility as a Service’ offers.

Resistance to Sharing: As many people value their personal space, support for a significant rise in ride-sharing may not be as high as some predict. Rethinking vehicle design for strangers travelling together is a priority.

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Automated Freight: The significant automation of expressway trucks is of huge commercial interest. It will transform long-haul journeys, and so is the principal focus for regulation and trials across all levels of AV.

Controlled Environments: Controlled environments have demonstrated the early steps for AV and are growing steadily. Airports, port terminals, factories, mines, and even dedicated highways, all provide safe areas for development.

Data Sharing: More and deeper data sharing are pivotal in enabling the AV ambition. Mobility brands eventually agree the protocols for V2X interaction and so support the use of open data sets.

Cyber Security: With the threat of hacks, denial of service, vandalism, and theft of data, organisations seek to make AV more secure through adopting common approaches for closed, collaborative systems.

Remote Support Centres: Manned call centres provide oversight, support, and emergency response for all AVs. In the absence of drivers, most public transport vehicles require remote human supervision.

At the halfway stage it is clear that, across the varied markets, there are areas of alignment - but also notable nuances in approach to AVs that are different country to country. From our discussions to date we highlight nine key issues already emerging as significant:

1. **Safety is a pre-requisite:** Expectations are high, but as many advances are already in process, improvements look likely.
2. **Fleets are now driving progress:** In terms of the core business model the momentum is clearly behind the robo-taxi concept.
3. **Automated trucks are coming:** Freight has much to gain in terms of efficiency, it has regulatory support and wide industry support.
4. **Congestion is a conundrum:** While all aim for less congestion, and the role of connectivity will be pivotal, user behavior and TNC strategy could initially mean more.
5. **Multiple options for the last mile:** There are many alternatives in the mix all bridging different needs and location gaps.
6. **First vs widespread deployment:** Where and why we see initial AV services may not necessarily align with where mass impact will occur.
7. **Deeper collaboration will be needed:** Moving from partnerships to long-term multi-party collaboration is seen as a critical enabler.
8. **Standards may not be pivotal:** Comprehensive global and regional standards may not be essential for AV: Rather standards will evolve based on business needs.
9. **Regulators are influencing deployment:** Proactive regulation is attracting companies, but the balance of light vs. heavy approaches may impact this.

Hosts and Participants

Each of the expert workshops undertaken around the world to date have been hosted by different organisations, all keen to both bring together informed people in their region to challenge, debate, and define the key future issues for the development and deployment of autonomous vehicles, as well as support the creation of a wider global view. Los Angles was hosted by LA Metro, Frankfurt by Hochschule Fresenius University of Applied Sciences, HOLM and Deutsche Bahn, Singapore by the Lee Kuan Yew School of Public Policy at NUS, Wellington by the New Zealand Transport Agency and ADVI (Australia and New Zealand Driverless Vehicle Initiative) and, lastly, Melbourne by Transurban.

We thank them for all their enthusiasm, help, and guidance.

We would also like to thank the 130 industry leaders, regulators, academics, technologists and policy advisors who have already taken the time to participate in this project, and who were prepared to voice an opinion and challenge the status quo. Without their help, we would be unable to drive the discussion forward. We thank them all, most sincerely.

A Wicked Problem

As several commentators have recently highlighted, the future of autonomous vehicles can be considered to be a complex system and a “wicked” problem.[1] And, as has been recognised for many years now in the world of public policy and beyond, wicked problems are particularly tricky to address.[2] A wicked problem is a social or cultural problem that is difficult or impossible to solve for as many as four reasons:

1. Incomplete or contradictory knowledge,
2. The number of people and opinions involved,
3. The large economic burden,
4. The interconnected nature of these problems with other problems.

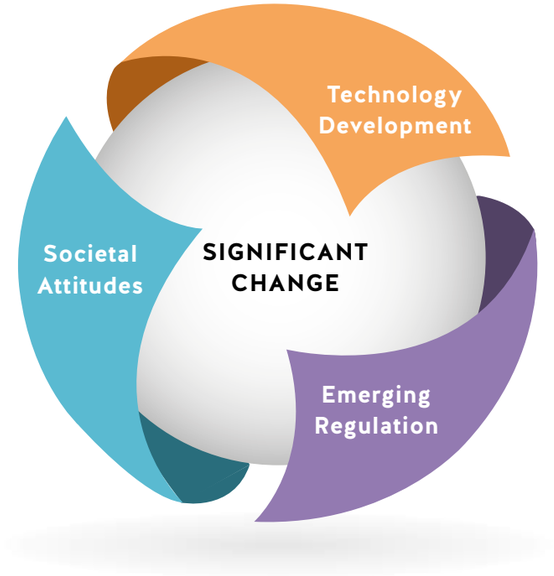
If we are going to make progress on this, then we need to not only talk to the advocates, but also to the cynics, as well as the agnostics. We have to engage with the innovators, researchers, policy makers, and the human behaviour experts. We should understand the perspective of government, urban planners, and transport networks, just as much as those of the large manufacturers, big tech, and multiple start-ups. We must also understand the consumer point of view.

Moreover, we need to recognise that the view in California is not the same as that in Shanghai, Mumbai, or Dubai. Nor is it the same as in Singapore, Tokyo, Brussels, London, and Tel Aviv, or for that matter, in Washington DC, Wellington, Melbourne or Toronto. Around the world, for perfectly understandable reasons, different experts, even within the same area of practice, will have alternative views on the future of both AV development and deployment. Moreover we should recognise that by having such discussions and sharing insights we may influence thinking. In order to gain clarity, we have therefore adopted the Future Agenda Open Foresight approach to anticipating future change for AVs.

What is Open Foresight

Future Agenda uses Open Foresight to help organisations share their understanding and interpretation of future developments. This methodology, detailed below, is effective in untangling the uncertainties around the significant change which usually results from a convergence of technology development, consumer/societal behaviour, and emerging regulation.

We have found that sharing ideas and challenging assumptions with an informed audience in a collaborative manner, helps to reduce uncertainty about the future, and enables organisations to design and assess development trajectories toward the future, including scenarios, action plans, and innovation ideas.



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Project Approach

Developed in 2010 as an enhancement of previous collaborative approaches to expert-led views of the future, the Open Foresight methodology is based on the idea of bringing together diverse groups of informed people in key locations around the world to debate and build on a key topic of interest. Starting with an initial perspective that is a synthesis of the existing views of potential change, experts in one location critique, evolve, and add to the perspectives from elsewhere, before considering the pivotal areas that they believe will have the greatest impact, and drive change over the next decade in depth. The output from one workshop discussion then becomes the input to the next. By undertaking workshops in different locations around the world, we gain a global view of the key issues that matter, and identify regional perspective.

Each discussion is undertaken under the Chatham House Rule, so that no comments are attributed directly to a participating individual or organisation.[3] However, the insights from every event are made public, and all summary reports and other outputs from the programme are shared under creative commons. Participants gain from immersive interaction with peers on a topic of mutual interest, and everyone benefits from access to the informed views that result. This resulting foresight can then be used by different organisations to challenge strategic assumptions, broaden horizons, highlight new opportunities, and inform future policy, innovation, and investment decisions.

For the AV topic, an initial perspective was created in the summer of 2018, and used to both engage partners, hosts, and lead experts, as well as identify what are the primary centres of innovation, technology development, and AV deployment that should be included in the project. With initial planning undertaken over the winter, five expert workshops were then undertaken in Q2 of 2019. Starting in Los Angeles, a sprawling mega-city with complex transport needs, operating within a highly diverse technology and policy ecosystem, we first gained the California view on the initial perspective and added additional issues. These were then built on in Frankfurt, a major hub for innovation in the heart of Germany and therefore a key influence for Europe. In June, the project moved on to the densely populated nation state of Singapore, to gain the perspective from this Asian leader, a centre for innovation with a reputation as a pioneer in future thinking and planning, before then heading further south. In Wellington, opinions were added from a relatively sparsely populated country with a proactive perspective on transport challenges and opportunities, before ending the first phase of the project in Melbourne – a recognised leader in multi-modal transport integration on the coast of (with the exception of Antarctica) the world's lowest, flattest, driest, and emptiest continent – but one where the mining sector has been a pioneer in automation.

This interim report summarises the insights to date, ahead of a second tranche of expert workshops taking place in Q4 of 2019, and the final report at the end of the year. If you have any comments on the points raised, would like to be involved in future discussions, or would like to host an additional event as part of this programme, please do get in touch.

Where We Have Come From

Automated Driving

The possibility of developing an autonomous vehicle has been explored for many years – indeed it was part of the GM Futurama exhibit at the 1939 World's Fair. Initially funded by government subsidies and industry consortia in the US, Japan, and Europe, wider interest was piqued through demonstrations and competitions, notably the US Department of Transport in San Diego in 1997, and then DARPA's Grand Challenges in 2004 and 2005. It was, however, the 2007 DARPA Urban Challenge which brought the real possibility of self-driving vehicles into the public arena, and most significantly, captured the imagination of Google executives who went on to launch their own self driving car project in 2009.

Since then, funding and talent has largely shifted from the public to the private sector and has grown rapidly. There has been significant progress in technology development and regulatory freedom to undertake testing on roads. Silicon Valley giants such as Tesla, Uber, and Waymo, the spin off from Google, are all attracting significant media interest. GM, Ford, Toyota, Hyundai and other established brands are also working on this, albeit with less hullabaloo, and there are parallel developments for automated freight led by Volvo, Scania and co. More recently, China has entered the fray with companies such as Baidu very much part of the collaborations moving the sector forward. Expectations around the possibilities of a driverless car near you are running high.

Active Safety Systems

In parallel with the growth in automated driving activity, the traditional vehicle industry has been introducing a steady stream of active safety systems aimed at assisting humans to avoid crashes. Beginning in the late 1990s with warning-only systems, these evolved to active control intervention in the 2000s. By 2010, a well-equipped premium vehicle had adaptive cruise control, automated emergency braking for forward collisions, lane departure prevention, blind spot monitoring, night vision with pedestrian detection, sign recognition, and drowsy driver detection. Over the ensuing years, these features rapidly became available across mid-range cars, and today, a $30,000 car in the U.S. can be purchased with all this and more. For several car manufacturers such as Volvo, Mercedes, and Toyota, active safety features are now standard on most of their models. This is good news for overall road safety.

That said, innovation in safety systems may have slowed the development of highly automated driving, as established vehicle manufacturers had no "forcing function" to introduce it into the market, and no evidence at the time that their customers were ready for it. It took innovation from technology companies such as Google and others to drive change. The rapid increase in venture funding, plus consumer fascination, has forced car-makers to consider shifting from an "equipment model" to a "service model;" so much so, that most automotive brands are now investing in offering automated ride-hailing services (robo-taxis).

Importantly, field active safety systems were developed during the 2000s, which resulted in new capabilities in algorithm innovations focused on road driving, the development of automatic steering and braking actuators, and a steady reduction in the cost of sensor hardware, as sales volumes increased. While a radar sensor cost about $1000 at the turn of the century, today the cost is in the range of $100 for similar capability; a significant reduction. While it may seem like "the start-ups have done all the innovation," this long process of applied engineering by the traditional vehicle industry has served as a key enabler for bringing automated driving to the public.

Future of Autonomous Vehicles

Where we have come from

1939 GM Futurama Concept - World's Fair – New York

1945 Cruise control invented

1953 RCA Labs test wire-guided miniature car

1963 UK TRRL automatic vehicle guidance research project launched

1967 Remote controlled car tested at Ohio State University

1968 Vienna Convention on Road Traffic enforces driver control of car

1977 First Semi-Automated Vehicle Test - Tsukuba, Japan

1980 German Bundeswehr tests military robot vehicle

1987 EU Eureka Prometheus Project launched

1991 US Congress passes the ISTEA Transportation Authorization bill

1994 Eureka Prometheus project robotic cars drive 1000km

1995 Carnegie Mellon first US coast-to-coast autonomous drive 4500km

1995 Mercedes S Class drives from Munich to Copenhagen using computer vison

1996 Advanced Cruise-Assist Highway Research Association Demo – Japan

1997 USDOT Automated Highway System Demo - San Diego, California

1998 Google founded

1999 Mobileye founded – Tel Aviv

2000 Adaptative cruise control launched by Bosch

Baidu founded

2003 Tesla Founded

2004 DARPA Grand Challenge – California

2005 DARPA Grand Challenge – California

2007 DARPA Urban Challenge – California

2008 Rio Tinto launch Mine of the Future project

2009 Google Self-Driving Car project launched

2010 TUB self-driving vehicles demo in Germany

Uber founded

2011 Nevada authorises AV testing

2012 Florida authorises AV testing

Peloton truck AV company founded

2013 FlixMobility founded in Germany

Amazon acquires Kiva Systems for $775m

Lyft founded as Zimride

Google completes 300,000 automated driving miles

Google completes 500,000 miles of autonomous driving

Caterpillar starts robotics trail

NuTonomy spun out of MIT

Port of Rotterdam launches automated guided vehicles

2014 UK Government allows AV testing

Oxbotica spun out of Oxford University

Mercedes S Class includes semi-automated features

Google fully automated prototype tested

NIO founded in Shanghai

2015 Apple launches project Titan

Uber recruits key talent from CMU robotics centre

Tesla Autopilot capability introduced

Audi, BMW and Daimler acquire HERE for $3bn from Nokia

Volvo launches Drive Me project in Sweden

2016 Volvo pledges that by 2020 no one will be killed in a Volvo

GM invests $500m in Lyft autonomous vehicle partnership

GM acquires Cruise Automation for $1bn

Apple invests $1bn in Chinese ride share Didi Chuxing

Ford and VC firms invest in NuTonomy

Qualcomm acquires NXP for $39bn

Toyota and Uber announce partnership

Amazon predicts drone deliveries within 5 years

Tesla announces Autopilot

Google | **Baidu** | **Tesla** | **Lyft** | **Uber** | **Volvo**

Lyft announces partnership with NuTonomy

Peugeot-PSA announces partnership with NuTonomy

Uber completes 2m miles in automated testing

Bosch and Nvidia announce AI partnership

Intel acquires Mobileye for $15bn

Apple starts testing autonomous vehicles

Ford invests $1bn in Argo AI

Audi and Nvidia announce AI partnership

Daimler and Nvidia announce AI partnership

2017 Intel invests in HERE

Waymo spun off as separate company from Google

Amazon drone testing in Cambridge, UK

Tesla Autopilot completes 300m miles of operation

US Federal AV policy agreed

Pony.ai founded

Samsung acquires Harman Industries for $8bn

Uber AV prototypes in San Francisco and Pittsburgh

Drive.ai spun out of Stanford University

Uber acquires Otto truck start-up

Starsky Robotics truck technology unveiled

Baidu announces Apollo AV platform and fund

US Federal AV policy 2.0 agreed

Ford Lyft partnership announced

Lyft partners with drive.ai

Waymo testing without a safety driver

NuTonomy acquired by Aptiv for $400m

Tesla semi-truck announced

Beijing permits AV testing on public roads

2018 US Federal AV policy 3.0 agreed

Waymo semi truck announced

Self-driving Uber car kills pedestrian

Baidu completes 140,000 km of self-driving in a year in Beijing

Volvo launches Vera autonomous platform

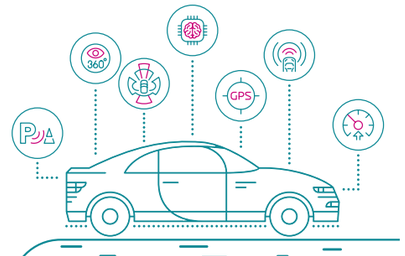
Lyft completes 5,000 self-driving car rides in Las Vegas

