# Infrastructure Victoria

## AV / ZEV International Scan

INFRASTRUCTURE VICTORIA

L.E.K.

with input from ARUP

**4 June 2018**

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# Agenda

- **Executive Summary**
- Introduction & approach
- Findings about Zero Emissions Vehicles
- Findings about Autonomous Vehicles
- Findings about other New Mobility market models
- Implications for Victoria
- Appendix

# Scope



- Infrastructure Victoria is currently formulating advice to the Victorian Government about the infrastructure requirements for the implementation of automated ("AVs") and zero emission vehicles ("ZEVs")
- L.E.K. Consulting and Arup were engaged by Infrastructure Victoria to inform this advice by assessing the state of automated and zero emissions vehicle technologies in international markets over a period of five weeks
- The report focuses on insights from approximately 15 international markets identified and agreed between L.E.K. / Arup and Infrastructure Victoria as leading markets for different technologies and regulatory approaches
- The report establishes a fact base about infrastructure requirements for the implementation of these vehicles from primary and secondary research conducted over a five week period, and identifies a number of lessons learnt from overseas experience and implications for Victoria
- Infrastructure Victoria also engaged a number of other providers to inform its advice to Government on topics related to this international scan, such as Energy, ICT Infrastructure, Population & Land Use, Transport engineering, and Transport modelling

# Executive Summary



- The three technologies examined are all relatively immature, but to different degrees
  - Electric vehicles ("EVs") are the most advanced, but remain below 2-3% penetration in almost all markets
  - There are hydrogen passenger vehicles for sale in some markets, but uptake appears to be less than 7,000 vehicles in total worldwide*
  - There are no passenger AVs for sale, with the first deployments expected in the next few years
- The international scan has identified a wide variety of activity underway by industry and governments, and many potential interventions the Victorian Government could chose to make
- However, the relative immaturity of the technologies means that:
  - with a small number of exceptions, there is limited evidence to support the linkage between a specific government intervention and adoption of a technology at scale
  - there is some anecdotal evidence of particular interventions accelerating trial or initial small scale deployment
- While a wide variety of standards are being developed and assessed, they broadly fall into two categories
  1. The standard is largely agreed and the logical path is to adopt the emerging global standard
  2. No global standard has been determined, with OEMs or regulators in scale markets favoring different approaches. In this case, given the immaturity of the technologies and Victoria's position as a technology-taker, it would be premature to choose a particular approach over another
- The scan does provide a menu of potential interventions (infrastructure-related and other) that the Victorian Government could chose to make, depending on its overall policy objectives for AVs and ZEVs. A number of these potential interventions have ramifications beyond AVs and ZEVs alone
- Given the breadth of technologies, issues and countries surveyed, this study should not be considered exhaustive, but instead representative of emerging directions around the world

Notes: * According to Information Trends, 6,475 HFCVs had been sold globally from 2013 through to the end of 2017

# Executive Summary: EV interventions to consider



- The only apparent “must do” activity identified from the scan is to facilitate, catalyze or sponsor **zero emissions electricity production.** Without this, EV deployment will likely have little impact on “well to wheel” emissions
- There are a variety of “could do” actions relating to EVs should the Government choose an active policy position and seek to kick start EV adoption. Some of these are infrastructure related, but many are not:
  - The most impactful appears to be **direct subsidy on EV purchases**, delivered to consumers at the point of sale. Any such scheme would need to be carefully designed to avoid over-subscription
  - **Non-financial incentives** such as access to priority lanes, parking etc. appear to have an impact on initial uptake, but would likely need to be phased out over time as demand grows
  - **Switching the government vehicle fleet to EVs** can act as a catalyst for OEM attention and supporting infrastructure investment. Likewise **EV taxis** and **electrification of buses** can also signal intent
  - Seeding investment in certain types of **public EV charging infrastructure (particularly “fast charging”)**, along major regional corridors or in areas with limited off-street parking occurs in some markets but this appears to be an expensive intervention with limited impact
  - There are examples of government **interventions to facilitate private installation of home charging infrastructure** in new dwellings, but few examples of installation rights like often used for other utilities
  - There are several examples of state or country level **vehicle emissions targets,** the announcement of **outright bans on internal combustion engine (“ICE”) vehicles at a future date,** or **explicit targets for the number of EVs**
  - Specific interventions to **manage electricity demand** may also be required, but there is no consensus on how this should best occur, given unclear demand and the relative immaturity of smart chargers and V2G
- In terms of standards
  - **Type 2** plugs have emerged as the leading standard in Australia. This gives Australian OEMs flexibility as it accommodates all “fast charging” extensions, making it accessible to a number of EVs
  - Standards for fast charging and “smart chargers” are under development, but not yet solidified

# Executive Summary: HFCV interventions to consider



- The “must do” activity emerging from the international scan is to **facilitate or sponsor zero emission hydrogen production** in Victoria, without which Hydrogen fuel cell vehicles (“HFCVs”) will deliver little in terms of emissions reduction
  - Currently **water electrolysis** is the only mature technology that would deliver zero emissions hydrogen for HFCVs
  - A decision to support development of a hydrogen sector would be broader than HCFV considerations alone
- In terms of potential interventions
  - Seeding the **investment in hydrogen re-fueling infrastructure,** in collaboration with the private sector, appears to have been important to generating initial uptake. This investment is most frequently targeted in **specific geographic clusters or corridors**
  - **Direct fuel subsidies** have been used in Japan to bring the cost of operation towards ICE parity
  - Government support for **hydrogen production, storage and transport** could also be considered, but does not appear common
  - Beyond Japan’s 800k HFCV target for 2030, **specific HFCV uptake targets** have not been observed, with HFCVs more implicitly included under more technology-neutral **ZEV and emissions reduction targets**
  - However, specific targets have been set for the deployment of hydrogen refueling infrastructure in Japan, California, Germany and South Korea
- **In terms of standards**
  - There is an internationally recognized ISO hydrogen fuel purity standard that Victoria could adopt, although a higher standard is also under discussion by the EU
  - Standards for hydrogen production, storage, transport, safety and refueling stations also exist but are currently being further developed, and Japan is reviewing its regulations to reduce their substantial cost implications

# Executive Summary: AV interventions to consider (1/2)



- The relative immaturity of AV technology makes it much more difficult to identify specific Government interventions. There is a high level of uncertainty both in the technology capabilities and the standards that may emerge
- Much of the government activity is directed towards trial protocols and clarification of rules that will apply in the future, with a particular focus on safety
- With regards to infrastructure specifically, the international scan has not identified any “must do” actions in the near term. However there are wide variety of possible interventions that may be necessary, depending on how the technology evolves
  - The case for **widespread investment in the road network is weak** with significant consensus that AVs will need work with the current infrastructure
  - **Line markings, and road signs** are two areas that may require investment to improve compatibility with AVs, but this remains unclear
  - Likewise, **increasing road maintenance, changing road design, and certification of roads** are all areas where no definitive view has yet emerged
  - There is no obvious requirement for a Government role in mapping (other advising for planned disruptions), but the possibility exists of a role for a government endorsed **data intermediary or brokerage**
  - Changes to **curbside infrastructure** to facilitate more drop off**,** as well as changes to **parking infrastructure** are both recognized as likely**,** but with very modest on the ground changes to date
  - In terms of communications, **dedicated short range communications (“DSRC”) and cellular** appear likely to be complementary technologies, but there is considerable uncertainty over the likely technology emphasis. There is no obvious or required government interventions beyond those that have already been made to allocate spectrum
  - **Satellite based augmentation systems** (“SBAS”) are already being developed and trialled in Australia, but may need some additional local focus on AV applications. While the long-term need is somewhat unclear, highly accurate GPS is at least an important backup system, and is widely assumed to be required for AVs

# Executive Summary: AV interventions to consider (2/2)



- There are many non-infrastructure interventions under consideration, including in Australia. The scan has not identified anything specific that is not already being actioned by either the NTC, AustRoads or ARRB or other Commonwealth bodies (e.g. cyber security etc)

- A range of options exist for the Victorian Government to further enable an environment that is supportive for AV trials, yet the objectives, benefits and investments in trials would need to be clearly articulated, as part of Victoria's broader policy objectives

# Executive Summary: New mobility market models



- We have examined initial trends observable from a range of early stage new mobility market models such as rideshare, Mobility as a Service*, on-demand public transport and dockless bike share, with a focus on emerging infrastructure impacts
- While the penetration of these models remains modest, there is early stage evidence of infrastructure impacts that may have some parallels with AVs and ZEVs
  - Rideshare has created capacity, pricing and management issues regarding curbside access (particularly at airports but also in other congested areas). Operators have responded with new rules, tariffs and by building new infrastructure
  - Rideshare vehicles waiting/circulating for jobs (either passenger rides or food) have caused congestion and public nuisance issues, leading to regulations or the need for “geofencing” of apps to reduce these impacts
  - There is also emerging / anecdotal evidence of rideshare increasing overall traffic volumes, impacting public transport (“PT”) mode share, changing access patterns to PT and reducing car parking volumes
  - MaaS demonstrates the difficulty in developing shared “digital infrastructure” and the difficult choices governments are facing with regards to the participation model
  - On-demand public transport requires specific rules (typically developed on a case by case basis) for pick up and drop off locations
  - Dockless bike share shows how quickly fixed infrastructure (docking stations) can be made redundant by a new business model. It is also creating public amenity issues governments introducing tighter rules and fines for nuisance bikes
- Victoria should monitor these trends carefully to identify likely analogous trends for AVs and ZEVs

Note: * MaaS is defined as an app that offers an one-stop-shop for information, booking and payment for different forms of transport

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# Infrastructure Victoria has formulated seven scenarios to explore how Victoria's vehicle fleet may evolve in the future



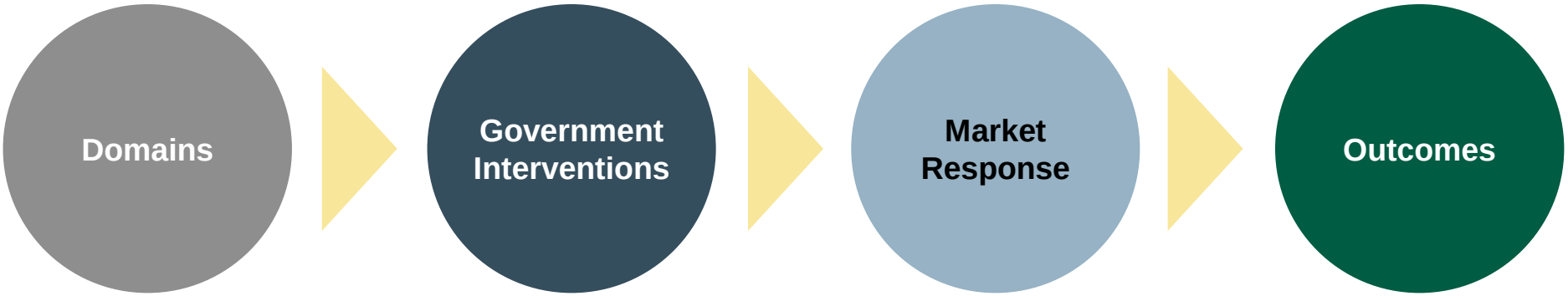
| Scenario | Year | Driving model | Power source | Ownership / market model |
|---|---|---|---|---|
| **Electric avenue** | 2046 | Non-driverless | Electric | Private |
| **Private drive** | 2046 | Driverless | Electric | Private |
| **Fleet street** | 2046 | Driverless | Electric | Shared |
| **Hydrogen highway** | 2046 | Driverless | Hydrogen | Private |
| **Slow lane** | 2046 | Non-driverless and driverless | Electric and petrol / diesel | Shared / private ownership |
| **High speed** | 2031 | Driverless | Electric | Private |
| **Dead end** | 2046 | Non-driverless | Petrol / diesel | Private |

**These scenarios represent "bookends" among a wide range of possible outcomes. IV has not yet formed a view about their relative attractiveness or the policy interventions that might be required to pursue or avoid any scenario**

Source: Infrastructure Victoria

# The international scan has examined evidence linking a range of possible government interventions (relating to AVs and ZEVs) to observed outcomes






*Which topics are the subject of government interventions to achieve particular outcomes?*

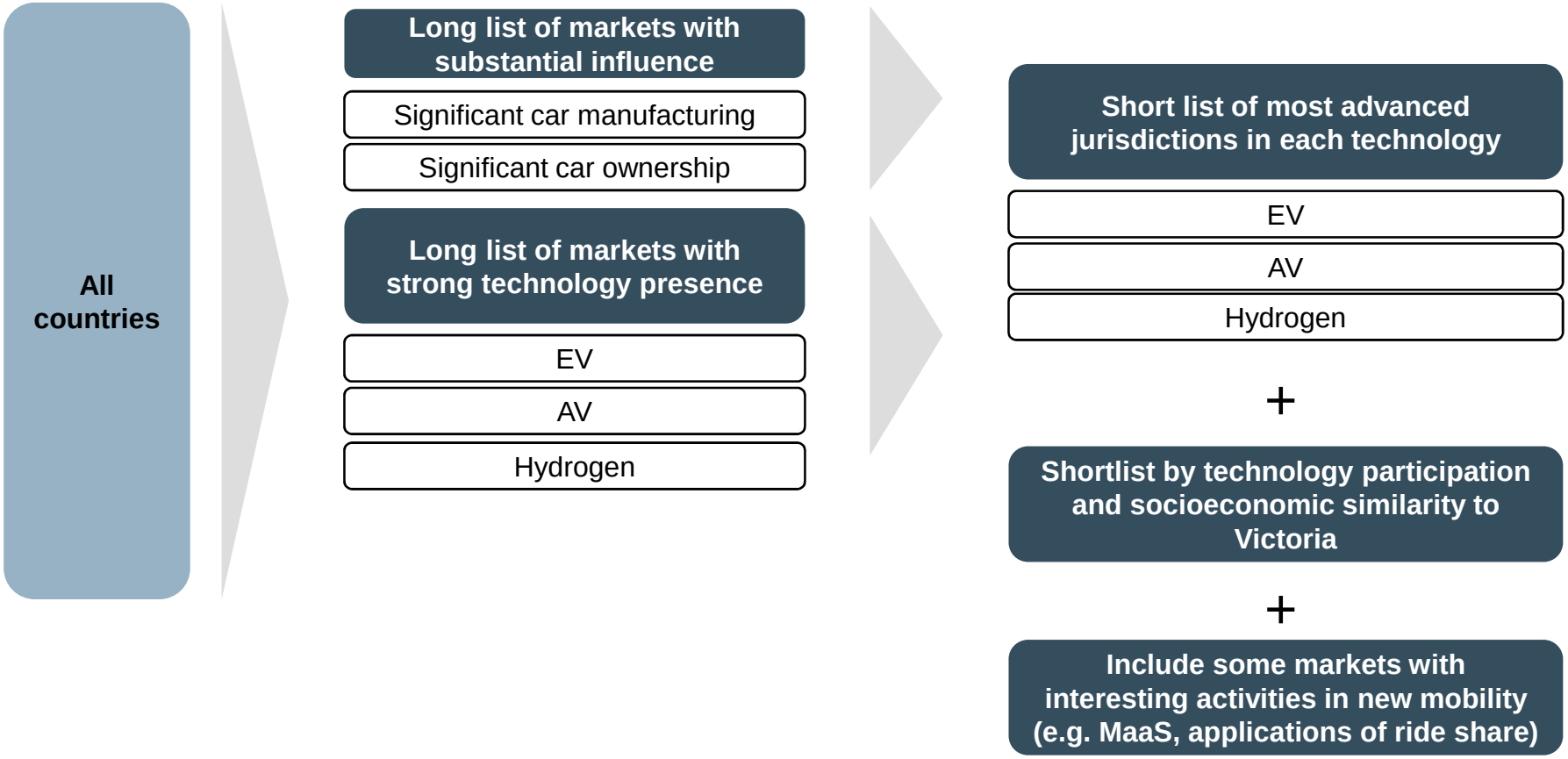
*What are governments doing in relation to a domain to influence private decisions and outcomes?*

*What choices are people and businesses making in the context of these interventions?*

*What can be observed or is expected in terms of outcomes?*

# Focus markets were selected by identifying influential and advanced markets for technologies, and ensuring coverage of similar markets and activities of interest






**A prioritised shortlist of 10-15 markets was identified with focus on specific technologies in certain markets – see appendix for details on markets considered**

# Outcomes and interventions have been examined using examples from 15 markets to understand potential policy options and implications for Victoria



| Market | Geography | AV | EV | Hydrogen | Other New Mobility |
|---|---|---|---|---|---|
| Australia – Victoria | ANZ | ✓✓ | ✓✓ | ✓✓ | ✓ |
| Netherlands | Europe | ✓✓ | ✓ | | |
| Singapore | Asia | ✓✓ | | | ✓ Bike Share |
| U.S.^ | North America | ✓✓ | ✓✓ | ✓✓ | ✓ Ride Share |
| Norway | Europe | | ✓✓ | | |
| China* | Asia | ✓✓ | ✓✓ | | |
| Japan | Asia | ✓✓ | ✓ | ✓✓ | |
| Germany | Europe | ✓✓ | ✓ | ✓✓ | |
| South Korea | Asia | ✓ | ✓ | ✓ | |
| United Kingdom | Europe | ✓ | ✓ | | ✓ MaaS, Ride & Bike |
| Canada | North America | ✓ | ✓ | | ✓ Ride Share |
| France | Europe | ✓ | ✓ | | |
| Helsinki, Finland | Europe | | | | ✓ MaaS |
| New Zealand | ANZ | | | | ✓ MaaS |
| Dubai | ME | ✓ | | | |
| Australia – Sydney | ANZ | | | | ✓ DRT |

**Key** ✓✓ Primary focus ✓ Secondary focus

Main research focus

Note: ^ Where different AV approaches are employed at the state level in the US, particular emphasis was placed on California and Arizona, and hydrogen was focused on California; * Likewise in China, particular emphasis was placed on Beijing and Shanghai areas

# Research across these markets has focused on a range of dimensions



## Dimensions


- **Community**
  - People
  - Public
- **Fleet**
- **Infrastructure**
  - Transport
  - Energy
  - Communications
  - Cities
- **Institutions**

- **Legislate** – application (or signalling about the application) of laws, rules or policies by government
- **Spend** – expenditure of public money, whether or not expecting a return on the spend
- **Monitor** – passive information gathering and reporting without other interventions

- **Standard setting**
- **Investment choices**
- **Usage behaviours**

- **Scenario outcomes e.g.**
  - Speed of uptake
  - Favoured technology
  - On-going subsidy
  - Second order effects
- **Target outcomes** – 10 Victorian target outcomes identified by Infrastructure Victoria, broadly relating to:
  - the community
  - the environment
  - the economy
  - performance of transport and energy systems

Note: Infrastructure Victoria identified 10 target outcomes related to the community, the environment, the economy, and transport and energy infrastructure
Source: Infrastructure Victoria

# There are a wide range of potential government interventions that are observed or contemplated in different vehicle markets in this study



| Domains | | Government interventions (examples) | | |
|---|---|---|---|---|
| | | Legislate | Spend | Monitor |
| **Community** | **Users** | Licencing<br>Privacy | Awareness & Education | Opinion tracking |
| | **Public** | Liability<br>Safety | Awareness & Education | |
| **Fleet** | **Vehicles** | Standards<br>Permitted uses | Incentives<br>Government fleet | Statistical collection |
| **Infrastructure** | **Transport** | Road charging<br>Access rules | Road upgrades<br>Mapping | Statistical collection |
| | **Energy** | Usage<br>Interoperability | Charging / fuelling infrastructure | |
| | **Communications** | Spectrum for V2V/V2I<br>Interoperability | Transmission<br>Passive infrastructure | |
| | **Cities** | Planning rules | Public spaces<br>Smart sensors | |
| **Institutions** | **Agencies** | Roles | Capabilities | Oversight |

Focus of this work on topics most aligned with infrastructure

# In preparing this report, a broad range of interviews were conducted, complemented with research and data from secondary sources (1 of 2)



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## Expert Interviews

- General Manager, Maritime and Shipping Branch, DIRD
- Director for Environmental Standards, DIRD
- CEO, EVE Electric Vehicle Consulting, Italy
- CEO, Electric Vehicle Council, Australia
- Global Director – Energy Systems, ARUP, UK
- Principal Technology Leader, Australian Roads Research Board
- Associate Director, Advanced Technology and Research Group, UK
- Infrastructure Advisory & Digital Consultant, ARUP, UK
- Senior Consultant Infrastructure Advisory, ARUP, UK
- UK Autodrive Project Director, ARUP, UK
- Intelligent Mobility Leader Americas Region, ARUP, San Francisco
- Global Leader of Smart Mobility, UK
- Director Transport Futures (Connected & Automated Vehicles), VicRoads
- Policy Manager, Roads Australia
- Principal, Energy Sector, L.E.K. Consulting Australia
- Manager, Energy Sector, L.E.K. Consulting Australia
- Managing Director, L.E.K. Consulting Shanghai
- Co-Founder, Electric vehicle charging infrastructure network, Canada
- Chief Executive and Commissioner, NTC
- Leader of Intelligent Mobility, ARUP, Ireland
- Project Director – Compliance & Technology, NTC
- Senior Energy Market Analyst, AEMO Australia
- Founder, Electric vehicle charging infrastructure network, Australia
- Chief Business Development Officer, NAVYA Autonomous vehicles

# In preparing this report, a broad range of interviews were conducted, complemented with research and data from secondary sources (2 of 2)



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## Key Reports

### Autonomous Vehicles

- Autonomous Vehicles Readiness Index, KPMG, 2018
- Transforming Mobility, NRMA, 2017
- Preparing for the Driverless Revolution, Roads Australia, 2017
- Changing driving laws to support automated vehicles, NTC, 2017
- Privacy impact assessment on AVs, Austroads, 2017
- Guidelines for trials of automated vehicles, NTC and Austroads, 2017
- Driverless vehicle trial legislation, KWM, 2018

### Electric Vehicles

- Global EV Outlook, IEA, 2017
- Global EV capitals of the world 2017, ICCT
- People power, how consumer choice is changing the UK energy system, Green Alliance 2018
- J3016, SAE International, 2014
- OCPP 2017 and OSCP 2017, Open Charge Alliance
- Canada's ZEV Policy Handbook, Sustainable Transportation Action Research Team, 2017

### Hydrogen Fuel Cell Vehicles

- Hydrogen Safety Standards & Codes, NREL, 2018
- A Hydrogen Roadmap for South Australia, SA Govt, 2017
- Hydrogen's Role in the Future of Sustainable Transport, Hazer Group, 2018
- Public Attitudes towards Hydrogen Fuel Cell Vehicles, Wuppertal Institute, 2010
- Global Trends and Outlook for Hydrogen, IEA, 2017
- Guide to Safety of Hydrogen, ARC, 2017
- State of the States Fuel Cells in 2016, US Government, 2016
- Developing Hydrogen Fuelling Infrastructure, ICCT, 2017
- The Hydrogen Economy, NAP, 2004

### Other / New Mobility

- Mobility as a Service, Catapault Transport Systems, 2016
- FHV Base Aggregate Weekly Reports, NYC Taxi and Limousine Commission, 2018
- Annual Conference Procedings, Polis, 2017
- Future Transport, How is London responding to technological innovation, London Assembly, 2018
- Victorian Connected and Automated Vehicle Trials, Transurban, 2018 (AV)
- Corporate Websites, Major Automotive Groups
- Press Releases, News-sites



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# ZEVs are anticipated to benefit the environment, improve energy security, and reduce costs

## Technology overview

- Alternative fuels to power the drivetrains in vehicles include both non-renewables (e.g. natural gas) and renewables (e.g. biofuels and electric power from renewable sources)
- Whilst alternative fuels include fuels that can be used in modified combustion engines (e.g. biofuels, and natural gas), the market is moving towards "**zero local emission**" fuels based on electric drivetrains
- EVs use electricity to power the motor in the vehicle; there are multiple kinds of EVs:
  - **Hybrid (HEV)**: primarily powered by a traditional engine. The engine is used to charge a battery that functions as a secondary power source
  - **plug-in hybrid (PHEV)**: primarily powered by a battery. There is a back-up combustion engine to recharge the battery if required
  - **all-electric (BEV)**: powered by a battery only; must be charged through an outlet
  - **hydrogen fuel cell (HFCV)**: use hydrogen and oxygen to generate an electrochemical reaction to produce electricity
  - **range extended electric vehicles (REEV):** combustion engine used purely to generate electricity to charge the electric motor
  - **solar powered**: use solar cells to convert sunlight to energy. The vehicle can be charged while stationary or in motion, so long as sunlight is available. Batteries may be used as a secondary power source

**Key focus for this project:**

- **All-Electric**: qualifies as a zero-emission vehicle (ZEV), with no emissions at the tailpipe
- **Hydrogen fuel cell**: qualifies as a zero-emission vehicle, with only water as a by-product

## Key anticipated benefits

- Air quality improvements may reduce premature deaths and increase liveability in metro areas
- Environmental benefits: no local emissions are produced during use
- Energy security: reduced reliance on non-renewable and imported fuel sources
- Cost reduction: although the upfront cost is higher, running costs of EVs are approximately one third to one quarter of ICEs
- Reduction in noise in vehicle operations (particularly buses) will improve liveability around transport routes particularly with HFCVs

**Note: While EVs and hydrogen fuel cell vehicles will reduce local tail pipe emissions, it also necessary to consider the source of electricity generation (e.g. coal power stations v renewables) and hydrogen generation (e.g. steam reforming v electrolysis)**

Source: TfNSW; AECOM; Columbia University; L.E.K. research

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# Issues explored for Electric Vehicles

## Electric vehicles

| Elements | Issues explored in focus markets |
|---|---|
| 1 Uptake of EVs | • Global EV uptake targets<br>• Current EV uptake levels<br>• Government fleet and public transport uptake |
| 2 Approaches to incentivising EV uptake | • Financial EV uptake incentives<br>• Non financial EV uptake incentives<br>• Financial incentives for infrastructure investment |
| 3 EV charging infrastructure and standards | • Batteries<br>• Plugs<br>• Charging infrastructure<br>• Smart charging<br>• Future charging techniques |
| 4 Development of charging infrastructure | • Public or private funding<br>• Location of infrastructure<br>• Common use rights |
| 5 Impact of EVs on electricity network infrastructure | • Demand profile changes<br>• Demand management strategies (V2G) |
| 6 Other considerations for EVs | • Battery recycling<br>• Accident response |

1

# The International Scan has identified key government interventions and market activity in support of Electric Vehicles across focus markets

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| Interventions and market activity | Australia | US | Norway | China | Secondary and other markets |
|---|---|---|---|---|---|
| Gov't fleet and public transport uptake | ✓ | ✓ | ✓ | ✓ | ✓ |
| Significant financial uptake incentives | | ✓ | ✓ | ✓ | ✓ |
| Non-financial uptake incentives | | ✓ | ✓ | ✓ | ✓ |
| Government led infrastructure roll-out | ✓ | ✓ | ✓ | ✓ | ✓ |
| Home charging incentives | | ✓ | ✓ | | ✓ |
| Demand management strategies | | ✓ | ✓ | | ✓ |
| V2G trials | | ✓ | | | ✓ |

✓ = Government interventions identified and evidenced through the international scan

**Implications for Victoria: While the International Scan will have identified most key government interventions across these dimensions in these markets, there are likely to be additional interventions omitted due to scope constraints**



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# A number of governments have set targets for EVs either in absolute numbers, or as a share of vehicles purchased by a future date

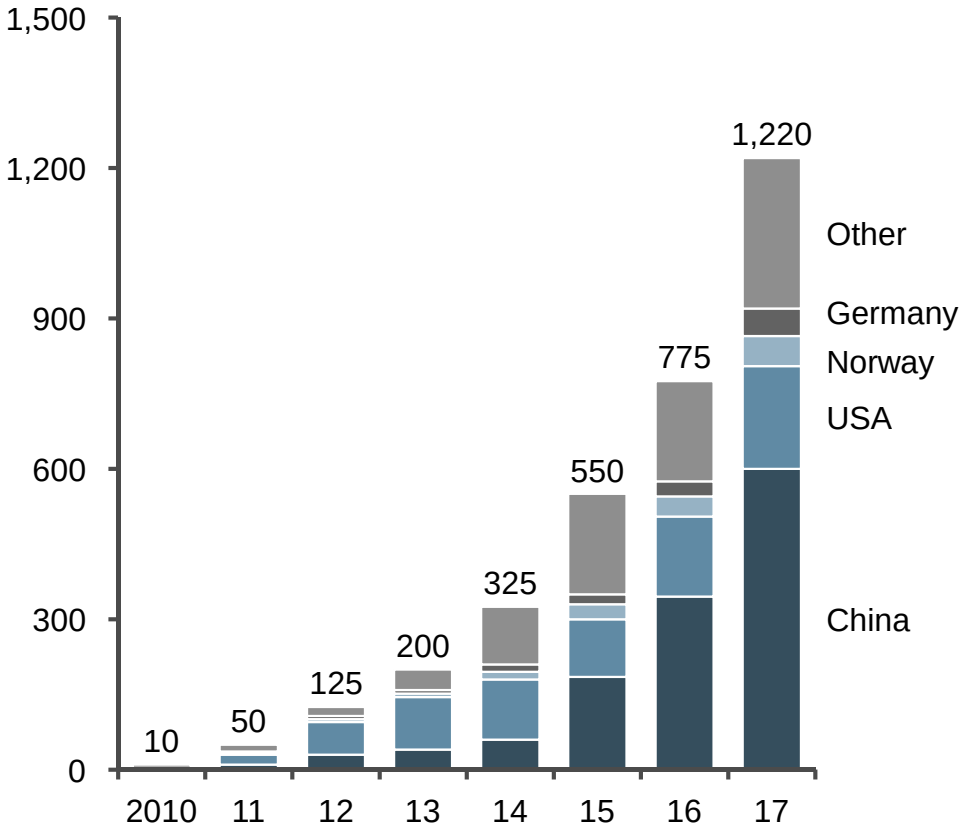
| Geography | Target |
|---|---|
| **Australia** | Does not currently have a nation-wide goal to encourage EV uptake |
| **New Zealand** | 64k EVs on the road by 2021, representing c.2% of all cars |
| **The US and California** | California aims to have 5m ZEVs on the road by 2030, representing c.25% of all vehicles<br>The US government want to make EVs as cost competitive and convenient as ICE vehicles by 2022 |
| **The UK** | 1.7m EVs on the road by 2020, representing 5% of all cars |
| **France** | 50% of all cars purchased to be low emission by 2025, representing c. 2m ZEVs |
| **The Netherlands** | 30% of car sales to be ZEV by 2025, representing c.150k EVs |
| **Germany** | 1m EVs sold by 2020, equating to c.25% of the car market |
| **Norway** | 100% of car sales to be ZEV by 2025, equating to c.200k EVs |
| **South Korea** | Upgraded their target from 200k to 250k EVs in use by 2020 |
| **Japan** | Total EV and PHEV ownership to reach 1m vehicles by 2020, representing 20% of annual vehicle registrations |
| **China** | EVs to reach 20% of national production by 2025, representing 7m EVs |

1

# The number of plug-in hybrid and EVs commercially available and in development is growing, with sales accounting for c.1.5% of passenger vehicles

**Annual global sales of electric vehicles and plug-in hybrids (2010-17)**

Thousands of vehicles




- Data sources for EV sales typically group together the sales volumes of plug-in hybrids and EVs
- Vehicle range is expected to be the most significant area of investment for OEMs in the near future - battery technology is currently the critical constraint on extending driving range
- OEMs have generally developed strong capabilities in engineering and integrating hybrid / electric vehicles, and outsource a similar amount of development work for hybrid/electric vehicles compared to traditional vehicle projects

Note: * Plug-in electrics include four-wheeled plug-in HEVs and extended range EVs capable of 60mph; ** Electric vehicle sales were not recorded for each year between 2000 and 2010

Source: L.E.K. Analysis of AFDC, HybridCars.com, EV Volumes, Ward's Auto, Bureau of Transportation Statistics, L.E.K. interviews and analysis; GoAuto.com.au



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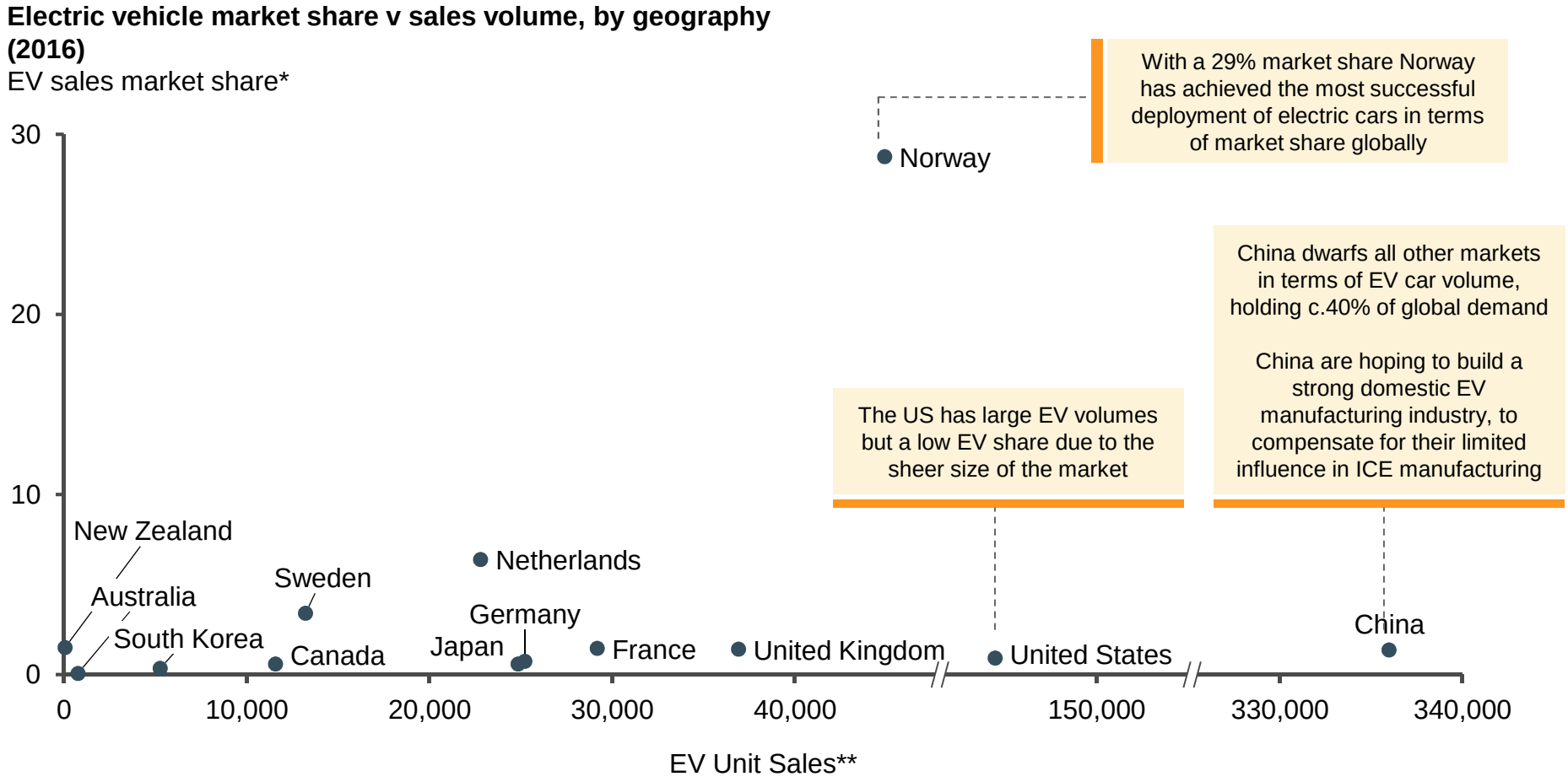
# Norway, China, the US and the UK are the global leaders in EV uptake

**Electric vehicle market share v sales volume, by geography (2016)**




Notes: * Both battery electric and plug in hybrid due to data limitations, with market share defined as the number of new registrations of electric cars divided by the total number of new registrations at the country level; ** Number of new passenger car registrations by market (battery electric vehicles and plug in hybrid electric vehicles)

Source: International Energy Agency; Clean Technica; Business Financial Post; L.E.K. research and interviews; Which Car; Westpac; Transport NZ



L.E.K.