China permits city governments to issue AV road licences

Baidu begins mass production of Apollo self-driving bus

Uber shuts down AV truck project

Waymo completes 5m miles of testing



2020 and beyond

Didi Chuxing spins out self-driving car unit

Ford acquires Journey Holding and Quantum Signal AI

Baidu completes 1m miles of test driving

Toyota partners with Baidu's Apollo platform

Amazon announces launch of drone delivery for Prime

Apple acquires Drive.ai

Volvo and Uber launch self-driving production car

Lyft IPO

Uber IPO

Rio Tinto starts autonomous truck mining with Caterpillar Inc

Tesla 'Autonomy Day' announcements

2019 Tesla driver killed in Autopilot mode

Port of Rotterdam tests autonomous navigation

California DMV grants permit to Waymo for testing

Apollo shuttle bus trial at Shanghai Expo

Waymo subsidiary established in Shanghai

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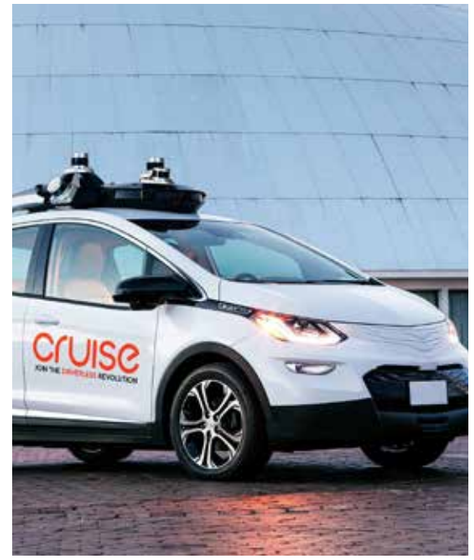
Development vs. Deployment

The period 2017-2018 signalled a turning point due to a tragic crash in which an Uber prototype robo-taxi under test in Arizona collided with and killed a pedestrian, even though a safety driver was at the driver controls.[4] Additionally, several Tesla drivers died while using the AutoPilot function.[5] Based on the limited information available, it appears that in each of these cases, either the safety driver or the vehicle owner was not adequately fulfilling their "co-pilot" responsibility to monitor the system and intervene when the system capability was exceeded. This raises significant challenges relating to shared human-machine control, and in part motivates the implementation of fully automated vehicles which do not rely on human control. Given these and other recent developments, some assert that automated driving has proceeded past the Gartner Hype Cycle[6] 'peak hype', and may be heading towards the 'trough of disillusionment'. Indeed, it is notable that Google - which started its automated driving programme around 2009, and continued via Waymo - still has not launched a full commercial driverless product or service; this is an eternity in Silicon Valley development time.

This decade has seen massive investments in getting from a basic working unit to a robust, high availability, fail-safe, cost effective product that the market would accept. This long incubation period has been due to the need to put in the hard and slow work of getting it right in terms of safety, robustness, and service efficiency. While some observers may be impatient or disillusioned, developers of highly automated vehicles are focused on detailed engineering and testing within a process permeated by careful functional safety analysis and implementation of best safety practices to launch commercial products and services.[7] Completing a comprehensive safety validation process is a key part of achieving regulatory, public, and industry acceptance of new vehicle technology to bring viable solutions to market. Today, therefore, we can see myriad locations where autonomous vehicle technology is being developed, and other areas where initial deployment is underway. Many of these align, but others are progressing because of proactive regulation and investment.

The OEM Position

From a car industry perspective, the advent of vehicle automation is by now a given. Not only are many of the factors of the ideal road trip fulfilled by automation, but mobility can also be expanded for the disabled, elderly, and others who cannot presently drive. The current level of investment, testing, and product development across robo-taxis, robo-trucks, robo-buses, and robo-cars, is at a remarkably high level. In fact, the automotive industry and investment community have "caught the vision" and fully embraced automated driving, propelling a complete reformation of what it means to be a vehicle manufacturer. Based on the premise that substantial new sources of profits will result from individuals extensively using low cost automated mobility, total investment to date is in the tens of billions of dollars, with more to come. The AV sector raked in over $10bn in VC financing in 2018 alone.



The business case for shared and automated mobility was elaborated on by the former President of General Motors Dan Ammann, who in 2017 asserted that the lifetime revenue generated by one of its automated vehicles could, over time, be in the "several hundred thousands of dollars," compared to their average of $30,000 in revenue from one of their traditional products.[8] This general viewpoint has been expressed by other carmakers. Due to the strength of the autonomous vehicle business case, OEMs are backing up their aspirational language with substantial investments, joined by the broader tech industry. For example, Toyota has invested hundreds of millions of dollars in Uber[9] In early 2019, the German VDA car industry association estimated that Germany's car industry alone will invest 18bn euros in "digitisation and connected and automated driving" by 2021.[10] Independently, extensive robo-taxi public road testing is underway by numerous start-up companies. Industry leaders have announced that driverless mobility services will be available starting this year.

The Forward View

The autonomous industry is on the cusp of transformation. So much so that Mary Barra, CEO of GM, suggests that we will see more change in the next 5 to 10 years than we have in the past 50. The sector, which currently has revenues of over $2tn per annum, is expected to reposition its focus from product sales to becoming a service delivery, and in so doing, revolutionise the way people, goods, and services move about. This is such a significant shift that some see that AV will act as a 'catalysing technology' with far reaching social and economic consequences. Much focus is on land-based AV, but there is also growing excitement for the sea and air.

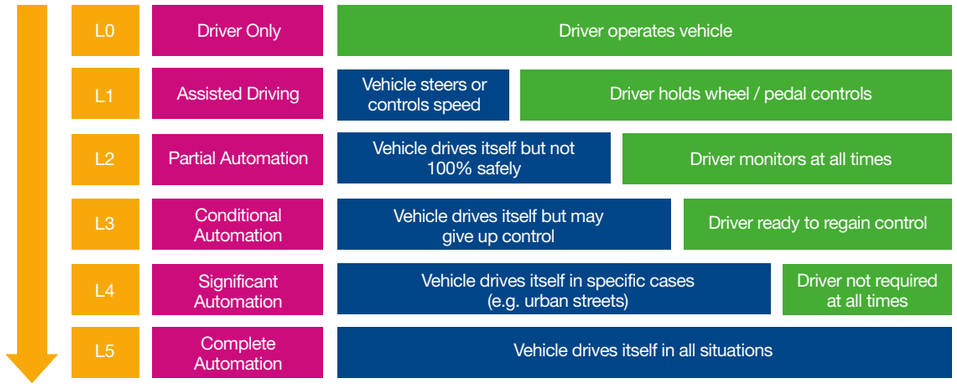
In recent years, many analysts have been working hard to quantify the opportunity:

- BCG sees that by 2030, the shift to "shared, autonomous, and electric vehicles" will account for 25% of all US journey miles.[11]
- McKinsey estimates that up to 15% of all new vehicles sold in 2030 could be fully autonomous.[12]
- Accenture suggests by 2035, as many as 23m AVs will be on the US highways – just under 10% of all registered cars and trucks.[13]
- Goldman Sachs has forecast the global AV market to be $96bn by 2025, and that by 2050, the total annual economic benefit of AV adoption could be over $3.5tn.[14]

While there is already growing enthusiasm and investment, many recognise that, independent of technology availability, it is going to take some time to change the whole vehicle fleet – maybe up to 25 or 30 years. There are just over 1.3bn vehicles in the world today and around 100m new ones are sold every year - so simple replacement without market growth would take at least 13 years. Add in a projected addition of another 700m vehicles over the two decades, and from launch, some are suggesting more than 20 years as the minimum for significant change in the total fleet.[15] Others consider that it may be quicker, as perhaps we have already reached 'peak car' volume in the US and Europe. BCG suggests that by 2030, global sales will plateau at around 100m annually, and that by 2035, 30% of the vehicle fleet will be electric and 25% will be autonomous.[16] In the UK, the Government has an objective to see fully driverless cars on public roads by 2021. According to KPMG, by 2030, 75% of the UK motor-park (vehicles in use) will comprise connected vehicles, of which around 40% will be partially automated, but less that 10% will be fully autonomous.

BCG assessments in 2017 suggested that initial adoption rates will be faster in Europe and the US (20% by 2025) than in Asia (10% by 2025), but deeper in Asia later on (75% by 2035) than Europe and the US (30% by 2035).[17] Today, opinion is moving towards Asia deploying faster, with the likes of McKinsey envisaging that China will start mass adoption of highly autonomous vehicles in 2027.[18] As ever, government plans set the pace, and a mandate from the Chinese central government requires that 50% of all new vehicles sold in China by 2020 must have partial or full autonomous functions.[19] Globally, there are clearly great expectations around AV, but how will this potential change actually occur, and at what speed? A significant number of elements need to align, so many believe it will take more time than some would wish. If you compare this to other transport innovations, automatic transmission took 50yrs to scale, GPS took 35yrs, while airbags took 25yrs.[20]

The AV Roadmap



The most commonly used definition of automation levels is that of the Society of Automotive Engineers (SAE), which identifies six separate levels (L0-L5) ranging from fully manual to fully automated systems. This classification system is based on the split of responsibility between the human and the computer system, from all human responsibility at L0 to all computer responsibility at L5. While widely adopted and logical in order to discuss the various approaches to automation, some suggest that the 6 levels should not be interpreted as representing a sequential deployment path. In fact, some levels (such as level 3, in which a human is relied upon for a safety fall-back role) may not have a sufficient business case for deployment.

The Future of Autonomous Vehicles
Interim Report from Multiple Expert Discussions

Opening Questions

In the 2018 initial perspective, ‘Autonomous Vehicles: Mapping the Emerging Landscape’, we reviewed many of the key recent developments and issues raised in and around the field. As well as exploring the various potential benefits of AVs and the multiple use cases across goods transport and people movement, we also looked at some of the specific opportunities and concerns. These included urban delivery, platoon and fully automated freight, passenger vehicles, public transport, as well as the application of AVs at sea and in the air. Across this, we also considered many of the pivotal drivers of adoption from the impact on safety, public opinion, regulation, and insurance to both the key technologies and the associated matter of technology readiness. We also examined some of the common misconceptions that are being made between connected vehicles and autonomous vehicles. All of these are detailed in the initial perspective document, and from them, we identified a number of key questions. These are some of the major points that need to be answered if all are to have a better view of the field, the opportunities, and the attendant timescales to impact.

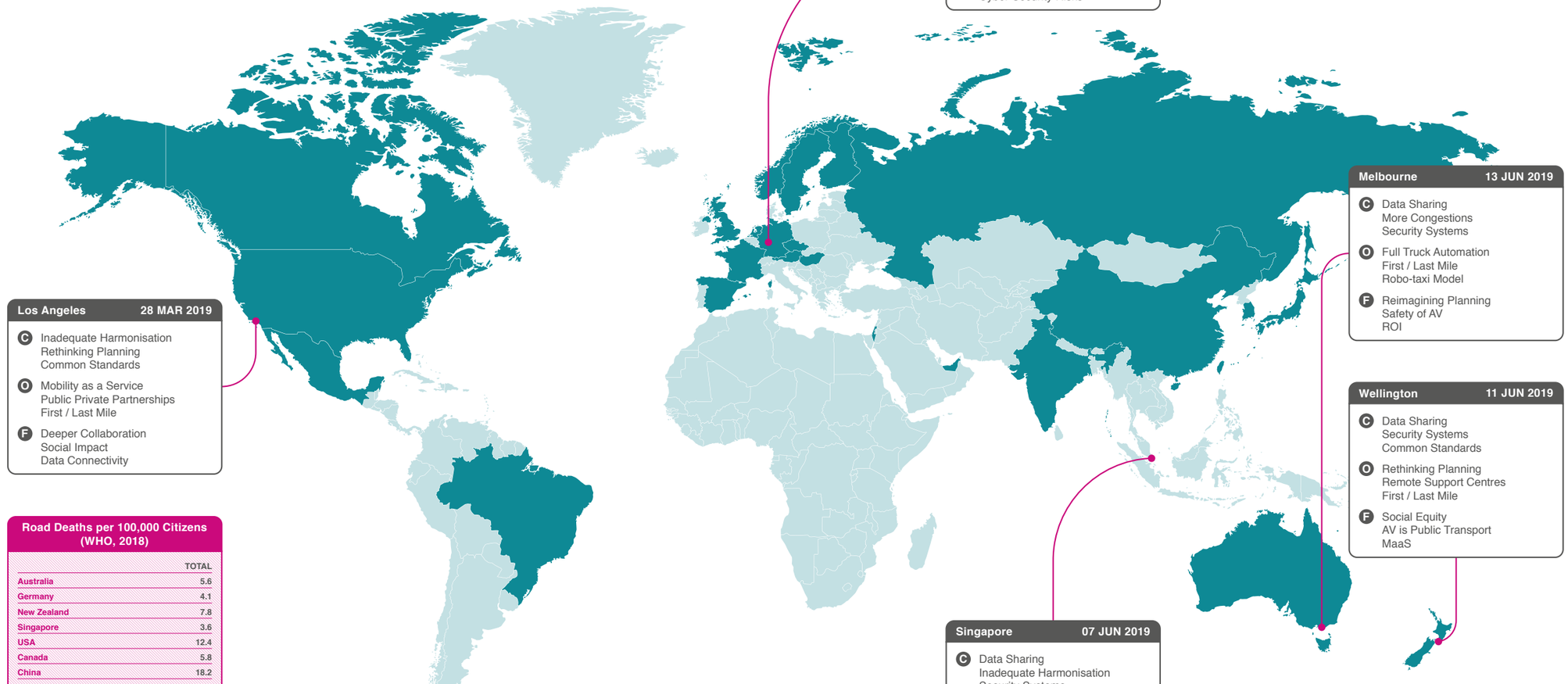
The twelve original critical questions, that were proposed as pivotal to how the future AV landscape will emerge, were:

1. Where will be the key hot-spots for AV development and deployment?
2. Which sociopolitical forces may accelerate the adoption of full Level 4/5 automation?
3. Where is advanced regulation most likely to act as a catalyst for AV deployment?
4. What level of safety (crashes) is acceptable for the full launch of AV in the next decade?
5. Will AV increase or decrease total traffic flow and congestion?
6. Will automated mobility services replace, reduce, or extend the reach of public transport?
7. Of all the technologies in the mix, which ones are in greatest need of further development before the benefits of AV can be realised?
8. What are the distinct benefits of AV that are not already coming from current and future-connected ADAS?
9. How important will international standards and commonly shared technologies be for AV adoption - or will it be more regional?
10. Which will be the pivotal organisations, cities, and governments that control adoption rates?
11. Who will lead on integrating all the various systems needed to enable AV to operate?
12. Who will customers trust more to deliver a safe, reliable, and comfortable AV experience?