2

# Upfront financial incentives that lower the price of EVs are an important factor to drive uptake. A range of approaches are used internationally

| Incentive approach | Incentive scheme | Implications for Victoria |
|---|---|---|
| **Self-sustainability** | **Norway** employ the **biggest incentives in the world** to encourage ZEV uptake - key incentives employed include reduced taxes for the consumer on tolls, roads, and the 25% VAT, reduced import taxes for manufacturers and reduced company tax. Norway recently decided that their **generous subsidies were unsustainable**, as Government funding per trip spent on EVs is exceeding that for public transport. The Norwegian Electric Vehicle Association is investigating ways to help EVs 'pay for themselves', such as asking EV owners to pay 50% road tax<br><br>In 2015, the **Danish** Government begun phasing out of the 180% import tax break on electric cars, citing budget constraints and the desire to level the playing field with ICEs. As a result, EV sales plummeted in by 80% in 2016 from 2015 sales. In April 2018, the Government changed the phasing out to only begin once either 5k new EVs were sold (until 2018), or in 2019. The phase-out envisages a 100% phase out of import tax subsidies by 2022. Consumers are therefore delaying their purchase of EVs until post 2018 to avoid the early triggering of the subsidy phase-out | *Incentives are key to achieving critical mass. However, there are risks about the sustainability of some incentives impacting key funding sources, like registration fees* |
| **Fraud resistant** | The **Chinese** national per-vehicle subsidy offered to EVs, introduced in 2016, is being phased out and replaced as it had negative unexpected consequences. Subsidies intended to encourage EV uptake by increasing EV affordability to end users led manufacturers to distort sales numbers in order to obtain subsidies. A new dual-credit scheme will require car-markers to produce a minimum number of EVs in order avoid purchasing 'credits' from competitors | *Attaching subsidies to the EV sales volumes may result in manipulation and fraud if not carefully administered* |
| **Minimising emissions** | In Jan 2018, the **Chinese** government reformed their EV subsidy policy again to encourage production of more efficient EVs. The policy change encourages production of longer-range EVs by offering larger subsidies to vehicles with a 400km range, and decreasing subsidies to vehicles with <150km range. It also subsidises vehicles with better battery power/weight and power consumption metrics<br><br>**France** have ended subsidies for PHEVs in order to switch consumer EV uptake preference from less-emissions friendly PHEV towards BEV. A similar approach was taken in China in 2017, reducing incentives for PHEVs in favour of incentivising long-distance (>400km) BEVs | *While an initial EV subsidy policies are important to achieving uptake, incentives may be re-purposed to focus on ZEVs in particular* |
| **Quota-driven phase out** | As of 2011 **the US** government offers tax credits up to AUD $10k per EV sold for the the first 200k EVs sold per OEM before it begins to get phased out, being halved every quarter after the sales quota has been met.<br><br>GM is expected to reach 200k car sales by the end of 2018, suggesting all tax credits on GM cars would be removed by mid-2020. Tesla are also in threat of reaching the quota in 2018 | *When considering subsidies, Victoria may choose to add phase-out quotas from inception* |

Source: Ministry of Finance China; Energy US; Elbil Norway; AutoVista Group; L.E.K. research and analysis

2

# Non-financial incentives are also important for encouraging EV uptake. These non-financial incentives take a number of different forms internationally

| Incentives | Incentive scheme | Implications for Victoria |
|---|---|---|
| **Availability of charging stations** | Offering a large network of fast and standard publically-available charging stations is seen as a key non-financial incentive to encourage EV uptake. While there are many examples of this globally, Norway is the standout. **Norway** currently offers a significant number of charging stations, allowing long distance EV trips. A charging station is available every 50km on all main roads within the country. In addition, the EU specifically invested EUR 10m for a network of 180 charging stations, allowing EV owners to travel from Norway to Italy.<br><br>A global analysis across 12 countries investigating the correlation between charging infrastructure roll-out and EV uptake has found that, while public charging infrastructure is important, it appears to have had little effect in encouraging early adoption | *Large investments in public charging infrastructure will not in isolation drive EV uptake* |
| **Parking schemes** | While not free, EVs in the **Netherlands** get priority screening for the parking permit list. In addition, there are free floating parking permits for car sharing companies with fully electric fleets<br><br>In 2014**, Germany** gave local governments permission to allow free EV parking and reserved EV parking spaces. However, in a country with already limited city centre parking, the benefit to passengers has been limited | *Free parking is a beneficial incentive to continue to encourage EV uptake, but does not appear to encourage uptake alone* |
| **Exemption from anti-congestion policies** | **Beijing** has implemented a license plate lottery system to greatly limit the number of new vehicles registered in the city, where by only 1/725 license plate applicants are granted a license plate. The city also employ road spacing techniques, where by traffic is reduced by placing restrictions on locations that vehicles can enter based on their license plate number. EVs are exempt from such traffic condition limits | *A similar policy may help Victoria both reduce congestion and increase EV uptake* |
| **Bus lanes and high occupancy vehicle (HOV) lanes** | The **California** government allow a certain number of PHEVs and BEVs to use their High Occupancy Vehicle (HOV) lanes using a sticker system, where sticker colours correspond to level of 'clean air' provided by the vehicle. Similar to bus lanes, HOV lanes exclude certain vehicles in order to reduce congestion.<br><br>The Californian government however is concerned about 'further erosion of HOV lane capacity' due to increasing number of EVs on the road and un-monitored carpool cheaters. | *While HOV lanes are effective when EV uptake is low, their effectiveness is modest in the long term due to reduced attractiveness from increased usage* |
| **City-wide schemes** | The **Mayor of London** has introduced a 'Neighbourhoods of the Future' scheme with 6 select neighbourhoods offering different non-financial incentives for EV uptake. Incentives include:<br>- a zero emission zone in Fulham<br>- EV only parking in the City Fringe<br>- EV qualified mechanics in Harrow<br>- loaning electric vans and trucks to businesses in Sutton | *Different non-financial incentives to encourage EV uptake could be used at once across different suburbs to test effectiveness* |

Source: WEF: Electric vehicles for smarter cities; City of Amsterdam; AutoNews; NY Times; California Air Resources Board; L.E.K. Executive Insights



L.E.K.

2

# Some markets are also more directly incentivising EV use by proposing bans on ICE vehicles or establishing taxes or access rules based on emissions

| Incentive topics | Incentive scheme | Implications for Victoria |
|---|---|---|
| **Ban on diesel and petrol vehicles** | **France** has been paving the way in Europe in the movement towards banning diesel by announcing in 2016 that Paris will ban all petrol and diesel cars on roads by 2030. This was followed shortly after by similar diesel and gasoline bans on new vehicle sales from **Norway** (2016), the **Netherlands** (2017), the **UK** (2017), the **US** (2017) and most recently by **Germany**<br><br>In addition, residents of Paris willing to sell or scrap their used ICE vehicles receive financial aid through both a c.EUR1k environmental bonus and a c.EUR2.5k 'thank you for switching to electric' bonus | *Incentives and other complementary measures are expected to be paid by some governments when instituting bans on diesel and petrol vehicles* |
| **Ultra Low Emission Zone (ULEZ)** | **London** implemented the Low Emissions Zone in 2008 to charge heavy-pollution vehicles for driving through Greater London. A comparative study in 2015 found the zone failed to reduce emissions, citing a lack of decline of diesel cars and lack of improvement in diesel efficiency as the cause.<br><br>In 2020 **London** will try again with the new Ultra Low Emissions Zone (ULEZ). A similar zone to the LEZ but with higher emissions requirements, the zone promotes walking, car sharing or ZEVs as an alternative to ICEs. To improve from their last attempt, London will include private-owned public charging stations, council-owned residential charging stations and rapid charging hubs | *Victoria may consider introducing LEV or ULEZs by implementing road pricing targeting emissions in certain areas* |
| **CO2 based taxation scheme** | In order to encourage adoption of ZEVs, **the Netherlands** are taxing all vehicles (including PHEVs) that produce CO2 emission on a g CO2/km basis. Taxes start at EUR6 / g for a 1-79g CO2/km vehicle (which includes PHEVs) up to EUR476 / g for a 174g CO2/km vehicle.<br><br>In January 2018 a tax for the sale of vehicles emitting >1g CO2/km was introduced, which includes all vehicles except ZEVs. | *Carbon based taxation may be an efficient way to encourage not just EV uptake, but ZEV uptake*<br><br>*Australia could use a distance based CO2 tax to replace revenue lost through reduced consumption of fossil fuels* |

Source: City of Paris; C40; Transport for London; London Councils; CityLab; EAFO; IEA Global EV Outlook; EV Box



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2

# Australian governments have established a range of explicit emissions targets and policies about zero emissions vehicles

| Policy approaches | Australian examples |
|---|---|
| **Australia-wide schemes** | South Australia, Western Australia, the ACT, and Hobart signed a **Memorandum of Understanding** with the **Electric Vehicle Council** at a meeting in Adelaide on 1 December 2017, agreeing to develop a plan to increase the share of EVs in their fleets and to consider how to use their combined market power to promote the public uptake of electric vehicles<br><br>The **UN Climate Summit** organisation **The Compact of Mayors** requires that participating cities have ambitious plans to reduce emissions, and has been signed by over 7.5k cities. In Australia, councils in almost all states have signed up, with varying levels of commitment**. Melbourne councils** have a plan to buy renewable energy directly from solar and wind suppliers, while **Sydney** has a host of measures in place such as changing lighting to LEDs, and is installing solar panels on a range of public buildings. |
| **Connecting rural charging** | With a large rural population, **WA** (through non-for-profit Australian Electric Vehicles Association) has partnered with electricity-retailer Synergy to introduce charging points in remote areas. The state aims to have a charging station within a 1 hour of charge / 100km across the whole state<br><br>**Queensland**'s electric highway allows EVs to travel from Cairns to Coolangatta for free, however fees for charging will come into place in 2019. The highway will be overseen by the newly formed Queensland Electric Council |
| **Carbon neutral / renewable energy** | In 2017 **Adelaide** announced their target to become the first Carbon neutral city in the world by 2025. SA already have 41% renewable energy and a plan to convert the governments 4.5k fleet to EVs<br><br>**Victoria** has committed to renewable energy generation targets of 25% by 2020 and 40% by 2025 |
| **Electric buses and government fleets** | In **Victoria**, commercial vehicle manufacturer SEA Automotive received government funding to design a fleet of 100% electric trucks and mini-vans<br><br>**NSW** recently undertook a trial of transferring part of its government fleet to EVs in rural areas to remove stigma around EV range anxiety<br><br>The **ACT** declared in 2017 that they will be powered by 100% renewable energy by 2020, and have net zero emissions by 2050. The state government trialled electric buses in 2017, and while it is too early to compare to the rest of the fleet, they are intending to purchase 40 more in 2018 |

Source: City of Paris; C40; Transport for London; EAFO; IEA Global EV Outlook; EV Box; the Guardian



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2

# In order to ensure increased EV uptake translates into reduced emissions, it is necessary to consider "well to wheel" rather than just "tailpipe" emissions

- The **UN Climate Summit** organised two compacts to combat global GHG emissions. **The Compact of Mayors** has been signed by over 7.5k cities, each with varying levels of commitment. Cities are encouraged to upload their climate action plan to track progress – most **capital cities in Australia have committed including Melbourne**

- A number of markets across America and Europe have established CO2 emissions standards
  - **Norway** have the strictest standards for emissions – the country wanted to achieve <85g CO2/km per passenger kilometre in all new cars, and have already reached this goal in 2018
  - Globally there are two competing standards for tailpipe emission reduction. The **EU** standards require 95g CO2/km tailpipe emissions for all passenger vehicles by 2020, and 73g by 2025. Meanwhile **the US** have take a less stringent approach and set their standards at 144g CO2/km tailpipe emissions by 2020 and 107g CO2/km by 2025. The Environmental Protection Agency is currently calling for the US standards to be lessened citing a slow adoption of EVs and lower oil prices as reasons why the current standards are too high
  - The Climate Change Authority of **Australia** has proposed our national emissions standards follow the US standards, suggesting an emission reduction to 144 CO2/km in 2020 and 105g by 2025. The decision was based off consumer preferences being more aligned to the US, where larger, automatic cars are preferred
  - There are concerns that the 105g CO2/km standards will burden Australian car owners, as only 2 of the top 20 vehicles sold in Australia in 2017 would meet the new emissions standards. International OEMs may be unable to meet their emissions targets while selling the cars that Australians want to buy, which are larger than typical vehicles purchased in Europe

- There are two ways in which 'zero emissions' has been defined globally. Tank-to-wheel emissions is the more commonly used definition which only includes emissions created while driving the vehicle, known as tailpipe emissions. However the second definition of well-to-wheel or cradle-to-grave emissions includes tailpipe emissions as well as all other emissions created in producing the fuel for the vehicle. In the case of electric vehicles, this means considering the emissions created in producing the electricity
  - **China** has one of the most carbon intense electricity production mixes in the world, which means a switch from ICE to EVs does not currently have a significant impact on reducing GHG emissions in China. However, China are aiming for well-to-wheel emissions of 100g CO2/km by 2030 by improving their energy supply mix.
  - **Victoria** also relies on brown coal for its electricity generation. This implies Victorian vehicles will find it difficult to be 'well-to-wheel' zero emissions vehicles until a greater portion of energy is sourced from renewable energy

Source: Paris Agreement 2015; European Commission; Climate Action Programme; Climate Change Authority Australia; Global Covenant of Mayors; The Verge; The Australian; ABC News

2

# Governments also use a range of measures targeted beyond private passenger vehicles to increase the utilisation of EVs and deployment of EV infrastructure

| Trial topic | Description | Implications for Victoria |
|---|---|---|
| **Government fleet electrification** | As of February 2018, **Paris** have 16 ZEV police vehicles in their fleet. The police department opted for Volkswagens as they were the only EV on the market that could supply both the 250km range and internal space needed for a police vehicle | *Victoria could encourage passenger EV uptake by leading by example and converting its government fleet to ZEVs* |
| **Electrification of public transport** | **Oslo** has a goal to achieve zero emission from its municipality fleets and public transport by 2020. Oslo's trams and buses already run largely on hydro-electricity, and the city will add an additional 70 electric buses by January 2019<br><br>The **ACT** government trialled two electric buses in 2018, which will run until 2019. The buses have a range of 450kms, and travel c.250kms per day before charging overnight at the bus depot. The ACT are intending to purchase 40 more in 2018<br><br>**China** have c.99% of the 385k electric buses on the roads worldwide in 2017. Every five weeks, Chinese cities add another c.10k ZEV buses to their fleet - the equivalent of London's entire working fleet. A large portion of these buses are operating in Shenzhen | *Victoria could encourage consumer acceptance of EVs by demonstrating the capabilities of electric buses* |
| **Taxi industry electrification** | **Oslo** will have an emissions-free taxi industry by 2020. To meet the requirement for a zero emissions taxi fleet in Oslo, the EV taxis must have a range of at least 300 km, accommodate at least four passengers, have a large enough luggage space, and be able to transport passengers with different needs.<br><br>Charging infrastructure for taxis is often shared with other transport sector operators, however Oslo are also building dedicated quick and semi-quick charging stations specifically for the taxi industry | *Victoria could consider specifying characteristics of the taxi fleet to showcase EV capability and promote investment in public charging infrastructure* |

Source: Bellona; EV Global Outlook 2017; ACT government; Neighbourhoods of the Future



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2

# Section Summary: Approaches to incentivising EVs (1 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Features of successful financial incentives schemes in overseas markets*** | There are many financial incentives seen in overseas market<br>● Upfront subsidies to consumers<br>● Upfront subsidies to OEMs<br>● Upfront subsides based on range<br>● Upfront subsidies based on technology<br>● Tax credits for consumers<br>● Quotas and caps on incentives | *Upfront incentives lowering the price of EVs appear to be the most effective means to increase uptake*<br><br>*Challenges to overcome include:*<br>● *Ensuring incentives are financially sustainable – phase-out quotas may be an option*<br>● *Ensuring equitable access to incentives, and targeting of incentives to avoid manipulation or fraud*<br>● *Focussing on ZEVs incentives where possible, as opposed to hybrids* |
| ***Features of successful non-financial incentives in overseas markets*** | There are many non-financial incentives for EV ownership seen in overseas markets<br>● Investment in public charging stations<br>● Parking benefits for EVs<br>● Exemptions from anti-congestion policies<br>● Access to special road features<br>● Bundles of benefits | *While many commentators see availability of public charging infrastructure as an important factor, it is not on its own an important factor increasing EV uptake, given the current prevalence of home charging for EV owners*<br><br>*Public infrastructure becomes more important for rural and long distance charging. This topic is discussed in more detail in section 4*<br><br>*Non-financial incentives may mesh well with existing Victorian objectives. Incentives could:*<br>● *Reduce consumers 'range anxiety' by demonstrating ample public charging infrastructure options*<br>● *Increase availability of inner-city parking for EVs by dedicating parking spots*<br>● *Reduce congestion for EVs by permitting access to bus and transit lanes* |

Source: EV Global Outlook 2017; ICCT 2017; Statista



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2

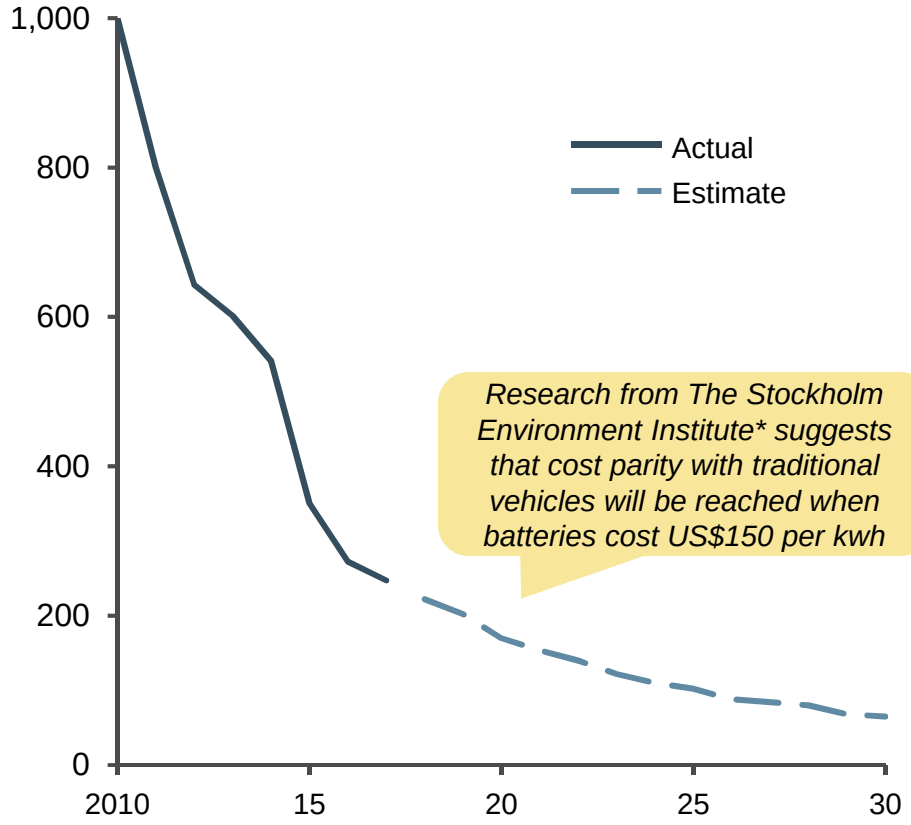
# Section Summary: Approaches to incentivising EVs (2 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Uptake incentives can be tied to emissions incentives in a number of ways*** | • **Diesel bans** in France are being paired with financial incentives to scrap ICEs<br>• Low or ultra-low emissions zones have been trialled in London with varying levels of success<br>• **Emissions-based taxes** can be employed, either as a once-off sticker price tax, or a progressive emission tax places on the emissions per vehicle per km | *Emissions-based CO2 taxes per km could be used to replace revenue that may be lost in fuel excise* |
| ***Tailpipe emissions targets*** | • Emissions can be measured in two ways: "well-to-wheel" and tailpipe<br>• Many countries are establishing vehicle **CO2 emissions** standards in line with either the **EU standard** (73g/km by 2025) or the **US standard** (slightly over 100g/km by 2025)<br>• Due to their car-usage demographics, the US have a less strict emissions target – Australia are planning on adopting a similar target due to similar vehicle preferences | *If Australia adopts the US emissions target, it may have adverse impacts for OEMs and consumers, as the majority of vehicle models currently demanded by Australians fall outside of the new emissions standard* |
| ***Local government – led EV fleet uptake*** | • Government police fleets are being converted to ZEVs in Paris<br>• China are the world leader in electric buses<br>• Electric buses are being added to the public transport fleets in the ACT, Oslo and Shenzhen<br>• Oslo has specified the characteristics of taxis that must be ZEVs by 2020 | *Government-led EV uptake may help overall uptake reach critical mass, thereby encouraging private investment in charging infrastructure and leading by example for passenger EV uptake*<br><br>*Government led examples Victoria may wish to explore include conversion of police or other emergency response fleets, electric buses as part of public transport infrastructure, EV taxi fleet and EV government passenger vehicle fleet* |

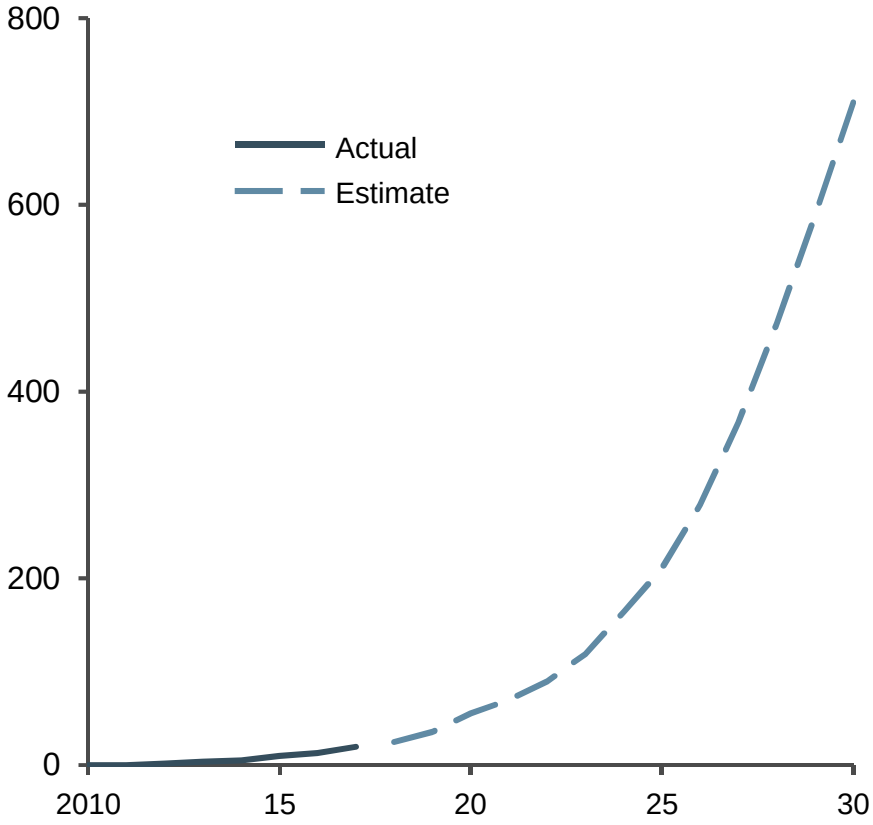
3

# Battery technology is evolving quickly. Battery prices are falling, and there is a trend towards larger battery capacities

**Estimated cost of lithium-ion battery packs (2010-30F)**
US dollars per kWh




**Estimated global demand for EV battery power (2010-30F)**
GWh per year




Note: * Researchers Bjorn Nykvist and Mans Nilsson
Source: L.E.K. Analysis of Bloomberg New Energy Finance; Green Car Reports; Clean Technica; Climate Council of Australia

3

# There are five key types of plugs currently used for EVs. The standards are being led by OEM choices, and each supports different charging rates

| Socket type | | Region of use | Capacity | Description | Charger compatibility | Car compatibility | *Current Australian use* |
|---|---|---|---|---|---|---|---|
| **Type 1** |  | Common in Japan and US | AC 7.4kW | Single phase and 5 prongs | Level 2 | BMW, Nissan, Mitsubishi, Porsche, Mercedes, Volvo | BYO cable to most existing charging stations |
| **Type 2 "Mennekes'** |  | Common in Europe | AC 22-43kW | Triple phase and 7 prongs | Level 2 | Renault and Tesla | BYO cable to most existing charging stations |
| **CHAdeMO** |  | Europe and US Developed in Japan | 50kW DC extension | Extension of Type 2 plug | Level 3 – DC | Mitsubishi and Nissan | No cable required |
| **CCS/SAE Combo** |  | Common in Europe and Asia | AC and DC | Extension Type 1 and 2 | Level 3 – DC | Audi, BMW, Volkswagen, Porsche | BYO cable may be required for type 2 |
| **Tesla** |  | Global | 50, 150 and 350+kW DC | Extension of Type 2 | Level 4 – Super charger | Tesla | Due to the higher capacity, the charger is currently not compatible with non-Tesla vehicles |

Source: Federal Chamber of Automotive Industries; Clean Technica; Electric Vehicles in Europe

3

# There are currently four modes of charging common to the EU and US. Higher modes draw more current for faster charging times

| Mode | Level | Common use | Power capacity | Voltage | Max current | Description | Time to charge (100km range) | *Implication for Victoria* |
|---|---|---|---|---|---|---|---|---|
| **Mode 1** | **Level 1** | Household or workplace charging | AC 3.3-7.4kW | 120 - 240V | 10-16A | Regular electric socket | c.10-14 hours | *Prohibited in the US due to lack of earthing* |
| **Mode 2** | **Level 2** | Household or workplace charging | AC 11-22kW | 240V or 400V | 10-16 or 32A | Regular socket with EV specific infrastructure | c.6-8 hours | *Common home charging option for EVs* |
| **Mode 3** | **N/A** | Designated charging areas | AC 50kW | 400-500V | 80-250A | Connects the EV directly to the grid | c.1-3 hours | *Globally recommended option for day-to-day charging* |
| **Mode 4 'Fast charging'** | **Level 3 DC** | Designated charging areas | DC 50kW | 400-600V | 80-250A | Connects the EV directly to the grid | <1 hour | *A number of companies offer fast-chargers in Australia* |
| **'Supercharger'** | | Future charging standard for fast chargers | DC 120-350kW | 400-800V | 300-500A | Connects the EV directly to the grid | Capacity beyond what a current battery can charge at | *Currently only offered by Porsche (Tesla V3 out soon)* |

Source: Federal Chamber of Automotive Industries; Clean Technica; Electric Vehicles in Europe; IEC



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3

# Public fast chargers are more expensive to install than standard chargers, however are preferred by a number of organisations in recent charger rollouts

- When rolling out public charging infrastructure, the infrastructure owner may choose to install standard charging (AC, <50kW) or 'fast charging' capabilities (Level 3 DC and above). Fast charging allows direct current to flow directly into the EV battery, allowing a higher current to be used while supported by batteries and vehicles, and the EV can be charged in a shorter period of time

- In order to access a fast charger, one of the extension plugs (CHAdeMO, CCS, Tesla) is added onto a base plug (either Type 1 or Type 2) to enable the direct current flow. These are widely available within Australia
  - In Jan 2013, the Commission in Brussels approved a common European charging connector system. Type 2 was declared a common standard for charging ports in Europe, however before the declaration Type 2 was considered the 'de facto standard' as it uses three-phase power, consistent with electricity grids in Europe. The support of the Commission by declaring Type 2 as standard has given 'support to other European countries which have not yet begun activities in charging infrastructure'
  - In Jan 2010, the California Air Resources Board ruled all EVs must be equipped with Type 1 charging capabilities. Type 1 is the accepted standard by OEMs in the US because it uses single phase power, consistent with electricity grids in the US

- Not all EVs are able to accept fast charging
  - Some older EV models do not have the battery capacity to receive 50kW of energy
  - Only the Tesla vehicles have battery capacity to receive charge above 50kW from the Tesla 'super chargers'

- A number of organisations globally are leading towards installing DC chargers in their latest infrastructure rollouts. These examples are covered in more depth in Section 4
  - The NRMA **in NSW** will roll out Australia's largest fast-charging network
  - Walmart in **the US** has committed to supplying 1k fast chargers in the US
  - Shell has collaborated with IONITY, a joint venture between BMW, Daimler, Ford, Volkswagen, Audi and Porsche to create a network of 350kW chargers at 80 Shell petrol stations across **Europe**

- Fast charging infrastructure is more expensive than standard AC charging, and draws significantly more current from the grid
  - According to EVSE, a public AC charger can cost between $2-3k to set up, where as DC fast charging infrastructure can cost $40-100k per station. This is due to the additional transformer infrastructure and labour required in set up
  - As highlighted in the Vector case study in section 5, one home fast charger (50kW) requires the same energy as 9 homes with traditional (7kW) chargers

Source: EVSE; Autoblog; Mennekes; L.E.K. research and analysis

3

# "Smart charging" is an emerging trend with standards and protocols that are still under development (1 of 2)

| Infrastructure | Use cases | Examples |
|---|---|---|
| **'Dumb' charger** | A stand alone charger<br>● Connected to the grid and to the EV<br>● Payment done through non-internet based mechanisms | This technology is common in most home chargers |
| **Smarts within the EV** | There are a number of smart features that are included within the EV, rather than the charging infrastructure. These include:<br>● Setting charging limits e.g. charge to 80% capacity<br>● Delay onset of charging e.g. start charging in 2 hours | Tesla and Chevy Volt EVs currently offer these features |
| **Network charger** | Communicates with the end user through the internet using a **network provider.** This includes:<br>● Operational status of charging station<br>● Location (to be shown on mapping apps like PlugShare)<br>● User-recognised charging through online systems<br>● Monitoring and reporting of statistical data | This technology is common in most public chargers |
| **Demand management** | Communicates with electricity suppliers and the internet to improve demand management. As this technology is in its infancy, it is predicted it will include functionality such as:<br>● A dynamic pricing model<br>● Charging station electricity management<br>● Charging reservations by EV users | This technology is advanced and is not widely common<br><br>Smart chargers in the **Netherlands** consider the best charging times to utilise renewable energy sources, grid capacity and V2G |

Source: Living Lab Smart Charging; Open Charge Alliance; ICCT 2017; ARUP

3

# "Smart charging" is an emerging trend with standards and protocols that are still under development (2 of 2)

| Technology | Use cases | Implications for Victoria |
|---|---|---|
| **Open Charge Point Protocol (OCPP)** | There are a number of providers that offer 'back office' services for charging stations that transfer information between an EV and charge point operator (E.g. Tritium, Chargepoint, JETCharge)<br><br>Variations in back office providers is blocking the maximisation of information sharing and limiting demand management efficiency. The Open Charge Alliance (OPA), developed in the **Netherlands**, aims to unite countries in encouraging open charge systems to develop an international standard<br><br>A number of charge point operators have joined OCPP globally and in Australia, in exchange for a small fee to the OPA. There are a number of incentives for charge point owners to use OCPP in their charging infrastructure. These include:<br>● Easy access to software updates, as administered by the OPA<br>● Ability to change charge point infrastructure without having to change charge point operator<br>● Familiar user interface and payment method across OCPP for all EV users<br><br>OCPP is not widely adopted in the **US** because the DOE was not specific on their network provider protocols when offering grants for charging infrastructure. Interoperability has since been a focus of the DOE after it launched the Electric Vehicle-Smart Grid Interoperability Centre in 2013 to harmonize standards<br><br>**Canada** are actively encouraging OCPP. In their recent EV infrastructure inquiry, the BC provincial government consider the inclusion of OCPP to be 'highly desirable' when investigating charge point operators | *Victoria may wish to investigate the potential for OCPP to be utilised in Victoria to improve energy system security*<br><br>*Victoria may wish to promote the use of OCPP when offering charging infrastructure grants* |
| **Open Smart Charging Protocol (OSCP)** | OSCP communicates a 24 hour forecast of the available capacity of the electricity grid. Based on this forecast, network operators can generate charging profiles for EVs that make optimal use of available capacity without overburdening the network | *While still in development, Victoria may wish to consider if current network infrastructure could accommodate OSCP* |

Source: Living Lab Smart Charging; Open Charge Alliance; Electric Vehicle Council; BCUC



L.E.K.

3

# There are some interesting alternative approaches to batteries and charging under development, including battery swapping and induction charging

| Technology | Use cases | Implications for Victoria |
|---|---|---|
| **Inductive charging while moving** | In-wheel charging motors are being trialled **in Japan** that will collect charge while driving over charging lanes with embedded power transmission coils and sensors. Current research concerns focus on the wear and loss of effectiveness of wheels in snow, and the ability to commercialise the product with necessary road agencies<br><br>10kms of the Autobahn will become an eHighway as the **German government** work with Siemens to allow electric charging of hybrid trucks while moving. The charging will have >80% efficiency | *Inductive charging is currently being trialled for both moving and stationary vehicles*<br><br>*A number of techniques are being used in inductive/wireless charging, including under-car charging and in-wheel charging*<br><br>*The risks and benefits of inductive charging are still being investigated* |
| **Stationary inductive charging** | A trial done in 2016 by **the US DOE** saw inductive charging achieve 90% efficiency when charging directly to the under-car 20kW battery. There are concerns about the safety of human proximity to the high-frequency magnetic energy transfer.<br><br>In 2015 **Transport for London** began trialling stationary inductive charging for their diesel-electric hybrid buses. Buses can charge wirelessly while they wait at their bus terminals.<br><br>**US** company Plugless currently offer the world's first **automated wireless EV home charging**, using aftermarket receptacles added to EVs to charge when beside a charge pad. | |
| **Battery swapping** | Battery swapping was trialled by **Israeli** company Better Place in 2007 with 37 swapping stations across Tel Aviv and Jerusalem. Partnering with Renault to provide battery-swapping feasible EVs, the company offered robots to switch out EV batteries in under 5 mins, allowing for further range. The business model allowed Better Place to retain ownership of the batteries, therefore decreasing the price of the EV. Better Place filed for bankruptcy in 2013 and cited low OEM uptake, an unfamiliar business model and lack of incentive and subsidy support from governments as the levers of their collapse<br><br>'Batteries as a service' has been popular in **India** for 5 years, as consumers did not want to bear the price burden of owning the battery in their electric rickshaws. Indian company Lithion Power invested $1b in 2018 to expand the service for passenger EVs by swapping, leasing or renting batteries<br><br>Mercedes in **the US** trialled battery swapping in 2009 but discontinued testing due to risk of electrocution during a manual horizontal battery change. | *Battery swapping has been trialled internationally, but failed without OEM or government support. If battery swapping becomes successful in overseas markets, Victoria may need to match overseas government funding arrangements*<br><br>*The risks and benefits of battery swapping are still being investigated* |

Source: The Guardian, RenewEconomy; Green Optimistic; The Drive

3

# Section Summary: EV Charging infrastructure and standards (1 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Choosing a current plug standard for EV charging infrastructure investment*** | • There are 5 key types of plugs currently used by EVs, each supporting different charging capacities. Two of these are foundational plugs, while three are "fast charging" extensions to the existing plug types<br>• OEMs have typically chosen one or two of the plug types for their vehicles<br>• "Type 1" plugs are common in Japan and the US, while "Type 2" are common in Europe<br>• There are also five different "levels" or "modes" of charging, specifying different voltages and currents for different charging rates. These classifications differ internationally - the US predominantly use 3 levels of capacity, and Europe use 4 modes of capacity<br>• The Federal Chamber of Automotive Industries has recommended that Australia adopts the "Type 2" charging plug as standard, which is capable of level 2 charging<br>• Tesla has adopted an extension of Type 2 for its "super charger". This means that its vehicles can use Type 2 chargers for slower charging, but others cannot use its "supercharging" capabilities by connecting to a "super charger" | *It appears that Type 2 charging may be emerging as the leading standard in Australia. This gives Australian OEMs flexibility as it accommodates all "fast charging" extensions, making it accessible to a number of EVs* |
| ***Choice between standard charging and fast charging infrastructure*** | • Fast-charging is becoming the more common charging capacity choice for new infrastructure roll-outs globally<br>• While fast charging plug sockets are generally compatible with all EVs, the high level of current is not compatible with some older EVs<br>• Fast chargers are more expensive to install than standard chargers<br>• Fast chargers draw more from the grid, so charger locations need to consider grid capabilities | *If Victoria decide to support charging infrastructure roll outs, they may wish to support "fast chargers" in line with other jurisdictions. This offers value to EV users to charge significantly quicker, enabling increased utilisation*<br><br>*However, Victoria should consider the incompatibility and expense of fast charging infrastructure. Grid capacities will also need to be considered before choosing fast charging locations* |

3

# Section Summary: EV Charging infrastructure and standards (2 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Developing technology for EV charging*** | Inductive charging is currently being trialled in **moving and stationary EVs**. Inductive techniques vary globally – **in-wheel batteries** are being trialled in Japan, **under-car charging** is being tested in the US<br>● Germany are currently upgrading the Autobahn for **heavy-vehicle inductive charging**<br>● London are employing inductive charging for their **hybrid-buses**<br><br>Battery swapping has previously been employed in various jurisdictions<br>● Israeli's market leading battery-swapping company filed for bankruptcy citing **lack of OEM and government support**<br>● Indian battery swapping is being expanded from rickshaws to all electric vehicles due to the **cheaper offering for EV ownership**<br><br>There are some concerns regarding the **safety** of both battery swapping and inductive charging | *There may be some specific use cases for induction charging that Victoria may wish to consider, including at the end of electrification bus routes, but it appears unlikely to be the predominant charging technology due to its cost and reduced efficiency* |
| ***Changing EV charging standards including "smart" charging*** | ● "Smart charging" comprises of the infrastructure required to support a number of smart charging technologies, including V2G and demand management<br>● "Smart charging" standards are being developed to address a range of issues in current EV charging infrastructure, such as incompatibility between the vehicles and infrastructure, and the challenges of managing grid impacts of EVs<br>● Some EVs are incorporating more technology within the vehicle<br>● Some EV charging infrastructure utilises open charge point protocols to enable easier management and usage of the facilities, particularly for managing impact on the grid<br>● Canada is promoting Open Charge Point Protocol (OCPP) to avoid interoperability issues arising in the US<br>● An open smart charging protocol is under development to coordinate loads on the electricity network from EV charging | *Victoria may wish to investigate the potential for OCPP to be adopted by utilities and operators in the state* |

4

# There are three key ways in which charging infrastructure is developed to support EVs

| | Category | Charging type | Description | Considerations |
|---|---|---|---|---|
| A | **Private** | Home charging – off road | Charging station is attached to the garage or side of the house | • Requires off-street parking, therefore more suitable to houses in suburban areas as opposed to apartment buildings or inner-city suburbs<br>• Difficulties in effectively utilising day-time generated solar PV to charge EV at night |
| B | **Public shared** | Street charging – on road | Municipality or private supplied public charging stations on a suburban or inner-city street | • Street charging is usually AC, requiring cars to be parked on suburban streets for c. 8 hours to receive a full charge<br>• May require extension cords being used in the street, resulting in tripping hazards<br>• ICE vehicles parking in designated EV charging could limit charging availability |
| | | Work charging | Building management, office or individually supplied wall charging units | • Buildings may require retrofitting<br>• May be able to benefit from rooftop building solar<br>• Can accommodate day-time charging |
| | | Destination charging - shared | Municipality, government or private supplied public charging stations located at 'destinations' including shopping centres and petrol stations | • EV owners may face conflicts with inoperable plugs<br>• Includes a combination of fast and standard charging |
| C | **Public exclusive** | Destination charging – exclusive | OEM supplied 'public' infrastructure only accessible by certain EVs | • Tesla chargers can only be used by Tesla EVs<br>• Teslas can use all other chargers with their adaptor plugs |

4
A

# Approximately 80% of EV owners charge their vehicles at home. This presents challenges where off-street parking is limited or for renters (1 of 2)

| Home charging technology | Technology impacts | Implications for Victoria |
|---|---|---|
| **Connection with solar** | Charging an EV from home solar presents challenges, including mis-match between solar generation times and consumer EV charging times and a lack of capacity versus vehicle needs. Trials are being done in **the US** by Vivint and Chargepoint to offer 'Fully Integrated Solar', which combines a solar energy system, EV charger, home battery and smart home technology | *Private companies have taken the lead on integrating solar with home charging, and introducing solar to public and workplace charging* |
| **Lack of home parking infrastructure** | Home charging stations attached to the wall or garage of a home often come with an extension cord of c.5-10m, to reach from the charging station to the EV. EV charging becomes difficult for EV owners without accessible private parking, or in apartment buildings that lack necessary infrastructure.<br><br>**Transport for Victoria** are also concerned with the impact EVs will have on street parking:<br>*"… Councils will not want tripping hazards on their footpaths through over-stretched charging cords. But there is limited street parking in Melbourne's inner suburbs. Victoria do not have a solution yet …"*<br>*Policy Analyst, Transport for Victoria*<br><br>National Grid has forecasted home-charging is not the way of the future in **the UK** due to limited off-street parking, suggesting home charging will migrate to petrol-station based charging. A number of **German** states have agreed with this statement. | *There will be substantial segments of the Victorian population (e.g. in high density or potentially rented accommodation) who will require access to public charging infrastructure* |

Source: DOE; Ohm home now; Transport for Victoria; AutoVista Group; L.E.K. research and analysis

4
A

# Most EV owners charge their vehicles at home. This presents challenges where off-street parking is limited or for renters (2 of 2)

| Home charging technology | Technology impacts | Implications for Victoria |
|---|---|---|
| **Permits for home installation** | **In California**, field inspections and building permits are usually required for the installation of a home EV charging unit. While some cities in California are expediting the permitting process, others still charge $USD 200 on average per permit. Permits and site visits conduct load calculations in line with the California Electric Code | *Victoria may wish to implement home charger permit requirements* |
| | In 2017, **San Francisco** introduced an EV Readiness Ordnance which includes provisions stating that new construction or major building renovation require the installation of Level 2 chargers in 10% of the parking spaces and conduits enabling additional installations in another 10%. The ordinance also requires the capacity to handle the simultaneous charging of vehicles in 20% of the parking spaces, and enabling the use of charging management systems to scale up and provide charging for up to 100% of the spaces<br><br>While a large portion of the population in **Shanghai and Beijing** reside in high-rise buildings, there has current been limited government research and investment into ensuring older buildings are EV ready to support government EV objectives<br><br>In the **EU** as of 2019, every newly built or refurbished house from Cyprus to Lapland must have an EV charging station, and by 2023 EV chargers must be installed in 10% of all buildings' parking spaces<br><br>ChargePoint, a **US** public and private charging infrastructure supplier published recommendations regarding 'how to get your Home Owners Association to say "yes"' to installing a home charger. Advice to EV owners includes proposing a fair, scalable plan to the HOA and to consider a community model<br><br>**Energy Safe Victoria** offer advice on the installation requirements for solar panels, gas installations and electrical infrastructure, and Victorian landlords must pay all installation and initial connection costs for electricity, gas and oil supply.<br><br>Part 20A of the *Telecommunications Act* requires developers of new properties in Australia to **install fibre-ready pit and pipe** for use by telecommunications carriers | *Victoria may wish to introduce a provision to require EV ready buildings and infrastructure or rights for tenants to install charging infrastructure* |

Source: DOE; EV Readiness Ordnance California; the Guardian; AGL Australia; Victorian Parliament; Energy Safe Victoria; Department of Communications; ChargePoint; L.E.K. research and analysis

4
A

# There are some public and private incentive schemes to increase home charging installations

There are a number of views about how best to assist home owners for their increase in electricity bills associated with home EV charging. Incentives currently take the form of rate assistance schemes from utilities, or grants from federal government

| Home charging incentive | Incentive outcome | Implications for Victoria |
|---|---|---|
| **Public grants for home and business chargers** | In **France**, the federal government offer tax credits equivalent to 30% of a home charger or subsidies for the installation of residential or workplace chargers.<br><br>In **London**, the Government division for the Office of Low Emissions Vehicles (OLEV) provides grant funding for up to 75% of the cost of installing a domestic EV charger. | *To assist with home and business charging set-up, the Victorian government may choose to offer grants* |
| **Rate assistance** | AGL in **Australia** offer $1 a day charging for EVs by installing an additional digital metre. Although, AGL admit 'If you drive your EV infrequently, charge at night with an off-peak tariff or use a PV system, your existing AGL plan might be cheaper. AGL also offset 10% of carbon emissions resulting from EV charging. Energy Australia similarly offer tailored EV electricity rates depending on suburb and EV type, also given as a daily rate.<br><br>Widely employed in the **US** by all leading utilities, price ranges 10-20c difference between on and off peak. However, this model may lose effectiveness as other technologies develop; an increase in home-solar would make the on-peak tariffs less effective, and V2G arbitrage may decrease the off-on peak price gap | *Rate assistance schemes are primarily utilities led, requiring little government intervention* |

Source: AGL; Click Energy Australia; OLEV; ICCT; National Grid

4
B

# Governments can influence the rollout of public EV charging infrastructure in a variety of different ways (1 of 2)

While OEMs, utilities, insurance companies charge point operators all have a role to play in developing public EV charging infrastructure, government agencies have also played a considerable role in a number of jurisdictions

| Funding mix | Funding examples | Implications for Victoria |
|---|---|---|
| **Government grants** | In **Norway**, the government has funded multiple rounds of public charging infrastructure. Its first round in 2010 funded 100% of the installation cost of normal speed EV chargers, which cost up to 50k AUD per charger.<br><br>However as these charging stations were rolled out before standards were adopted, the technology is now almost obsolete due to advances in technology and high maintenance costs. In 2014 the government released another round of funding for fast chargers, which was considered relatively new technology at the time, once again supporting 100% of installation costs | *Government funding issued before agreed charging standards are confirmed may result in expenditure on obsolete infrastructure* |
| **Bans on private funding** | **California** previously banned utility investment in EV pubic charging infrastructure with a concern it would limit private investment. However, the ban was lifted in 2015 in an attempt to increase charging infrastructure in the state. Since the lift of the ban, public utility companies have begun investing in fast-charging points across the state | *Banning utility investment in charging infrastructure may hinder EV uptake* |
| **State-owned charging infrastructure** | **China's** state-owned electric utility State Grid Corporation (SGC) is working to build national networks of fast charging stations, aiming to have one charging station per 2k vehicles by 2020. This build was government mandated, and is currently operating at a loss<br><br>**Australia** has varying level of state-funded charging infrastructure. In **Queensland**, the state government, in collaboration with local councils invested over $3m on 18+ fast chargers. However in **Victoria,** there is currently no state-funded charging infrastructure. According to AustRoads, Commonwealth supported infrastructure is unlikely to be rolled out in Australia in the near future. | *State funding may act as a catalyst to encourage private investment into EV charging stations as EV uptake increases* |

Source: ICCT; Elbil; VicRoads; WEF; VicRoads; Queensland Government; Renewable Energy World; Global EV Outlook 2017; AusRoads

4
B

# Governments can influence the rollout of public EV charging infrastructure in a variety of different ways (2 of 2)

| Funding mix | Funding examples | Implications for Victoria |
|---|---|---|
| **Public-private collaborations** | Source London, **London's** largest citywide electric-vehicle charge point network, was initially developed by Transport For London through a consortium of public and private organisations including Heathrow Airport, IKEA, Whittington Hospital, London Underground and Capital Shopping Centres. It is now managed by French transportation company Bollore. The project currently provides more than 850 charge points across London and plans to install another 4.5k by 2018. | *Private-public consortiums utilising pooled funds and infrastructure knowledge may be an efficient way to encourage EV uptake in Victoria* |
| **Private sector activity** | Solar is being more widely considered for public charging infrastructure and work destination charging. A number of examples are present in the US<br>• DC Solar offer charging stations in **Las Vegas, Arizona, California, Ohio, Florida, and North Carolina**<br>• Envision Solar are deploying solar powered EV stations in **San Diego**<br>• Brightfield Solar expanded its offerings to include 100 charging stations installed at retail locations in NC, TN, and MA. The company's stations are powered with up to 15.3 kilowatts of solar | *The private sector will be able to make out business cases for installation of some public charging infrastructure without government support* |

Source: ICCT; Elbil; VicRoads; WEF; VicRoads; Queensland Government; Renewable Energy World; Global EV Outlook 2017; AusRoads; L.E.K. interviews

4
C

# Tesla has privately funded the rollout of one of the most advanced EV charging networks worldwide. Usage is restricted to Teslas due to its current and plugs

- The global Tesla charging network is exclusive to Tesla EV owners.
  - the network contains +5k DC 'Superchargers' and +9k AC destination chargers
  - non-Tesla EVs are unable to connect to either a Supercharger or a destination charger because of both the unique Tesla plug, and the higher level of current (Tesla offer c.100A, while other EVs are generally limited to 40A)
  - Tesla does not permit the use of adapters at its charging stations in order to charge non-Tesla cars
- Tesla received limited to no funding for the roll-out of their exclusive charging infrastructure
  - in both the US and Australia, Tesla self-fund their Supercharger infrastructure networks
  - in Australia, Tesla also include a home-charging set for free on the purchase of a vehicle
- Globally, EV charger infrastructure funding has been directed towards private companies with more accessible charging plugs
  - in Queensland, the state government funded $2.5m for Tritium to roll out fast-chargers using both CCS and CHAdeMO plugs
  - in Germany, the federal government allows private companies and municipalities to apply for some of a EUR$300m charging infrastructure grant, with the pre-requisite that the charging points are publically accessible to all

**Implications for Victoria: if the Victorian government are to fund the roll-out of charging points, they may wish to fund chargers that are more accessible to a large number of EV users across a range of vehicle makes and models**

Source: Tesla; Eltis; Renew Economy

4

# There are some natural locations to locate public charging infrastructure (1 of 2)

| Charger location | Examples | Implications for Victoria |
|---|---|---|
| **Destination charging - Petrol stations** | Shell has collaborated with IONITY, a joint venture between BMW, Daimler, Ford, Volkswagen, Audi and Porsche to create a network of 350kW chargers at 80 Shell petrol stations across **Europe.** Shell hope to add charging stations to 50% of their petrol stations by 2020<br><br>Until recently in **Japan**, petrol stations were restricted from including EV charging infrastructure due to fire safety concerns. Previously EV charging stations were not allowed within 10m of a gas pump, which was restricting on small stations. The restrictions relaxed in 2018 in an aim to encourage EV uptake further | *Victoria may see the retail sector support the rollout of public charging infrastructure.*<br><br>*Victoria may need to consider reviewing laws regarding supply of electricity to the public.* |
| **Destination charging - Shopping centres** | Walmart in **the US** has committed to supplying 1k fast chargers in the US (Under 'Project Gigaton'), in a bid to reduce emissions from their supply chain. Walmart are aiming to 'increase family convenience' by providing a one-stop shop, allowing users to charge their vehicles while they shop. The fast chargers provided by Walmart will take customers c.30 mins to charge their EV, encouraging EV owners to spend money in store while they wait<br><br>Target recently announced they will expand their EV charging points by 600 points by 2020. Target will collaborate with Tesla, ChargePoint and Electrify America to install the chargers in parking lots<br><br>**In Canada**, it is against the law for a business to charge for electricity consumption unless they are a utility. Therefore, non-utility charging infrastructure suppliers, such as OEMs and private companies, must offer free charging. Two alternative revenue streams may include charging for parking, or charging for marketing | |

Source: Walmart, Target; Shell; IONITY; Nikkei



L.E.K.

4

# There are some natural locations to locate public charging infrastructure (2 of 2)

| Charger location | Examples | Implications for Victoria |
|---|---|---|
| **Public charging hubs** | **Oslo** offer the world's largest charging garage. The garage, developed via a public-private project between the city and a real-estate company, offers 100+ multi-speed charging stations. The stations offer the latest technologies including smart charging, battery reserve and V2G. In order to add accessibility to all users, the garage includes the ability to pre-book charging, which is utilised by both fleet operators and car-sharing services | *Government could consider supporting development of charging 'hubs' as well as individual public chargers* |
| **Regional towns** | Fast charging stations offered in regional towns can be considered a tourism technique, as they will require EV owners to pass through when engaging on long-range drives. RAC introduced Australia's first 'Electric Highway' **in WA** in 2015 comprising of 11 DC chargers. **Queensland's** Electric Highway has not only benefited EV owners by increasing their drive range, but has drawn tourism to the towns along the highway that have been hosted the fast-charging infrastructure.<br><br>*"… Adding fast chargers to the towns was as much about emissions control as it was about introducing self-drive tourism …"*<br>*Director Transport Futures, Vic Roads*<br><br>The NRMA **in NSW** will roll out Australia's largest fast-charging network. The network will include 40 50kW chargers supporting both CHAdeMO and CCS fast charging plugs. All chargers will be a maximum of 150km apart, allowing for rural access across majority of the state | *Using regional Victorian towns to create an 'electric highway' could benefit the tourism industry in the towns selected* |
| **Demand-based locations** | The locations of new charging stations in **Amsterdam** are determined using a demand-based approach, where locations are selected and requested by EV users through online communication with the municipality. This demand-based location selection is only available to end users when there are no private or off-street alternative solutions. | *As an alternative approach to choosing infrastructure locations, the Victorian government may wish to employ demand-based location decisions* |

Source: Queensland Government; ICCT 2017; NRMA

4

# Section Summary: Development of charging infrastructure (1 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Charging EVs with residential solar PV*** | • Commercial trials of combined solar/battery/smart home technology | *Private companies are promoting solutions that are under developed* |
| ***Lack of home parking*** | • Providing public charging in areas where home charging is not feasible appears to be the most common solution proposed<br>• On-street charging from private connections or from connections from public infrastructure, but this creates tripping risks and clutter | *Victoria may need to develop a plan to address changing needs for those who cannot charge EVs at home* |
| ***Promoting EV ready homes and buildings*** | • Mandating minimum charger installation requirements<br>• Mandating passive infrastructure to enable subsequent installations of EV charging infrastructure<br>• Permits for installation of house EV charging infrastructure | *Victoria may consider implementing EV infrastructure requirements for new builds, particularly for multi-residential developments, to reduce barriers to EV uptake and demands on public charging infrastructure* |
| ***Public and private incentives for home charging*** | • Governments in the UK and France are offering **tax credits and subsidies** for the purchase of home charging infrastructure<br>• Rate assistance schemes employed globally include offering **cheaper electricity prices overnight**, to encourage off-peak consumption<br>• Australian companies are offering **capped-price unlimited daily charging** for EVs as an incentive to encourage EV owners to switch electricity provider | *Victoria could encourage home charging by subsidising charger installations*<br>*There are a range of emerging commercial offers for energy to charge EVs that can be difficult to compare*<br>*Victoria could consider extending its energy comparison tools to enable greater coverage and information* |

4

# Section Summary: Development of charging infrastructure (2 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***How governments can support development of public EV charging infrastructure*** | • The Norwegian government funded development of public charging infrastructure from 2010, but changes in infrastructure standards mean that technology is becoming obsolete, requiring new rounds of investment<br>• As the roll-out of Tesla's charging infrastructure has been globally self-funded, it is able to offer plugs that are not compatible with non-Tesla vehicles<br>• State funded infrastructure is common in China and Australia<br>• Public and private partnerships are used in the UK for some rollouts | *There are many options available for Victoria to promote the development of public EV infrastructure*<br><br>*The Victorian government may wish to refrain from supporting EV infrastructure development until it is clearer what the standards will be when used in Australia*<br><br>*Private developments can result in the need for greater total investment in charging due to incompatibilities* |
| ***Where public charging infrastructure should be created*** | • Petrol stations and shopping centres are seen as natural locations to establish public charging points<br>• Installing charging infrastructure in regional towns along truck routes provides opportunities to draw visitors and enable long distance travel with EVs<br>• Digital engagement between government and the community is used to provide data to target government investment | *The Victorian government could consider developing better data management surrounding the supply and demand for EV charging to better target its investments*<br><br>*Commercial development of EVs charging infrastructure can be accelerated with government support*<br><br>*Victoria may wish to follow WA and QLD's lead in creating an "electric highway" to accommodate rural charging* |



L.E.K.

5

# The impact of EVs on electricity networks is unknown. This may increase load overall or in specific locations, but may also smooth demand

The impact of EVs on electricity networks depends on a number of factors beyond the current network configuration:

- **Charge type adopted** - While public charging stations are offering 50kW fast charging capabilities, this same level of charging is not available from home chargers. The maximum output from a home charger is 11kW
- **Extent of home charging** – Currently it is estimated that at least 80% of charging is done at home, however the most popular time to charge is after work. This coincides with existing peak demand globally, adding additional pressure to the grid
- **Placement of public charging infrastructure** - Neighbourhood and destination-based fast chargers operating at 50-120kW are placing large amounts of strain on the grid in locations where such levels of energy were not previously required, and creating need for network investment that is not linked to dwellings
- **Demand management technologies** - demand management policies and technologies such as V2G and smart charging can enable EVs to smooth the demand profile. This would be done by drawing energy from the grid in low demand, and potentially by adding energy back into the grid in peak demand

## Case study: Vector

**Vector in NZ** suggest the key considerations for EV grid network impact are:

- Time of day charging – NZ statistics suggest EV owners will only need to charge every third day, but range anxiety will possibly cause more frequent EV charging to 100% filled each evening. The charge required in the evenings to charge an EV at peak time from 80-100% is more than required to charge from 0-20% in off-peak
- EV uptake and network charging – EV penetration in cities will be higher than rural areas. Even within cities, some neighbourhoods will see 'clustering' due to higher income levels, existing infrastructure or peer-influencing early adoption
- EV range and battery size – only 4% of batteries are currently over 50kWh, but this is expected to increase with release of Tesla and Porsche 'super batteries'. Larger batteries will take longer to charge, and may make overnight charging unfeasible with lower modes of charging
- Consumer charging behaviours – consumer preferences between slow, standard and fast charging will drastically impact the home energy requirements. One home fast charger (50kW) requires the same energy as 9 homes with slow (7kW) chargers

Source: Climate Institute; AEMO; ARUP; AutoVista Group; Vector; L.E.K. interviews

5

# Electricity network operators are considering how to prepare for increased uptake of EVs. One response is to utilise demand management strategies

| Response | Use cases | Implications for Victoria |
|---|---|---|
| **Grid and charger communications for demand management** | Pepco, a **US** public utility, piloted reduced chargers from Level 2 to 1 rate of charge for an hour during a demand response event. However, the trial found that the ongoing costs of the communications link were too expensive under their trialled model<br><br>In 2016, the **Californian** government began to install EV charging infrastructure that incorporates demand management capabilities. The charging operator uses internet connected chargers to instantly respond to electricity operator signals by reducing or cutting off car charging until the grid is stabilised. | *There are challenges to using grid/charging integration to manage demand, including who funds the communication to offset EV impacts on grids* |
| **Pricing and charge rate demand management strategies** | There are a number of demand management charging techniques that utilities can implement to help manage demand on the grid. These include:<br>• A **UK** utility launched a trial using automatic aggregators. The trial intended to shift local demand patterns using a 'time of use' tariff. The tariff is designed to reduce network congestion at times when the sun is shining. Consumption could be shifted manually or automatically – 5% of demand was shifted manually compared to 13% when using automated functions<br>• **San Diego Gas & Electric's** day-ahead, price-varying EV rate reflects circuit and system conditions and the changing price of energy throughout the day, to be accessed through a phone app.<br>• **Southern California Edison** recently trialled leveraging afternoon peaks and load reduction strategies to learn more about driver responsiveness to pricing signals. The program included a high, medium and low price option which equated to the level of charging disruption and charging speed (Level 1 or 2) offered. The trial found that drivers preferred maximum optionality | *There may be a need to review government regulations impacting the ability of electricity providers to set variable rates and demand management strategies to accommodate EVs* |
| **Including V2G in demand side response strategies** | Recently **in Texas**, an increase in small scale renewables displaced synchronized generators, resulting in increased grid volatility. The Electricity Reliability Council pioneered Fast Frequency Response (FFR) in order to reward electricity sources that can respond within half a second of a signal from the dispatcher. The pilot included 37MW of battery storage and 100kW of grid connected EVs. FFR successfully lead to a 37% improvement in the rate of frequency change in case of a sudden loss of generation.<br><br>E.ON in **the UK** also expects V2G to become a significant player in the primary response market by 2030, overtaking central generation and other DSR as the primary response source. | *V2G is not currently a mature technology for promoting energy network stability, but may be in the future* |

Source: Green Alliance; SEPA Power; E.ON UK

5

# Another response globally is to upgrade existing network infrastructure. The value and funding of these infrastructure upgrades are key issues

| Issue | Use cases | Implications for Victoria |
|---|---|---|
| **Infrastructure upgrades required** | In 2014, **Norway** were an early adopter in developing charging infrastructure. To accommodate uptake in the absence of smart technology and network management, expensive grid reinforcements were needed. Suburb demand spiked when EVs in close proximity charged at peak times, which may have been avoided with smart infrastructure<br><br>The Electric Avenue conducted studies in **the UK** in 2016 suggesting that 32% of low voltage feeders will require infrastructure upgrades by 2050 to cope with clustered EV uptake. Analysis was based on home charging units of 3.5kW, meaning results will be exacerbated when including the impact of 7kW-50kW home charging capacities.<br><br>Similar research was conducted by the Municipality Utility District in **Sacramento**, anticipating that 17% of transformers will need to be updated by 2030 to accommodate EV uptake | *A number of jurisdictions have considered that their current grid infrastructure may not be sufficient to support an uptake in EVs, resulting in actual or planned infrastructure upgrades* |
| **Costs of funding infrastructure upgrades** | In **New Zealand,** there are concerns that new infrastructure funding would likely be triggered by EV owners desiring home fast charging, and subsequently subsidised by non-EV owners under current NZ regulation. It may also lead to "free-riding" as network investments on low-voltage grids are triggered by connection requests, which the requesting EV owner may have to financially cover, but will likely be utilised by other EV owners nearby | *There may be a need to review regulatory policies about who pays for upgrades to enable EV charging* |

Source: Green Alliance; SEPA Power

5

# Vehicle-to-grid technologies and standards are at an early stage of development

| Technology | Use cases | Implications for Victoria |
|---|---|---|
| **V2G impact on vehicle, meter, grid ad plugs** | In order to enable V2G, 'smarts' need to be included across a number of elements. This includes the grid and local network communications, a smart meter, a bi-directional plug, a user interface and a compatible vehicle.<br><br>Vehicle - In late 2018 Nissan will introduce the first smart-charging vehicle to **Australia** with their new Nissan Leaf, which will include V2G capabilities. It is unclear which standards Nissan will follow<br><br>Meter and grid - V2G presents similar issues for home infrastructure as solar PV, involving two-way flow of energy feed-in tariffs. Attaching EVs to home charging infrastructure to flow energy into the grid has not been widely tested.<br><br>Plug - **In Japan,** V2G uptake is being led by a post-Fukushima consumer desire for energy security. CHAdeMO, the Japanese-originated DC charger plug is the first DC plug with the ability to allow bi-directional flow of energy. | *The practical issues for V2G may start to become apparent soon, Australia will receive its first V2G ready EV in 2018*<br><br>*Wide utilisation of solar PV systems in Victoria may make V2G more viable with less infrastructure required* |
| **V2G trials** | As of April 2018, **London** EV owners will undertake a 2 year trial using the new OVO 6kW V2G charger, as funded by the UK Department for Business, Energy and Industrial Strategy. In a bid to develop the 'distribution energy system of the future', the OVO charger employs artificial intelligence to learn, adapt, optimise and detect consumer behaviour and usage. This information will be fed to the government to build an efficient energy demand model<br><br>JUMPstartMaui, a project between **Japanese** development management company Nedo and **Hawaii** saw 80 volunteers equipped with V2G capabilities to successfully discharge their EV into the grid. This created a 'virtual power plant' allowing the grid to draw energy from EVs in times of need.<br><br>In June 2018 **UK** company Drive Electric will launch their V2G trial. Drive Electric fund the user interface, to be connected to CrowdCharge charging stations using the CHAdeMO plug, and is applicable to Nissan Leaf, Kia Soul and Mitsubishi Outlander. | *V2G is still in its infancy*<br><br>*Victoria may wish to wait for trial outcomes before supporting infrastructure development* |
| **Impact on battery life** | The impact of V2G on battery life is still undetermined as international studies have found conflicting results, and suggest more study may need to be done in this field. A 2017 study from the **University of Hawaii, US** found that the additional cycling reduces the battery's overall lifespan by inducing more usage of the cells. However, a 2017 study from the **University of Warwick, UK** suggested V2G improves the lifespan of the batteries by reducing capacity and power fade | *The impact of V2G on battery life is still uncertain* |

Source: Living Lab Smart Charging; Open Charge Alliance; ICCT 2017; UK BEIS; Tesla; Electric Vehicle Council; ChargeDevs; L.E.K. interviews and analysis



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# Section Summary: Impact of EVs on electricity network infrastructure