As we then moved forward to engage in the series of expert discussions in key locations around the world, exploring the key uncertainties and so gaining a rich, informed, and credible view, these twelve questions have become the cornerstone of the starting point of the dialogue. They, along with the supporting insights, became the ‘stake in the ground’ on the future of autonomous vehicles, that we then invited multiple experts to challenge, amend, build up, and refine in the various workshops. At the halfway point, after the workshops in Los Angeles, Frankfurt, Singapore, Wellington, and Melbourne, plus additional parallel discussions in Japan, the UK, and the Netherlands, we have collated a number of different, informed views on what experts across many key regions think are the answers to these questions and the future of AVs. These have all been synthesised in the following section of this document.

Future of Autonomous Vehicles
Key Insights at Halfway Point

FUTURE AGENDA
Open Foresight



Frankfurt — 22 MAY 2019

- C: Common Standards; Inadequate Harmonisation; More Congestion
- O: Truck Automation; Incentives for Collaboration; First / Last Mile
- F: Communication between Systems; Acceptance of Accidents; Cyber Security Risks

Melbourne — 13 JUN 2019

- C: Data Sharing; More Congestions; Security Systems
- O: Full Truck Automation; First / Last Mile; Robo-taxi Model
- F: Reimagining Planning; Safety of AV; ROI

Wellington — 11 JUN 2019

- C: Data Sharing; Security Systems; Common Standards
- O: Rethinking Planning; Remote Support Centres; First / Last Mile
- F: Social Equity; AV is Public Transport; MaaS

Singapore — 07 JUN 2019

- C: Data Sharing; Inadequate Harmonisation; Security Systems
- O: Robo Taxis; Truck Automation; Urban Delivery
- F: Environmental Impact; Insurance and Liability; Less vs More Congestion

Los Angeles — 28 MAR 2019

- C: Inadequate Harmonisation; Rethinking Planning; Common Standards
- O: Mobility as a Service; Public Private Partnerships; First / Last Mile
- F: Deeper Collaboration; Social Impact; Data Connectivity

Road Deaths per 100,000 Citizens (WHO, 2018)

	TOTAL
Australia	5.6
Germany	4.1
New Zealand	7.8
Singapore	3.6
USA	12.4
Canada	5.8
China	18.2
India	22.6
Israel	4.2
Japan	4.1
S Korea	9.8
Sweden	2.8
UAE	18.1
UK	3.1

C Top 3 Challenges O Top 3 Opportunities F Top 3 Future Issues

Top 25 AV Ready Nations
KPMG https://home.kpmg/content/dam/kpmg/nl/pdf/2019/sector/autonomous-vehicles-readiness-index-2019.pdf

The Future of Autonomous Vehicles
Interim Report from Multiple Expert Discussions

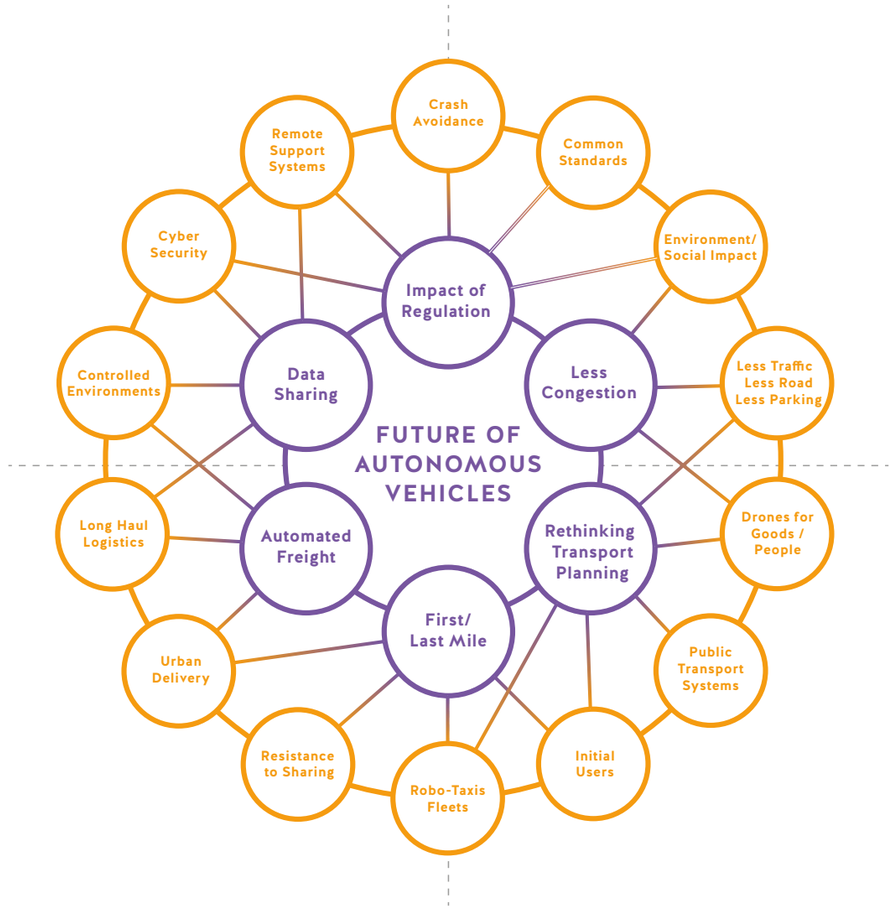
Key Insights to Date

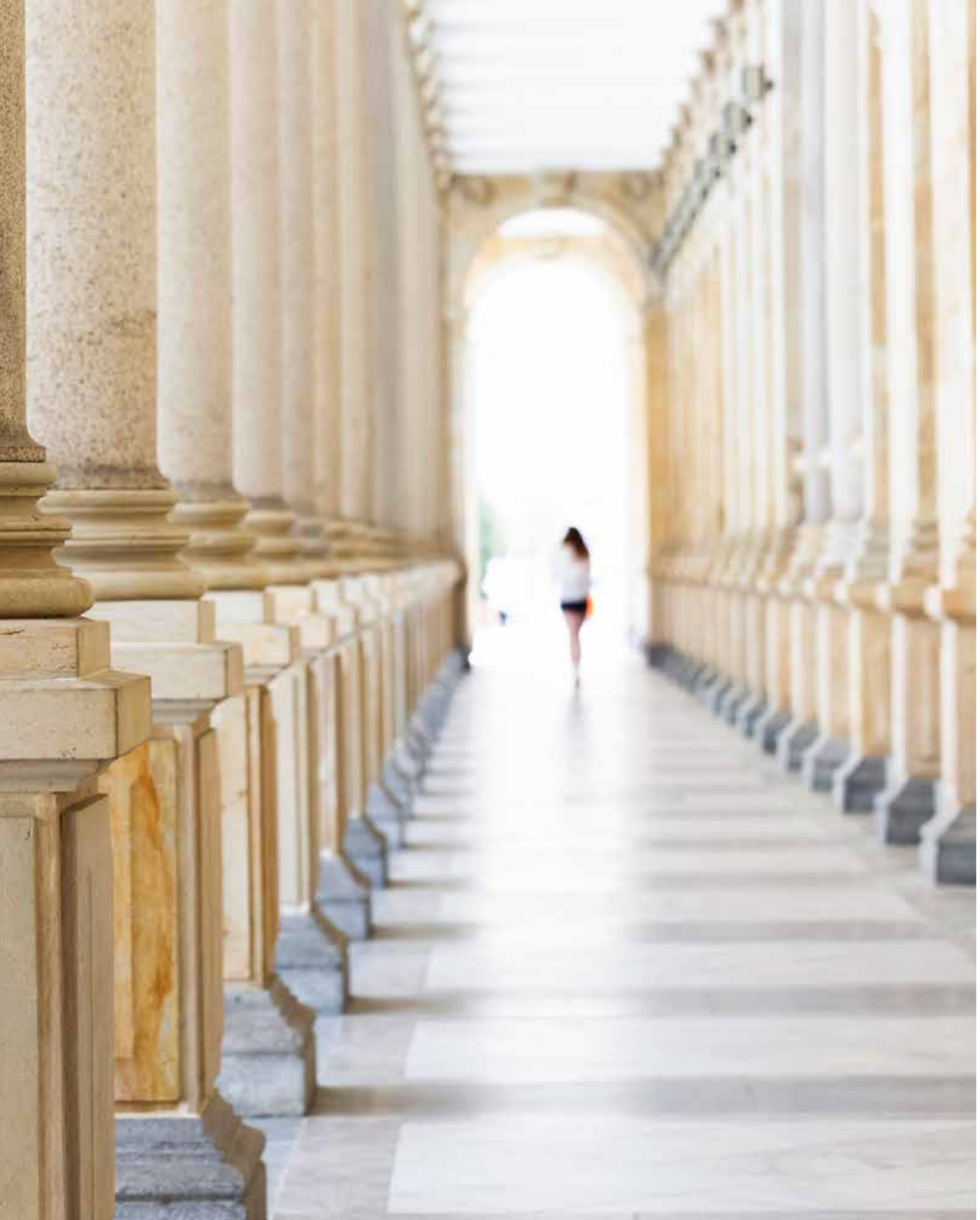
From the discussions in the first batch of workshops, a number of key issues were prioritised, debawivotal high-level macro drivers of change that can be considered to be the focus of greatest debate. These are:

- Impact of Regulation;
- Less Congestion;
- Rethinking Transport Planning;
- First/Last Mile;
- Automated Freight;
- Data Sharing.

Underlying and connected to these, there are also fourteen additional priority topics of focus. These are related to the macro drivers and can be mapped as shown in the diagram below:

Collectively, these twenty areas cover a broad range of the autonomous vehicle landscape, and the comments and feedback gained from the initial workshops provide both detail on how they are being considered, and the level of alignment in the various locations. These are all summarised below.





Impact of Regulation

The regions that gain most initially will be those where there is advanced regulation to act as a catalyst for AV deployment. Addressing information sharing, collaboration, and liability are critical.

While technology development and business models are the priority for many, for those focused on making autonomous vehicles meet the expectations of impact in the future, the role of appropriate and supportive regulation is pivotal. Especially in the main regions for deployment, having the regulation suitably aligned with other developments is a growing area of focus for many governments, cities, and companies alike. In some cases, this is more hands-on, and in others, more hands-off, and in several locations, such as Sweden and Singapore, proactive approaches are already creating supportive environments.

"Profit motives will need to become aligned with public good."

Although there have been a number of recently announced alliances, the initial discussions in Los Angeles highlighted that foremost, there has to be even more collaboration. This is not just sharing information and dialogue between OEMs, regulators, and technology developers, but deeper collaboration across the board: between public and private systems, around emerging infrastructure needs, and on business models. *"Profit motives will need to become aligned with public good."* There was recognition that today, many cities/states/nations are operating *"with a patchwork of regulations that are seen as ineffective."* Moreover, if we are to see *"smart regulations that support AV deployment,"* then, as was proposed by some in LA, alongside the regulators, ultimately there may need to be *"an oversight entity as part of a public/private consortium"* that can both *"inform about city-wide plans and also ensure alignment of future transport visions."* Elsewhere, experts felt that this is only one approach, and that other more practical, less extreme options may be adopted.

A primary issue is therefore *"the need to establish belief in the necessity for collaboration, as at the moment, there is no incentive across private brands to partner with each other."* Regulation can potentially play an important role here, in enforcing key partnerships, including public-private partnerships (P3) to be part of the roll-out of AVs. They can align all the players to the value chain and *"ensure that MaaS is an end-to-end system for buses and taxis alike."* In Singapore, where the government is designing the regulatory environment to become a hub for AV, it is aiming to *"create the collaborative space that is not available elsewhere in the world."* As one exemplar to look at here, several in our varied discussions mentioned the approach taken by the Swedish regulator that has an independent mandate scope, and set up policy sandboxes to enable better dialogue.

In Frankfurt the perspective was that *"we are at a crossroads with some nations restricted by old regulation, some fragmented, and others wanting harmonised regulation,"* and that "by 2030, we need coordinated and flexible regulations that are enabling and testing AV implementation." Fundamentally, a closer relationship between industry and policy makers is vital – one that supports greater technical synchronisation (including standards), particularly on V2V and V2I, and also seeks to align liability and insurance.

"We are at a crossroads with some nations restricted by old regulation, some fragmented, and others wanting harmonised regulation, by 2030, we need coordinated and flexible regulations that are enabling and testing AV implementation."

The liability issue was paramount in Singapore, where it is a key issue for deployment, as currently *"there is no common understanding of what should be insured."* Whereas fleet operations largely use business-based insurance, for private vehicles there is a conundrum. Insurance companies are, for example, debating whether premiums increase or decrease. While in some markets, there are already discounts for vehicles fitted with ADAS, in an AV world, premiums could rise, as *"although there are fewer crashes, the cost of an accident and repair may be high."* While insurance (risk) per mile may go down compared to today, cover per vehicle will probably increase. From a regulatory perspective, there is the need to clearly define who covers what, and where are the limitations on liability. For example, *"if an insurance company does not provide cover for hacking of AVs, is that covered by the government?"* Maybe it would in Singapore, but not everywhere. Moreover, if we are to have more information to support claims for liability, *"will all AVs require a black box, like planes"* to provide the necessary confidence and traceability? Many OEMs are either already doing or planning this, but few regions have made it a required part of regulation. As Singapore seeks to be an enthusiastic adopter of AV, the standard setter for ASEAN, and so the regional first mover, *"clarity over liability"* is a priority.

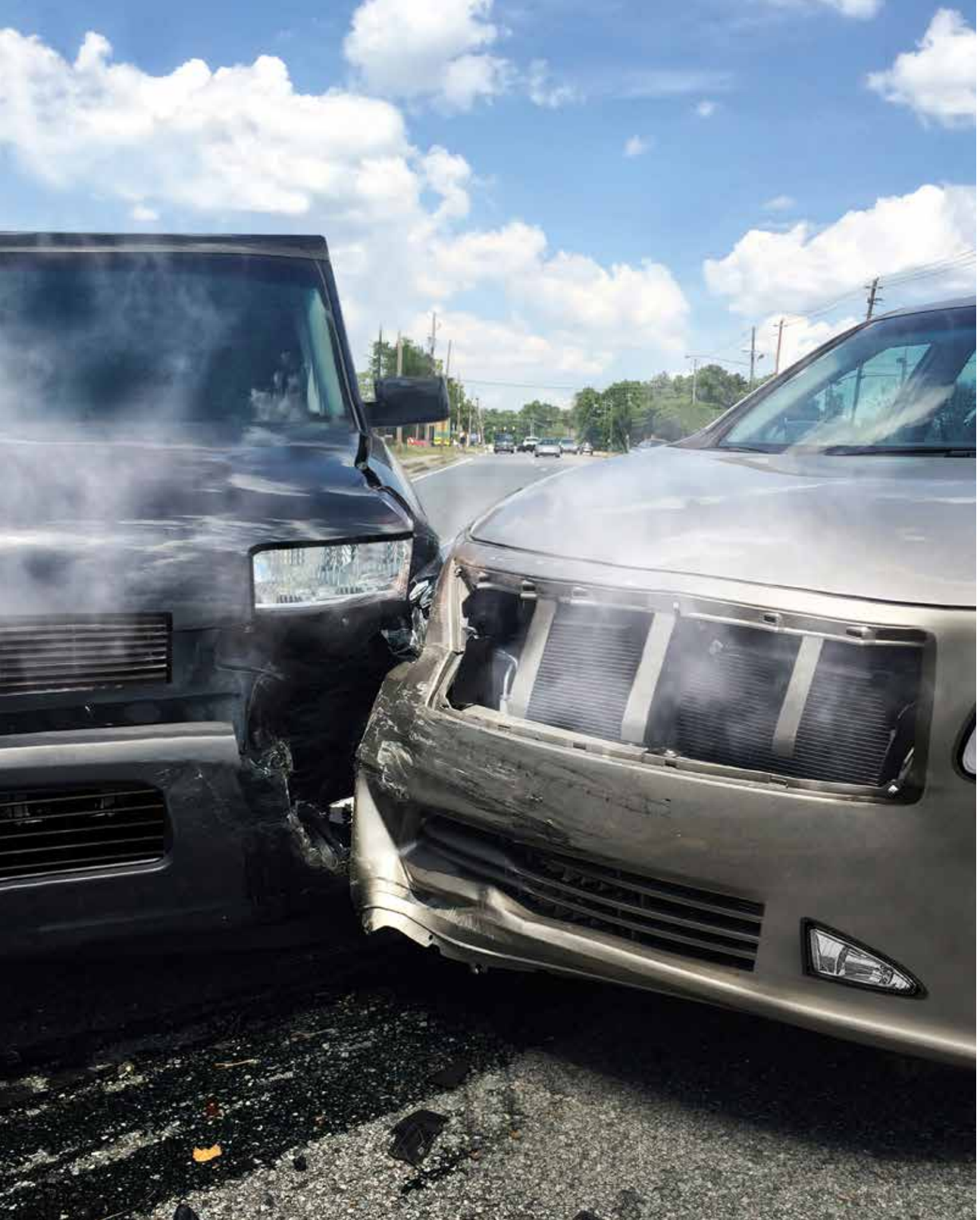
"If an insurance company does not provide cover for hacking of AVs, is that covered by the government?"

Over in New Zealand, regulators themselves see that a major shift is required, from regulating products and services to *"focus on risk and outcomes."* If by 2030 there is a comprehensive new approach to AV regulation in place for all levels of automation, then *"there has to be both more collaboration with the private sector and associated capability development,"* as well as different methods and processes that enable a rethink on regulation. *"UAV regulation in New Zealand is already moving from prescriptive guidelines to risk-based approaches,"* and the same may apply to land-based AVs.

"There has to be both more collaboration with the private sector and associated capability development."

Lastly, in Melbourne, one view on future regulation is that government should take an "ROI perspective," where "the return for AV deployment is going to have to work at both a private and public level." For **private,** commercially driven models, "we will see many trials ahead of pilot deployment in niche markets, and then scale-up and optimisation." For the **public** city-driven scenarios, "the priority will be developing and agreeing frameworks including road use pricing." What needs to be overcome is the "tension between public and private sector ROI" and, as one expert suggested, on who gains what from transport provision: "why should the private sector make money and not the public sector? What is wrong with government making profits?"

"Why should the private sector make money and not the public sector? What is wrong with government making profits?"



Crash Avoidance

Reducing accidents and road deaths caused by humans is a political priority behind support for AV. While benefits can be gained from ADAS, the promise of significant safety improvements is pivotal.

Improved safety, and especially a reduction in road deaths, is at the fore of many arguments for the adoption of AVs. However, as expectations of near 100% safety performance abound, there are some key questions on how perception and reality may align. In Los Angeles, the opening view was that *"while we expect net accidents to decrease with AV, the psychological effect of an AV vehicle crashing (and the driver not being responsible) will cause issues."* Media coverage of single deaths is skewing the debate on system safety compared to existing ADAS options. In Germany, some raised concerns, common in other discussions, as to what level people will trust the technology. While in New Zealand, the focus was on public and political perceptions. In a country where *"200 deaths from an earthquake in Christchurch led to rapid change in regulations, we have 350 road deaths a year, but have no change in relevant areas."* Action follows media and political focus. Therefore, many consider that *"this is all about public perceptions of risk and the ability to do something about that."*

"This is all about public perceptions of risk and the ability to do something about that."

It was, however, in Australia where the safety topic was explored in greatest depth. Opinion here was that over the next decade, *"the core focus for AV safety will be to reduce deaths and injuries."* If there are large scale trials, more driver education, and there is *"a verifiable reduction in road deaths, then public confidence in AVs will grow."* Moreover, while many see that 'lives saved' and 'crashes avoided' will be at the core of driver education, stakeholder engagement, and building public trust, to achieve this there needs to be significant additional work. *"We will need new guidelines and standards,"* and *"all of this will be underpinned by new, deeper safety research."*

Building on the success of ADAS, more trials, new regulation and international standards, then the social acceptance of AVs will grow: *"as technology matures, we see improvements in safety and the enabling infrastructure and institutions align."* However, to achieve this there needs to be more government input, a clearer recognition of the ethics, and better understanding of the role of virtual simulation in safety validation. Maybe there are lessons to be learned from how clinical trials are used in pharmaceuticals, or even from the introduction of jet airliners in the 1950s without proof data, in order to deploy and learn at the same time.

One final warning was whether in the long-term future, humans will have the knowledge and *"ability to take control of a vehicle if needed – in the event of an emergency or a system failure."* Will we become *"so dependent on the technology and lower our situational awareness, that we both lose the capability to drive"* and also lack any skills to deal with vehicle failures?

"The core focus for AV safety will be to reduce deaths and injuries."

Common Standards

International standards and commonly-shared technologies may be essential for driving global rather than regional AV adoption. Without them, a more fragmented approach will be taken.

The idea that we will require common standards for AV is one that has very different reactions in various locations. Although many agree that *"international standards and commonly-shared technologies will be essential for driving global rather than regional AV adoption,"* others differ strongly. In Singapore, for example, opinion was that *"we may see consistent approaches in one location (e.g. Japan), but that does not mean that they will be the same everywhere."* Moreover, *"global agreement will be difficult to achieve, and so will take a long time (if it ever happens)."* And some asked, *"why should China and the US have the same standards?"*

"Why should China and the US have the same standards?"

In New Zealand, it was acknowledged that with technology moving faster than standards, perhaps we need a change of perspective. As systems not people increasingly make decisions, perhaps we should, for instance, be licensing the vehicle to operate rather than the driver, and so *"shift from testing drivers and giving them a driving licence, to having standards for AV systems to meet."* Although not all standards will be accepted by every region, this will mean encouraging OEMS and other Level 4 system providers, such as robo-taxi and AV truck service firms, to define new international standards that can apply across different regions. In addition, it is about *"an increasing integration of standards across vehicles, roads, and telecoms"* – so again, yet more collaboration than today. Within this context, there is recognition of the need to *"ensure that the infrastructure keeps up,"* which may mean more shared functional standards, with self-certification key for compliance. Here, *"there may be several lessons from the likes of the GSMA[21] on how the mobile industry has managed standards without constraining progress."*

"There may be several lessons from the likes of the GSMA on how the mobile industry has managed standards without constraining progress."

Getting into some of the detail of common standards in an increasingly complex system in Los Angeles, several highlighted the need for *"the creation of comprehensive data models that can support standard development."* If *"by 2030, we envisage global common standards and open data sets"* to enable MaaS at scale, then the key challenge is how best to ensure data sharing with common communication standards between AVs and everything else – infrastructure, other vehicles, and the wider transport networks, and bridging between social, data science, and AI. This will, however, require a change of priority for mobility providers, as the *"companies will have to be willing to share data (and not focus only on monetising it)."* Elsewhere, others see that this is a big ask.

"Companies will have to be willing to share data (and not focus only on monetising it)."

Environmental and Social Impact

Ensuring that autonomous vehicles are cleaner than alternative options may be a pre-requisite in many cities, while the benefit of AVs for wider society is a crucial issue for wider endorsement.

High on many wish-lists is that the introduction of AVs will lead to a tangible improvement in both environmental and social impact of transportation. Some advocates concur, but others have concern.

From an environmental perspective, implicit with many assumptions about the future of autonomous vehicles, is that while *"current technology performance suggests that robo-taxis may well be hybrids,"* in the longer term, the majority of cars and delivery trucks will be electric vehicles. In many regions, the transition to AV and EV may be in parallel; *"AVs will be EVs."* As such, the concerns about the environmental impact of EVs – source of electricity, batteries, recycling, charging infrastructure, and long-term energy storage – may well be applied to AVs. Given the momentum behind EVs, *"the future of AVs will have to navigate the same environmental maze"* in parallel, and not be impeded by it. Moreover, as discussed in the next section, there is another key question of whether AVs will decrease or increase congestion, and also impact urban air quality, noise levels, and volume of traffic on the streets.

In terms of social impact, we have already heard several different views, but there have been common questions about inclusivity and access.

In Los Angeles, the primary concern was about how to ensure that cheap, ubiquitous mobility can bridge the gap and provide transport access to the poor, low-income neighbourhoods, as well as the middle-class suburbs. In a city where some felt that *"there are areas that taxi drivers refuse to go to,"* will AVs be able to *"provide equal opportunity to access for all, and so act as a catalyst for wider empowerment and social change?"* In Frankfurt, the ethical considerations of AV on society, including access to mobility, were a source of focused debate with division in the room on whether or not they will have significant impact by 2030. However, all were agreed that *"AVs should provide a service for all, not just the urban elites."* Singapore's strategy is to ensure all citizens have access to good public transport, with AVs as part of the mix, while for both Australia and New Zealand, issues of social equity and access were both raised in the context of rural, as well as urban residents.

"AVs will be EVs."

As driving jobs are eliminated, questions were raised about the pace at which this may occur: over a few years or a few decades? In the US, questions are raised on how the workforce can best be retrained, and how we can *"ensure the replacement for the jobs that AV replace and make redundant."* For example, will bus drivers become non-driving support supervisors on AV shuttles? In New Zealand, passenger safety and confidence were considered to other reasons why, in the initial years at least, a change of role from bus driver to supervisor may be on the cards. In Germany, where today there is a shortage of drivers, the elimination of jobs was not a great concern. Similarly, in Singapore, but here too there was also recognition that *"bus drivers may become conductors."*

"AVs should provide a service for all, not just the urban elites."

Less Congestion

Decreasing congestion on the roads is a core ambition for AV advocates, but many recognise that with mixed fleets operating for several years, we may initially see an increase in urban traffic.

One of the core targets for the adoption of AVs in many countries is to reduce congestion, and this is part of many a business case. However, in several locations there are doubts as to whether this will happen in the first decade or so. Based on the experiences of New York, London, LA, and other cities where the arrival of Uber and other TNCs (transportation network companies) or MSPs (mobility service providers) has led to a net increase in vehicles, many city leaders have concerns.[22] The debate here is whether or not we have reached 'peak car' use, and so, whether if current TNC vehicles do become AVs, will this happen without adding more traffic. Some also consider that self-driving cars that don't need to park could clog many city streets.[23] Others disagree and argue that, *"as endless driving will consume significant energy, operators will look for other options with a better ROI,"* and hence less congestion.

"As endless driving will consume significant energy, operators will look for other options with a better ROI."

"With mixed fleets, we will have more vehicles for a time - it will be worse before it gets better."

While many see that twenty or thirty years ahead, when the vast majority of vehicles could be autonomous, urban mobility will be more efficient, but in the next decade, we could see slower traffic. A good number of experts agreed that *"the introduction of AVs to existing infrastructure will initially increase urban congestion – especially with fleets of ride-hailing robo-taxis."* In New Zealand, where some challenged whether *"we know enough for certain about the number of vehicles that will be on our streets,"* several concurred that for the first years of AV deployment, *"with mixed fleets, we will have more vehicles for a time - it will be worse before it gets better."* Likewise in Australia, some felt that, while *"less congestion is an important aspiration for future cities,"* and so *"there is a push towards it, we are not likely to achieve it by 2030."* Others, however, have different views.

Less Traffic – Less Road – Less Parking

Effective deployment of AVs as part of integrated public transport systems may mean not only fewer vehicles on the roads, but also parking spaces can be removed and roads can become narrower.

In Singapore, there is a strong belief that the impact of AVs will not only lead to less congestion, but if new plans are implemented, then *"by 2030, we will have fewer roads, fewer parking spaces, and more efficient travel flows."* The adoption of AVs is highly integrated into a masterplan to increase public transport usage from today's 67% to 80% of journeys by 2030.[4] *"With smart connectivity and smarter traffic management, Singapore will provide more flexibility for transit system consumers, and a more inclusive infrastructure."* There will be less traffic on Singapore's streets, and so they can be narrowed, with parking spaces reclaimed and repurposed, thus making way for wider pavements for pedestrians; part of the ambition to make it one of the world's leading 'walkable' cities. In our discussions, there was consensus on what will be needed to deliver this: *"pivotal ingredients include the upgrading of traffic lights and lane control systems, enhanced software management systems, and the introduction of real-time pricing for roads and vehicles, coupled with more flexible lane use at different times of the day to help maximise flow."* Moreover, *"accommodating more public and private connected vehicles and an increased flexibility of pick up and drop off points will be essential."*

"Pivotal ingredients include the upgrading of traffic lights and lane control systems, enhanced software management systems, and the introduction of real-time pricing for roads and vehicles, coupled with more flexible lane use at different times of the day to help maximise flow."

"With smart connectivity and smarter traffic management, Singapore will provide more flexibility for transit system consumers, and a more inclusive infrastructure."