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Impact of EVs on electricity networks*** | • EVs are expected to **change the level and profile of demand**, but it is unknown whether this will have a net positive or negative impact on the grid<br>• Key drivers of grid impact are charge type adopted, extent of home charging, placement of public charging infrastructure and demand management technologies<br>• Solutions being investigated globally include **high-voltage charging garages** in Norway and **mandatory demand management 'smart charging'** infrastructure in homes in the UK | *The impact of EVs on the networks in Victoria and around the globe are unclear* |
| ***Investment in electricity network infrastructure to support higher EV uptake*** | • There are two approaches that are considered to prepare the grid for EVs internationally; **improving demand side response management systems**, and **upgrading the grid infrastructure**<br>• Few decisions have been made internationally about how to move forward<br>• **Demand side response** requires enablement through installation of smart infrastructure and **reform of tariff structures**<br>• Infrastructure investments may require reconsideration of the rules about who pays for infrastructure upgrades | *The investment required in networks in Victoria and around the globe is uncertain*<br><br>*Network owners show a desire to invest in assets to earn regulated returns*<br><br>*This is a complex issue that Victoria should investigate further* |
| ***Contribution of technology to energy system security and reducing infrastructure investment needs*** | • In order for V2G technology to work, coordination is required across **the EVs, home chargers, public chargers and the grid**.<br>• While only Nissan will offer EV V2G and only CHAdeMO are offering plug bi-directional flow, the infrastructure issues associated with V2G may be similar to existing bi-directional solar PV infrastructure<br>• **V2G trials** are currently being conducted in London and Hawaii | *V2G technology and trials are currently at a low level of maturity*<br><br>*While trials and research are still being conducted into the effectiveness and practicality of V2G, the Victorian government may wish to watch for outcomes before considering supporting investment in V2G* |



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# The international scan highlighted a number of potential issues associated with increased EV uptake for Victoria to consider beyond infrastructure

## Battery recycling

The EV batteries have a life-span of c.10-15 years, after which c.95% of the battery can be recycled

Tesla Australia currently ship their used batteries to the **US** to be recycled

One large facility is operated by Umicore in **Belgium** and others are planned in **Europe**

The **Australian** battery recycling industry is relatively undeveloped because of the low number of batteries exiting vehicular use

## Safety of emergency crew

There are potential public safety issues associated with EVs in emergencies or accidents

**Explosion risk –** while OEMs have taken measures to ensure that their batteries will not explode in a crash, batteries may ignite or become electric hazards. **Tesla** have several layers of protective coating on their battery to prevent explosions, and have received a 5 star ANCAP rating for their Model S and X in Australia

**EV identification –** when an EV is in a crash, it may be challenging for emergency crews to recognise if the vehicle contains an electric battery. While **the US** National Fire Protection Association and NHTSA* require firefighters to look for labels alerting to high voltage, there is no further specification. **Tesla** and **Nissan** both have released identification and response guides

**Fire and electrocution risk–** Electric batteries may catch on fire or become electrocution risks when they are broken. EV fire will take longer to put out than an ICE fire, and can reignite up to 24 hours later. While **Tesla** suggest their vehicles are 5x less likely to catch fire than an ICE, **Californian Highway Patrol** suggests they are as dangerous in crashes as ICEs

Note: * National Highway Traffic Safety Administration
Source: Tesla; Nissan; Bloomberg; ICCT 2018; Teslanomics; US NFDA; NHTSA; ANCAP; ABC

# Agenda

- Executive Summary
- Introduction & approach
- **Findings about Zero Emission Vehicles**
  - Electric Vehicles
  - **Hydrogen Vehicles**
- Findings about Autonomous Vehicles
- Findings about other New Mobility market models
- Implications for Victoria
- Appendix

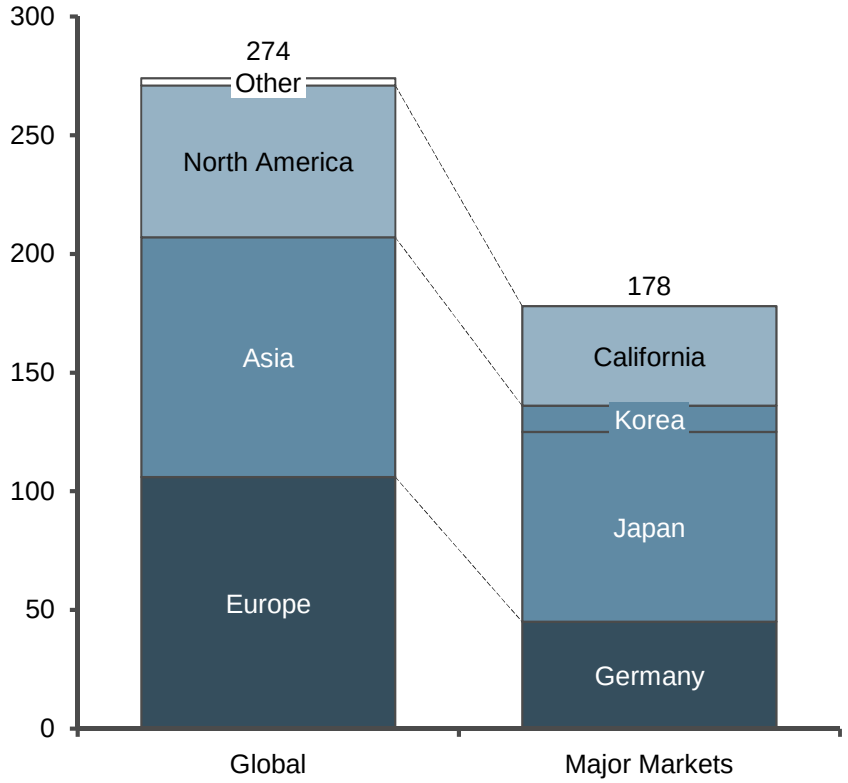
# Hydrogen Fuel Cell Vehicles

## Overview of Hydrogen Vehicle International Scan

| Elements | Issues explored in focus markets |
|---|---|
| 1 Hydrogen vehicle uptake | • Key markets for hydrogen vehicles<br>• Government aims and goals<br>• Government support mechanisms<br>• Challenges for HFCV adoption |
| 2 Hydrogen production, storage and usage by vehicles | • Hydrogen production<br>• Hydrogen storage and delivery<br>• Hydrogen pressure and purity requirements |
| 3 Approaches to developing storage and refuelling infrastructure | • Hydrogen station placement & design<br>• Funding mechanisms for hydrogen refuelling stations (HRS)<br>• Hydrogen infrastructure standards |

# The key current markets for Hydrogen Vehicles are Japan, Germany, California and South Korea

**Hydrogen refuelling stations in operation, by geography* (2018)**




**There are 3 key hydrogen cars publically available in select markets**

| Car | Make and Model | Description | Availability |
|---|---|---|---|
|  | Honda Clarity | The Honda FCX Clarity is based on the 2006 Honda FCX Concept and was the first hydrogen fuel cell vehicle available to retail customers | For sale in California<br><br>Testing in Europe |
|  | Hyundai ix35 FCEV | The fourth generation is the 2012 ix35 FCEV. In January 2018 Hyundai announced that NEXO will be the name of its new, dedicated Fuel Cell EV | For sale in California, Canada, South Korea, Germany and selected European markets |
|  | Toyota Mirai | Toyota launched its first production fuel cell vehicle (FCV), the Mirai, in Japan at the end of 2014 | For sale in US, Japan, Germany, UK, Denmark, Belgium, Norway |

Notes: * Non-exhaustive
Source: Fuel Cell Works; Fast Company; AFDC; Honda; Fuel Cells and Hydrogen Joint Undertaking website; Hyundai; Toyota

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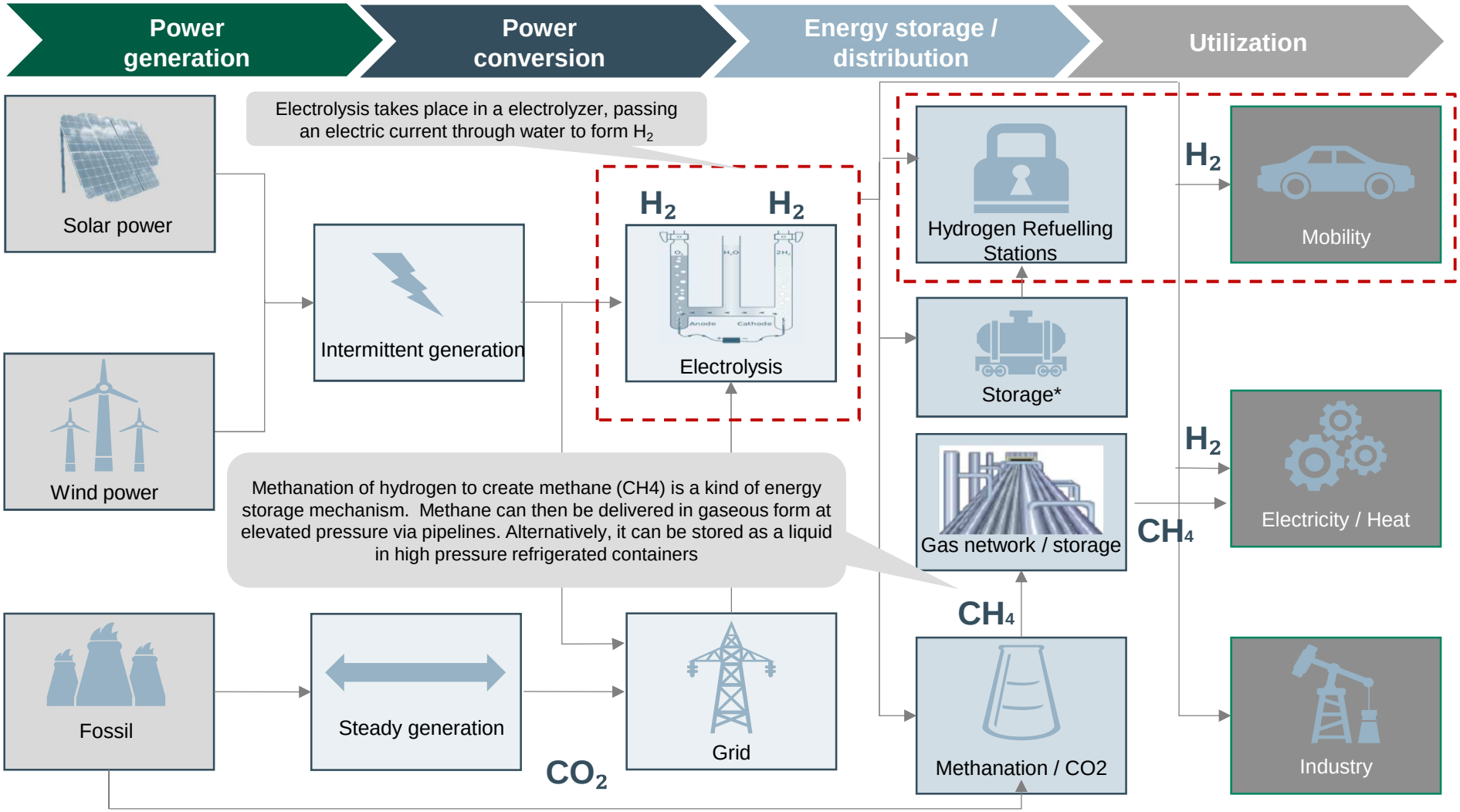
# The hydrogen energy value chain involves many applications beyond transport, including 'power to gas' storage to drive various applications




Notes: * Physical based storage mechanisms (compressed gas, cold/cryo compressed, liquid $H_2$)
Source: European Power to Gas; L.E.K. research



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# A range of Government support mechanisms have been deployed internationally to support hydrogen fuel cell vehicles

*INDICATIVE*

| Support / Incentive Mechanism | Japan | California | Germany | South Korea | China |
|---|---|---|---|---|---|
| Hydrogen fuel subsidies | ✓ | | | | |
| Funding for HRS | ✓ | ✓ | ✓ | ✓ | ✓ |
| R&D grants | ✓ | ✓ | ✓ | | |
| Hydrogen network plan | ✓ | ✓ | ✓ | ✓ | ✓ |
| Hydrogen production support | | | | ✓ | |
| Hydrogen development centres | | | | | ✓ |
| Heavy duty hydrogen vehicles | ✓ | ✓ | ✓ | ✓ | ✓ |
| Consortiums / partnerships | ✓ | ✓ | ✓ | ✓ | |

✓ = Significant level of support

**The most common support mechanisms among the jurisdictional leaders relate to the deployment of hydrogen refuelling infrastructure and research and development grants. The formation of consortiums / partnerships are also important**



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# Germany, California, Japan and South Korea, have broad policy objectives for developing their early leadership positions in the HFCV market

| | Japan | California | Germany | South Korea |
|---|---|---|---|---|
| **Policy Influences and Drivers** | **Industrial demand<br>Major automotive industry<br>Diversifying energy mix** | **Clean energy and air policy** | **Industrial demand<br>Major automotive industry** | **Industrial demand<br>Major automotive industry<br>Emissions reduction** |
| **Hydrogen Stations** | An alliance of 11 Japanese car makers* and energy firms has pledged to build 80 new hydrogen stations in the next four years | Via Assembly Bill 8, California has a target to fund construction of at least 100 hydrogen fuel cell stations "as quickly as possible" and reach 200 HRS by 2025** | 100 stations by 2020 to support basic coverage for Germany, 400 stations by 2025 to support market roll out and 1000 stations by 2030 for commercial rollout | Goal of 310 hydrogen refuelling stations by 2022 |
| **HFCV** | The Japanese Ministry of Economy, Trade and Industry (METI) released a hydrogen strategy that calls for about 40,000 hydrogen-powered vehicles on Japan's roads by 2020 | By mid-century, 87% of cars on the road will need to be full ZEVs. This will place California on a path to reducing greenhouse gas emissions by 80% by 2050 | No specific HFCV targets announced.<br><br>However, 1m electric cars on the roads by 2020 is targeted | The Korean government has also announced ambitious plans to reduce overall $CO_2$ output by 37% by 2030 compared to business as usual |
| **Other aims and initiatives** | Japan is also aiming for 1.4m households using fuel cell units to power their homes by 2020, rising to 5.3m households, or about one in ten, by 2030 | 5 million zero-emission vehicles (ZEVs) on California roads by 2030 | The Federal Ministry of Transport and Digital Infrastructure is supporting the construction of a hydrogen facility in Wendlingen. | The Government agency has announced that it will be investing $11 million over three years to commercially produce hydrogen. |

Notes: * Toyota, Nissan and Honda; ** Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) directs the California Energy Commission to allocate $20 million annually
Source: L.E.K research and analysis



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# Hydrogen fuel costs: some governments provide R&D support or fuel subsidies, while some automotive manufacturers contribute free $H_2$ refuelling

| Cost type | Cost / subsidy example | Implications for Victoria |
|---|---|---|
| **Existing Hydrogen Refuelling Cost** | • It costs US$13 -$16 per kilogram for hydrogen fuel, which equates to approximately $80 to fill up the Honda Clarity<br>• For the Honda Clarity, at a price of US$14, this translates to an operating cost of $0.21 per mile or $0.13 per kilometre versus about $0.07 per kilometre for a petrol driven VW Golf* | *While hydrogen fuel costs are expected to decrease by 2020, the fuel is currently priced above petrol*<br><br>*Subsidies have been introduced by both the Japanese government and OEMs to decrease the price of hydrogen and increase HFCV uptake*<br><br>*It is too early to understand the impact of either government or OEM subsidies on HFCV uptake* |
| **Future Hydrogen Refuelling costs** | • The **National Renewable Energy Laboratory (NREL)** forecasts that hydrogen fuel prices may fall to US $8-10 per kilogram between 2020 and 2025<br>• A kilogram of hydrogen has approximately the same energy content as 3.8L of petrol and a HFCV travels about twice as far as a conventional vehicle given the same amount of fuel energy<br>• Thus, a HFCV using US$8 per kg hydrogen fuel would eventually cost about $0.12 per mile or $0.075 per kilometre, which is in line with conventional ICE vehicle costs | |
| **Government subsidies** | In Dec 2017, **the Australian** Renewable Energy Agency (ARENA) announced a $20 million funding round for early stage research and development into hydrogen. The funding round is the first time ARENA has sought applications from the research sector and organisations involved in the hydrogen energy creation and supply chain<br><br>The **Japanese** Central Government provides generous subsidies to the hydrogen sector. The fuel price is subsidized to come in below US$10 per kilogram, so filling up a typical hydrogen vehicle would cost about US$50 | |
| **OEM subsidies** | Honda, Toyota and Hyundai all provide 3 years of hydrogen fuel with their initial sales and lease offerings in select jurisdictions, which shield early market adopters from the initially high fuel price<br><br>Toyota offers fuel incentives for the 2017 Toyota Mirai in the US. Complimentary fuel is provided for 3 years or up to a maximum of $15,000, which ever comes first. The Mirai must be fuelled at hydrogen stations conforming to the latest Society of Automotive Engineers (SAE) hydrogen fuelling interface protocol standards or laws that may supersede such SAE standards | |

Notes: * Assuming fuel economy of 7L/100km, and petrol cost of US$1/L
Source: US Energy Department; ARENA; L.E.K. research



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# In the short to medium term, a variety of challenges exist for HFCV adoption including cost competitiveness and lack of established infrastructure

| Challenges to fuel cell adoption | Description | Implications for Victoria |
|---|---|---|
| **Cost competitiveness** | • The powertrain of HFCVs is currently more expensive than ICEs by a significant margin. In terms of fuel cost per km, HFCVs are currently more expensive than ICEV (approximately double)<br>• There are hydrogen passenger vehicles for sale in some markets, but uptake appears to be <7,000 vehicles in total worldwide** | *Cost competitiveness is an important barrier for hydrogen vehicle uptake globally* |
| **Hydrogen production and distribution capacity** | • Other than economics, the biggest barrier to widespread adoption of HFCV is the infrastructure required, which would be similar in scope to existing fuel distribution for ICEs (requiring zero emission hydrogen equivalents for electrolysis stations, compression stations, pipelines, regional terminal stations, specialised trucks and fuel station storage etc.)<br>• The infrastructure requirements will also differ based on the hydrogen production method utilised. Therefore concentrated applications (e.g. ports, airports, large logistical centres etc.) are more likely to be cost effective | *Lack of refueling infrastructure is a key barrier to HFCV uptake.*<br>*Concentrated applications (e.g. ports, airports, large logistical centres etc.) are more likely to be cost effective to address* |
| **Environmental impact** | • Hydrogen can be obtained by several means but the vast majority produced today is not carbon neutral. Hydrolysis using renewable energy sources is a CO2 neutral process and is not yet economic at scale ($18.70/kg H2*) but is predicted to fall to $9.10/kg by 2030*.<br>• Additional means of producing CO2 neutral hydrogen include natural gas reforming with carbon capture and storage (CCS) and coal gasification with CCS | *Currently water electrolysis is the only mature technology that would deliver zero emissions hydrogen for HFCVs* |
| **Efficiency** | • The drivetrain of HFCVs is heavier than ICEs in small applications (passenger cars). However in heavy applications, the fuel-cell system can deliver longer ranges with less weight given the small weight penalty of a large hydrogen tank | *HFCV technology is still in its infancy* |

Notes: * Australian Renewable Energy Agency forecast; ** According to Information Trends, 6,475 HFCVs had been sold globally from 2013 through to the end of 2017
Source: Hydrogen Energy Supply Chain; L.E.K. research and analysis



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# Summary: Uptake of hydrogen vehicles

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Why governments internationally are demonstrating leadership for hydrogen fuel cell vehicles*** | Leading jurisdictions (**Germany, California, Japan and South Korea**) have established early leading positions in the **HFCV market**<br>Jurisdictions such as **Norway** are positioning themselves for leadership in **hydrogen production** to supply leading hydrogen markets | *The industrial context is an important factor influencing the attractiveness of hydrogen infrastructure for HFCVs*<br>*Emissions reduction goals are also a factor in markets like California and South Korea*<br>*There are a number of ancillary benefits to being positioned in the HFCV market including the stabilisation of power grids*<br>*There are emerging opportunities to be involved in the supply chain of the hydrogen economy* |
| ***How governments can support development of hydrogen infrastructure and uptake of HFCVs*** | Support mechanisms are wide ranging and are both **financial** and **non financial** in nature<br>**Support for refuelling stations** are a common mechanism used to accelerate HFCV uptake internationally<br>**Consortiums and partnerships** bringing together industry with Government bodies are common | *If the Victorian Government wished to accelerate the adoption of HFCVs it could contribute to the development of an initial number of hydrogen refuelling stations*<br>*To achieve this it would likely seek partnerships with hydrogen utility companies or automotives to help accelerate roll-out of HFCV technology* |
| ***Key challenges for hydrogen fuel cell vehicle adoption*** | The biggest barriers to widespread adoption of hydrogen are the current **cost competitiveness** of HFCV operations, and the **lack of hydrogen infrastructure** | *Concentrated applications (e.g. ports, airports, large logistical centres etc.) are more likely to be cost effective* |



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$H_2$ 2

# Natural reforming of gas and coal gasification account for c.95% of global hydrogen production. This process can be considered a potential ZEV hydrogen source when integrated with CCS

| $H_2$ production technologies | % of global $H_2$ production | Description | Advantages | Drawbacks | Maturity |
|---|---|---|---|---|---|
| **Natural gas - Steam methane reforming (SMR)** | c.95% | • Methane from natural gas is heated with steam and a catalyst (Nickel) to produce a mixture of carbon monoxide and hydrogen<br>• Carbon dioxide and other impurities are removed from the gas stream, leaving pure hydrogen<br>• Most widely used hydrogen generation process<br>• Carbon neutral when combined with CCS | • High energy efficiency: 80%<br>• Low electricity consumption: 800kWh/h<br>• Cost effectiveness in obtaining a high level of purity: €2-6 /kg of hydrogen | • High emissions of greenhouse gases: 10kg of CO2 for 1kg of hydrogen |  |
| **Natural gas - Partial oxidation (POX)** | | • Hydrogen is produced through the partial combustion of methane with oxygen gas to yield carbon monoxide and hydrogen<br>• Synthesis gas purification and separation<br>• No catalyst needed | • High energy efficiency: 80%<br>• Used to exploit heavy oil residues | • High emissions of greenhouse gases<br>• Lower cost effectiveness: €4-12/kg of hydrogen<br>• Very high electricity consumption (19,000kWh/h) |  |
| **Coal gasification** | | • Hydrogen is produced by reacting coal with oxygen and steam under high pressures and temperatures to form synthesis gas (a mixture consisting primarily of carbon monoxide and hydrogen)<br>• Hydrogen is removed by a separation system<br>• Can be carbon neutral when combined with CCS technology | • Mature process<br>• Large-scale, integrated gasification combined cycles (IGCC) are considered an attractive option for centralised cogeneration of electricity and $H_2$, with comparably low CCS costs | • Additional research is needed to develop CCS technologies that minimise carbon dioxide release at target costs<br>• More expensive than SMR as the cryogenic process currently used to separate the required oxygen from air is expensive |  |

**Implications for Victoria: Zero emission hydrogen production infrastructure is a key barrier to increasing HFCV uptake in line with Victoria's policy objectives**

Source: IEA, ENEA, NREL, Report from *Assemblée Nationale*



L.E.K.

$H_2$ 2

# A range of other zero emission hydrogen pathways exist including electrolysis, which accounts for c.4% of global hydrogen production

| $H_2$ production technologies | % of global $H_2$ production | Description | Advantages | Drawbacks | Maturity |
|---|---|---|---|---|---|
| **Water electrolysis** | c.4% | • Uses direct current electricity to split water into its basic elements of $H_2$ and oxygen<br>• Positively charged ions move to a negative electrode, receive electrons and are reduced. Negatively charged ions move to a positive electrode<br>• Electrolysis can use both liquid and solid types of electrolytes<br>• Carbon neutral if electricity is produced from renewable sources | • No emissions of greenhouse gas, assuming use of renewable electricity<br>• Purity of $H_2$: c.99% (vs. c.95% for SMR and POX)<br>• Used to store low volumes of $H_2$ | • Lower cost effectiveness than SMR: €5-10/kg of hydrogen<br>• Lower energy efficiency (c.60%) than SMR<br>• Significant energy needed (39kWh electricity and 8.9L water) to produce 1kg $H_2$<br>• High carbon footprint if electricity is not generated by renewables |  |
| **Biological processes** | <1% | • Derive $H_2$ from organic matter using microalgal photo-synthesis and cyanobacteria.<br>• Carbon neutral source of $H_2$ | • Less energy intensive than thermochemical and electrochemical processes | • Difficult to produce $H_2$ at scale |  |
| **Photo-electrolysis** | <1% | • Production of $H_2$, using sunlight to illuminate a water immersed semiconductor<br>• Carbon neutral source of $H_2$ | • Lower capital costs than combined photovoltaic-electrolysis systems | • Lack of technological maturity |  |
| **Biomass (pyrolysis, gasification, anaerobic digestion etc.)** | <1% | • Uses a controlled process involving heat, steam, and oxygen to convert biomass to $H_2$ and other products, without combustion<br>• Carbon neutral if combined with CCS | • Biomass gasification is a relatively mature technology pathway | • Since basic feedstock availability is limited, production from biomass will not benefit from large economies of scale |  |

**Implications for Victoria: Currently water electrolysis is the only mature technology that would deliver zero emissions hydrogen for HFCVs**

Source: IEA, ENEA, NREL, Report from *Assemblée Nationale*



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$H_2$ 2

# Hydrogen storage for the transportation industry is primarily undertaken via pressurisation. Metal hydride technology shows promise, but is in its infancy

| Storage | Technology | Description | Advantages | Drawbacks | Maturity |
|---|---|---|---|---|---|
| **Gas storage** | **Pressurisation** | • Hydrogen gas steeled in tanks<br>• Between 200 and 700 bar | • Proven industrial process | • Low volumetric density and high pressure required for filling (2 kWh/l at 700 bar)<br>• 10-15% energy loss during compression |  |
| **Liquid storage** | **Liquefaction** | • Hydrogen cooled down to cryogenic temperatures (253°C) and stored in tanks | • Moderate cost: 200-270€/kg of $H_2$ | • More expensive than gaseous storage<br>• Loss of c.33% of the energy contained in the liquid<br>• Specific applications (e.g. space) |  |
| | **Cryo-compression** | • Liquid hydrogen stored in a low-temperature tank and at high pressure | | | |
| **Solid storage** | **Metal hydride** | • Storage of hydrogen at low pressure and in the form of metal hydrides | • High volumetric density: c.150 kg $H_2/m^3$<br>• Low pressure storage<br>• Ambient temperature | • Higher costs |  |
| | **Nano-structured materials** | • Carbon-based materials | | | |
| | **Other** | • Absorption - storage on solid composites<br>• Complex hydride - combination of alkaline metals, hydrogen and other elements<br>• Clathrate - $H_2O$ cage structure containing guest molecules (e.g. $CH_4$)<br>• Formic acid - decomposition into $H_2O$ and $O_2$ | | |  |
| **Other** | **Hydrocarbons** | • Fuels (e.g. methanol) reformed into $H_2O$ tanks to fuel-cells | | |  |
| | **Ammonia** | • $H_2O$ extracted and vice versa from ammonia via a membrane (CSIRO) | ▪ Allows hydrogen to be transported as ammonia | | |

**Implications for Victoria: Victoria will need development of hydrogen storage infrastructure in order to enable HFCVs**

Source: IEA, European Association for Storage of Energy

Emerging technology | Leading technology | Early stage development



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# Hydrogen storage and delivery: how hydrogen is delivered and stored, has a variety of impacts on station and user cost

| Storage and delivery | Description | Considerations | Implications for Victoria |
|---|---|---|---|
| **Distributed v centralised production** | The location of production has ramifications for cost and delivery. Distributed production facilities (on-site) reduce delivery costs but have higher production costs compared to centrally located hydrogen production facilities (which have higher volumes) | • Currently and in the near term, distributed production via water electrolysis and small-scale natural gas reformers is suitable. Water electrolysis is a proven technology that can be used in the early phases of building a hydrogen infrastructure for the transport sector<br>• In the medium-long term, centralised production will become viable with increased volume and demand for hydrogen | *Victoria will need development of hydrogen generation and storage infrastructure in order to enable HFCVs* |
| **Hydrogen transport and storage** | Internationally, hydrogen is transported from the point of production to the point of use via pipeline, over the road in cryogenic liquid tanker trucks, by gaseous tube trailers, or by rail<br>Pipelines carrying natural gas are also capable of delivering hydrogen gas, and these two gases can even be transported together and separated at the point of use | • Although existing efforts have been concentrated on molecular hydrogen, emerging technologies in Australia and internationally are focused on the transport of liquid or solid form hydrogen<br>• CSIRO have developed technology to transport hydrogen as ammonia (NH3) to bowsers, where it can be converted back to high-purity hydrogen via a membrane | *Victoria should anticipate the need for some government support for the private sector to develop hydrogen generation and storage infrastructure* |

Source: CSIRO; NAP; L.E.K. research

2

# There are established standards for hydrogen pressure and purity for use in fuel cells in hydrogen vehicles

- **Hydrogen Pressure:** Most hydrogen fuel cell vehicles store hydrogen as a compressed gas. Liquefaction could be a possibility to increase range for heavy duty vehicles such as lorries, ferries and aircraft, but high losses and safety concerns due to boil-off make it incompatible for low-utilisation vehicles
  - In the past, 350 bar storage has been used for passenger vehicles. This standard is now used for buses given their substantial roof storage space
  - Globally, 700 bar storage is the most common option for passenger vehicles, which provides a greater range, at somewhat higher cost
- **Hydrogen Purity:** Manufacturers have adopted the international ISO 14687–2 purity standard to limit damage to fuel cells from impurities, by providing hydrogen purity of 99.97%
  - manufacturers are seeking high levels of purity in order to allow for reduced stack catalyst loadings which will allow for HFCV powertrain cost reductions
  - higher purity will lead to increased fuel production costs, but the reduced purchase costs of HFCVs removes a more significant barrier to the uptake of HFCVs

| Standards topic | Considerations | Implications for Victoria |
|---|---|---|
| **OEM adoption** | • The latest hydrogen fuel cell vehicle – the Hyundai Nexo – will use a 700 bar hydrogen storage tank. The vehicle replaces the hydrogen powered ix35 that was launched in 2013<br>• The Toyota Mirai high pressure hydrogen tank has a nominal working pressure of 700 bar and has a hydrogen storage mass of approximately 5.0 kg | *Australia may wish to adopt the ISO 14687-2 purity standard to ensure that hydrogen available is suitable for use in HFCVs produced by OEMs in line with this standard* |
| **Government influence** | • Guidelines for appropriate hydrogen purity have been laid out in International Standard ISO 14687-2. Minimum hydrogen purity is set at 99.97% for fuel cells in road vehicles<br>• The United Nations are in the process of releasing a Global Technical Regulation that will unify the regulation requirements for the entire hydrogen storage system based on the guidance from SAE J2579<br>• A recent EU funding call targeted 99.999% purity (5N or 10 ppm) for fuel cells used in stationary and transport applications. It is unclear if the standard will be adopted | |

Source: H2FC; L.E.K. research

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2

# Summary: Hydrogen production, storage and usage by vehicles

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Hydrogen production methods and associated emissions*** | The main methods for generating hydrogen are **carbon intensive**. **Water electrolysis** accounts for a small proportion of global hydrogen production, but **can be zero emission**<br>Hydrogen production via **coal gasification** or **natural gas reforming** could also be a carbon neutral process if combined with **CCS technology**<br>**Research** into **alternative production methods** is ongoing and includes **thermolysis and bio-production** | *Zero emission hydrogen production infrastructure is a key barrier to increasing HFCV uptake in line with Victoria's policy objectives*<br>*Both cost and emissions resulting from electricity generation must be considered to evaluate whether electrolysis is a viable enabler for HFCV uptake*<br>*The Victorian Government could consider investment into ongoing research efforts to reduce costs of generating hydrogen with zero emissions* |
| ***Hydrogen transport, storage and delivery infrastructure for HFCVs*** | Governments tend not to be directly involved in the hydrogen value chain for HFCVs<br>There are different hydrogen transportation methods available, including **transport in natural gas pipelines** and **separation at the destination**<br>There is a **range of mature hydrogen storage methods** available | *Victoria need to develop hydrogen generation and storage infrastructure in order to enable hydrogen storage for HFCVs*<br>*Victoria should anticipate the need for some government support for the private sector to develop hydrogen generation and storage infrastructure*<br>*If gaseous hydrogen transportation by pipeline is conducted, separation at the point of use will be required*<br>*Alternatively, the emergence of liquid or solid hydrogen transport will dictate infrastructure requirements if technological maturity is reached* |
| ***Maturity of standards for convenient, safe and environmentally friendly use of HFCVs and hydrogen infrastructure*** | There are **established international standards** for hydrogen **pressure** and **purity** to use in fuel cells for hydrogen vehicles<br>**Higher purity requirements** are being considered that may lead to increased fuel production costs, but the reduced purchase costs of HFCVs removes a more significant barrier to the uptake of HFCVs | *Australia may wish to adopt the ISO 14687-2 purity standard to ensure that hydrogen available is suitable for use in HFCVs produced by OEMs in line with this standard* |

3

# There are existing hydrogen infrastructure standards that Victoria can leverage to enable a safe, efficient and user friendly hydrogen supply chain

A range of standards apply for the design, construction and use of hydrogen refuelling stations

- **The International Standards Organization (ISO):** The ISO Technical Committee (TC) 197 is a technical committee developing international standards in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen
  - The centre piece of the TC197 standardization work program is the “Fuelling Family” of standards organized under ISO19880 to address the most critical installation and component requirements for HRS. TC197 has 14 active Working Groups developing 15 international standards for hydrogen refuelling stations (HRS), electrolysers, ground and on-board storage, fuel quality and quality control.
- **Other standards**: remaining questions of standardization relate to the creation of a uniform and user-friendly customer experience, such as the ability to accept universal payment.
  - Such standards can encourage quicker fuel cell vehicle adoption by minimizing alterations to consumer behaviour, and can reduce costs using uniform testing, design, and approval procedures

| Jurisdiction | Standards | Implications for Victoria |
|---|---|---|
| **EU** | The European Union has requirements for hydrogen infrastructure, including that vehicle connectors comply with **International Organization for Standardization (ISO) 17268**, that hydrogen fuelling stations comply with ISO/TS 20100, and that hydrogen fuel quality complies with ISO 14782-2. | *Victoria can leverage International ISO standards for overarching standards relating to the production, storage, transport, measurement and use of hydrogen* |
| **Japan** | Japan is streamlining its HRS regulations and focusing on regulations on operations, materials, location, clearance/distance and transport. This work is being led by the government organisation NEDO, the **New Energy and Industrial Technology Development Organization**. Cost reduction has also been achieved for hydrogen refuelling stations by deregulation, mass production and simplification of system components | |
| **USA** | In Oct 2017, NEDO and the U.S. Department of Energy's Fuel Cell Technologies Office (FCTO) within the Office of Energy Efficiency and Renewable Energy announced a collaboration on hydrogen and fuel cell data sharing of safety research and development. It is intended that this partnership accelerates progress towards mutual goals, including energy security, resilience, and economic growth. | |

Source: ISO; ICCT; ARC; L.E.K. research

3

# HRS infrastructure has most often been catalysed initially by public grants, followed by public-private partnerships

| Jurisdiction | Standards | Implications for Victoria |
|---|---|---|
| **Public funding sources** | Assembly Bill 8, enacted in 2013 in **California**, included a provision to fund at least 100 hydrogen stations with a commitment of up to AUD $27m per year. The Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) provides financial support for these hydrogen stations.<br><br>The UK's Office of Low Emission Vehicles has announced a new AUD $40m fund that will match successful proposals for hydrogen infrastructure build-out. A total of AUD $740m is projected to be able to cover the complete network<br><br>The **Japanese** government financially supports the hydrogen infrastructure build-out with support for stations, on the price of hydrogen, and at vehicle purchase. Japan funds stations up to two-thirds of initial capital expense. It also subsidizes hydrogen fuel in order to reduce the price to $10 per kilogram, because early station fuel revenues are unlikely to offset costs for at least several years. Japan has both federal and local subsidies for the purchase of new fuel cell vehicles | *Most initial investments in hydrogen stations globally have been through public grants. However, cost sharing between government and industry is more common for in-development stations, and many governments are attempting to steer investments more toward commercially viable business cases over the longer term* |
| **Private station ownership** | In 2018, **the UK** H2Mobility consortium is well into the building and expansion phases. UK H2Mobility estimate AUD $110m will be needed before 2020, and the resulting network will largely be able to cover its own operating and maintenance costs shortly thereafter | |
| **New business models** | **Germany** offers to cover half the initial outlay for hydrogen stations through two phases of its National Innovation Programme (NIP). The first NIP funding totalled AUD $1,080m through 2016, which was partially used to build the first 20 stations. The second NIP commits at least AUD $385m through 2026, matched by equal funding from private industry. The NIP work is managed by the Clean Energy Partnership, a public-private partnership which has set up the H2Mobility consortium of companies to plan the network and construct stations | |

Source: ICCT; NIP; H2Mobility; L.E.K. research



L.E.K.