While other locations such as Melbourne express doubt on the practicality of such measures, in Singapore, with *"the adoption of AVs starting in the development of new estates and urban districts, and then migrating across the nation,"* the assumption is that the country will meet the *"need to be more effective in accommodating movement of more people and goods within less physical space."* With, as usual in Singapore, a central role for government, the alignment of connectivity standards as part of the wider IoT ambition of a global Smart City, the necessary data for and from vehicles and traffic flows to deliver efficient AV operation will soon be in place. Others, however, are concerned that in Singapore, *"there may be a tension between policy that accelerates deployment, and too much regulation that limits attracting AV providers to the nation."* Although recognising the need to *"accommodate a changing mix of AVs, EVs, and regular cars for the next decade or so,"* in the workshop, there was firm belief that *"we will have a significant reduction in the number of vehicles even by 2030."* As such, *"congestion will decrease significantly."*

Drones for Goods and People

Investment in timely drone delivery services accelerates deployment in several locations, but the roll-out of air-taxis may not be as widespread as many hope. Large scale impact is limited.

The potential for drones and air-taxis to have an impact on how we move goods and people is a field of growing media attention.[5] With tests underway in locations from China and Dubai, to the US, New Zealand, and Australia, the possibility of people moving seamlessly through airspace from point to point, while thousands of smaller drones are also delivering multiple packages, is evidently raising questions about coordination. How multiple automated systems can work without collision, is highlighted in the call for some sort of *"air-traffic control for drones with a flight control network able to self-manage UAV air routing."* For the fast movement of time-sensitive goods, there was general support - with some caveats. By contrast, for moving people, many have doubts of significant impact any time soon.

In Frankfurt in particular, there were several voices in support of drones for goods, with opinion including that *"this is super-important for the last mile."* Especially for body organs, such as kidneys, and other medical supplies, many saw an immediate need. With companies such as Zipwire now scaling in Rwanda, some also envisaged wider application in other locations, where *"from an infrastructure perspective – drones are cheaper than a new road."* Equally in mountainous regions, such as the Alps, or highly congested urban areas, others saw potential benefits in terms of time and cost. With the expectation that military applications and internal logistics, used within the controlled environments of large factories and warehouses, may continue to drive technology development and cost reduction, the future for drone delivery was seen as credible. With the likes of Amazon busy undertaking trials, and UberEATS joining in for fast food delivery, major players driving the initial commercial business cases can be identified. Considered views, however, suggested that the support for a broad range of applications is "best for fast-growing mega-cities, especially those in Asia," and that, wherever they are used, "the need for regulation is clear."

"These are high cost options - only credible for replacing helicopters for the wealthy."

For air-taxis, we heard few voices of support. In New Zealand, where Alphabet has been undertaking initial testing of its Kitty Hawk prototypes, there was agreement that *"these are high cost options - only credible for replacing helicopters for the wealthy."* In Melbourne, our workshop took place the day after regulatory approval for initial testing by Uber.[6] However, participants felt that this area was *"over-hyped"* and that services *"will not be widespread by 2030."* With the "high cost of engineering" and limited current use of helicopters at scale, few felt that we will see widespread impact. Singapore experts concurred that *"there will be a high price point for this, so limited application (e.g. Dubai) – but we may see use in several cities of very high congestion (like Sao Paulo),"* where helicopters are already part of the established transport mix for the elite.

"From an infrastructure perspective – drones are cheaper than a new road."

Rethinking Transport Planning

For AV to have impact, it may be necessary to rethink a more flexible approach to planning. Poor coordination between transit systems, urban planning, and future solutions, may delay the benefits.

As well as being embedded into the Singapore masterplans for new towns, the potential for AVs to enable a fundamentally different approach to planning was particularly embraced in both New Zealand and Australia. There today, much town and transport planning is seen to be "a closed system" that is typically *"long-term but with little flexibility,"* and this needs to change. In Melbourne, the current plans (prepared in 2016) do not include AV. With car parks full, and growing demands on public transport capacity, the need for a rethink or a reimagining of planning is seen as a priority.

"AV use would provide an opportunity to reduce the space required for parking, and so giving land back – which changes density options."

In Wellington, the proposal was for a more *"proactive method for fully integrating AVs into the planning world."* This would involve wider partner involvement, including from the private sector, and the development of *"more agile approaches to planning, complemented by more adaptable infrastructure."* As such, in a radical move, planning could *"no longer solely be a government-led activity but would become an industry/system partnership."* Maybe as new towns and suburbs are approved, *"AV use would provide an opportunity to reduce the space required for parking, and so giving land back – which changes density options."*

In Australia, again a more collaborative approach involving the private sector is advocated, but there was also a suggestion of a change in ambition. Perhaps *"2030 future mobility planning will be focused on economic impact, where mobility outcomes are tied to economic growth."* There could be *"targets for 20% active transport, 20% AV, 20% personal transport, and 20% public transport vehicles."* With the potential for the removal of car parks and the creation of new public open spaces, *"new city designs can have more proactive sustainability targets."* Potentially, a *"national diverse mobility authority could have oversight,"* with more *"state-based direction influencing revenue, productivity, and mobility."* This is a direction that others see Australia as being uniquely able to accomplish. Citing examples including the Western Sydney Aerotropolis[27] and Melbourne's active transport planning,[28] key implications could include changes to road pricing that becomes more dynamic and linked to a wider view, different mobility choices, and the end of the two-car household.

"2030 future mobility planning will be focused on economic impact, where mobility outcomes are tied to economic growth."

Public Transport Systems

As autonomous buses are introduced, other mobility solutions will also have to be used to fill transportation gaps. Security, flexibility, reach, and interconnectivity are primary criteria.

The opportunities for AVs to help improve public transport efficiency, quality, and reach are clearly multiple and noteworthy. In Singapore, where the plan is to move from *"67% public transport use to 80% by 2030, the role of AVs in enabling this is significant."* In Los Angeles, there is recognition that *"we don't want to go door to door for everyone,"* and that *"200 m to 300 m walks are important for improved public health."* New Zealand sees *"a shift from inefficient public transport to an intermodal mix of seamless, safe journeys,"* while in Australia, the view is that *"by 2030, we should aim for equal access to mobility."* Each location, however, has different priorities.

To accelerate AV integration into public transport, a key issue in Los Angeles, largely addressed over 10 years ago in other cities like London, Hong Kong, and several European capitals, was the principle of *"a single mobility payment system"* that can provide door-to-door transport across multiple modes of travel, including those provided by private organisations such as the TNCs. With *"single consolidated fee provision for customers,"* collaboration and data sharing are essential between all parties.

In Singapore, the big issue was how to make public transport more attractive to those currently using their own private vehicles. *"Most significant for adoption by many who prefer personal travel (currently in their own vehicles), will be how to allow more personalisation of public transport systems – be that robo-taxis, AV buses, or other parts of the network."* Achieving this is seen to be primarily enabled by the *"digital configuration of spaces in small vehicles (robo-taxis), as well as in larger systems (trains and buses),"* accompanied by physical *"new form factors, enabling vehicles to morph for different use cases,"* and so accommodate different numbers of people at key times, while also *"recognising dynamic needs for different vehicles with associated market pricing."* As well as increasing public acceptance of AVs for all, it was argued that this would also help to contribute to the government strategy of integrating an attractive AV user experience as part of the public transport system, and the associated trials already underway in new AV towns such as Punggol[29] and Tengah.[30]

For those in New Zealand, the core ambition for the *"intermodal mix of seamless, safe journeys"* requires more trials of options, better network planning, and *"more research on emerging use trends and mobility needs of the population."* In addition, *"ensuring that mobility for the disadvantaged is taken care of"* as a priority by government. Within this and overlapping with previous comments on the social impact of AV, was concern about the implications of removing drivers from a passenger safety perspective. The security of the *"last passenger on the bus"* challenge, especially late at night, was, for instance, highlighted as something they may well need human oversight – initially in person, on each AV and then remotely.

> "By 2030, we should aim for equal access to mobility."

Finally, in Australia, *"where many public transport systems are currently struggling to provide more capacity,"* the growth of MaaS and last mile solutions are seen as a key addition in the mix by 2030. While much of this may be provided by corporate platforms, there was recognition that *"we may need to leverage the private sector to help with the lower socio-economic segments of the population,"* and that *"government subsidy may be key."* However, given that personal transport may become cheaper in an AV world because of a reduced labour cost, there may be more funding in the overall system for this. Other notable comments in Melbourne were that *"it is critical to have government policy driving us away from private vehicle use,"* and reiterating some of the points from Singapore, *"we need to radically rethink about what the AV is from a design/human factor point of view."*

First/Last Mile

Improving the inefficient first/last mile is a major opportunity with health, energy, and efficiency benefits. Scooters, bikes, and small autonomous robots in urban environments, all play a part.

A primary opportunity for AV for both people and goods is in improving and bridging the first/last mile. Whether for getting access from home to public transport, connecting to work or leisure destinations, or for the delivery of parcels to the home or office/factory, the first/last mile has been seen as an area for greater efficiency for some time - and the arrival of AVs seems set to address this.

As some suggested in Frankfurt, *"freight and people movement have the same overall conditions, but a different execution. They require better hub infrastructure, embedded processes, and the right vehicles."* However, others see two different use cases. *"For people, this is about bikes, buses, scooters, etc., linked to multi-modal hubs; for goods, it is connecting to logistics depots."*

For people movement in Los Angeles, distinction was made between urban and suburban locations, where time between home and hub may be significantly greater. *"Often, suburban is a 20-mile round trip, which is not efficient for single pods/robots."* Rather, *"you need bigger vehicles for multiple delivery/drop offs (like the current human driver approach)."* By contrast, *"the scooter model doesn't work in the suburbs – they are never where you need them to be – it is very much an urban/dense living model – so what works in urban areas does not necessarily work elsewhere."*

In Germany, there were also calls to *"differentiate between the urban and rural context."* Parallel discussions in Tokyo reinforced the fact that for Japan, providing transport access for ageing rural populations is a core part of the government's AV strategy. On the negative side, there was concern in LA that *"AV scooters could cripple/grid-lock the system."* Notable, however, in all three locations, was that people seem fine to 'drive themselves' on scooters and bikes in order to bridge the gaps.

In New Zealand, where *"first/last mile transport is currently fragmented across user choice/payment systems with little cohesion,"* it was proposed that, in addressing this challenge, from a public sector perspective, *"we need to rethink the purpose of many local and personal transport options to be about herding people towards the right hubs, from where they can access mass systems and the CBD,"* and also look more at the *"cost/benefit of getting people onto public transport."* In addition, there were calls for better AV/public transport integration, customised services with lots of user choice, and maybe a *"single digital identity"* for transport access.

In Singapore, the national strategy is for AVs to be concentrated very much on the connection between home/work and public transport, and in Australia, there is more of an initial focus on the need for *"changing consumer behaviour away from car ownership,"* perhaps by *"educating the public on cost per mile,"* as well as by providing *"better integration of timetables, ticketing, and payment systems"* so that consumers are able to see AVs as *"a logical transport choice."* A key question raised was *"how to drive patronage of last mile AV to be viable for everyone – not just the few."*

For goods, those in LA considered that, again, urban and suburban areas require different solutions. That said, many consider that suburban is *"a perfect place to develop and test AV technology, and can help to increase public awareness."* In Singapore, the aspiration for future urban delivery via *"small, clean, slow-moving, autonomous robots,"* was seen as an *"accelerator of technology development/deployment,"* but not a core driver of large-scale change. In several locations, but not all, there was recognition of the roles that drones could play in some scenarios. One perspective in Singapore was that *"maybe urban delivery robots and drones should be considered together as two parts of the same challenge."* In Australia, it was, however, cautioned that *"competing against today's white vans is a challenge – they are cheap, flexible, and dynamic."*

For both use cases, for the first/last mile there were several warnings about how best to implement AVs. In Germany, it was clear that *"nothing will change unless the regulation changes,"* while in LA, there was concern about funding, as *"new (TNC) companies are all trying to exploit (publicly funded) infrastructure at no cost – they have to change their view on how they will make a contribution."* Maybe, it was suggested, *"the city should tax AVs and robots using its roads and pavements (sidewalks) to help pay for infrastructure."* Those in Melbourne felt that, if we are expecting between 20% and 30% of vehicles to be autonomous by 2030, then for business models to be viable at scale, regulation will also play a role to *"ensure that public contracts involve data and billing platform sharing."*

Initial Users

Although AVs may have significant benefit for those without access to affordable mobility – especially the young, elderly, and disabled – from the start, autonomy has to be attractive for all users.

The question of who the initial users for passenger AV will be, is one that also has different views around the world. A core element of several government strategies in Europe[31] is that part of the attraction of AV deployment is that *"it will have the greatest appeal for those without access to affordable mobility, or who are uncomfortable about driving - the young, elderly, and disabled."* In the five initial expert workshops, this has not been supported. Rather, these mobility users are considered to be just part of the mix.

"It will have the greatest appeal for those without access to affordable mobility, or who are uncomfortable about driving - the young, elderly, and disabled."

In Singapore, it was suggested that such specific targeting might *"be seen as a negative by the mainstream."* Instead, it was proposed that, as *"providing effective transportation for the whole population is the number one priority,"* then *"AVs need to be designed for everyone from the start, and not segmented."* This was agreed with in LA, where opinion was that *"this is not about purpose-designed vehicles,"* as *"in the future, all AVs will be designed to accommodate everyone."* Moreover, *"creating AVs for individual elderly/disabled people is adding yet more single occupancy vehicles onto the roads."*

The position explored in Australia in particular, was that *"AV has to be cost-competitive,"* and that the people for whom it is, will be the initial users. Furthermore, it was highlighted that, unlike in planes and trains, *"many passengers may get motion sickness in cars,"* so some of the initial use cases based on extra working time or even relaxed reading, may need to be rethought if that issue cannot be addressed. However, others believe that *"this is not AV-specific."* Some consider that *"if it were a large problem, then Uber and similar companies would not be having high ridership today."*

In terms of initial affordability, there was some concern in several locations that *"personal AVs will cost more than human-operated vehicles, so, other than for the wealthy, public adoption will lag several years behind ride-hailing and taxi services."* In Singapore, this was further supported by a discussion of the higher potential cost of insuring expensive AVs. However, in Australia, it was noted that *"in mining, the price difference between an automated and a normal truck was initially $1m ($4m vs $3m) – but as the tech developed, this dropped significantly".* Robo-taxis were, however, consistently seen as a stepping-stone whereby OEMs develop efficiencies and economies of scale, so their eventual rollout of highly automated vehicles is affordable.

"Personal AVs will cost more than human-operated vehicles, so, other than for the wealthy, public adoption will lag several years behind ride-hailing and taxi services."

Robo-Taxi Fleets

Robo-taxis are increasingly seen as the way forward for passenger vehicles and could change both travel patterns and car ownership decisions. They are a core part of 'Mobility as a Service' offers.

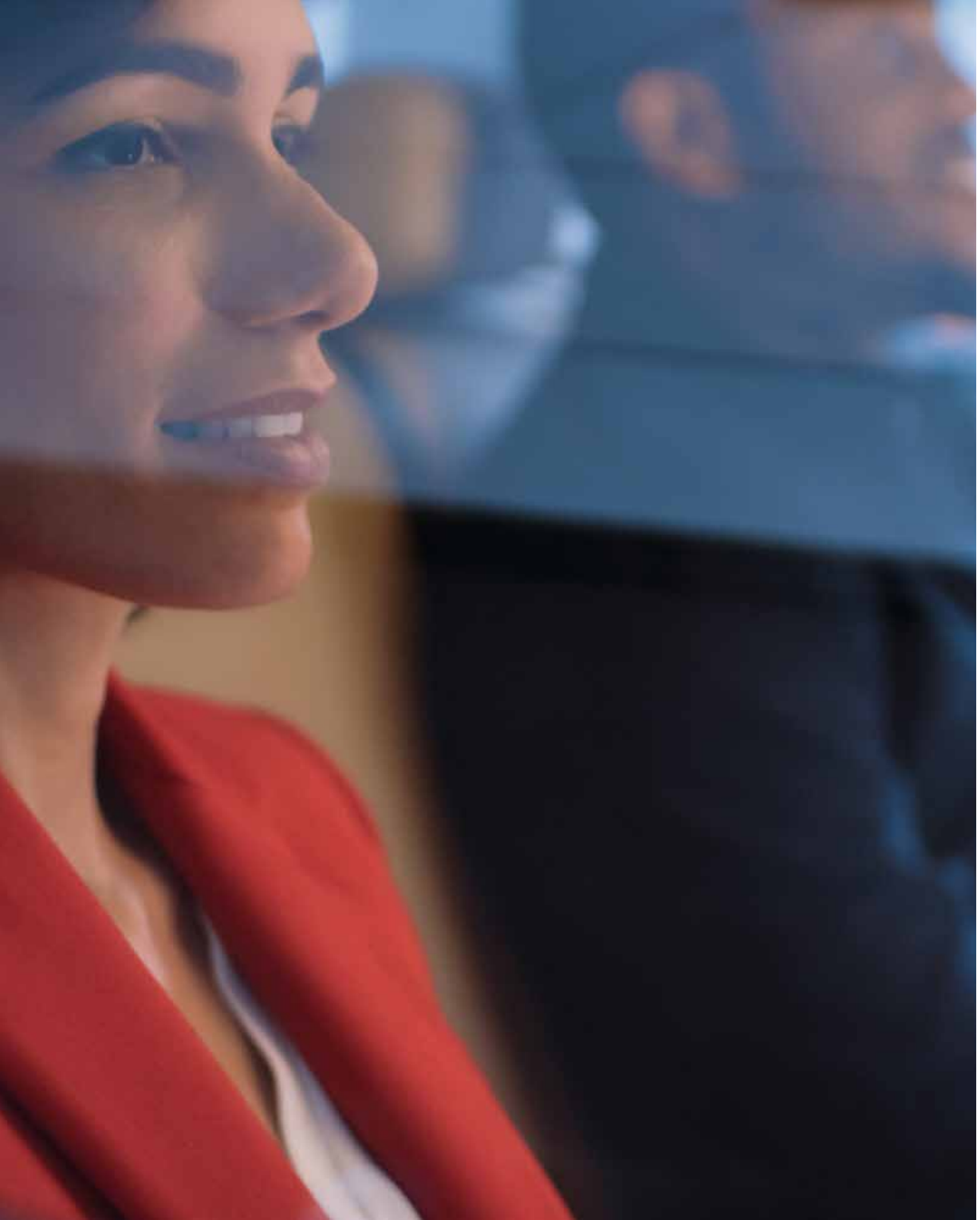
Perhaps the most significant change in recent years across the autonomous vehicle landscape has been the growing support for the robo-taxi model. *"Fleet is increasingly seen as the way forward for passenger vehicles - this could change both travel patterns and car ownership decisions."* Having started via the TNCs, in Los Angeles, the view is that *"OEMs are now driving this. The fleet opportunity is very important, and it is providing rapid AV learning for OEMS."* However, integrating them into the wider transport infrastructure, especially at key intermodal hubs, is critical. In Frankfurt, several had faith that robo-taxis could help to lower congestion in some areas, while others envisaged more urban traffic. As discussed earlier, there is mounting uncertainty over this issue with the key questions related to the number of additional vehicles added to the overall fleet, and, as addressed in the next section, how many people there will be in each one at a time.

"OEMs are now driving this. The fleet opportunity is very important, and it is providing rapid AV learning for OEMS."

In New Zealand, the role of robo-taxis as a core part of MaaS was explored in depth. Here, opinion was that *"the future of seamless transport services is clearly driven by both the product availability and the willingness of current drivers to switch to a subscription service provided by the TNCs."* A core assumption is that *"to have a viable and affordable subscription model, you need to have lots of customers contracted to paying a small amount at an agreed frequency."* While integration with other forms of (public) transport including scooters and bikes, and associated single ticketing systems and APIs were again seen as vital, *"delivering the value proposition to the consumer for both cost and experience"* was seen as a lever to result in a step change. *"When subscription services become cheaper and provide a better service than the private vehicle, then this will take off exponentially,"* and in the AV context, the use of robo-taxis is core to this. However, it was recognised that MaaS can work well without AVs, and a switch to AV is not certain. Although the likes of Uber and Mevo[32] can break even in cities with human drivers, for rural areas it was suggested that AV will be critical to making MaaS economically viable – with or without government subsidy.

In Singapore, there was focus on how the robo-taxi model can deliver cost reduction per km, and several felt that *"the overall net benefit will be making travel and transportation cheaper per mile - even if some elements of the system cost more than today's equivalents."* But others asked, *"what is the AV business model? Who is paying for it? What is driving deployment?"* One response was that *"many OEMs have not been planning far enough ahead, by making current vehicles suitable for robo-taxi deployment, whereas Tesla has increased the cost of its vehicles by including 'future proof' sensors in existing models."* Those in Australia also questioned price and ROI for robo-taxis, and whether or not the *"cost of obsolescence"* is being properly factored into business cases.

"The overall net benefit will be making travel and transportation cheaper per mile - even if some elements of the system cost more than today's equivalents."



Resistance to Sharing

As many people value their personal space, support for a significant rise in ride-sharing may not be as high as some predict. Rethinking vehicle design for strangers travelling together is a priority.

A crucial unknown for robo-taxis as part of the transport solution is users' willingness to share rides. While the sharing of vehicles is not considered to be a problem (it is addressed by access, not ownership business models), the willingness to share an AV with a stranger, but without a driver, is a potential challenge for some. *"As many people enjoy their personal space, some see that public interest in a significant rise in sharing vehicles may not be as high as expected."* Here, however, *"we need to be clear that shared ride is not same as micro transit"* – it could be a more intimate experience.

"We need to be clear that shared ride is not same as micro transit."

One common view across all locations was that *"this may well be a generational issue,"* and *"it is very much age-specific – the young are ok, but not others."* Others suggested that *"population density is key here – in San Francisco, it works because we know people are heading in the same direction."* Several felt that there would have to be change in vehicle design. In LA, it was voiced that *"Uber-Pool is not designed for sharing – the vehicles we use put people too close together. and in future, AVs will be better configured to give passengers more space – we will not be using existing vehicle designs – how they are configured will be key to overcoming people not wanting to share."* In Frankfurt, parallels were drawn with other shared spaces: *"if you look at fitness studios, there is no resistance to sharing space – it is all about the price point – and cleanliness."*

Whatever the link, in most locations, experts felt that this core human behavioural issue has to be addressed and should not be overlooked or trivialised. The economics of MaaS and the implications for congestion *"depend on multi-person trips,"* and so ensuring a wide uptake of ride-sharing is pivotal.

"Uber-Pool is not designed for sharing – the vehicles we use put people too close together. and in future, AVs will be better configured to give passengers more space – we will not be using existing vehicle designs – how they are configured will be key to overcoming people not wanting to share."

Automated Freight

The significant automation of expressway trucks is of huge commercial interest. It will transform long-haul journeys, and so is the principal focus for regulation and trials across all levels of AV.

The opportunities for autonomous vehicles in freight have been at the fore for the past 20 years. Indeed, until the recent acceleration of interest in the robo-taxi business model, many experts have felt that it is in the area of freight and logistics where the first mass deployment of AV technologies would be witnessed. Within this context, one of the initial areas of focus has been for platooning, which is now gathering regulatory support in many nations. Most agree that *"there is no real opposition to level 1 truck automation, and regulators are supportive of platooning, since it offers societal as well as business benefits."* In Melbourne, one view was that by 2030, *"Level 1 AV will be in place - but will have low impact on productivity."* The big prizes for freight may come later. Platooning, for instance, can evolve into higher levels of automation, such as driverless followers.[23]

The key shifts acting as catalysts for the fuller automation of freight across different markets, include *"greater cost pressures, the wages of drivers, driver shortages in many key regions, continued growth in transportation, and rapid technology development."* As was concurred in Los Angeles, *"the significant automation (level 4) of highway trucks is of huge commercial interest to the freight community, and will transform long-haul journeys,"* and across the US, many states are looking at proactive regulation to support this.

"The significant automation (level 4) of highway trucks is of huge commercial interest to the freight community, and will transform long-haul journeys."

In Germany, experts see that *"by 2030, we will have level 1 and 2 autonomy realised, and will be in preparation for level 3."* While probably not at level 4, it was suggested that *"long haul will take the lead alongside controlled environments such as ports and terminals."* Already, *"the technology is developing well, and many new players will enter the market."* However, *"with the US probably in the lead, regulation will play a pivotal role here."* One notable suggestion was that *"public funding can play a functional role in driving uptake – for example, low or no tolls on highways for AV trucks."*

"By 2030, we will have level 1 and 2 autonomy realised, and will be in preparation for level 3."

In Australia, *"with the vast distances involved, the logistics sector will lend itself quicker to greater automation."* While *"there will be different levels and speed of progress in cities and regions,"* opinion was that *"by 2030, we will see fully automated trucks for long haul interstate highways, and also in some specific environments - such as smaller urban deliverers and waste collection."* In particular. as part of the change, it was suggested that *"dedicated lanes and dedicated operational time windows will play an important role as regulation gradually changes."*

Globally, today the consensus is that *"we will need more pilots on the roads to build public trust, drive regulation, and hence public funding."* These pilots clearly have to address a number of issues, but many may well *"focus on building public awareness and demonstrating new use cases,"* as well as *"exploring different ownership models and various vehicle configurations, in order to gain community acceptance."*

Controlled Environments

Controlled environments have demonstrated the early steps for AV and are growing steadily. Airports, port terminals, factories, mines, and even dedicated highways, all provide safe areas for development.

Within any discussion of autonomous vehicle use, distinction has to be made between those required to function on the open road, and those that are operating within so-called controlled environments. Within, for example, mines, airports, port terminals, and industrial sites, there is significant use of automation already in place. However, as was agreed in most locations, while *"controlled environments are good test-beds for technology to be introduced into the real world,"* in most regions, *"there are more complex challenges to be addressed for this on the open road."* As was asked in LA, *"how can AVs within the ports move outside the boundaries and mix with the wider infrastructure?"* While in Singapore, there was push back to think about controlled environments through a different lens, as they can *"include dedicated lanes in cities – so don't just think of this as terminals and other closed areas."*

"How can AVs within the ports move outside the boundaries and mix with the wider infrastructure?"

"Controlled environments are good test-beds for technology to be introduced into the real world."

Data Sharing

More and deeper data sharing are pivotal in enabling the AV ambition. Mobility brands eventually agree the protocols for V2X interaction and so support the use of open data sets.

The need for more and better data sharing between key parties in the AV ecosystem was highlighted in many discussions. In Los Angeles, this, *"and deeper collaboration on protocols,"* was seen as essential to enable full AV impact. In Frankfurt, there was a call for more *"sharing options between manufacturers and public authorities,"* while in Singapore, there was a request that *"we must set clear standards for key devices – including both the data needed and the access systems."*

However, there seems to be a problem as currently, few of the key private players are willing to share little, with peers and public systems, beyond the minimum information. In Germany, car companies revealed that *"we don't have clarity on how all the required information will be available to the vehicles."* In addition, some felt that *"currently, there are too many data protocols out there – so VWs don't talk to BMWs: companies are not sharing information because of competition."*

"Currently, there are too many data protocols out there – so VWs don't talk to BMWs: companies are not sharing information because of competition."

Some sort of open data system within trusted parties was consistently called for - but without much detail on what and with whom. It clearly needs to encompass V2X modes but having agreement on what is shared is a key gap to be filled, and quickly. In New Zealand, there was recognition that for areas like high definition mapping, *"we should not be betting on one type of coordination,"* but rather seek to have multiple options available. Maybe, as suggested in Singapore, *"building the ecosystem through partnerships with academia, will be pivotal."*

"We must set clear standards for key devices – including both the data needed and the access systems."