3

# Refuelling infrastructure is being developed in "clusters" and "corridors" in leading hydrogen markets

| Infrastructure style | Description | Country Examples | Implications for Victoria |
|---|---|---|---|
| **Clustering / Lighthouse Communities** | Stations are clustered together within a limited geographic area. This strategy enables and supports a majority of early adopters | The **Los Angeles** metro area has been targeted as a lighthouse community due to its potential for early adopters. This was jointly planned by the auto industry and government experts within the California Fuel Cell Partnership. Hydrogen stations have been planned for communities throughout the San Francisco Bay Area and Los Angeles area<br><br>As per its 2013 roadmap, the **UK H2Mobility** consortium has a strategy, similar to California's, where major population centres contain the highest density of stations, with supporting stations sporadically located along major longer-distance travel routes. According to the roadmap, a total of 65 planned stations would create sufficient coverage to start the early market. As of April 2018, 14 HRS are currently in operation in the UK. | *The Victorian Government could consider supporting the deployment of HRS in clusters or corridors in key regions with potential early adopters* |
| **Corridors / Hydrogen Highway** | Placing stations to strategically create a corridor system which allows for broader coverage.<br><br>Corridor stations may have fewer regular customers but larger re-fuel volumes and consequently different specifications with regards to capacity, number of pumps etc. Corridors are broadly considered as a precondition for most prospective owners | In **Germany**, about 60 of the first 100 stations are in six major metro areas, and the remaining 40 are connectors and destination stations<br><br>**Japan**'s Strategic Roadmap for Hydrogen and Fuel Cells called for 100 HRS in 2016 concentrated in 4 hubs (Tokyo, Nagoya, Fukuoka, Osaka); the four initial clusters in Japan were connected via a major corridor highway. 320 HRS are forecast by 2025. 11 Japanese firms have signed a Memorandum of Understanding to expand the fuel cell market by building the HRS in Japan | *If hydrogen take up accelerates, the Victorian Government may need measures to ensure access to hydrogen infrastructure in less densely populated areas* |

Source: ICCT; H2Mobility; L.E.K. research

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# Summary: Approaches to developing storage and refuelling infrastructure

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Standards relating to the deployment of hydrogen infrastructure*** | There are existing standards for the design, construction and use of hydrogen refuelling stations<br>**Japan** is **streamlining its HRS regulations** and focusing on regulations on operations, materials, location, clearance/distance and transport | *Victoria can leverage International ISO standards for overarching standards relating to the production, storage, transport, measurement and use of hydrogen*<br>*Victoria may wish to engage with OEMs about the aspects of ISO standards that require legislative backing to support efficiency, safety and coordination in the hydrogen fuel chain* |
| ***Government support required to assist deployment of hydrogen infrastructure*** | Across key markets, initial development of HRS infrastructure generally appears to be supported by **public grants**<br>**Cost sharing** between **government** and **industry** is becoming more common<br>Governments are attempting to steer investments toward **commercially viable business cases** over the **longer term** | *As illustrated by California, Japan, Germany and the UK, the Victorian Government could consider public funding to start the initial growth phase of HRS infrastructure*<br>*The Victorian government could consider public-private partnerships for later stage development of hydrogen infrastructure* |
| ***Strategies to deploy hydrogen refuelling infrastructure*** | **Refuelling infrastructure** is being developed in "**clusters**" and "**corridors**" in the leading Hydrogen markets<br>**Clusters** are connected by placing stations to strategically create a **corridor system** or **'hydrogen highway'** | *The Victorian Government could consider supporting the deployment of HRS in clusters or corridors in key regions with potential early adopters*<br>*If hydrogen take up accelerates, the Victorian Government may need measures to ensure access to hydrogen infrastructure in less densely populated areas* |

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emissions Vehicles
- **Findings about Autonomous Vehicles**
  - **Overview of AVs**
  - Key findings
- Findings about other New Mobility market models
- Implications for Victoria
- Appendix

# The International Scan has identified key government interventions and market activity in support of Connected Autonomous Vehicles across focus markets

*NOT EXHAUSTIVE*

| Interventions and market activity | Australia | China | The Netherlands | Singapore | US | Japan | Germany | Secondary and other markets (incl. UK) |
|---|---|---|---|---|---|---|---|---|
| Physical infrastructure upgrades | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Road usage and AV access | ✓ | | | ✓ | ✓ | | | ✓ |
| ICT infrastructure and standards | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| Mapping and positioning | ✓ | ✓ | | | | ✓ | | |
| Public and user safety | ✓ | | ✓ | | ✓ | | ✓ | ✓ |
| Data protection | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Policy support | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

✓ = Government interventions identified and evidenced through the international scan

**Implications for Victoria: While the International Scan will have identified most key government interventions across these dimensions in these markets, there are likely to be additional interventions omitted due to scope constraints**

# Eight jurisdictions that are leading the path towards AVs have been the focus of research in this international scan

**Overview**

| Geography | Description |
|---|---|
| **Australia** | The NTC and Austroads are creating infrastructure and policy guidelines to support both AV implementation and public safety. Regulation and standards to support AV R&D, testing and implementation are being developed at the state level. AV trials are permitted on public roads in VIC, NSW and SA, and WA by exemption |
| **The US** | The US has the greatest number of AV company headquarters (163) and strong automotive industry links. As of April 2018, 21 U.S. states plus the District of Columbia have enacted legislation related to autonomous vehicles. The US has a highly innovative but largely disparate environment with little uniformity regarding the adoption of national standards for AVs |
| **Singapore** | Singapore is hosting a range of AV pilots. The country requires that all test AVs undergo a vehicle safety assessment before they are approved for on-road trials. Singapore's 2017 amendment to its Road Traffic Act allowing self-driving vehicles to be tested on public roads has accelerated the country's readiness for AVs. The focus of AV deployment is for public transport |
| **Japan** | The 2017 *Public-Private ITS Initiative/Roadmaps* states the government's aim to have the world's safest road transport system by 2020 and to build and maintain "a society with the world's safest and smoothest road transport" by 2030. Japan has the highest number of AV-related patents of any country |
| **Germany** | The German government legislated self driving car trials on public roads in 2017. AUD $150m from the Government has been established for digital test beds, including the Digital Motorway Test Bed (A9 Motorway). Germany has a significant automotive OEM industry |
| **The UK** | The UK aims to become a leader in AV technology to promote industry, safety, and innovation. The government has matched industry funding in projects, such as UK Autodrive, and reduced regulatory barriers to bringing trials to public roads. It is also a member of the C-Roads platform on C-ITS |
| **China** | There are significant investments being made in AV technology in China, however this push is predominantly from the OEMs and technology companies. While many cities allow trials on public roads, China is more strict on regulations such as privacy and cybersecurity. 5G testing is underway in China, but it has not yet committed to a particular communication technology |
| **The Netherlands** | The Netherlands has significant investments in research and infrastructure, including AUD $140m on a connected traffic light scheme. The government released an AV (Trials) Bill in 2015 with 'ambition to lead' in AV technology. The Netherlands sought to unite innovation efforts through leading the Amsterdam Declaration in 2017 signed by all EU member states |

Source: GM; L.E.K. research

# For the purposes of the international scan, AVs have been defined as vehicles capable of operating at SAE levels 4 and 5

Overview

- Level 5 allows all functions of driving to be automated, without geofences or limitations on the conditions in which the vehicle can operate
- Level 4 autonomy allows all functions of the driving to be automated in most, but not all, use cases. Exceptions where the driver must manually drive include unusual terrain or weather conditions. Level 4 allows for empty vehicles with no safety driver
- It is worth noting that Austroads have found that Level 3 vehicles onwards rely heavily on interactions with infrastructure, such as road markings, and thus level 3 could also be considered AVs

| SAE level of autonomy | | Control: Steering/ Acceleration/ Deceleration | Control: Monitoring of driving environment | Control: Fallback performance of dynamic driving task | Control: Ability to drive in all terrains |
|---|---|---|---|---|---|
| 5 | **All use cases autonomy** *"Robo-taxi"* |  |  |  |  |
| 4 | **Limited use case autonomy** *"Brains off"* |  |  |  |  |
| 3 | **Conditional automation** *"Hands off"* |  |  |  |  |
| 1-2 | **Functional automation** |  |  |  |  |

Legend

Defined as AVs for this study

Source: Company Websites; Press; L.E.K. research

# Autonomous vehicles are vehicles embedded with complex software that interprets the vehicle's surroundings and controls the driving task

**Overview**

***Connected and autonomous vehicles remove the task of driving from a human operator, allowing the vehicle to make decisions and control the driving functions. Key elements are:***

**Connectivity**
Autonomous vehicles may communicate with other vehicles (V2V) and their surroundings (V2I) using radio frequencies


**Sensors**
The vehicle is equipped with sensors that allow it to 'see' its surroundings. These can include cameras, GPS, Radar, and LIDAR

**Decision making software**
Embedded within the car is software that interprets sensor and communication data and determines the actions that must be performed for both travel objectives and safety

**Actuators**
The software controls the physical mechanisms of the car, in the same way that a human driver would. It has the ability to control acceleration, steering, brakes, lights etc.

**Data**
Sensor data, pick up/drop off and payment information can be collected from the trip. Trip details can be used to assist in mobility planning, and sensor data, such as LIDAR can be used to update maps. Interaction with unusual hazards can be fed back into the AI to assist in the learning process of the automated driving system

Source: L.E.K. research

# Sensors are used to interpret information from different positions and different distances

Overview

***The most common sensors are radar, LIDAR, cameras and ultrasound. Each operates under different conditions, and captures a different type of information, using proprietary standards***

## Long Range Radar

- Over-the-horizon radar (80m-200m)
- The defacto sensor used in Adaptive Cruise Control (ACC)
- Less expensive than LIDAR

## LIDAR

- Detection system which works on the principle of radar, but uses laser light
- Many OEMs are acquiring dedicated LIDAR companies
- The most expensive sensor, but costs are coming down

## Camera

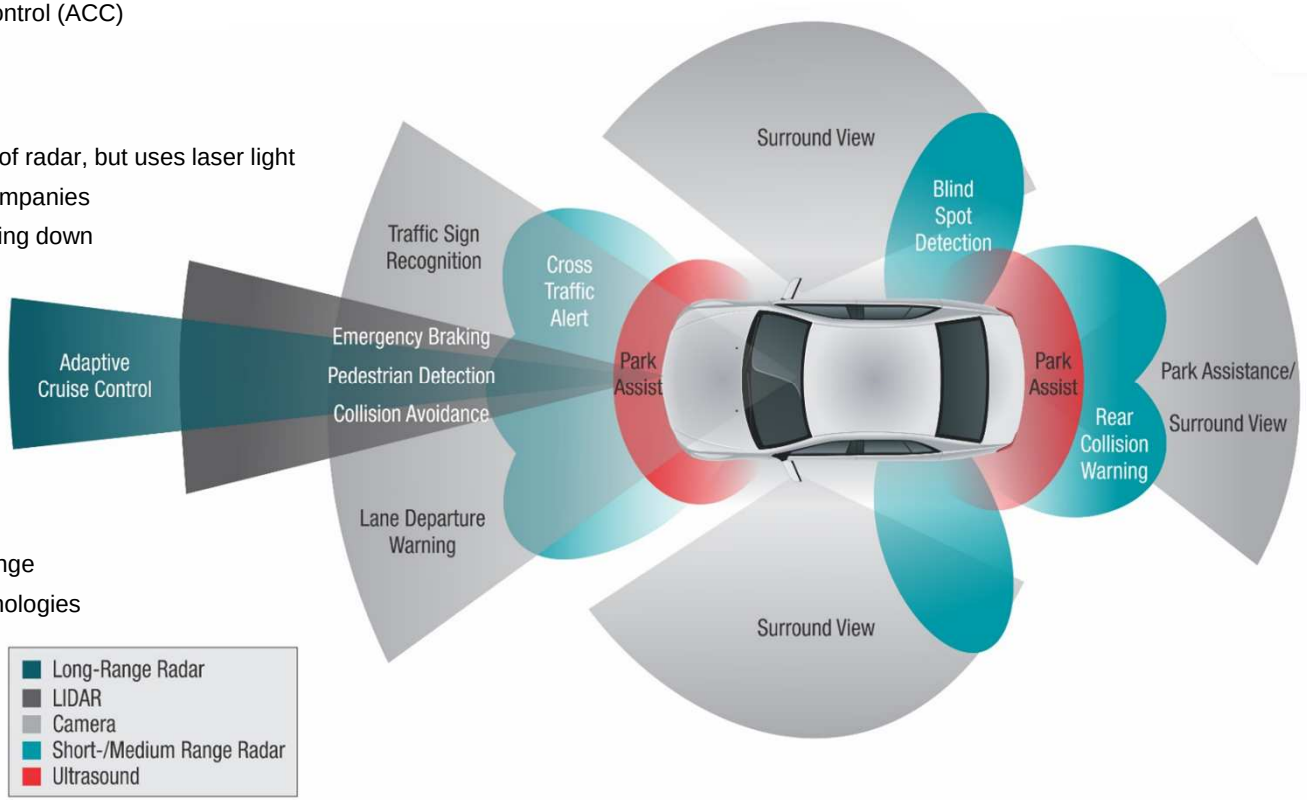
- Capture texture, colour and contrast info
- Pixel resolution continues to climb
- Low-price point

## Short/Medium Range Radar

- Short Range Radar (SRR) 0.2 to 30m range
- Medium Range Radar (MRR) in the 30-80m range
- Computationally lighter than other sensor technologies

## Ultrasound

- Important role for automated parking
- Currently can only be used at very low speeds



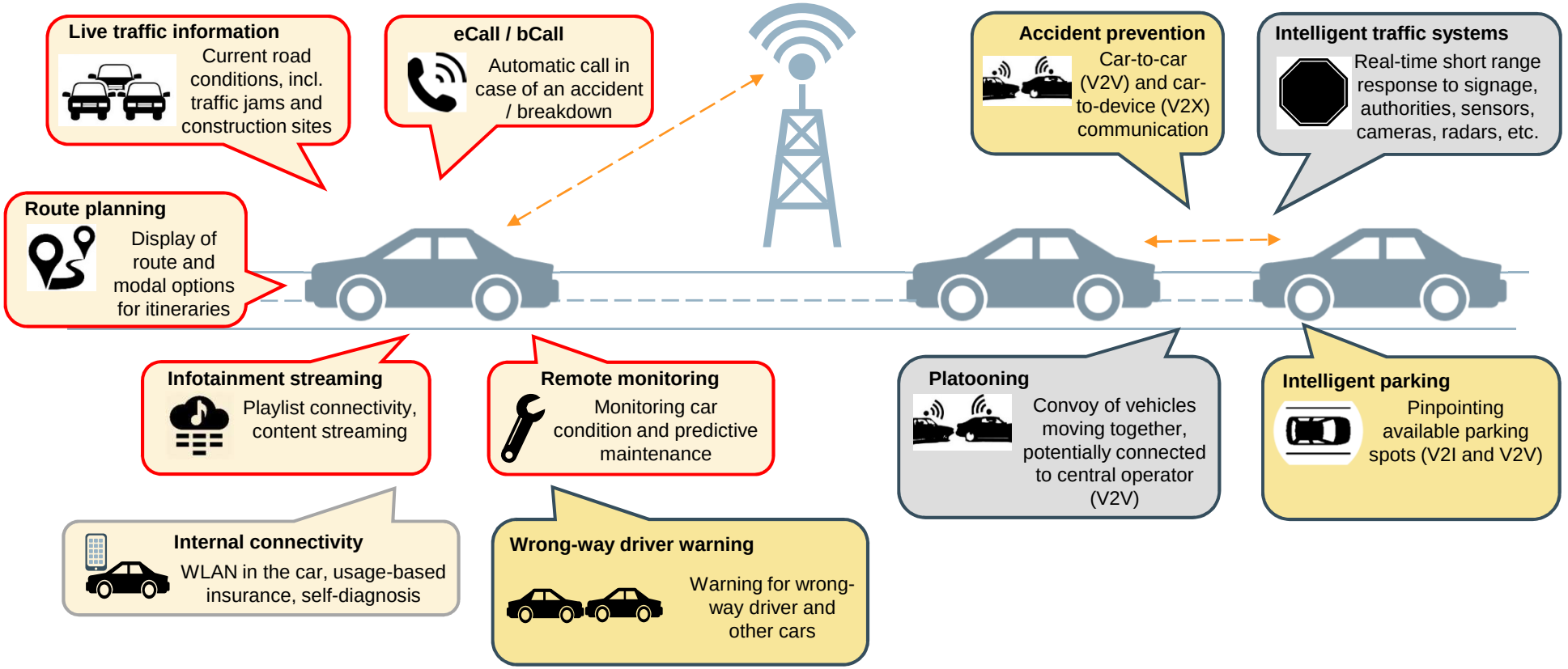

Source: TheDrive; Texas Instruments

# A range of communication features exist for CAVs that are underpinned by cellular and DSRC connectivity

Overview

## Connectivity features of a connected vehicle

## Connectivity features of an autonomous vehicle




**Key**

- 4G / 5G dependent
- DSRC*
- Currently on the road
- Early stage
- Not currently available

Notes: * The potential use of 5G for some of these applications is being considered
Source: L.E.K. interviews, research and analysis

# AVs will use various forms of communication technology to communicate with other vehicles, infrastructure, pedestrians and other devices

Overview

### V2I – Vehicle to Infrastructure
V2I is a communication method between vehicles and street components such as intersections or signs. The ad hoc connection allows bidirectional information exchange for uses such as green light speed optimisation

### V2V – Vehicle to Vehicle
V2V is communication between road users. V2V is typically faster than V2I as the only interaction is with vehicles in your immediate vicinity. This allows systems such as automatic brake lights

### V2P – Vehicle to Pedestrian
Pedestrians include people walking, cyclists, and those on mobility scooters. Vehicle systems alert drivers to pedestrians. Other methods, such as handheld devices allow pedestrians to receive warnings from vehicles

### V2D – Vehicle to Device
Devices, such as smartphones, can communicate with cars. These systems allow functionality such as keyless cars trialled by Volvo, which can be opened and started using an app

### V2X – Vehicle to Everything
V2X describes all vehicle connections, including vehicles which can communicate to using all of the above channels. Netherlands is seen as a leader in V2X due to its smart traffic light system, used to manage traffic flow and prioritise emergency vehicles

Source: US DOT; BBC; ITS International; L.E.K. interviews

# Most AV trials currently use hybrid or ICE vehicles. However, it is expected that AVs will increasingly use zero emission technology

**Overview**

## It is expected AVs will primarily be EVs:

1 **Technical Ease**
The analytical and computing task of controlling an EV is less complex than an ICE due to the fewer number of moving parts on board

*"… A lot of brands are reasonably comfortable with the notion that there won't be a fully autonomous vehicle that's not also an electric vehicle…"*
*Coby Duggan, GM, Volvo NZ, Drive Electric Article*

2 **Timing**
The shift towards autonomous vehicles is occurring simultaneously with the rise of electric vehicles and also connected vehicles, which increases the likelihood these trends will merge

*"… We're in the middle of three big paradigm shifts. One is electric; the second is autonomous drive; and the third is the connected car. All three shifts are being developed in parallel…"*
*Dean Sheed, GM, Audi NZ, Drive Electric Article*

3 **R&D Expenditure**
A large amount of AV R&D expenditure from OEMs relate to 'electric drives'. For example, General Motors is committed to 'Zero emissions. Zero crashes. Zero congestion.'

*"… There's no need for an autonomously driven car to be electric, but there's a deep connection…"*
*Dean Sheed, GM, Audi NZ Drive Electric Article*

**The infrastructure implications concerning zero emission vehicles are covered in the ZEV section of the report**

Source: Drive Electric; L.E.K. research and interviews

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# Key issues explored for Connected and Autonomous Vehicles, with a focus on issues with the most significant impact on physical infrastructure

Focus of this work on topics most aligned with infrastructure

| Topics | Issues explored in focus markets |
|---|---|
| 1 Physical infrastructure upgrades and investments required for AVs | • Wholesale upgrades to road infrastructure<br>• Road infrastructure modification<br>• Parallel investment in smart infrastructure (C-ITS)<br>• Designated AV certification<br>• Parking related infrastructure and curb-side space |
| 2 Road usage and access for AVs | • Road space allocation, pricing infrastructure, and special access features<br>• Implications of planned disruptions for AV requirements<br>• Modifications to curb-side infrastructure to accommodate changed usage patterns<br>• Requirement for increased road maintenance |
| 3 ICT infrastructure and standards required for AVs | • Which communication technology (4G, 5G, LTE, DSRC, WiFi) will underpin AV rollout<br>• The choice of overall communication standards |
| 4 Mapping and positioning | • Satellite-based augmentation systems (SBAS) to assist with absolute AV positioning<br>• Approaches to 3D mapping for AV technology and positioning<br>• The extent of Government involvement in 3D mapping |
| 5 Public and user safety considerations for AVs | • Control of a vehicle under high SAE levels<br>• Non- driving tasks in fully automated vehicles<br>• Insurance frameworks<br>• Ethical decisions |
| 6 Data protection and sharing for AVs | • Data sharing and privacy protection<br>• CAV specific cybersecurity standards<br>• Software security and updates |
| 7 Policy support for AVs | • Primary objectives for Government leadership in AVs internationally<br>• Mechanisms used to support the deployment of AV technology<br>• Restrictions are placed on permits for AV trials |

Research and findings about topics from Mapping and positioning onwards are found in the Appendix

**Research and findings about topics from mapping and positioning onwards are set out in the Appendix**



L.E.K.

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# Significant investment in overhauling road infrastructure by Government is considered unlikely to be required for the deployment of AV technology

## Perspectives on Large Scale Infrastructure Investments

### OEMs

- OEMs lack leverage to make requests to Government for wholesale network changes and are working with existing infrastructure in test markets

*"… OEMs are designing AV technology for the existing road infrastructure…"*
*Principal Technology Leader, Australian Roads Research Board*

### Road Agencies

- Road agencies have supported pilot activity and test beds, but have predominantly adopted a wait and see approach for large scale infrastructure investment as the risk of stranded assets is high
- However, Highways England has recently invested AUD $35-45m for connected 4G corridors along primary port routes

*"… Highways England are working with a communications partner and a network communications specialist to rollout connected 4G corridors…"*
*Infrastructure Advisory & Digital Consultant, ARUP, UK*

### Industry experts

- Primarily see potential large scale infrastructure investments in the discussion phase. Uncertainty on the specifics of AV technology remains a key barrier

*"… Three reasons have constrained large scale investment; a) no-one yet knows where to invest b) Governments are typically lacking money to invest and c) OEMs are typically working to be adaptable as a first pass…"*
*Intelligent Mobility Leader Americas Region, ARUP, CA*

**Implications for Victoria: It appears reasonable to assume that Victorian Government will not need to make substantial investments in wholesale upgrades to road infrastructure**

Source: L.E.K. research and interviews

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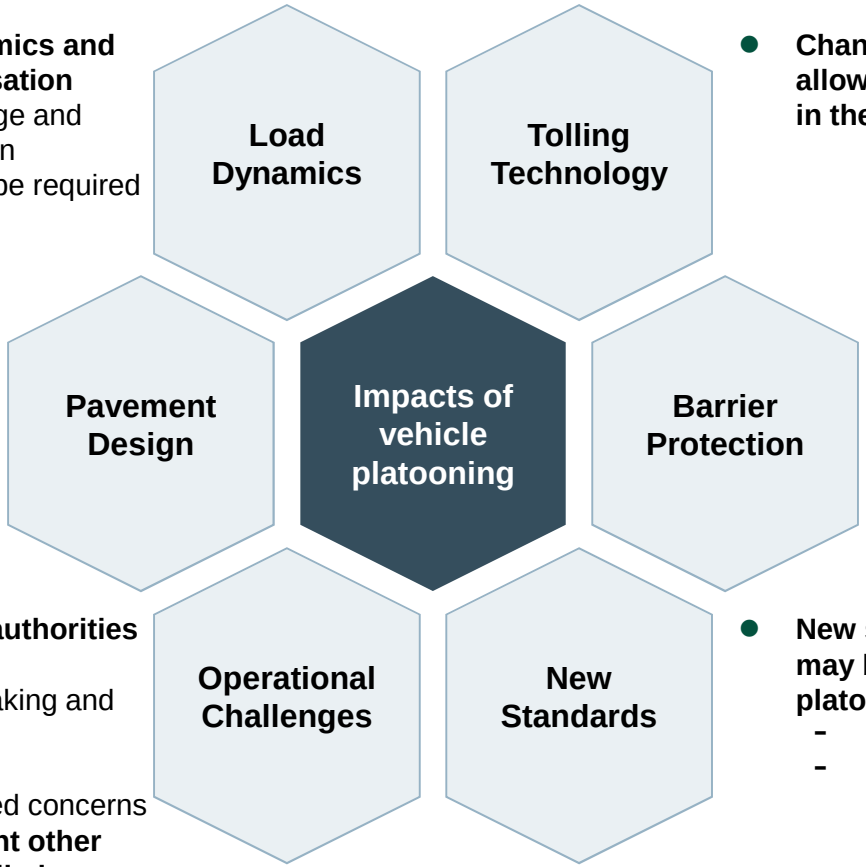
# Platooning of AVs may pose specific challenges and have implications for road design and standards

- **Changed load dynamics and increased road utilisation**
  - changes to bridge and pavement design standards may be required

*Operating rules and algorithms that take account of design limits may be the preferred approach*

- **Changes to pavement design to account for new load volumes**




- **Changes to toll technology to allow identification of each unit in the platoon**

- **Increased protection for barriers at critical physical infrastructure**
  - I.e. protecting bridge piers in situations where a high speed road exists under a rail bridge

- **Operational problems for road authorities and other drivers**
  - I.e. situations such as overtaking and entering and exiting on freeways/motorways
  - Transport for NSW has raised concerns that **platooning may prevent other vehicles from accessing slip lanes and merging**

- **New standards or additions to old ones may be required for roads that support platooning**
  - line marking and signage
  - need to reconsider minimum distances between on/off ramps and weaving in design
  - cellular coverage

**Implications for Victoria: There appears to be potential for technology to mitigate the need to change road designs to account for platooning (e.g. via automatic adjustment of spacing between vehicles)**

Source: Austroads; Transport for NSW; L.E.K. research and interviews



L.E.K.

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# Specific investments and upgrades in road infrastructure may support optimising transport networks for the widespread usage of AVs

| Topic | Description | Country Examples | Implications for Victoria |
|---|---|---|---|
| **Road signage & lane marking** | • Static signs including fonts, characters spacing, design, use of advisory signs, words/condition inconsistencies<br>• Electronic signs including refresh rates and LED sign readability<br>• Line marking variability and visibility | • ERAP* and ECAP** released papers that call for the "establishment of a maintenance policy to ensure that road markings on **Europe's** roads remain visible to the driver and the intelligent vehicle at all times, irrespective of weather conditions"<br>• The **European** Road Federation define a good line marking is one whose "minimum performance level under dry conditions is 150 mcd/lux/m² and which has a minimum width of 150 mm for all roads"<br>• In mid-2018 the **Californian** Department of Transport will replace 4 inch line markings with 6 inch (150mm) to allow driverless cars to 'read the road' easier | *Standardisation of road elements across Australia would assist compatibility and uptake of AVs*<br>*Investment into specific road infrastructure elements may help to accelerate the uptake of AVs*<br>*ITS investments may be a potential substitute for road signage investments in the long term* |
| **Smart infrastructure / Connected and Intelligent Transport Systems (C-ITS)** | • C-ITS includes systems to increase traffic safety and to decrease congestion and emissions by using information technology | • **The Netherlands** is seen as a leader in this field, due to their smart traffic light programme<br>• Emerging infrastructure upgrades are centred around intersections and the ability for traffic signals and movements of other cars to be factored into decision making | *It is not clear that smart infrastructure is essential for AV deployment. It could be a valuable tool for achieving broader network outcomes (e.g. traffic congestion management)*<br>*Any investment into smart infrastructure should be made in the context of a broader network management 'smart city' strategy, with a view to avoiding stranded assets due to rapid technology evolution in this space* |
| **Road certification** | • Road certification works by evaluating and defining roads that are suitable for specific vehicles and uses | • **California and Arizona** have taken the approach of permitting trials across entire cities or states<br>• **China** has opened roads in some districts of Guangzhou to driverless cars<br>• **Baidu** received a permit to test its vehicles on 33 roads spanning c.105km in the less-populated suburbs of Beijing<br>• **Singapore** approved roads within one business park as appropriate for AV use before expanding the autonomous vehicle zone to public roads on residential estates | *It is unclear whether Victoria will need to implement an AV road certification regime beyond trials. It will likely depend on the requirements and limitations of AV technology and speed of market deployment*<br>*It is likely to be more applicable in more remote locations where road conditions are more variable* |

Notes: * European Road Assessment Program ** European Car Assessment Program
Source: ERAP; ERF; California Department of Transport; Better Benutten; Asia Correspondent; SFMTA Municipal Transport Agency; Transport Authority of Singapore; L.E.K. research and analysis



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# AVs will need less space to park and will reduce the overall demand for parking at destinations. AVs will increase the need for drop-off zones

| Topic | Approaches and examples | Implications for Victoria |
|---|---|---|
| **Curbside management** | • The International Scan did not identify any changes to curbside infrastructure occurring in anticipation of AVs<br>• However, the rapid increase in demand for rideshare has prompted discussion regarding how best to deal with the subsequent increasing demand on curbsides<br>• The National Association of City Transportation Officials in **the US** suggests in a recent study that it plans to redesign curbsides to include pickup and drop-off areas for driverless vehicles and ride-hailing services like Uber and Lyft<br>• CityLab in **the US** are also researching and testing difference scenarios of curbside management<br>• No conclusive findings on how best to redesign the curbside and no actions have yet been made | *An increase in pick up and drop off zones could be considered by Victoria around transport nodes to key destinations* |
| **Changing design of car parks** | • **Australian** industry body ADVI expect that with AV uptake, CBD parking garages will become redundant, and will be repurposed as housing, retail or green spaces<br>• As the demand for bays in multi-storey carparks decline, there are discussion globally regarding how best to repurpose the buildings. In **the US** in 2014, old parking bays were refitted into micro apartments by the Savannah College of Art and Design, and a large multi-storey carpark has been repurposed into an artistic hub by Carl Turner Architects in **the UK** in 2017<br>• An LA apartment development in **the US** will have parking with higher ceilings, light wells, and level floors that is designed to be converted to other purposes (gyms, retail shops, more pick-up and set-down space) when ride sharing and AVs reduce car ownership and reduce demand for parking<br>• Technology is also changing the way the way carparks are used. **Hamburg Airport** is trialling autonomous parking. Vehicle owners can book a space at the airport using an app, and leave their vehicles outside car park on arrival. Vehicle sensors will then direct the car to a space without a driver inside. The tests are being carried out using Volkswagen, Audi and Porsche vehicles. A similar trial is also being conducted in **Stuttgart**, where by Daimler, Mercedes-Benz and Bosch collaborated to trial driverless parking in the multi-storey Museum carpark | *Government may wish to mandate that parking structures are built to similar standards as inhabited buildings for simpler repurposing of these structure in the future (e.g. conversion to residential or commercial space)* |
| **Avoiding building parking structures** | • While a number of organisations (airports, in particular) are needing to consider reduced investment in car parking infrastructure in anticipation of AV uptake towards the end of investment horizons, no decisions to refrain from investment have been announced at this time<br>• **Boston** design firm Arrowstreet are investigating the impact AVs will have on car park designs. They believe that when AVs are parked efficiently, they may require 60% less space than current vehicle parking<br>• In an urban planning response to the introduction of AVs and the change in vehicle parking behaviour, **Buffalo, Miami and Seattle** are replacing minimum parking requirements for new developments by instead capping the amount of parking that developers may provide | |

Source: Arrowstreet; Idaho Statesman; MRCagney; NACTO; CityLab; Mercedez-Benz; Schiphol Airport; L.E.K. and ARUP research, analysis and experience

1

# Summary: AV overview and physical infrastructure upgrades and investments required for AVs (1/2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***The likelihood that AVs will require wholesale upgrades to road infrastructure*** | • The prevailing view is that AV technology is designed for existing road infrastructure without reliance on wholesale changes or upgrades<br>• Therefore, significant investment into road infrastructure by Government is considered to be unlikely<br>• Platooning may pose specific challenges although it is currently unclear whether these challenges will be able to be addressed through technology solutions or whether road infrastructure will need to be upgraded<br>• Some jurisdictions are making targeted investments to accelerate deployment and uptake of AVs (e.g. line markings and signage) | • *It appears reasonable to assume that Victorian Government will not need to make substantial investments in wholesale upgrades to road infrastructure*<br>• *However, there may be some advantage in targeted investment to smooth early implementation and rollout*<br>• *Road elements may require improvements to optimise AV access, such as preventing slip lane access from being blocked by platooning vehicles* |
| ***The extent to which specific elements of road infrastructure may need to be modified for AVs*** | • Global trials are indicating that line markings, signage, and on/off ramps can prove challenging with early stage AV technology<br>• Minimum standards for road elements, i.e. road markings are outlined in European standards | • *Standardisation of road elements across Australia would assist compatibility and uptake of AVs*<br>• *Investment into specific road infrastructure elements may help to accelerate the uptake of AVs*<br>• *ITS investments may be a potential substitute for road signage investments in the long term* |
| ***The extent to which parallel investment in smart infrastructure (C-ITS) would complement AV deployment*** | • To date, automotive and technology companies have chosen to develop AVs that are mostly independent of roadside infrastructure and systems<br>• However Singapore, the Netherlands and some US states are investing in the research, trialing or rollout of 'smart infrastructure'<br>• Standards are not yet well developed for "smart infrastructure", creating risks of asset stranding | • *It is not clear that smart infrastructure is essential for AV deployment*<br>• *Smart infrastructure could however be a valuable tool for achieving broader network outcomes (e.g. traffic and congestion management)*<br>• *Any investment into smart infrastructure should be made in the context of a broader network management 'smart city' strategy, with a view to avoiding stranded assets due to rapid technology evolution in this space* |



L.E.K.

1

# Summary: AV overview and physical infrastructure upgrades and investments required for AVs (2/2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Whether certain roads will need to be designated AV certified*** | • Some jurisdictions have certified a specific set of roads for AV trials - for example, Singapore, US and China are all trialling road certifications | • *It is unclear whether Victoria will need to implement an AV road certification regime beyond trials. It will likely depend on the requirements and limitations of AV technology and speed of market deployment* |
| ***Influence of AVs on parking related infrastructure*** | • Given their current maturity, AVs are not yet significantly impacting parking related infrastructure<br>• However, Autonomous Vehicles are expected to reduce the need for parking at the destination. A fleet AV ownership model would likely result in further reduction in demand for parking<br>• Airports and other large building developments internationally are starting to build flexibility into parking infrastructure to enable easy conversion to access infrastructure or alternative uses like shops to future proof long term infrastructure investments | • *An increase in pick up and drop off zones should be considered around transport nodes to key destinations*<br>• *Parking structures could be built to the same standards as inhabited buildings for simpler repurposing of the structure in the future (e.g. conversion to residential or commercial space)* |

Source: Channel News Asia, L.E.K. research and interviews



L.E.K.

2

# Road space allocation for AVs, such as the exclusive use of HOV lanes, is being considered by some jurisdictions

| Geography | Description | Approaches and examples | Implications for Victoria |
|---|---|---|---|
| **Wisconsin, US** | • Wisconsin highway planners are studying the possibility of placing driverless vehicle lanes on I-94 to serve Foxconn's mega factory in Racine County | • It is proposed that the lane would start with driverless vehicles first sharing the HOV lane with regular cars, and gradually creating an exclusive driverless lane as more cars become autonomous | *Although the weight of evidence is that dedicated lanes will not be a technical requirement for introducing AVs, there may be specific trials or use cases for the use of dedicated lanes that the Victorian Government could consider* |
| **Seattle, US** | • VC firm Madrona Ventures floated the idea for replacing the I-5 freeway between Seattle and Vancouver with an "autonomous vehicle" corridor<br>• Madrona Ventures propose that a joint task force of key transportation decision makers and planners, as well as representatives of businesses involved in autonomous vehicle innovation, be created to develop a detailed plan for deployment of autonomous vehicles on I-5 | • In the early days of the transition, any autonomous vehicle, no matter its powertrain or number of occupants, would be allowed to use existing HOV lanes on the I-5<br>• It is suggested that the first step of allowing autonomous vehicles in the HOV lanes could begin immediately with SAE Level 3 and higher vehicles<br>• By 2025, that HOV lane would be closed to human drivers<br>• By 2030, the majority of the highway would be closed to human drivers, with the takeover complete by 2040 | |
| **Spain** | • INDRA is leading a European project to test autonomous driving on roads in Lisbon, Madrid and Paris, with a focus on bus-HOV lanes | • The pilots will be the first ones in Europe to include tests closed and open to traffic on different types of roads including the Bus-HOV lane that connects the M-30 beltway in Madrid | |

Source: JSOnline; EnGadget; Madrona Ventures; Indra; ITS International



L.E.K.

2

# Policies around designated drop off zones and restricted areas will need to be expanded to consider AVs, supported by technologies such as geofencing

| Drop-off topic | Description | Implications for Victoria |
|---|---|---|
| **Geofencing and designated zones** | Geofencing is used to enforce restrictions on automatic driver and navigation systems. Similarly geofencing can be used to detect drop off zones within a vehicle's radius to aid rideshare services<br><br>Designated drop-off zones have been created in **Washington D.C. and San Francisco** by repurposing car parking spaces. The zones aim to prevent cars from double parking while passengers alight, and are reserved for specific ride sharing services who have made an agreement with the local authority.<br><br>The zones were created after a study by the SF Police Department found that Uber and Lyft vehicles accounted for two-thirds of congestion-related tickets | *Victoria may need to work with OEMs and fleet owners to develop and ensure compliance with designated zones, such as special drop-off zones, and restricted areas* |
| **Restrictions with vehicle drop offs** | Conversely, restrictions on vehicle drop-offs, such as bans on ridesharing at **Boston and Detroit** airports are in place. Without a human driver, the rules will have to be converted to geofenced boundaries to allow the automated driver systems to comply | |
| **Zoning rules** | Similar zoning rules exist for ridesharing companies such as Uber. In order to limit the number of vehicles present at drop-off zones, such as at **Melbourne Airport**, drivers waiting to pick up passengers are placed into a virtual queue and must wait outside the airport complex until they are given permission to enter | |

Source: Land Transport Authority; Time; San Francisco Business Times, Uber; L.E.K. research



L.E.K.

2

# Planned road disruptions, particularly road maintenance and road works and special events, will require proactive management by local authorities

| Topic | Description | Examples | Implications for Victoria |
|---|---|---|---|
| **Road works and special events** | • Roadworks are a key aspect noted to be of particular concern to AV manufacturers and system suppliers<br>• Provision of real time information and information about planned works will help AV fleets re-route vehicles around roads affected by road works | • **Nissan** recently proposed a system called "Seamless Autonomous Mobility," which would allow connected cars to send a signal alerting a human when it approached a construction site<br>• 3M and the **Michigan Department of Transportation (MDOT)** is using 3M connected vehicle technologies along more than 5 km of an I-75 construction zone to begin exploring how vehicles react to a work zone environment | *It will likely be necessary to ensure that roadworks become well planned events and real time information is provided to AVs*<br>*This information may need to include physical changes to the road layout, which may be more complex for an AV to negotiate* |
| **Maintaining road serviceability** | • Undertaking maintenance as required to restore normal road conditions will be important with the increased utilisation of road assets | • Road operators are increasingly focusing on moving towards a more proactive mode of managing roadside infrastructure and away from reactive maintenance<br>• If AVs result in greater total vehicle kilometres travelled then the road maintenance requirements will increase accordingly | *Victoria may need to budget for higher levels of recurrent road maintenance spending* |

Source: The Hill; Washington Post; L.E.K. research and interviews

2

# Summary: Road usage and access for AVs

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Road space allocation and access for AVs*** | • Some geographies are proposing the use of HOV lanes for AV trials<br>• These may transition to fully dedicated AV lanes over time | • *The weight of evidence is that dedicated lanes will not be required to roll out AVs*<br>• *Consideration could also be given to the use of road space allocation to achieve desired network outcomes (e.g. encourage AV pooling, prevent platooning impacting other road users)*<br>• *Policies around designated drop off zones and restricted areas may need to be expanded to consider AVs* |
| ***Implications of planned disruptions for AV requirements*** | • A range of options are being considered to manage roadworks and other planned road disruptions such as special events:<br>- Do nothing and assume technology can manage<br>- Government regularly update maps with details of roadworks<br>- Vehicles are diverted around impacted streets<br>- Prescriptive approach to the layout of road works to help AVs navigate | • *Emerging consensus is that Governments may need to provide regular updates about planned disruptions to the network* |
| ***Modifications to curb-side infrastructure to accommodate changed usage patterns*** | • **San Francisco** is establishing specific pick up and drop off zones for Lyft and Uber<br>• **Washington, D.C., San Francisco, and Fort Lauderdale** are among the cities piloting alternate uses (at various times) of curbside space | • *Significant consensus that substantial change is likely at key nodes and destinations*<br>• *However, given significant uncertainty about future usage patterns, Victoria should carefully monitor developments to determine a course of action* |
| ***Potential for increased road maintenance costs*** | • There is some consensus that road standards may need to be higher to accommodate AVs, at least in the short term, and that increased traffic volumes may lead to greater maintenance | • *While this point remains uncertain, Victoria may need to budget for higher levels of recurrent road maintenance spending* |



L.E.K.

3

# Three forms of digital infrastructure are relevant to the operation of AVs and government planning

**Key forms of digital infrastructure**

## Communication technologies

- Use of wireless communications technologies
  - cellular
  - DSRC
  - RLAN/Wi-Fi
  - radio broadcast
  - satellite

**This digital infrastructure will be necessary to facilitate the reception and exchange of a range of data required by AVs**

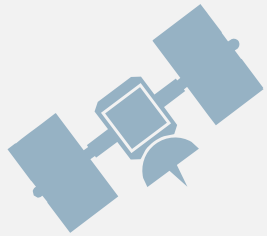
## Data management and access

- Data required by an AV to effectively and safely operate
  - includes data about the physical road environment (e.g. mapping data attributes)
  - also includes road traffic condition data, and other data required to support operation of the vehicle's systems, such as software updates, security certificates and diagnostics

**Government may have a role in data management and access through the provision and management of relevant data, directly or via 3rd party service providers**

## Positioning services

- Wireless services (satellite-based) that enable a vehicle's driving system to know its absolute position



**Used to match against a map representation of the road network, and/or to fuse with relative positioning data, received from its on-board sensors**

Source: L.E.K. research and interviews

3

# There are two main forms of communications technology – both DSRC and cellular will likely be used in Australia during the roll-out of AV technology

| Digital infrastructure technology | Description | Australian Context | Global Use and Standards | Implications & Considerations | Applications for AVs |
|---|---|---|---|---|---|
| **DSRC** | A short range wireless technology that provides designated licensed bandwidth, fast network acquisition and interoperability (V2V and V2I) | In Australia the ACMA is currently progressing a formal allocation process and device licensing for the 5.9 GHz band for use by ITS vehicle safety and mobility applications | Dedicated wireless transmission method (based on IEEE802.11p standard) | Works independently of cellular networks, Wi-Fi networks and satellite availability | *Safety applications and communication between vehicle based devices and infrastructure to reduce collisions* |
| **Third Generation Cellular Network (3G Cellular)** | Wireless network communications technology | Several 3G networks operate in Australia | 3G networks exist in is most jurisdictions worldwide with the exception of parts of Africa | Being a public cellular network which is not dedicated for sole use by AVs, it may be prone to issues of reliability | *Potential applications in non-safety critical applications and telematics (i.e. satellite navigation, GPS and mobile data)*<br><br>*Vehicle-to-Network (real-time traffic/routing, cloud services), V2I (traffic signal timing/priority) and V2P (safety alerts to pedestrians, bicyclists)*<br><br>*Higher speed and lower latency cellular (i.e. 5G) may eventually be used for V2V safety* |
| **Fourth Generation Long Term Evolution (4G-LTE)** | Easily deployable network technology, offering high speeds and low latencies over long distances | LTE supports deployment on different frequency bandwidths. 4G MHz bands currently used in Australia are: 700, 850, 900, 1800, 2100 and 2300 | 4G networks exist in North America, South America, Europe, most of Asia Pac and parts of Africa | Coverage is affected by obstructions (i.e. buildings, vehicles, trees and hills) which reduce the signal level available | |
| **Fifth Generation Cellular Network (5G)** | Based on the 4G LTE network but with enhanced peak download and upload speeds and lowest latency | Not currently deployed and the expected roll-out is from 2020 | 5G trials and field testing are taking place in the USA, France, Spain, UK, China, Russia, Japan, Sweden and Finland | Cost of infrastructure could be high initially and technology is still evolving | |

**Implications for Victoria: It is currently uncertain how these technologies will be used in providing connectivity for AV. It is likely that a combination of technologies will be used to some extent**

Source: Austroads; GSA; L.E.K. research and interviews

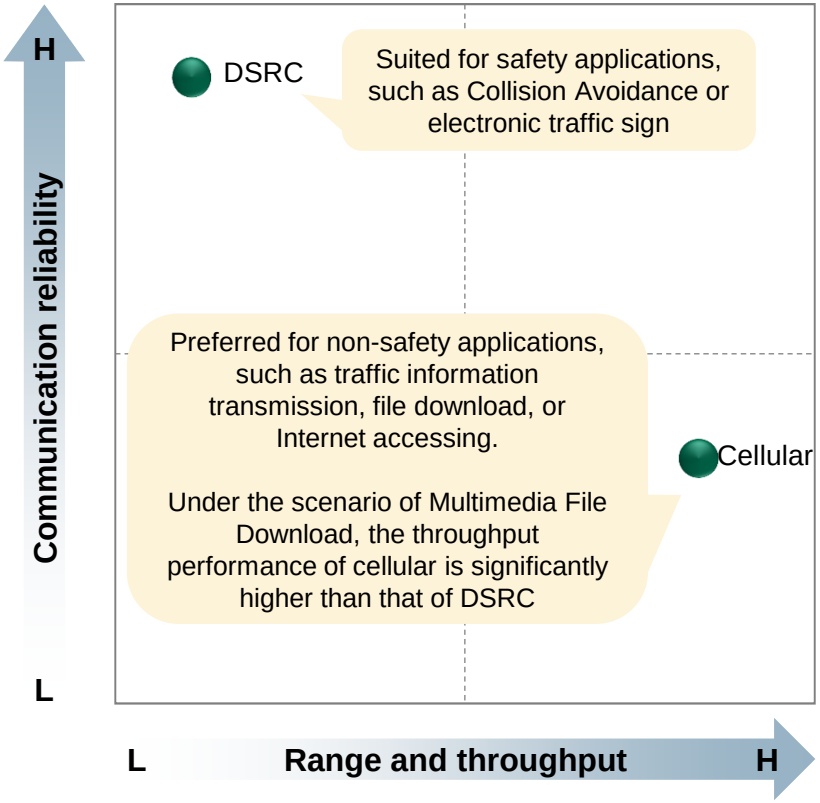


L.E.K.

3

# DSRC and cellular (3G/4G/5G) are best suited for different types of applications and it is likely that they will be complementary

## Conceptual representation of technology strengths




## International Positions

- **DSRC**
  - On December 13, 2016, the **US DOT** issued a proposed rule that would advance the deployment of Connected Vehicle technologies throughout the US light vehicle fleet. The rule will mandate equipping DSRC devices on all new light-duty vehicles produced in the USA
- **Cellular (3G/4G/5G)**
  - In **China**, there still exists a debate on whether DSRC should be utilized as the communication standard, since the LTE networks are widely deployed all over the country and have already been on the roadmap for many vehicle manufacturers and for telematics applications
- Some combination of DSRC and cellular will likely form the basis for how AVs will communicate. This will not only enable safe driving but also supply high-quality telematics services to the drivers

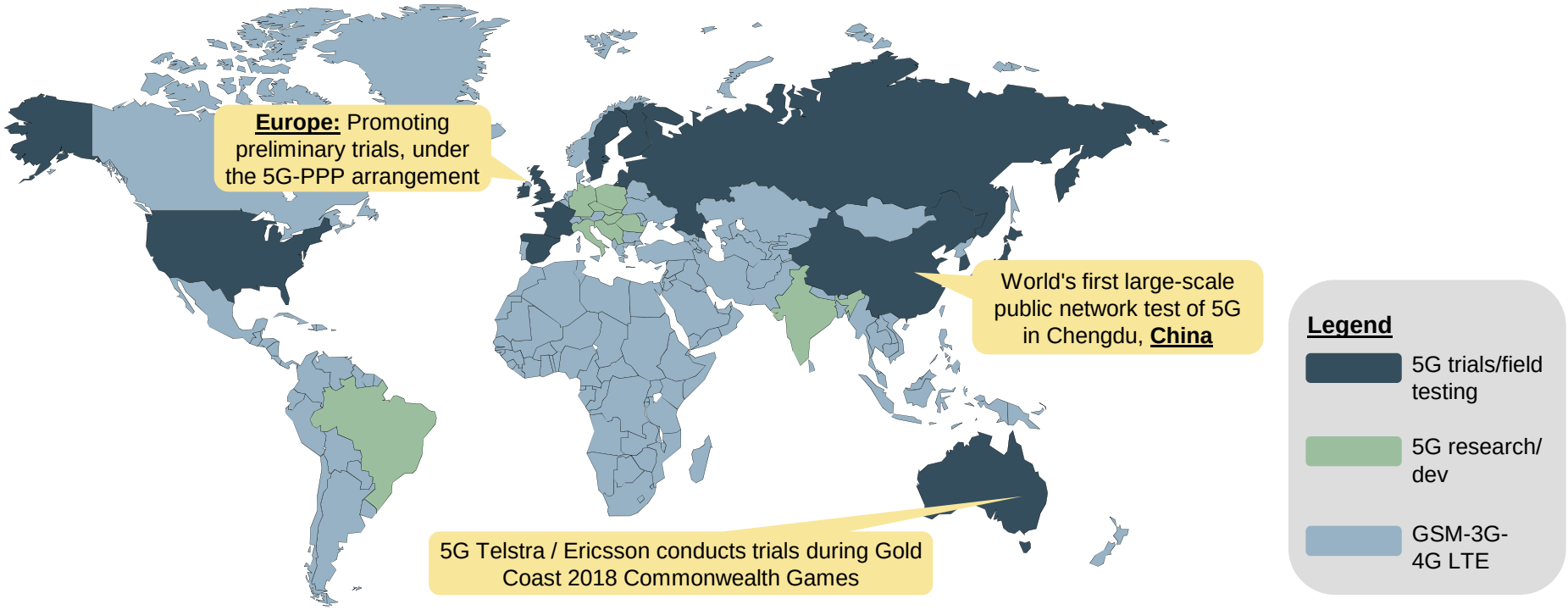
**Implication for Victoria: DSRC and 4G-LTE are two widely used and proposed candidate schemes for Connected Vehicle (CV) applications**

Source: Journal of Advanced Transportation; L.E.K. research & analysis

3

# 5G rollouts are at early stages and not yet in widespread commercial use

- 5G connectivity would have to prove significant reliability in testing to give OEMs confidence that it can be relied on in real world circumstances. However, it will enable significant enhancements to AV processing speed and is already being tested in AV specific applications
- South Korean and Spanish carriers announced successful demonstrations of 5G V2X communications technologies in Feb 2018
  - SK Telecom and the Korean Transportation Safety Authority set up a self-driving car pilot city in Hwaseong, covering 3.9m sqft with Samsung's 28GHz 5G cellular technology
- Telefónica conducted smaller-scale 5G-V2X testing with Huawei hardware in Madrid, Spain, focusing on a 5G feature called Ultra-Reliable and Low-Latency Communication (URLLC)




Source: Austroads; GSA; L.E.K. research and interviews

3

# The commercial rollout of cellular technology tends to be focused on population not geographic coverage, resulting in coverage gaps particularly in regional areas

| Challenge | Description | Implications for Victoria |
|---|---|---|
| **Regional area coverage** | • Cellular communications are critical for the road networks of the future and currently Australia has large areas with no coverage, particularly regional areas | *The Victorian Government may need to be proactive should market forces not provide appropriate services (for example rural areas) or be required to augment services within areas of restricted coverage (e.g. tunnels or valleys)* |
| **5G network roll-out limitations** | • Australia's role out of a 5G network will likely focus on urban areas, rather than complete geographic coverage, and is expected from 2021 | |

Source: Austroads; GSA; L.E.K. research and interviews

3

# A range of other communication technologies have also been associated with AV operation but are less likely to be used in Australia during the roll-out of AV technology

| Digital Infrastructure Technology | Description | Australian Context | Global Use | Implications & Considerations | Applications for AVs |
|---|---|---|---|---|---|
| **LTE Direct** | A device-to-device technology that utilizes licensed LTE spectrum | Not currently deployed in Australia | Leverages the global LTE standard as part of 3GPP release 12 | Commercial reality not yet apparent, and may require extended time before mainstream use | Device-to-device communication is being considered for safety applications |
| **LTE Broadcast** | LTE Broadcast enables multiple users to receive the same content simultaneously thus maintaining efficient use of spectrum and network investments | Limited trials undertaken by Telstra at sporting events | Vodafone Germany was the first European carrier to conduct live tests with LTE Broadcast in 2014 | Requires a data plan and requires many more transmitters (over 1000 times more) than DAB+ | Deliver sizeable firmware and HD map updates to a large vehicle fleet<br><br>High quality video content could be transferred to a moving car |
| **WiFi** | Wi-Fi or wireless LAN (WLAN) network, mainly using the 2.4 gigahertz band | Ubiquitous in most urban areas in Australia with wireless hotspots formed in businesses and homes | Wi-Fi is based on the (IEEE) 802.11 standards | Range of current networks is very limited (10m-20m)<br><br>Could be a useable form of AV communications for lower-importance updates | Potential applications in non-safety critical applications and telematics (i.e. satellite navigation, GPS and mobile data) |
| **Worldwide Interoperability for Microwave Access (WiMAX)** | A group of wireless communication standards launched in direct competition to the 4G (LTE) network | The technology was not adopted for use by the public in Australia | WiMax operates at a wide variety of frequencies internationally from 2.3 to 5.8 GHz | Unlikely to be used with AV technology in Australia. Only isolated coverage exists in Australia e.g. offered by iiNet in South Australia to cover fixed line blackspots | |

Source: Austroads; GSA; L.E.K. research and interviews

3

# Australia (via SCOTI*) has decided to favour US, International and European standards for C-ITS

**Higher applicability to Australia** ← → **Lower applicability to Australia**

## IEEE / SAE

- **US standards** set by the Institute of Electrical and Electronics Engineers and the Society of Automotive Engineers
- Includes 11 standards from the SDOs of IEEE, SAE and the NTCIP

## CEN / ISO

- **International standards** set by the European Committee for Standardisation (CEN) and International Organisation for Standardisation (ISO)
- The CEN/ISO December 2013 release comprises 71 standards

## ETSI

- **European standards** set by the European Telecommunications Standards Institute
- The 'ETSI May 2013 release 1' set of standards comprises 86 standards

## ARIB

- **Japanese** standards set by the Association of Radio Industries and Businesses
- 112 standards as of the April 2014 release

## TTA

- **South Korean** standards published by the Telecommunication Technology Association
- 5 published standards

**Implications for Victoria: While the US and international standards appear favoured, it is too early to determine the implications for Victoria without a view of OEM and market adoption**

Notes: * Standing Council on Transport and Infrastructure (SCOTI), is now renamed as Transport and Infrastructure Council (TIC)
Source: Austroads; China Law Insight; L.E.K. research and interviews



L.E.K.

3

# The key differences between the US and European C-ITS standards relate to channel allocation, message type, Geo-Networking and security

| | US Standards (IEEE/SAE) | European Standards (ETSI) |
|---|---|---|
| **Architecture and message types** | • Concentrates on using 5.9 GHz DSRC<br>- uses basic safety message (BSM) | • Designing an open hybrid platform<br>- uses a cooperative awareness message (CAM) and a decentralised environmental notification message (DENM) |
| **5.9 GHz channel allocation** | • Utilises 70 MHz spectrum of the 5.9 GHz band (i.e. 5.855 to 5.925 GHz)<br>- proposing, a channel switching concept which results in the one radio switching between the control channel and service channels | • Proposing to utilise 50 MHz (i.e. 5.855 to 5.905 GHz)<br>- considering dual radios which will enable the radio to simultaneously receive on both the control and service channels |
| **Geo Networking/multi-hop** | • Does not require GeoNetworking/multi-hop<br>- does not refer to a local dynamic map but does have map messages as part of SAE J2735 | • Proposes to include GeoNetworking/multi-hop which enables a C-ITS device to receive and then re-broadcast a message to other devices |
| **Security** | • Managed at the application layer in the US scenario<br>- only messages which lead to a safety warning be verified | • Managed at the network layer in the EU scenario<br>- all or almost all messages need to be verified |

**Implications for Victoria: While the US and international standards appear favoured, it is too early to determine the implications for Victoria without a view of OEM and market adoption**

Source: Austroads; China Law Insight; L.E.K. research and interviews



L.E.K.

3

# In addition to communication technology standards, specific standards around implementation will need to be developed

## Applications

- The C-ITS Platform of the EU's European Commission have identified 20 applications for C-ITS for which standardisation is required. The applications are split into two 'days', in order of urgency. Notable examples of applications are below

**Day 1**
- In-vehicle speed limits
- Emergency vehicle approaching
- Green Light Optimal Speed Advisory (GLOSA)

**Day 1.5**
- Information on fueling & charging stations for alternative fuel vehicles
- Vulnerable Road user protection

## Trial implementations

- The C-Roads Platform is working to establish communication standards, for both hardware and messaging formats, with 14 Day-1 services being tested within Europe
- C-Roads, a joint initiative of EU member states, is undergoing trials of connected infrastructure in 16 European states. These include:
  - Road works warnings in all 16 states
  - Green light optimal speed advisory in 9 states
  - Emergency vehicle approaching systems in the Czech Republic, Spain, Sweden and Finland
  - Signal violation warnings, when a vehicle (theirs or another road user) is at risk of violating a red light in 5 states

C-ITS stands to provide a number of benefits in vehicular communication and driver information for improved decision making

- Most C-ITS developments are still at trial or research phase, with little deployment to date. Some examples of connected infrastructure have existed for over a decade, relating to road pricing (electronic tolling) and speed monitoring. However the technology that provides feedback to drivers through digital communication does not have mature standards
- For reliable use of C-ITS communication, equipment in vehicles by different OEMs and across different road agencies / asset owners needs to align on standards and implement consistently

**Implications for Victoria: While there are a wide range of C-ITS concepts, its applications are still largely immature and standards are not yet consistently implemented**

Source: Infrastructure Australia, European Commission; C-Roads; L.E.K. research and interviews

3

# Working across multiple parties will involve a variety of data integration challenges, investment in digital assets and governance solutions

- Multiple stakeholders are involved in the provision of data for V2X applications, including mobile networks, private map companies, OEMs, and Governments and, in some instances, these stakeholders are competing parties
- However, the presence of multiple parties leads to various forms of data and a lack of standardization
- A need may exist for a "data broker" role to collate and integrate the range of data relating to connected transport applications
  - oneTRANSPORT is an example of a data brokerage project in the UK, bringing together over 300 datasets. More information can be found on the case study on page 111
  - As part of AECOM's global infrastructure consortium piloting connected and autonomous vehicles in the UK, Thingful, a company described as 'a search engine for the Internet of Things' are researching data comparability and standardisation
- A recent report by the Urban Transport Group, UK found that although merging data meant transport users were more fully informed about their travel choices and transport authorities were better able to plan and manage their networks, there were barriers to overcome.

  *"… One misconception is that the main problem is that transport authorities have lots of data and if they would only open it up then transport challenges would melt away. Opening up data can indeed open up the potential for new and innovative use, but there are also issues around the availability of data and its quality and compatibility in the first place – as well as privacy and trust issues on its use…"*
  *Director, Urban Transport Group, Open Data Incubator Europe*
- The data generated and used for C-ITS will have ancillary benefits and could be utilized by government bodies for city planning and other purposes

  *"… Planning agencies are excited about the potential of autonomous vehicles to give insight into how the roads are being used for planning functions, but they believe that this data will be free…"*
  *Global Leader of Smart Mobility, ARUP, UK*

**Implications for Victoria: The existence of a central organisation serving as a 'data broker' may enable local authorities to consolidate and share real-time data feeds within a single environment and allow allow independent data analytics and application developers to offer value-added data services and end-user applications**

Source: GlobeNewsWire; Thingful; Open Data Incubator Europe; oneTRANSPORT; L.E.K. research and interviews

3

# The UK oneTransport project provides a useful case study showcasing the value of an independent 'data broker' to co-ordinate data sets to tackle transport issues

A consortium of leading European industry, academic and transport authority partners, completed a two-year integrated transport project, funded by Innovate UK. The **oneTRANSPORT Project** was able to bring together more than 300 different datasets, coordinate eleven public and private partners' activities and utilized the Chordant™ platform, built on the global oneM2M™standard, to enable local authorities to consolidate and share real-time data feeds within a single environment

| Case study | Description | Implications for Victoria |
|---|---|---|
| **Silverstone Formula 1 Race Weekend** | • The project integrated and displayed real-time data from multiple data owners including Highways England, three local authorities, and private sector traffic and analytics companies<br>• This gave organizers an understanding of the approach and departure of 16,000 cars over the four-day event, and allowed them to optimally route traffic in and out of the seven on-site car parks | *The oneTRANSPORT project provides important insights into how neutral, national data infrastructure can enable data sharing across the public and private sectors to support new intelligent mobility* |
| **Oxford Park and Ride** | • This project enabled the sharing of data between Oxford Council, a public bus operator, two analytics providers and two app developers, to help manage traffic and congestion in Oxford City Centre.<br>• For example, as drivers approached the city, users would be provided with the answer to "is it better to drive into the city or use the park and ride"<br>*"… in a city, you have many carparks, all owned by different people, they don't release data to competitors.. But planning agencies are excited about the potential of autonomous vehicles to assist driving decisions…"*<br>*Global Leader Smart Mobility, ARUP, May 2018* | |
| **Watford Football Club Match Day** | • oneTRANSPORT enabled real-time data from multiple road and parking systems around Watford town centre to be combined and displayed, providing real-time insights into traffic behaviour and the impact of visitors around Watford on football match days<br>• Insights enabled interventions in signal timings and dynamic information displays that altered traffic and parking, which significantly reduced queues and congestion on key town centre roads and improved car park exit rates post-match | |

Source: GlobeNewsWire; oneTRANSPORT; ARUP; L.E.K. research and interviews

3

# A number of technologies can be used for relative and absolute positioning and mapping purposes

## Relative Positioning

- Relative positioning is the process of locating a vehicle by using information from its surroundings. This either occurs through the use of sensors, such as LIDAR, or through DSRC messages from other vehicles or infrastructure
- Current AV technology relies upon expensive LIDAR sensors and high-fidelity mapping of the environment in which AVs operate for relative positioning purposes
- LIDAR maps are used to contrast information from sensors to detect differences. The appropriate action is determined to respond to the unforeseen elements
- In the long term, it is believed that relative positioning may achieve sufficiently safe levels of operation for absolute positioning to primarily be used as a backup system

**Relative positioning is useful for fast responses and redundancy must be built-in by vehicle manufacturers to enable other sensors to take over if one fails during operation**

## Absolute Positioning

- Absolute positioning is the process of using advanced GPS to locate the vehicles exact co-ordinates and superimpose these onto a previously-created map of the road network. The vehicles current position, as well as the understanding of the surroundings from the map are then used to direct the vehicle, with some assistance from sensors
- It is predicted that AVs will primarily be reliant upon on-board sensors for relative positioning. However absolute positioning mechanisms such as GPS and SBAS will be an important addition, allowing absolute positioning to be used as a ‘back-up’ positioning mechanism
- Absolute positioning maps do not account for small and changing aspects of the environment, such as potholes. Traffic and accident data has been added to services such as Google Maps and Waze

**Absolute positioning currently enables simple tasks such as navigation, but granularity, speed, and reliability are barriers. Satellite based augmentation system (SBAS) improvements will assist towards solving these challenges**

Source: Gizmodo; MIT Computer Science and Artificial Intelligence Lab; ENC Mag; LAT Times; GMV; Aurora Summit; L.E.K. interviews and research

3

# Highly accurate absolute positioning is incorporated in many AVs as one of a number of sensors. It is unclear how important absolute positioning will be

| Topic | Description and examples | Implications for Victoria |
|---|---|---|
| **Absolute positioning requirements in AVs** | • Many AV developments internationally are use an "SBAS-enabled"* GNSS receiver to meet their absolute positioning requirements.<br>• These systems vary by internationally from EGNOS** (**EU**), WAAS*** (**USA**), MSAS^ (**Japan**), GAGAN^^ (**India**), SNAS*** (in development in **China**) and WADGPS† (in development in **Korea**)<br>• While GPS has a locational accuracy of c.2m, SBAS has an accuracy of <1m. The added integrity and precision of SBAS allows the signal to be used in more demanding applications in aircraft and at sea<br>• **Australia** and **New Zealand** do not presently have an existing SBAS service freely available for use. Further investigation and development of Australia's GNSS and SBAS capability is being undertaken by Geoscience Australia through the National Positioning Infrastructure project (GA NPI project) in collaboration with the Cooperative Research Centre for Spatial Information (CRCSI) | *Vehicles developed for the major markets of Europe, Asia, or the Americas are being developed to utilise the enhanced positioning technologies available in those regions*<br>*The lack of free access to an SBAS is a potential obstacle to some AVs being introduced to Victoria*<br>*It may not be feasible for vehicles sold in Australia to have equipment fitted (e.g. GNSS receiver) that is unique to Australia*<br>*The Victorian Government could advocate to the Commonwealth to ensure AV based applications are considered as part of the Australian Government's National Positioning Infrastructure (NPI) Capability* |
| **Absolute positioning in rural and regional locations** | • Large international organisations such as Google and Uber are creating 3D LiDAR maps for a number of cities globally<br>• As country roads are often more logistically difficult to map and encounter less traffic, there is less of an incentive these organisations to map the rural and regional roads<br>• Toyota and MIT's Computer Science and Artificial Intelligence Laboratory are developing systems that allow self-driving cars to drive on roads without 3D maps | *Improvements in relative positioning technology may be the means to enable AVs in rural and regional area, as relative positioning does not depend on the creation of high quality maps and highly accurate GNSS* |

Notes: * Satellite-based Augmentation Systems, which improve the accuracy and reliability of GNSS information; **European Geostationary Navigational Overlay Service; *** Wide Area Augmentation System; ^ Multi-functional Satellite Augmentation System ; ^^ GPS and GEO Augmented Navigation; ^^^ Satellite Navigation Augmentation System; † Wide Area Differential Global Positioning System

Source: Austroads; Gizmodo; GSA; MIT Computer Science and Artificial Intelligence Lab; L.E.K. research and interviews



L.E.K.