Cyber Security

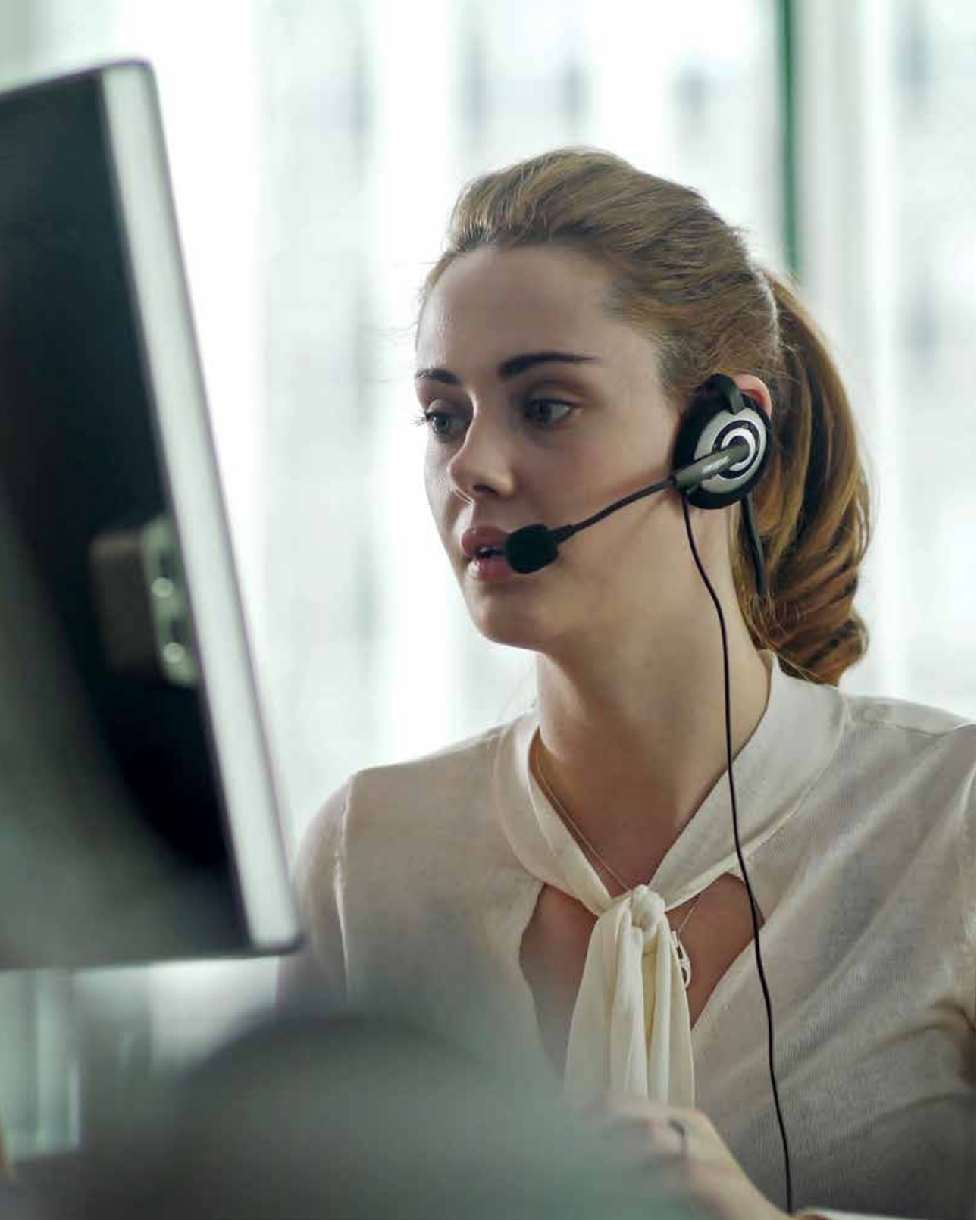
With the threat of hacks, denial of service, vandalism, and theft of data, organisations seek to make AV more secure through adopting common approaches for closed, collaborative systems.

Linked to more open data sharing and access to systems, is the associated security risk. *"System and infrastructure security"* were key concerns in Frankfurt, and there has to be some sort of closed system to address this. Priority is on preventing *"hacking, denial of service, theft of customer data, vandalism of sensors, trolls taking over robo-taxis, and using cars as weapons,"* as well as other cyber security threats, but also not constraining the necessary collaboration highlighted previously. As with all IoT systems, there is a balance between connectivity and risk, and for high speed AVs, this is a major challenge to address. In New Zealand, some questioned *"what happens if the whole system collapses? Who is able to drive a vehicle? How do we move? Do we go back decades?"* Is anyone planning for disaster recovery scenarios when a hack or an error takes down the whole network? Others elsewhere felt that this extreme was unlikely, as there are numerous overlapping safety systems likely to be in place.

"What happens if the whole system collapses? Who is able to drive a vehicle? How do we move? Do we go back decades?"

"Success for 2030 is that nothing will happen. Everything will work smoothly. There will not be major hacks of AVs or the infrastructure, people won't be injured, and the system will be secure."

A deeper exploration in Germany concluded that, if we can get this right, then *"success for 2030 is that nothing will happen. Everything will work smoothly. There will not be major hacks of AVs or the infrastructure, people won't be injured, and the system will be secure."* It was proposed that *"if AVs are closed systems, then the vehicles can be in control of what data is used and shared: verifiable information should only be used, and so all data has to be verified."* What is needed, it was suggested, are closed, but collaborative systems, with *"protocols that highlight which information is delivered to what vehicle in which way via what channels,"* and that within Europe, *"Germany can take a lead and set the standards for the rest to follow."*



Remote Support Centres

Manned call centres provide oversight, support, and emergency response for all AVs. In the absence of drivers, most public transport vehicles require remote human supervision.

While many aspire to a fully automated experience, where machines and systems can manage independently, the need for human input, at least for a transitionary period, was highlighted in several discussions. Most significantly, and as detailed most in Frankfurt, there is an operational support requirement for AV. For instance, *"autonomous public transport vehicles will not replace all of the functions currently undertaken by a bus driver: driving the bus, monitoring passengers, validating tickets, ensuring full functioning of the vehicle, and being the point of help in the event of passenger need."* New Zealand addressed similar points.

"There needs to be some sort of central management."

The German view was that, and as some OEMs have already proposed, *"there needs to be some sort of central management."* The common notion of this is a remote support centre able to take over control, override machine decisions, and interact with passengers from afar – not too dissimilar from how drones are 'flown' by the military, or how autonomous ships may operate in the next few years. *"By 2030, we can envisage fully connected manned control centres providing oversight, support, and emergency response for all AVs. Humans will have supervisory and, if needed, active control of AVs."*

"By 2030, we can envisage fully connected manned control centres providing oversight, support, and emergency response for all AVs."

Halfway Reflections

After the first five workshops, it is clear that, across the various markets, there are areas of alignment - but also notable nuances in approach to AVs that are different, country to country. From our discussions to date, we can see nine key issues already emerging as significant - all of which are intricately inter-connected, but collectively do indeed provide a highly 'wicked' problem. At this point, therefore, we would like to offer some half-way reflections on these topics:

1. **Safety is a pre-requisite:** Expectations are high, but as many advances are already in process, improvements look likely.
2. **Fleets are now driving progress:** In terms of the core business model, the momentum is clearly behind the robo-taxi concept.
3. **Automated trucks are coming:** Freight has much to gain in terms of efficiency; it has regulatory support and wide industry support.
4. **Congestion is a conundrum:** While all aim for less congestion, and the role of connectivity will be pivotal, user behavior and TNC strategy could initially mean more.
5. **Multiple options for the last mile:** There are many alternatives in the mix, all bridging different needs and location gaps.
6. **First vs widespread deployment:** Where and why we see initial AV services may not necessarily align with where mass impact will occur.
7. **Deeper collaboration will be needed:** Moving from partnerships to long-term multi-party collaboration is seen as a critical enabler.
8. **Standards may not be pivotal:** Comprehensive global and regional standards may not be essential for AV; rather, standards will evolve based on business needs.
9. **Regulators are influencing deployment:** Proactive regulation is attracting companies, but the balance of light vs. heavy approaches may impact this.

Reviewing each of these in more detail:

Safety is a pre-requisite: While safety has been one of the core discussion topics, participants acknowledge that overall system safety is improving steadily, as more ADAS-equipped vehicles are purchased and operated. As such, the additional contribution of autonomous vehicles in reducing today's human-caused crashes will be marginal. The AV safety conversation is more about ensuring these vehicles do not pose a new threat to today's road users; ideally, they will operate more safely than humans – and opinions on this are evidently setting high expectations. Cybersecurity also fits into this picture as another risk factor. However, participants in Frankfurt noted the high cybersecurity rigour with which the auto industry already designs vehicles and manages the system - but of course there is always room for greater robustness. Overall, a clear viewpoint emerged that safety validation processes for AVs, as are being implemented by tech developers and carmakers, are very sophisticated. Nevertheless, pressure must continue to be applied, to 'get it right'. Failing to meet the safety anticipations would be a major setback for AV deployment.

Fleets are now driving progress: Across the workshops, there was strong agreement that for the short and medium-term, the "action" lies in fleets, rather than privately-owned vehicles. As well as being the focus for the TNCs, robo-taxis will provide new revenues to passenger car OEMs, while technical learning occurs which can then be transferred to mass-market vehicles. This also simplifies the insurance picture, as fleet operators will work with insurers to price risk and devise appropriate coverage. Some well-capitalised companies (such as Waymo, Uber) are likely to self-insure their assets, and may extend this to liability as well. Resolving issues for the more complex world of personal auto insurance comes much later.

Automated trucks are coming: Experts were generally convinced that automated trucking and truck platooning are coming in the near future. Economically, full driverless freight operations are the "Holy Grail," with platooning acting as a stepping-stone. Although increasingly supported by regulation in a growing number of locations, level 1 platooning is not seen as having a broad societal effect. However, as driverless truck developments progress, they will begin to change supply chain operations in multi-faceted ways – many of which are yet to be elaborated. What, for example, are the effects on fresh produce grown in the western U.S. and shipped to Chicago in winter? Only trucks offer reliable shipping times, but these can be 4-6 days with a human driver, compared to a driverless truck making the trip in two days. Energy costs of climate control for the load are reduced, and the tomatoes can be picked ripe rather than green.

Congestion is a conundrum: Congestion remains a problem that autonomous vehicles cannot solve on their own – even though some expect them to do so. While in several cases, the arrival of TNCs like Uber has added traffic in cities, tomorrow's robo-taxis should not necessarily represent an additional increase over the current numbers of MaaS vehicles. In general, rising traffic volumes and a slowing of average speeds are age-old concerns, and will continue to be a primary focus for both advocates and critics. Here, the needs of society, cities, and tech firms will reinforce one another, so that moment-to-moment data sharing – which is likely to be via some combination of V2X and cloud - should improve traffic flow. Mobility service providers can deploy V2X on their vehicles, both to be a good citizen and achieve shorter trip times – an issue that is especially important in energy management for EVs. Another core component of easing congestion is the willingness of robo-taxi customers to ride share with strangers, and this will be pivotal to the outcomes of MaaS. Pricing levers can only go so far – at some point, this is about core user behaviour. So, what, for instance, will be the effect of a per-mile tax on robo-taxis, based on factors including occupancy? This and other unknowns create a conundrum for transportation planners who hope for less congestion in the end, but recognise that there

could be more in the medium term. As was noted in Melbourne, *"the return for AV deployment is going to have to work at both a private and a public level."*

Multiple options for the last mile: For both people and goods, the first/last mile is a hotbed of activity. In terms of public transit, alongside electric scooters, bikes, and other traditional options, the integration of TNC operations with public transport systems is a dynamic area with the promise of a win-win, when priorities are aligned. However, right now it is too early to draw conclusions on which combinations will gain priority, as the outcomes may vary dramatically from city to city. For goods, the growth of urban delivery will be very interesting to watch, as a broad portfolio of services can potentially be more agile than those serving people. As for drones, they are seen as part of a 'means to an end' for the last mile - more probable for goods than people in most scenarios - but not yet pivotal in this discussion.

First vs widespread deployment: It is important to avoid conflating the 'first' deployments of AVs with later 'widespread' deployment. Taking just passenger vehicles as an example, while initial robo-taxi services may be operating as early as 2020, city-changing levels of deployment will occur for only a few individual cities over the next decade. In many locations, widespread deployment will largely only start to play a role after 2030. Therefore, while regulators need to act to enable first deployment, planners have plenty of time.

In China however, the narrative may differ. A recent McKinsey analysis proposes that we are less than 10 years away from 90% of passenger-kms travelled in China being handled by automated vehicles.[34] The prediction is for 2025-27 to be the inflection point. There is visible impetus. WeRide just announced a partnership with a very large local taxi group in Guangzhou for the rollout of their robo-taxi services.[35] Equally, Baidu is ramping up activity and Didi Chuxing's autonomous driving unit is now an independent company and attracting more investment.[36] China will, however, clearly not be alone in launching robo-taxi services in the next decade; growth is likely to be robust elsewhere as well.

From our discussions, for **private,** commercially driven models, *"we will see many trials ahead, of pilot deployment in niche markets, and then scale up and optimisation."* For **public** city-driven scenarios, *"the priority will be developing and agreeing frameworks and roads, including road use pricing."* What needs to be overcome is the *"tension between public and private sector ROI,"* and, as one expert in Australia suggested on who gains what from transport provision: *"Why should the private sector make money and not the public sector? What is wrong with government making profits,"* with more *"state-based direction influencing revenue, productivity and mobility?"*

Deeper collaboration will be needed: Across all areas and all locations, there were extensive discussions of concepts around collaboration. Generally, these were in the context of government-industry collaboration (e.g. data sharing for safety validation), and sometimes referred to industry-industry collaboration (e.g. data sharing for development purposes). While in some workshops, discussions veered somewhat towards 'collaboration as an end in itself', rather than a means to an end, it is clear that many expect a step change from current levels.

In reality, tech developers will carefully assess what they want to keep under their total control, versus working multi-laterally. For instance, remote support is likely to be defined and implemented by the tech developers working on their own, and/or with private sector partners. How, therefore, can the public sector engage and be engaged? … So far, the view is probably via more dialogue (government-government/government-industry) and establishing consortia (government-government/government-industry).

Balancing simplicity and complexity will be crucial here. Government-industry and government-government dialogue through existing channels has, for instance, been occurring since the start of the AV era. A unilateral approach is employed by several in the AV ecosystem, and is driven by the desire for simplicity. In June, Uber released extensive info on their "Safety Case" approach for digestion by regulators and others.[37] While this is not 'collaboration' per se, it serves to enhance their dialogue with governments, while informing the broader community.

On the other hand, more formal consortia can be challenging and time-consuming to implement. Collaboration across the OEM technology development world is highly active, including the Ford/VW alliance for automated and electric vehicles, and Honda partnering with GM to bring Cruise robo-taxi services to market.[38,39] Additionally, the move towards verticalisation is accelerating - for example, Ford adding Quantum Signal AI to their stable of acquisitions, joining Argo AI and others.[40] Tech industry collaborations are a given; the challenges now and in the future will be in crafting effective government-industry interactions. One view is that new industry-government structures for managing AV integration into society could come in the longer term, but this may slow things down in the short term. A deeper dive into the various forms of collaboration in our future workshops will be valuable.

Standards may not be pivotal: Standards are a form of collaboration in which industry, and sometimes governments, have much at stake. However, if we look at today's ride-hailing services, it is clear they have not been hampered by a lack of standards. In workshops to date, the need for standards has been advocated by many, but we would caution that a key question for the future is: "does the automated mobility service work?" Looking at three areas of import:

- Standards are not necessarily required, particularly when data sharing is done through the cloud and software translates different data formats
- Standards are generally driven by economics, for instance to achieve economies of scale, a process which happens well downstream of initial system introduction.
- Standards to support inter-operability can be enablers to growing a nascent market.

Regulators are influencing deployment: Regulations form the intersection between geography and AV technology, and the regulators are seeking to build clarity and level playing fields via standards. This can provide more certainty, which in turn drives deployment, but not always. Companies deploying automated mobility services companies are all seeking to maximise ROI, and they have a widening choice as to where to deploy. Multiple cities and countries are competing to be welcoming; but other jurisdictions feel a need to add stringent conditions - as has been done in some places with human-driven TNCs.