3

# Section Summary: ICT infrastructure and standards required for AVs

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Which communication technology (4G, 5G, LTE, DSRC, WiFi) will underpin AV rollout*** | • There is no global consensus as to which technology will predominate, yet all may be used to some extent to support AVs<br>• 5G technology is developing rapidly and 5G trials and field testing are taking place in the USA, France, Spain, UK, China, Russia, Japan, Sweden and Finland<br>• Europe is primarily looking into LTE technology<br>• The US is conducting development into DSRC communications<br>• China has not yet committed to a particular communication technology | *Victoria needs to monitor international developments and respond accordingly*<br><br>*Communication technologies can be used for a variety of applications (V2X), but there is limited examples of scale roll out internationally* |
| ***The choice of overall communication standards*** | • Australia has decided to favour US, internationally recognised, and potentially European standards<br>• Austroads are working on the harmonisation of road data information and language across Australia and New Zealand | *While the US and international standards appear favoured, it is too early to determine the implications for Victoria* |
| ***Data integration challenges involved in the provision of data for V2X applications*** | • Working across multiple parties will involve a variety of data integration challenges, investment in digital assets and governance solutions<br>• The oneTRANSPORT Project in the U.K. was able to bring together more than 300 different datasets and coordinate eleven public and private partners' activities to enable local authorities to consolidate and share real-time data feeds within a single environment | *The Victorian Government should consider the benefits of a central organisation serving as a 'data broker' to consolidate and share real-time data feeds within a single environment* |
| ***The need for satellite-based augmentation systems (SBAS) to assist with absolute AV positioning*** | • Many AV developments internationally are using an SBAS-enabled GNSS receiver to meet their absolute positioning requirements<br>• Vehicles developed for the major markets of Europe, Asia, or the Americas will likely be developed to utilise the positioning technologies available in those regions<br>• It is unclear how important absolute positioning will be, but it is at least an important backup system | *The Victorian Government should advocate to the Commonwealth to ensure AV based applications are considered as part of the Australian Government's National Positioning Infrastructure (NPI) Capability** |

Notes: * Geoscience Australia and the Cooperative Research Centre for Spatial Information (CRCSI) is leading a test project of a Satellite-Based Augmentation System (SBAS) for the Australasia region. The CRCSI has called for organisations from across the aviation, road, rail, maritime, spatial, construction, mining, utilities and agriculture sectors to participate in the test-bed

Source: L.E.K. research and analysis



L.E.K.

4

# Governments are taking different approaches to supporting map and road data for AVs, particularly with respect to changed road conditions

| Topic | Description | Examples | Implications for Victoria |
|---|---|---|---|
| **Map and road condition data** | • AVs in the majority of cases will obtain map data from one of the major data providers (e.g. 'TomTom' and 'Here')<br>• Some AVs may also use their own created map data using proprietary mapping data that is unique to that vehicle supplier<br>• Austroads are working on the production of a standard that addresses harmonisation of road data information and language across Australia and New Zealand<br>  - the standard covers road assets owned by State or Local Government agencies<br>  - this includes the road itself plus roadside infrastructure, e.g. ITS, structures | • Start-ups focused on map data such as Civil Maps, DeepMap and Lvl5 have attracted mapping engineers from Google, Apple and Tesla, and raised more than $40m in funding<br>• China tightly regulates the collection, preservation, ownership, usage and export of geospatial data<br>  - the current PRC Surveying and Mapping Law* requires surveying and mapping in China be carried out exclusively by entities holding a license (ENM) issued by the relevant governmental authority<br>• The European Union historically has also taken a restrictive position on data collection and analysis, with rules which limit the ability of companies, such as Google, from collecting data in respect of road conditions and mapping street views | *It is unlikely a road operator will have a direct responsibility with the creation and updating of map data to a vehicle*<br><br>*Nonetheless, there may be data attributes for which a road operator is the authoritative source. Examples include speed zone changes, road closures, road works, changed lane use arrangements, permits, and restrictions*<br><br>*Automotive groups and map data providers have confirmed an interest in road operators providing this data in real time into the data supply chain*<br><br>*The data collected from AVs also has potential as a valuable resource for road authorities* |

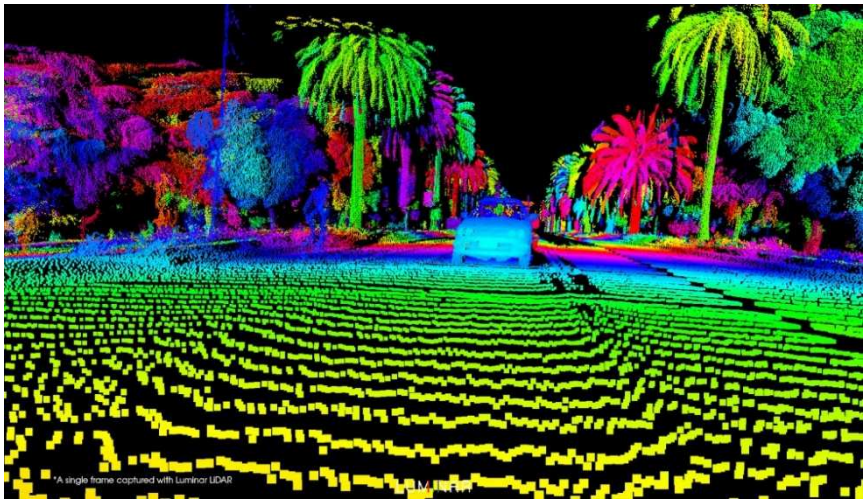
Notes: * 27th Session of the Standing Committee of the Twelfth National People's Congress of China effective on 1 July 2017
Source: Austroads; China Law Insight; L.E.K. research and interviews

4

# 3D mapping technology is generally being led by private players. However, Japan has applied government funds to advance mapping in its market

3D maps are an important component of autonomous cars as they allow driving conditions to be foreseen, such as change in gradients or potholes. The use of 3D maps means the required computation is lower, as the driving system needs only to identify differences between the map and its real-time surroundings.

**Google, Uber, TomTom, Tesla** and others are generating the 3D maps that autonomous vehicles depend upon. Eventually cars will feed data back into the maps, so the most widely used maps will become more reliable, which will in turn attract more users. The strength and reliability of the mapping component will become an important part of the value proposition of these companies. Currently, the mapping software used by competing companies is incompatible




**A single frame captured by LIDAR**

## Case study: Japan

The only government to have made a significant contribution to mapping is Japan who have partnered with a mapping firm and contributed funds to accelerate the AV-readiness of Japan's roads.

In 2016 the **Japanese** Prime Minister committed AUD $22m p.a. to develop critical technologies for autonomous vehicles, including maps.

The government has partnered with Dynamic Map Planning, which is incrementally mapping the terrain with the aim of having the technology available by the 2020 Olympic Games.

Japan has made a concerted effort to facilitate sharing of standards, and will provide the maps to the nine OEMs that invested in the venture

**Implications for Victoria: A handful of private players are likely to take leadership with the collection and provision of map data as crowd sourcing becomes possible**

Source: Luminar; New Scientist; Reuters; Clayton UTZ

4

# Summary: Mapping and positioning

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Approaches to 3D mapping for AV technology and positioning*** | **Dynamic maps** are **3D maps** that combine **dynamic information** such as **traffic jams, accidents, vehicles** in the vicinity of an automobile **with static information about structures** like roads and buildings<br><br>**Satellite based navigation systems** like **GPS** are important **absolute positioning** technologies. **Standards appear well developed** and receivers are capable of using multiple systems<br><br>There currently exists **no standard for map creation and data sharing** | *Despite investments to improve satellite navigation accuracy, commercially available systems are not sufficiently reliable or accurate for AV absolute positioning purposes*<br><br>*A combination of both relative (sensors, LIDAR) and absolute (satellite, cellular) will likely be initially used for 3D map generation in AVs* |
| ***The extent of Government involvement in 3D mapping*** | **Internationally**, **3D mapping technology** is generally being led by **private players**, including **Google, Uber, TomTom, Tesla, Baidu and Here Maps.** However, China and to a lesser extent the EU, have placed restriction on mapping data collection and use<br><br>**Japan** has been the only jurisdiction to apply significant **government funds** to advance mapping in its market **via a partnership with Dynamic Map Planning**<br><br>No standards for map creation and data sharing exist internationally, but this is under discussion. Austroads is investigating standards to harmonise road data information<br><br>Governments may need to provide up to date road works information | *The Victorian Government could consider the formation of partnerships with data and mapping companies to develop universal high resolution maps and location data services*<br><br>*A handful of private players are likely to take leadership with the collection and provision of map data as crowd sourcing becomes possible*<br><br>*The Victorian Government should monitor development of any international mapping standards and support Austroads harmonisation efforts* |

Source: L.E.K. research and interviews



L.E.K.

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emission Vehicles
- Findings about Autonomous Vehicles
- **Findings about other New Mobility market models**
- Implications for Victoria
- Appendix

# L.E.K. undertook a targeted review of other new mobility market models to distil potential infrastructure implications for AVs and ZEVs



| Model | | Definition |
|---|---|---|
| Rideshare |  | • Passenger travel in a private vehicle driven by its owner, for a fee, arranged by means of a website or app |
| Mobility as a Service (Maas) |  | • An app that offers an one-stop-shop for information, booking and payment for different forms of transport |
| On demand public transport (PT) |  | • Public transport offering flexible routing and/or timing, using small/medium vehicles operating between pick-up and drop-off locations according to passengers demand |
| Dock less Bike share |  | • Access to a fleet of bikes through a smartphone app. Bikes can be used for return or 1-way trips and don't have to be returned to a docking station. |

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Autonomous Vehicles
- Findings about Zero Emissions Vehicles
- **Findings about other New Mobility market models**
  - **Rideshare**
  - MaaS
  - On demand public transport
  - Dockless bike share
- Implications for Victoria

# Rideshare: Overview

- The rideshare offering has grown rapidly all over the world, with a number of local and global leaders
- Ride share uptake differs by geography
  - While ride share is popular in super-urban (i.e. inner city) locations, uptake is lower in urban and rural locations
  - The ability for ride share to take market share from taxis has been different around the world (e.g. much greater in China than the EU)
- There is some emerging evidence that rideshare has grown overall vehicle kms, and that rideshare (and ride pool in particular) will compete with PT for patronage if not actively integrated into public transit
- Governments internationally have attempted to regulate the rideshare market, particularly Uber. Techniques include
  - Capping the number of Uber drivers that can be employed
  - Banning Uber, ruling it ‘not fit and proper’
  - Adding a surcharge onto Uber prices
- The rideshare industry is constantly innovating e.g.
  - UberPool are expanding their offering to include carpooling and bike share
  - Autonomous vehicle trials are including ridesharing market models

# Asset owners have altered infrastructure access arrangements or built new infrastructure as rideshare has grown in popularity

| Topic | Description | Implications for Victoria |
|---|---|---|
| **Airport access** | Airports have had to make changes to accommodate rideshare operators<br>● La Guardia Airport, **NY** has chosen to build a new rideshare area near Terminal B, instead of a shuttle bus to a further away car parking area<br>● **Melbourne, Sydney and Canberra** Airports have introduced Uber wait zones, usually with fees (e.g. each Uber has an additional AUD $4 fee in Melbourne)<br>● **Heathrow** airport is building a new waiting area for 800 vehicles<br><br>Most airports charge a fee to rideshare operators. Fee structure examples include an annual permit, per trip fee or an activation permit. **San Francisco Airport** announced an increase to Uber/Lyft fees in May 2018 to help manage congestion, which included a premium for direct curbside access | *Victoria should monitor these developments carefully for indications of potential future AV impacts and policy responses* |
| **Taxi rank, bus and HOV access** | Cities have generally avoided granting rideshare providers access to taxi ranks, bus lanes or HOV lanes. To date, this has been a convenient way of providing taxi operators with a distinctive service.<br><br>Rideshare vehicles can use HOV lanes if they meet the minimum criteria for passenger numbers. In **DC,** Uber piloted "Digital Slug Lines" allowing commuters along the same corridor to pool rides and use HOV lanes | *Victoria should monitor developments carefully for implications about access rights for AVs* |
| **Curbside access** | **San Francisco** is considering special curbside pick up areas for Uber and Lyft by providing for pick up zones in crowded areas, to minimize the level of double parking | *Victoria should monitor these developments carefully for clues about the future needs of AVs. New curbside infrastructure should ideally include flexibility and optionality in its design* |

Source: National Academy of Sciences: TNC – Challenges and Opportunities for Airport Operators; ABC7 news; CBS New York; The Age; the Guardian; Washington Post; L.E.K. research and analysis

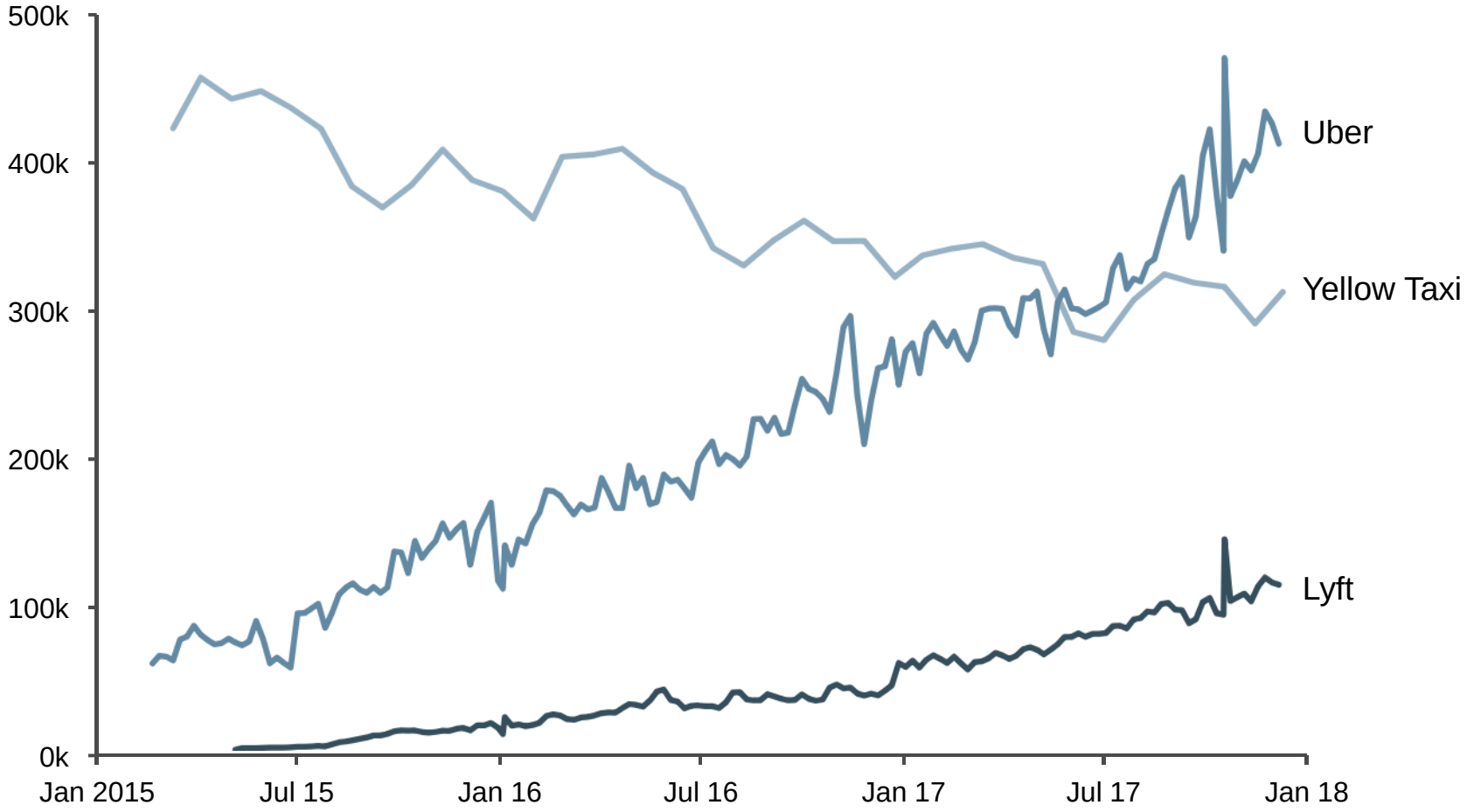
# There is emerging evidence of rideshare impacting overall traffic volumes, congestion and PT access, PT mode share and parking demand

| Topic | Description | Implications for Victoria |
|---|---|---|
| **Overall traffic volumes and congestion** | Following complaints, Uber has "geofenced" its app near **Heathrow Airport** to prevent drivers waiting in nearby villages and causing community concern (e.g. rubbish, blocked driveways etc.).<br><br>In **San Francisco**, Uber and Lyft are responsible for two thirds of all congestion-related traffic violations in the city<br><br>The UC Davis 2017 report into disruptive transportation has indicated that rideshare was adding to overall miles travelled, as a number of trips would either not have been taken, would have occurred by walking or bike. Other sources have suggested rideshare accounts for only 1% of total miles, so it is unlikely to be the sole source of changes in vehicle miles | *Victoria should monitor the congestion and traffic impacts of rideshare for indications about potential AV impacts* |
| **PT access** | Uber has reported that in some cities, 25% of trips start or end at transit hubs, including **New York, Connecticut, New Jersey and Philadelphia**<br><br>Uber has revealed 15% of trips in **Western Sydney** are to/from railway stations | *Victoria should monitor the linkage between rideshare usage and PT for indications about potential future AV impacts* |
| **PT mode share** | Anecdotally, rideshare is being associated with flat or falling patronage in public transport in a number of cities around the world<br><br>The UC Davis 2017 report into disruptive transportation suggested that rideshare users reduced their use of public bus services by 6% but increased their use of rail by 3% | *Victoria should monitor the impact of rideshare on PT mode share for indications about potential future AV impacts* |

Source: The Guardian; San Francisco Examiner; McKinsey; Uber; Roads Australia conference 2018; UC David Institute of Transport Studies

# Rideshare disrupted the mobility market and took off on its own, taking share from existing services, especially taxis

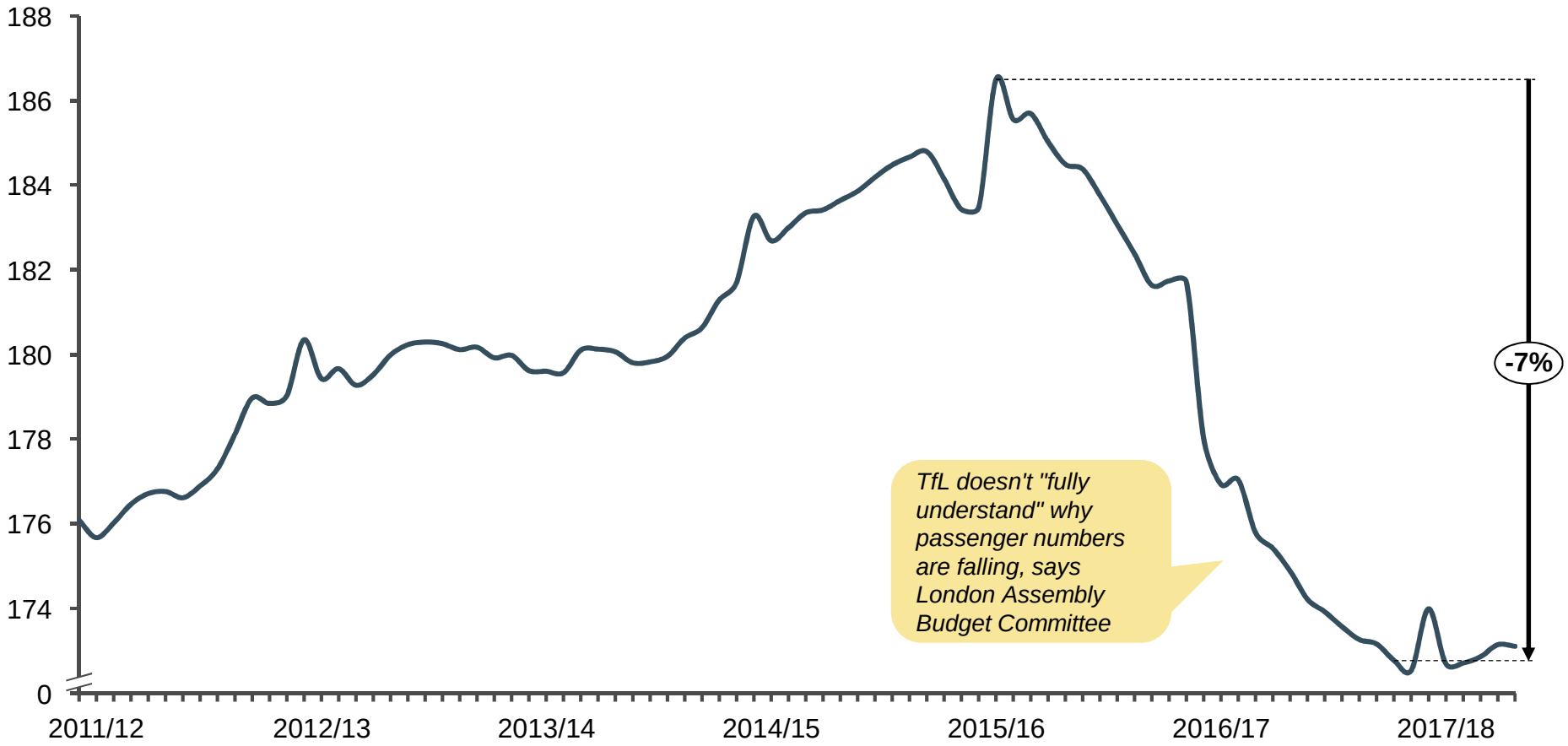
**NYC Daily Trips (2015-18)**




Source: Todd W. Schneider; NYC Taxi & Limousine Commision; Fivethirtyeight

# There are some indications that rideshare is contributing to a fall in PT mode share, most particularly on buses

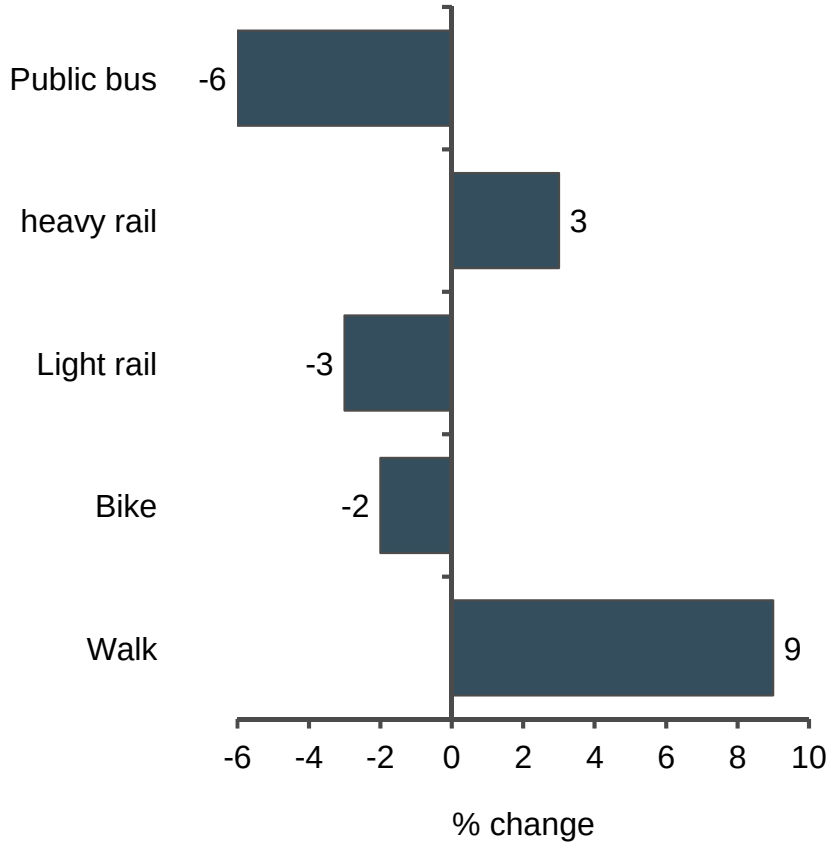
**Moving Average of bus journeys in London (2012 – 18)**
Millions of bus journeys per month




Source: UK Department of Transport

# One survey indicated that rideshare uses have reduced their use of bus services, but increased train travel

**Changes in transit use, biking and walking after adoption of ride-hailing services in the United States* (2016)**
% change




- On the whole, the majority of respondents indicated that there was no change in their transit use.
- However, based on the results of those who did change their behaviour, shared mobility likely attracts commuters away from bus services and light rail, and may serve as a complementary mode for commuter rail
- Based on the type of transit service in question the substitutive versus complementary nature of ride-hailing services varies
- When asked explicitly why one might substitute ride-hailing for public transit, the most popular response of all ride-hailing respondents was that “services are too slow”

Note: * Study was conducted on 6 major US cities
Source: UC Davis Institute of Transport Studies

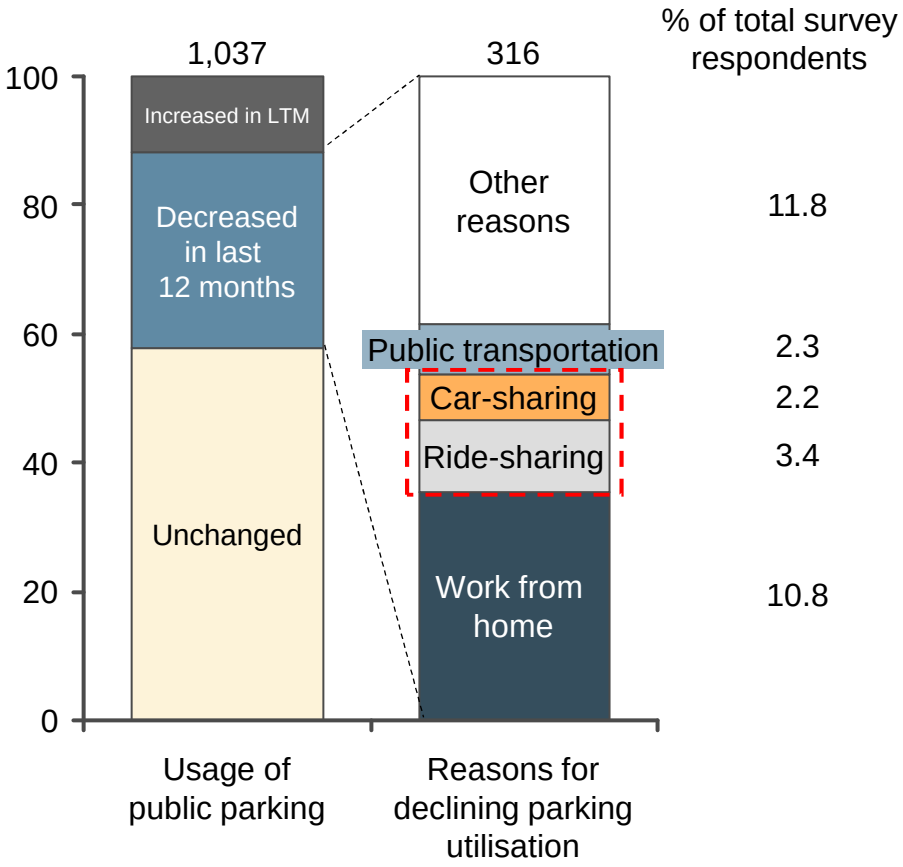
# Ridesharing is already complementing the mass transit network in some cities, with many journeys starting or finishing at transport nodes


*"…In areas underserved by public transport, Uber provides a reliable and fast connection that feeds commuters into, and effectively expands the reach of, existing public transport networks …"*
Uber, October 2015

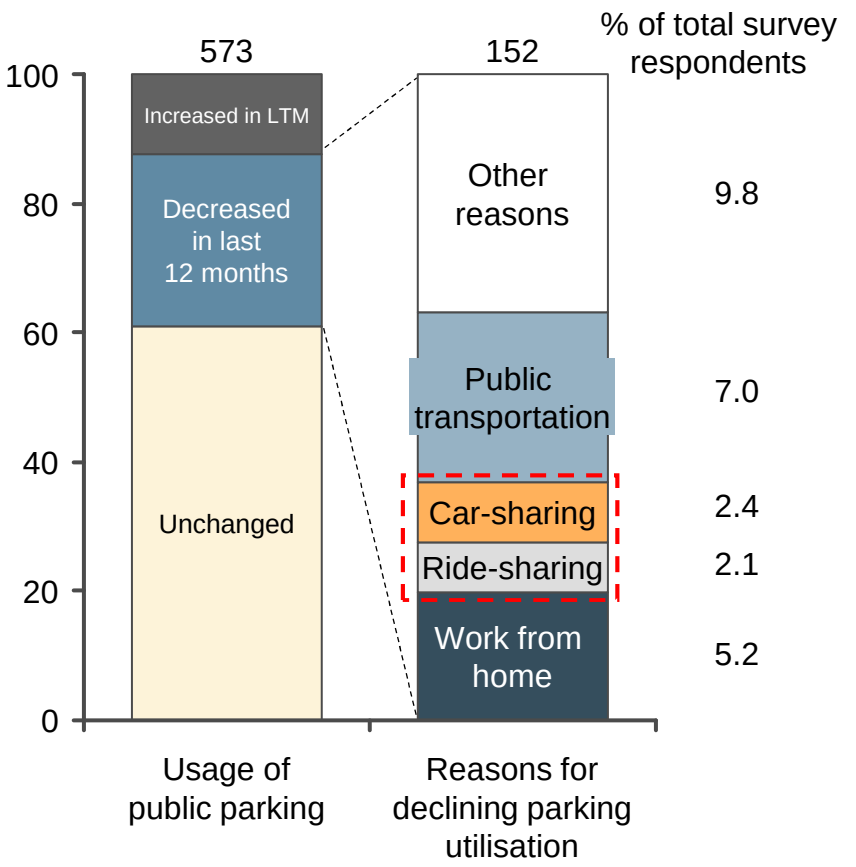
Note: Map shows data for a random selection of trips connecting people far from public transit to a metro station. Trips beginning or ending in the CBD have been excluded. Trips occurred between launch and 9th July 2015
Source: Uber newsroom

# There is some evidence that ride-sharing and car-sharing is decreasing car parking utilisation

**U.S. parking utilisation survey** *INDICATIVE*
Percent (N=1037)




**Germany parking utilisation survey** *INDICATIVE*
Percent (N=573)




Source: L.E.K. analysis

# There is emerging, albeit anecdotal evidence of rideshare impacting car parking volumes

| Topic | Description | Implications for Victoria |
|---|---|---|
| **Airport parking** | Dallas-Fort Worth International Airport, **Texas** states that while parking revenue was up in the first six months of the current fiscal year, it was nearly AUS $4.5m lower than projected. The reasons cites include the impact of Transport Network Companies (TNCs)<br><br>One study of airport parking impacts suggested "The available information, however, suggests that TNCs are causing a decline in parking and rental car revenues per airline passenger" | *Victoria should monitor these developments carefully for indications of potential future AV impacts on parking and policy responses* |
| **Other parking** | Uber has studied two garages in **San Fransico** in detail. Over a period of 3 years where employment grew 11% and population by 4%, parking demand was flat. Furthermore, late night exits from the two car parks were significantly reduced over this period<br><br>A leaked memo from the CEO of ACE car parking in **San Diego** said "demand for parking at hotels dropped by 5 to 10%, while restaurant valet demand is down 25%. The biggest drop has been at nightclubs, where demand for valet parking has dropped a whopping 50%"<br><br>The past year and a half has seen a 10% slide in the number of "transient units"—cars that park by the day or hour—at **Manhattan** garages, according to the trade group Metropolitan Parking Association | *Victoria should monitor these developments carefully for indications of potential future AV impacts on parking and policy responses* |