Singapore already has extensive requirements on AV provider testing, which is likely to continue for deployment. It is currently 'hot' for deployment plans because of its enabling approaches, but will this remain the case if regulations ask too much from AV providers who can turn their deployment planning elsewhere? Too heavy a hand from government may delay deployment, yet there is clearly a case for protecting the public good for safety and efficiency. For instance, one Melbourne participant raised the possibility of a "national diverse mobility authority" having wide oversight. In the workshops, we have seen the tensions between heavy-handed but enabling regulations, versus more hands-off 'wild west' environments such as the USA. The right approach for widespread deployment is yet to be determined.

The first tranche of our discussions around the world has evidently highlighted a number of important issues – some of which certainly require further debate. The future workshops will continue to explore both niches and commonalities.

Questions and Answers

Our Initial Questions

As mentioned earlier, from the initial perspective, we highlighted 12 pivotal questions to be addressed in this series of 2019 expert workshops. These were:

1. Where will be the key hotspots for AV development and deployment?
2. Which sociopolitical forces may accelerate the adoption of full Level 4/5 automation?
3. Where is advanced regulation most likely to act as a catalyst for AV deployment?
4. What level of safety (crashes) is acceptable for the full launch of AV in the next decade?
5. Will AV increase or decrease total traffic flow and congestion?
6. Will automated mobility services replace, reduce, or extend the reach of public transport?
7. Of all the technologies in the mix, which ones are in greatest need of further development before the benefits of AV can be realised?
8. What are the distinct benefits from AV that are not already coming from current and future connected ADAS?
9. How important will international standards and commonly shared technologies be for AV adoption - or will it be more regional?
10. Which will be the pivotal organisations, cities, and governments that control adoption rates?
11. Who will lead on integrating all the various systems needed to enable AV to operate?
12. Who will customers trust more to deliver a safe, reliable, and comfortable AV experience?

At the halfway stage, we have evidently gained opinions on most of these. Many discussions have added more context; some have addressed the issues locally, some globally, and others are still open for debate. In addition, several discussions have highlighted that the answers for AV for people and goods are different. This is a half-time snapshot:

Where will be the key hotspots for AV Level 4 development and deployment?

Although there are overlaps, it is evident that development and deployment should be considered independently.

Development of AV includes a wide range of issues such as software development, simulation, and track testing.

- For **people** AV, the US is clearly the centre of much attention, with Silicon Valley, Detroit, Pittsburgh, and Boston all at the fore. However, across Asia (China, Japan, and Korea), there is major activity, while in Europe, Germany and the UK are the primary hotspots. Lastly, Israel is very much on some radars.
- For **goods** AV, the US focus is very much in California. In Europe, alongside Germany and the UK, Sweden is a major centre, while in Asia, it is China and Korea moving ahead of others.

Deployment includes on-road testing with safety drivers, offering commercial services as well as full driverless commercial deployment, which will occur typically initially in these testing sites.

- For **people** AV deployment, with favourable regulations, Arizona is a notable centre, alongside Las Vegas, San Francisco, Pittsburgh, and Boston. Elsewhere Singapore, Japan, and the UK are the top locations.
- For **goods** AV deployment, the focus is very much in three proactive US states (Arizona, Florida, Texas), as well as Australia, and again, Singapore.

Which sociopolitical forces may accelerate the adoption of full Level 4/5 automation?

With **people** AV, demographic needs are playing an influential role. So, providing access for the significant and growing elderly population is important in locations such as Japan, and has become a focus for government mandates. Globally, and already evident in multiple regions, a more sustainable option for mobility in cities is a mounting concern for the young, and the alignment with urban electrification strategies is supporting rising synergy with AV technical requirements. For **goods** AV, the issues focus on drivers and freight volumes, but with different emphasis in various regions. So, the lack of, and hence high cost, of drivers is particularly important in countries like Germany, Australia and the US, more than in India and China. Globally, however, the continued growth of e-commerce, and complex routing for residential delivery, is driving demand and scale.

Where is advanced regulation most likely to act as a catalyst for AV deployment?

As we have seen, proactive regulation is a primary reason for companies to locate activities in one country or city over another.

- For **people** AV, in Asia, Singapore is further ahead, but China is moving fast and opening up major cities for full automation. Also notable is Japan, supporting testing and initial deployment in and around the 2020 Olympics. In the Middle East, as with previous innovations, the UAE can be flexible, and that is encouraging Dubai to be pre-emptive in some key areas.
- With AV for **goods,** again, Singapore is implementing a vision for a fully autonomous future, and China is acting quickly to achieve similar. Elsewhere, most notable is Sweden, which is being astute with its sandbox approach.

Across both fields, in the US, a more hands-off approach at Federal level is resulting in individual states being more proactive to attract deployment, while in Europe, the EU regulatory approval approach is slow by design, with commercial trials being done via regulatory exemptions. Full deployment here may therefore well lag behind some other regions. Lastly, Australia is implementing regulations on a stated timeline, and is seen to be another active location.

What level of safety (crashes) is acceptable for the full launch of AV in the next decade?

There is general agreement that AVs will need to be safer than human-driven vehicles, with lower crash rates and the data to prove it. Even though it is an expectation driven by media hype, most now also recognise that 'zero crash' is a very high target that is unlikely to be met. For the current testing phase, with safety drivers in the mix, it is seen as critical that the tech developers meet the highest standards of training and monitoring of their safety drivers, to avoid mishaps like recent incidences. Moreover, it is assumed by many that early deployment could see crashes with AVs caused by human drivers in other cars more frequently than the other way around. A key challenge here is that AVs cannot be 'too careful', and move in ways that slow traffic and irritate other drivers; they must perform in a human-like way and integrate seamlessly into the wider transport ecosystem.

Will AV increase or decrease total traffic flow and congestion?

This is a question with very different views around the world. In general, a core assumption being made is that the growth in human driven TNC vehicles reflect customer demand, and have already increased congestion in some city centres. As they are introduced, robo-taxis will replace these to some degree, but also increase demand due to lower pricing. Moreover, if there are more robo-taxis in the mix, then there will be system compensations – such as less personal car travel and less use of public transport. So, one strong opinion here is that there will be no net change in the volume of vehicles, but the expectation that more efficiency may increase the average speed of travel. Eventually, therefore, we would see a decrease in congestion.

Some are being bolder in aiming for quicker reductions in congestion. Singapore has the most extreme targets and has a decrease in congestion as a core part of its new masterplan strategy, with MaaS adoption also enabling the reclaiming of space currently used for parking as part of making more liveable cities.

Additional, but as yet uncertain, factors that could help to improve traffic flow include:

- High levels of adoption of ridesharing meaning fewer robo-taxis deployed,
- Incentives to limit robo-taxis roaming around empty until a rider is assigned,
- More night-time running of trucks reducing congestion during the day,
- Improved V2X connectivity and data sharing that can help smooth traffic flows.

Will automated mobility services replace, reduce, or extend the reach of public transport?

The integration of MaaS and public transport within the overall transport system is evidently influenced by the pre-existing norms that vary from city to city. Some locations already have extensive public transport networks, while others are more limited. Rail-based mass transit systems are seen as less likely to be impacted than road-based buses and smaller campus shuttles. The general view is that, if mobility needs are met via robo-taxis in areas where public transport is presently uneconomical, then this is all the better for transit agencies which are subsidised by public funds. In order to support this, there are more collaborations underway between transit agencies and the TNC, with paratransit special transportation services (for people with disabilities) in the US being taken over by TNCs in some cities. Moreover, in some locations with high risk neighbourhoods, where human drivers are reluctant to go, some see that automated vehicles may well improve access. In terms of design options, several are confident that a wider range of vehicle sizes and layouts, that may be available via robo-taxis and TNCs, could provide more flexibility than existing timetables. So, in locations where current services are provided by one of two sizes of bus, in the future there could be a wider range of, for example, 2, 4, 8, 12, 20 and 40 person AVs - so seating capacities adapt to market demand and provide improved access and reach.

Of all the technologies in the mix, which ones are in greatest need of further development before the benefits of AV can be realised?

With the momentum behind AV growing, extensive tech development is underway across all major technology categories (HD Maps, lidar, radar, computer vision, AI, V2X, INS, etc.). Associated funding is at vast levels across all fields. As such, while some speculate that one company presently has better technology for a specific task than another, given the scale of the opportunity, most would agree that, if there is indeed market demand for L4 services, then venture funding will appear to fund technology development and address any gaps. Private sector forces have already created eco-systems to serve current needs, and extensive evolution can be expected in the years ahead. So, if there is need for more focus in one area than another, the natural flow of innovation and funding will ensure that is met. As with traditional transport systems, a full portfolio of technologies helps to build and progress the balance, but without one universal common solution - and this is likely to continue. While LIDAR, INS, or HD Mapping may have short-term focus in certain cases, the proliferation of tech companies and the low probability of major convergence of customer requirements will mean a continued multi-technology, multi-tier ecosystem of technology for multiple future AV systems.

What are the distinct benefits from AV that are not already coming from current and future connected ADAS?

It is evident that with ADAS adoption growing, the crash rates for human-driven vehicles will begin dropping for both cars and trucks alike. This will happen without AV. However, AV can deliver a next level of safety benefits and help reduce road deaths and injuries now caused by distraction, drunk driving, and fatigue. Regarding the congestion challenge, only connected autonomous vehicles have the potential for a step change.

How important will international standards and commonly shared technologies be for AV adoption - or will it be more regional?

Standards are a means to an end, not an end in themselves. Moreover, in many fields, for disparate markets, there may be no strong economic reason to standardise. China will have different standards to the US and Europe, with other locations where domestic market size is significant, such as Japan and India, also having alternative approaches. Although Europe is busy setting regulations, many see that they are behind the curve and will lag behind other locations. Hence, there is more likelihood of regional rather than global standards.

In terms of commonly shared technologies, while, as with 5G, there will be global telecom standards for V2V and V2X communications for AVs, in other areas, variety will be driven by different brands taking their own views. AI software, for

instance, does not lend itself to standardisation. The unknown here may be around data sharing between competing companies. While some, like Tesla, currently have no incentive, and little desire to share its considerable data, others such as Waymo are planning to open up and make some of their information more widely available to all. How far this goes and whether it spreads across the full data portfolio, or just in niche areas such as ISAC (Information Sharing and Analysis Center) already used for cybersecurity in the US is, as yet, unclear.

Which will be the pivotal organisations, cities, and governments that control adoption rates?

For now, the focus is very much on regulation as being at the fore for encouraging deployment. However, while some are being highly proactive, there are concerns that they could veer towards becoming too heavy-handed. But adoption rates are not going to all be about national regulation – there are several other key factors at play that also vary from city to city. These include the access and quality of EV charging and regional energy storage, the quality of current public transport systems, and the implementation of rider-per-mile taxation, which makes sense from a public sector viewpoint in many cases. Also important is the HQ location/ initial testing locations for the organisations directly offering automated mobility services, which will comprise a growing mix, such as Ford, Toyota, GM Cruise, Waymo, Uber, Lyft, Grab, WeRide, Didi, and Baidu. Bringing all these together after the first 5 expert workshops, the candidate lead locations globally could include several key US cities (San Francisco, Pittsburg, Detroit), Toronto, Singapore, Shanghai, and Shenzhen, as well as London, Gothenburg, Munich, Tokyo, and Seoul.

Who will lead on integrating all the various systems needed to enable AV to operate?

It is clear that, while some level of independent approaches will be taken, the need for collaboration in AV deployment is vital, and so integration and partnerships are indeed going to be critical. While media focus is mostly on OEM collaborators, including the likes of GM. Ford, VW, BMW, and Toyota, other key integrators will be the more vertically integrated firms like Waymo and Uber, who are already selecting their lead manufacturing partners (Jaguar and Volvo respectively), as well as other existing mobility providers, such as Avis and Hertz. Alongside these, several tier 1 automotive suppliers are making acquisitions and building reach – ZF, Bosch, and Delphi spin-off, Aptiv, are some of the most prominent. Beyond these private companies, some see that major public transport authorities will also play an integrating role – either directly in London, Shanghai, and Singapore, or indirectly when operations are outsourced to private transport operators like Transdev and Keolis, in which private sector incentives motivate PTOs to implement AV.

Who will customers trust more to deliver a safe, reliable, and comfortable AV experience?

Although initial research suggested that the established OEM brands would be trusted more than the tech firms, over the past year or so, confidence in TNCs and others has been growing. Waymo, Uber, and Baidu are just as trustworthy as Ford, GM, and Toyota. Moreover, with all the integration, partnerships, and acquisitions underway, the emerging view seems to be that, as long as the whole system works, most consumers will be increasingly agnostic. Mobility services will be multi-platform and multi-brand, with regional as well as global players, that are all equally trusted to provide safe and reliable transport by their respective customers.

As we continue this project, we will seek to gain more conclusive answers on each of these and share them in the final report at the end of the year.

Additional 12 Questions

Alongside addressing these issues, the discussions have also raised further areas of uncertainty. In some regions there may be some clarity, but elsewhere there is still debate. As such, we have identified an additional 12 questions from the first tranche of workshops that we will seek to address in the second half of the project. These are:

1. What lessons can be learned from other sectors – for example, mobile and healthcare?
2. How much will AVs be tied to EVs, and therefore intertwined with charging infrastructure roll-out etc.?
3. Will air-taxis have impact beyond a few niche locations?
4. How will drones used for parcel delivery integrate with drones for other purposes?
5. How will planning evolve to become a public/ private partnership?
6. Will private companies contribute to the cost of the infrastructure, and will public sector agencies allow for this?
7. Will the growth of AVs mean more open/liveable/ walkable urban public spaces?
8. How will cities adapt today's public transport systems in an era in which automated MaaS overlaps their mission?
9. How will designers overcome resistance to sharing rides with strangers?
10. For what types of routes and freight will Level 4 truck automation happen first?
11. How will supply chain approaches be transformed by Level 4 truck automation?
12. What effect will growth in AV urban/suburban parcel/grocery/food delivery have on other road users?

Next Steps

As we move forward with this project, the plan is to undertake 5 more expert workshops and additional discussions by the end of the year. These will be in other areas of either high potential major AV development and / or deployment as highlighted in the map below. If you would like to be a co-host of any of these do get in touch, equally if there is another location that you would like to be included in the programme, do let us know and we will endeavour to accommodate in the mix.

Final Report

Following on from these events we will then produce and share a detailed final report. As well as additional insights from the additional discussions, this will also delve into more detail on some of the key issues raised, provide an updated overview of current technology development and also share recommendations and questions for those seeking to drive impact from the AV transition.

Contacts

Lastly, if you have any questions, feedback or other comments on this report, the global project or other topics of relevance please contact either of the core team:

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FUTURE AGENDA

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