Source: GovTech; Intervistas; Uber; Crains NY; L.E.K. research and analysis

# Governments have responded to rideshare in varying ways. The most severe reaction has been a complete ban of the service

| Geography | Description |
|---|---|
| **New York** | • In order to limit the taxi supply and protect the livelihood of taxi operators, New York operates a medallion based system. The influx of Uber drivers (who do not require a medallion) has caused the number or transport options to increase, which has significantly devalued medallions.<br>• NYC introduced a bill to cap the number of drivers that Uber could employ, which sparked protests from Uber. Uber offered free rides to anyone who was willing to protest outside City Hall. The bill was later scrapped |
| **Chicago** | • In 2017, Chicago increased the fee charged to every rideshare journey to fund public transport. In 2015, a 52-cent fee was added to every ridesharing trip. In 2017, an additional 15-cents has been added to the fee and will used to fund public transport initiatives. The fee is expected to generate US$16 million in 2018 and US$30 million in 2019 when the fee is raised by another 5-cents |
| **London** | • Transport for London (TfL) discontinued Uber's private hire operator licence after safety and security implications from insufficient background checks on drivers. Uber has launched an appeal and is allowed to continue to operate until the result of the appeal has been decided in mid 2018<br>• In 2016 Uber lost at an employment tribunal in which the UK rules that Uber drivers should be classed as employees, which contradicts Uber's business model |
| **Germany** | • Uber was issued a cease and desist order in 2014 due to safety concerns pertaining to unregulated vehicles and unqualified drivers who are not properly insured. A fine of EUR 250k per ride could be imposed, and employees may be jailed for six months.<br>• The injunction was revoked one month later due to having been filed too late after the launch of the service. A similar nationwide ban was imposed in 2015. Uber is now limited to UberX and UberBLACK services which require drivers to be licensed to transport passengers |
| **Sydney** | • The NSW government places a $1 tax on all Uber and taxi trips in January 2018. The revenue raised will be used to compensate taxi plate owners, however taxi drivers do not consider this to be adequate compensation |

Source: Citylab; BBC; NY Times; Wired; Reuters; L.E.K. research; ABC

# Section Summary: Rideshare (1 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Access to road related infrastructure*** | Airports have had to create new regulations, new pricing regimes and sometimes build new infrastructure to accommodate rideshare providers<br><br>Congestion issues at airports have emerged as usage of rideshare continues to grow<br><br>Cities have so far avoided offering rideshare providers access to taxi ranks, bus lanes or HOV lanes (unless they meet the normal criteria) | *It is likely that the different travel patterns arising with AVs will compel infrastructure owners to change access arrangements, pricing models, and potentially build new curbside infrastructure to accommodate different travel behaviours*<br><br>*Victoria should monitor early trends carefully to try and anticipate how significant these impacts could be*<br><br>*Where new infrastructure is being planned (e.g. drop off areas, car parking), it would be valuable to build in optionality and flexibility into the design* |
| ***Traffic, mode share and PT impacts*** | Rideshare providers waiting for rides (or food deliveries) are causing congestion and local problems<br><br>There is some early emerging evidence that rideshare is growing overall vehicle kilometres and impacting PT mode share<br><br>At least one city (Chicago) is directly surcharging rideshare and directing the funds at PT improvements<br><br>Rideshare is playing an increasing role in accessing PT, with 25% of trips in some US cities to/from a transit hub | *Victoria should monitor the congestion and PT impacts of rideshare (including delivery vehicles such as Uber Eats) for indications about potential impacts and required policy responses from a move to AVs* |

# Section Summary: Rideshare (2 of 2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Parking impacts*** | There is emerging anecdotal evidence that rideshare is slowly reducing demand for parking<br><br>An L.E.K. survey in the US and Germany suggested 2-3% of people had reduced their car parking due to rideshare<br><br>Uber has reported data from sample car parks showing declines in weekend and late night exits in particular<br><br>A number of airports and commercial garages have reported a fall (or slower growth in car parking volumes attributed in part to rideshare | *Victoria should monitor parking trends related to the uptake of ridesharing for indications about potential future AV impacts* |
| ***Licence to operate*** | There have been a variety of different responses to the arrival of rideshare, including<br>- Outright bans / not granting or removing a license to operate<br>- Significant levies on rideshare trips (either directed at PT or to compensate taxi plate owners)<br>- Caps on the number of drivers allowed | *Victoria should monitor global response to rideshare for indications about potential impacts and policy responses from AV uptake* |

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emissions Vehicles
- Findings about Autonomous Vehicles
- **Findings about other New Mobility market models**
  - Rideshare
  - **MaaS**
  - On demand public transport
  - Dockless bike share
- Implications for Victoria

# MaaS: Summary

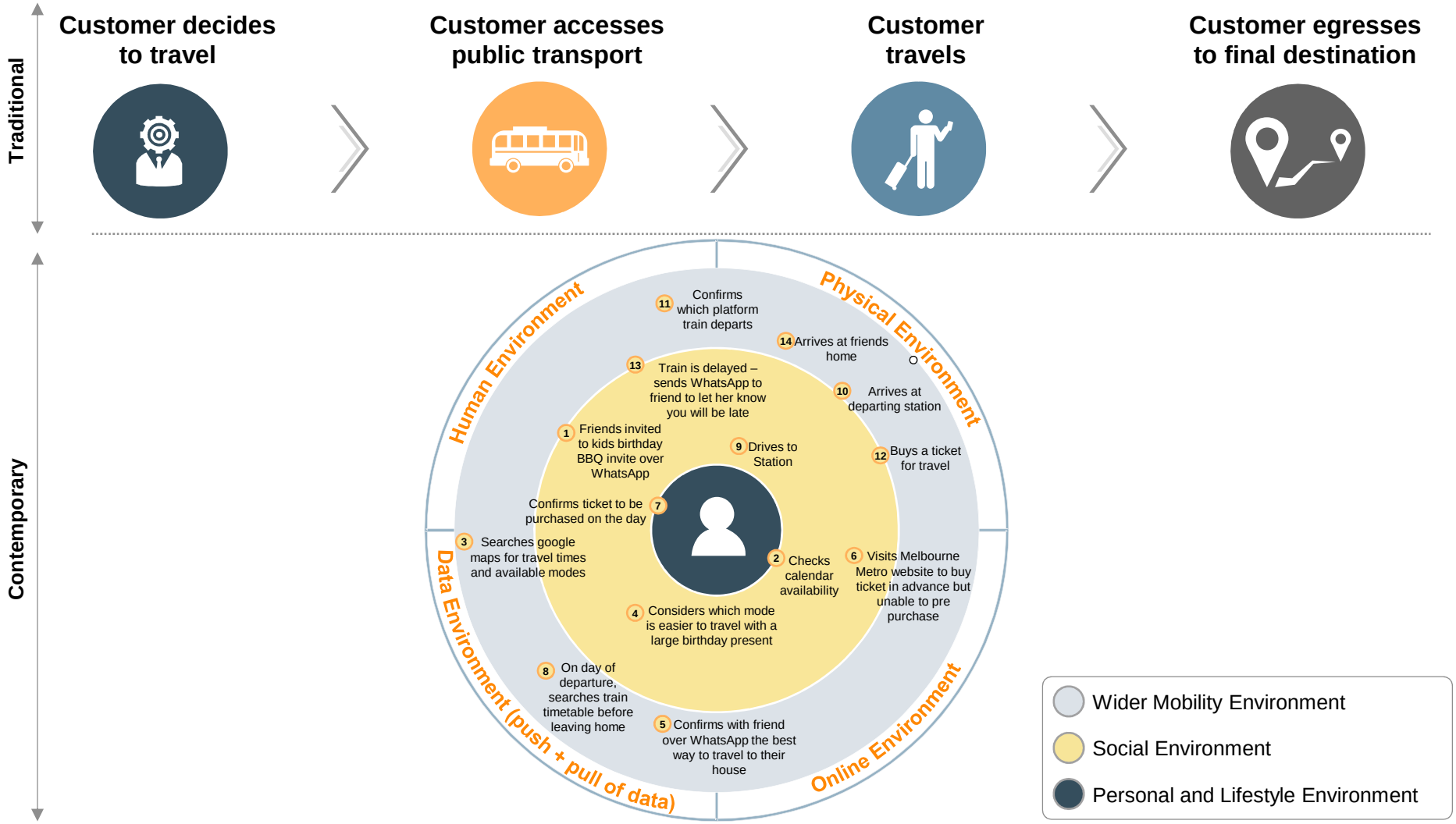
- MaaS appears to offer a compelling consumer proposition, integrating information, booking and payment into a single app, with the possibility of other value added services (e.g. personal preferences)

- While there is considerable focus and discussion about MaaS around the world, and many pilot schemes in operation, it is yet to achieve widespread adoption, for a range of reasons
  - Integration of payments has taken time; solving this issue may unlock more growth
  - Governments have generally been unsure about the right posture towards MaaS (hands off versus controlling), but own critical PT data and payment infrastructure; this has often slowed progress
  - MaaS also raises significant issues for Governments about pricing, allocation of subsidy, contracting and regulation, not easily resolved
  - Platform providers need to strike commercial deals with service providers, who are nervous about giving away customer relationships
  - There are a wide range of commercial entities that could aspire to leadership in MaaS (e.g. Google, CityMapper, Uber etc). No-one has yet been willing to place a large bet on its success

- The most advanced pilots are in Scandinavia, the US and NZ. Outside of Scandinavia, few have succeeded in achieving significant customer penetration

- The jury is still out on whether MaaS will overcome current barriers and succeed in the long run or “fail to launch”

# Mobility is a complex web of decision making moving between social, physical, data and online environments




Source: L.E.K. analysis

# MaaS centres around the principles of mobility, including lifestyle needs, travel choice and the journey experience

## Mobility-centric Principles

**Lifestyle Needs (i.e. Fit)**

- What do people value?
- What are the pain points in people's lifestyles?
- How do people seek out information?
- Would people be willing to share anonymised or personal data?
- How is the demand for car ownership changing?
- Are customers familiar with the journeys they undertake?
- What needs do people have for relevant and personalised content (e.g. confidence in arrival times)?

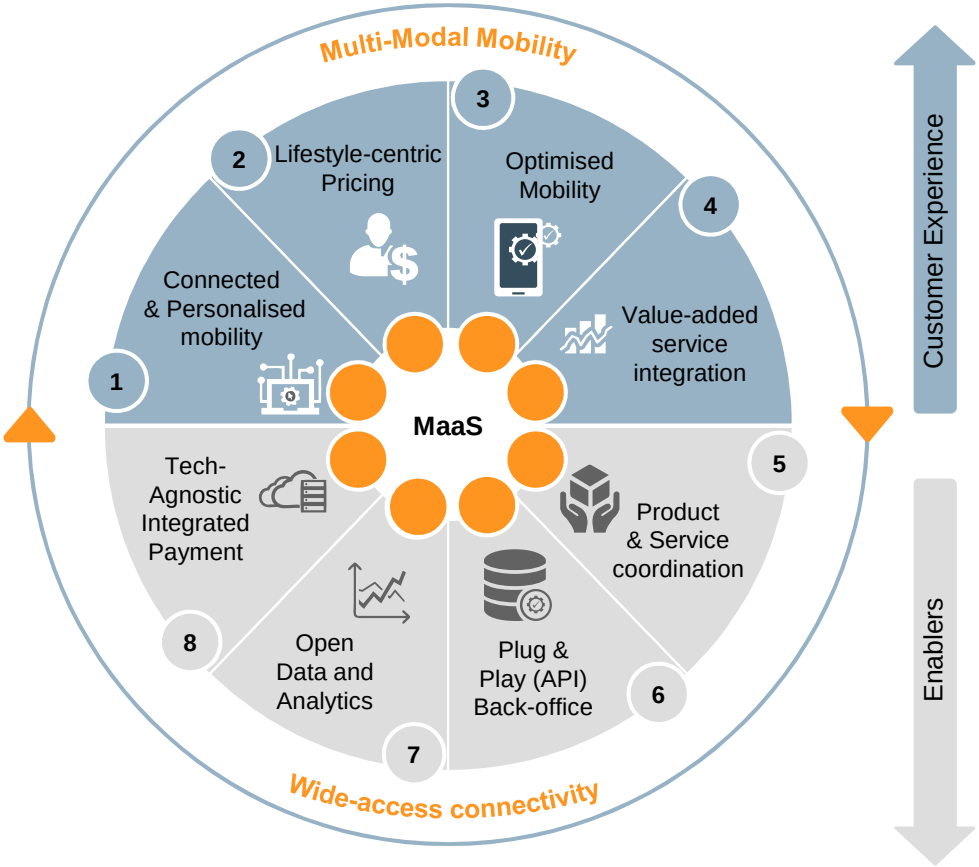
**Travel Choice**

- How are travel decisions made?
- How do we nudge travellers to certain modes?
- How is mobility consumption changing with changes in car ownership and growing congestion?
- How does the threat of virtual mobility impact travel choice?

**Journey Experience**

- What are the pain points in the travel experience? How can they be addressed?

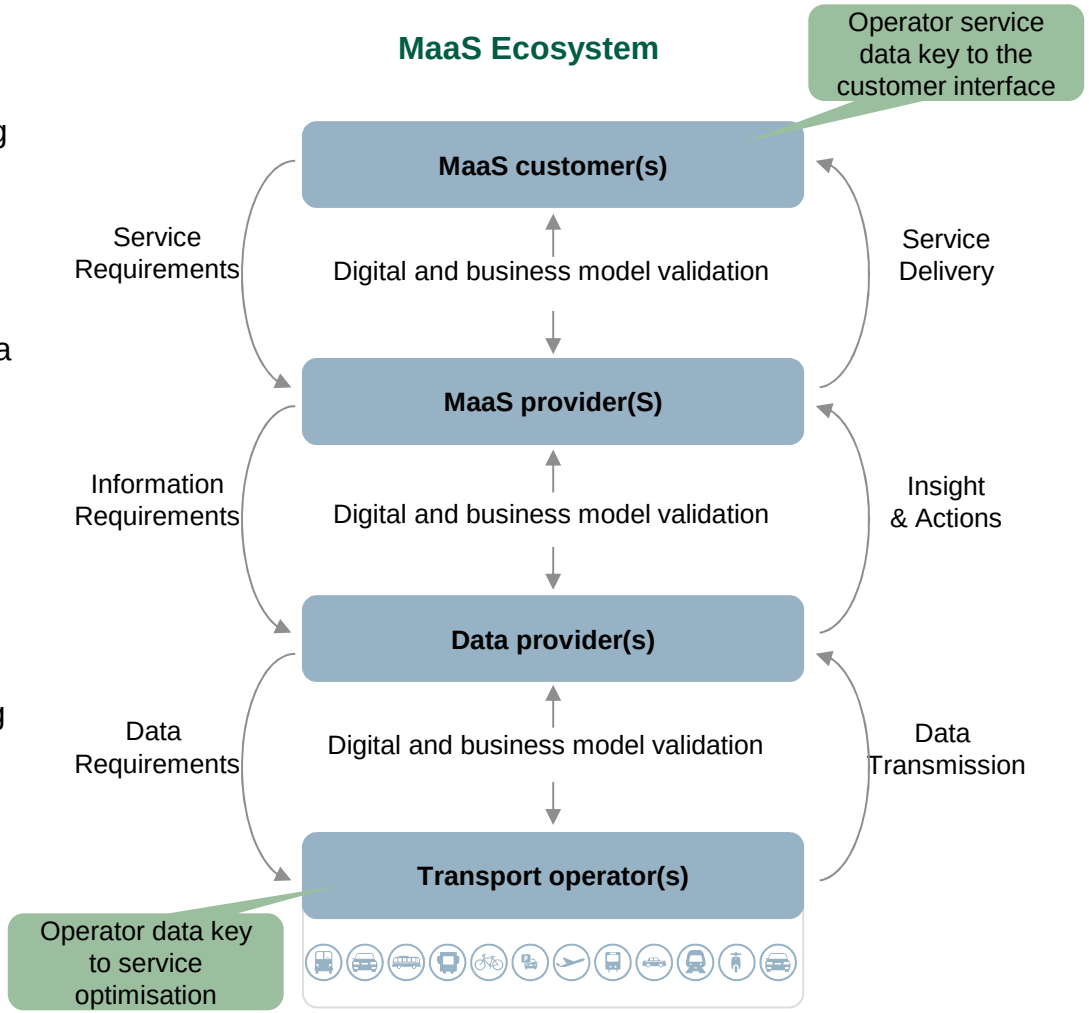
## MaaS Key Attributes




Source: L.E.K.

# MaaS digitalises travel decision-making into an application, allowing customers to optimise their mobility and lifestyle choices

- MaaS digitalises multi-modal journey planning, ticketing and payment into a platform accessible via an app (mobiles or tablets)
- MaaS focuses in on customer lifestyle factors such as:
  - how would one travel with a heavy parcel across a city? Or, how would one travel home from work late at night?
- MaaS relies on multi-modal service coordination, real time traffic and demand management information to help customers optimise their journeys
- The power of the data drawn on from a MaaS platform allows transport operators to segment markets, offering personalised products and pricing
- With an API back-office ('plug & play') structure, MaaS can include both transport and non-travel related products such as park 'n' ride, restaurant delivery and event ticketing




Source: Catapult

# While there are a number of MaaS offerings globally, several have faced challenges integrating non-PT modes and value-added services

Integrated into the value proposition
Not offered within the experience

| Scheme and Location | Description | Ticketing | Payment | Pricing | Value-Added Services | Non-PT Modes Included |
|---|---|---|---|---|---|---|
| **Smile:** Vienna, Austria | Door-to-door integrated transport mobility planner including booking and payment features. It was piloted with 1k users over 2014-15 | ■ | ■ | | | ■ |
| **Hannovermobil 2.0:** Hannover, Germany | €10 subscription to a digital, one stop mobility shop, with integrated mobile phone billings and discounted pricing encompassing train (BahnCard), car sharing (Stadtmobil) and taxi (Hallo Taxi) | ■ | ■ | ■ | | ■ |
| **Ubigo:** Gothenburg, Sweden | Monthly invoice subscription starting at €150 per month via an app enabling access to a range of transport modes including public transport, car rental and car sharing, taxi and bikes | ■ | ■ | ■ | | |
| **Whim:** Helsinki, Finland | Mobile app with three pricing options for monthly plans varying from pay-for-ride (free) to unlimited rides include (€500) | ■ | ■ | ■ | | ■ |
| **Föli:** City of Turku, Finland | An app allowing customers to real time plan, ticket and pay using debit/ credit cards or through mobile phone operator billing | ■ | ■ | ■ | ■ | ■ |
| **Emma Contracts:** Montpellier, France | Single key access to 30 or 365 day subscriptions to integrated transport packages | ■ | ■ | ■ | | |
| **RideMate:** Auckland, New Zealand | Compares cost and timing between travel options including bus, train, shuttle, carpool and taxis between Auckland Airport and Auckland CBD | ■ | | ■ | | ■ |
| **Choice:** Queenstown, New Zealand | Real time tracking and search options for taxi, ski shuttle, bus, rideshare, helicopter bookings, as well as snow conditions | ■ | | ■ | | ■ |

Degree of MaaS Customer Experience Integration

Source: Department for Transport, 2015, Feasibility Study for "Mobility as a Service" concept in London; L.E.K. Analysis

# There are a number of start-ups offering MaaS functionalities; government may have a role to play by integrating MaaS with existing public transport

| Company type | Examples | Rationale for leadership |
|---|---|---|
| **OS/ Map platforms** | Citymapper | Route optimization expertise; trusted navigational brand; existing integration capabilities |
| **Ride hail / pool companies** | UBER, DiDi | Route optimization expertise; operational data; existing relationships |
| **MaaS-focused start-ups** | RideMate, Choice, whim, moovel | Fully dedicated to MaaS functionality; first-mover advantage (piloting in several cities globally) |
| **City / Government** | City of LA<br>NZ Transit Agency<br>TfL | Strong desire to maintain control / influence over data, transport flows and infrastructure requirements |

- New mobility services are expected to increase the number of mobility options available to consumers, creating a need for platforms to aggregate and display each service model option for a given trip to consumers
- MaaS platforms are expected to enable consumers to compare the cost and convenience of different modes and purchase travel on a single platform
- Cities/Governments may play a large role in the development of MaaS platforms operating in their location given the need for the MaaS platform to integrate with public transportation

*Whim, Choice and RideMate are examined in more detail*

Source: Bank of America, Goldman Sachs, CNN, company websites, L.E.K. research and analysis

# Helsinki MaaS platform Whim launched in 2016, and is currently expanding to the UK

## Case study: MaaS Global – Whim, Helsinki

| | |
|---|---|
| **Program description** | • MaaS Global is intended to be a product which is exported around the world as a transport solution<br>• The company launched a pilot for its app, Whim, in Helsinki in August 2016<br>• Customers can plan trips, book services, and pay all within the same mobile app<br>• Whim will have three initial packages available:<br>– Monthly mobility: unlimited local public transport and bike share with a monthly quota to use on taxis, rental cars, long-distance trains and other services<br>– Enterprise edition: a fleet of rental cars with chosen mileage of taxi rides and catering packages, coupled with airport lounge access<br>– Ultimate freedom: access to all public transport, taxis, rental cars etc.<br>• The app implements a points system to facilitate discounting of different packages and incentivise certain behaviours<br>• MaaS Global (then MaaS Finland) was founded in 2015 by Sampo Hietanen<br>• Whim – MaaS Global's mobile application – was launched in June 2016, with a pilot undertaken shortly afterwards |
| **Costs** | • Costs should largely be comparable with those seen in existing offerings of transport as MaaS simply packages existing services together<br>• The nature of costs in MaaS services could be significantly different as a new transportation marketplace may be created<br>• There is the opportunity for more complex business models beyond simple pay-as-you-go model e.g. monthly subscriptions, rewards programs etc. |
| **Program success / failure and key outcomes** | • The company raised €2.2m in February 2016<br>• MaaS Australia is a part owner of MaaS Global |

Source: L.E.K. research

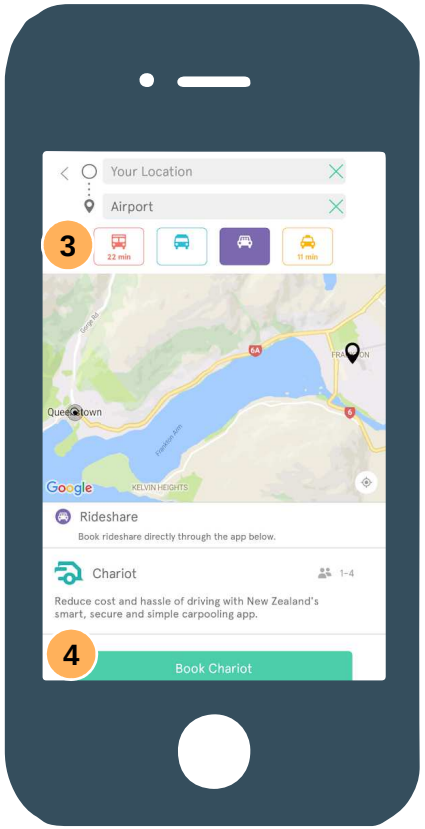
# In Queenstown, NZ Transport Agency has developed the Choice app to make travel and planning easier, particularly for visitors

## 1 Usability

- Simple interface
- Appropriate for tourists with multiple language options including English, Chinese, Japanese and German
- In-app real time transport tracking
- Provides updates on Queenstown ski field conditions

## 2 App Integration

- User can synchronise the app with their Facebook, Uber and other accounts


## 3 Options

- Public transport, private transport (e.g. helicopter bookings), taxi and ride share (e.g. Uber) options are available to compare
- Considers weather, delays and social media updates

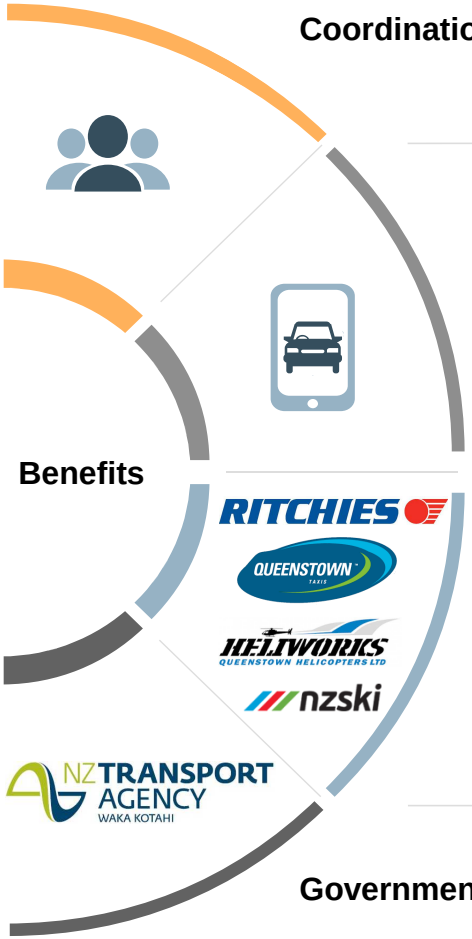
## 4 One-stop shop

- Ability to analyse transport options and book in the app
- In app rewards and discounts

Source: NZTA; L.E.K. Analysis

# Choice has provided Queenstown tourists with the opportunity to access personalised transport information and book their most efficient option

Choice




**Coordination**

- Assists visitors in accessing information and booking transport between Queenstown airport, the city and ski areas
- Facilitates the trip-planning process, providing a quicker, personalised journey for customers
- Information is simple, understandable and on one platform

**Transport accessibility**

- The app improves accessibility to transport information for the 2m tourists that visit annually

*"Choice is available in three languages and will be a boost for the tourism industry, reducing the language barriers for tourists using the local transport system"*

*Simon Bridges, former NZ Transport Minister, August 2017*

**Mobility suppliers**

- As the app is developed by the Government, suppliers have a greater incentive to participate

*"[The] obstacle of commercial rivalry was removed, and all transport providers had an incentive to get on board"*

*Simon Bridges, former NZ Transport Minister, August 2017*

**Government**

- Greater utilisation of existing government transport services
- Increased tourism as travel locations (e.g. ski resorts) become more accessible

Source: NZTA; L.E.K. Analysis



L.E.K.

# In Auckland, NZ Transport Agency has developed the RideMate app, incorporating transport options into one platform

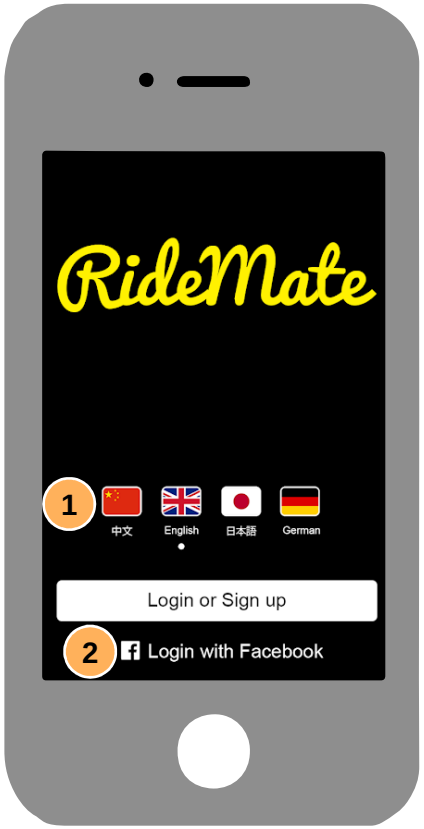
RideMate

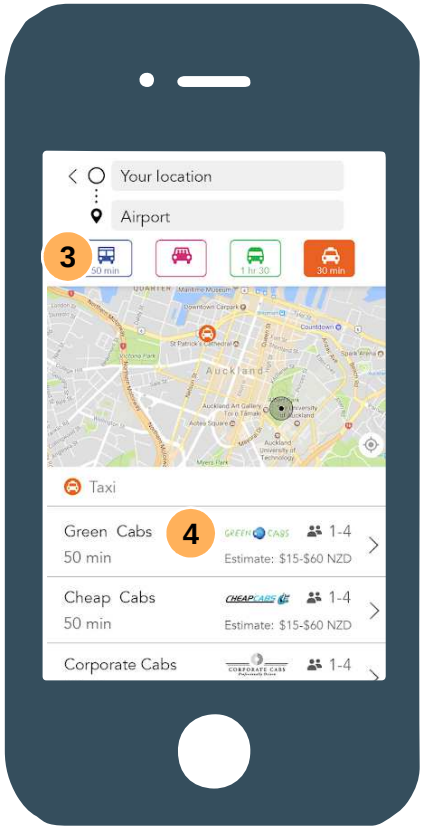
## 1 Usability

- Simple interface
- Appropriate for tourists with multiple language options including English, Chinese, Japanese and German
- Real time transport tracking
- Provides facts about Auckland

## 2 App Integration

- User can synchronise the app with their Facebook, Uber and other accounts




## 3 Options

- Public transport, private transport (e.g. shuttles), taxi and ride share (e.g. Uber) options are available to compare
- Considers weather, delays and social media updates
- Informs on risks of congestion and delays, including flights

## 4 One-stop shop

- Ability to analyse transport options and book in the app
- In app rewards and discounts

Source: NZTA; L.E.K. Analysis



L.E.K.

# In Auckland, RideMate brings transport stakeholders to one platform, enabling them to coordinate more efficiently

RideMate


**Coordination**

- Displays live travel times, informing of delays and congestion
- Users compare and select their optimal option

*"Loved that the one app could tell me what the prices were for different taxi companies and how long each would take."*

*RideMate App User, February 2018*

**Transport accessibility**

- Four language options provides transport information to a larger user base, particularly tourists
  - Auckland International Airport had 19m visitors in 2017 and anticipates this to increase to 40m by 2044
- The app is free and easy to download

**Mobility suppliers**

- As the app is developed independently by the Government, suppliers have a greater incentive to participate
- The ability to offer in-app rewards and discounts allows mobility suppliers to reach new customers

*"The ability to see all companies in one place helped me make a smart choice."*

*RideMate App User, March 2018*

**Government**

- Enables data to be collected and used for transport planning

*"The data has provided valuable insight into our operational performance across both our assets and processes"*

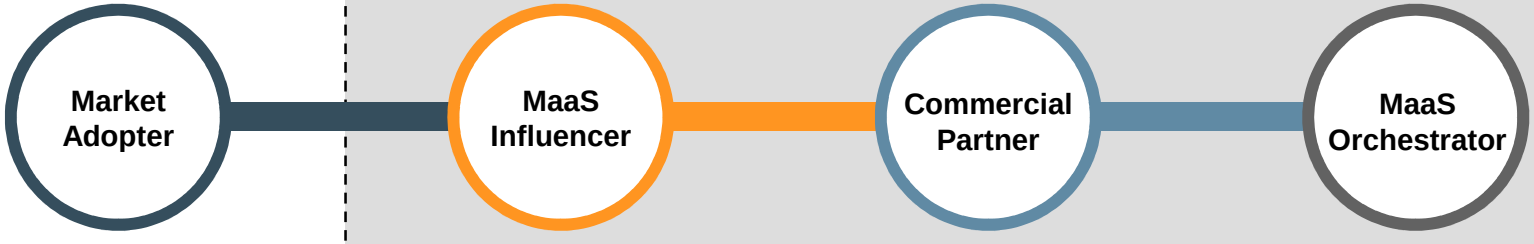
*Mark Croudace, Auckland Airport Operations, February 2018*

Source: NZTA; Apple; Technative; L.E.K. research



L.E.K.

# Governments appear to be struggling to decide the right participation model for MaaS




**Left to the market**

Let the market develop the MaaS platform and determine the terms and conditions. Open Government's retail channels to third-parties and provide open, unified APIs to Government's data

Have no formal role in the development and operation of the MaaS platform, but form relationships with key players to influence the MaaS platform

Form partnerships with third-parties to develop elements of the MaaS platform and negotiate the role of each partner, including their level of investment

**Full Control / Involvement**

Develop and control the end-to-end MaaS platform, integrating all mobility services, and providing the front-end customer app, back-office engine and payments engine

- Based on selected private conversations with Governments around the world, L.E.K's observation is that they are struggling to decide the right level of involvement
- The potential benefits of MaaS appear relatively clear:
  - use data for future planning and for real time network control / management
  - incentivise travellers to change behaviour (e.g., cycle, ride share)
  - enable informed policy planning as new types of transport proliferate
- Specific questions they are facing include:
  - Whether to establish/specify/control the MaaS platform themselves, or to allow multiple platforms to develop
  - Whether to contribute PT data, and payment infrastructure to MaaS platforms
  - What sort of commercial agreements are required with modal providers
  - Implications for contracting and subsiding existing services (e.g. buses)

# Section Summary: MaaS

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Speed of development*** | MaaS can be considered "digital infrastructure" supporting transportation<br><br>While the concept of MaaS has existed for several years, the speed of development has been relatively slow<br><br>This is attributed to:<br>- Government's taking time to decide their participation strategy for MaaS<br>- Difficulty in integrating payments into MaaS across multiple modes<br>- Difficulty securing commercial deals with service providers<br>- Lack of a clear and compelling proposition for customers | *Victoria should monitor developments in MaaS as an example of multi-party digital infrastructure, that may have analogies for the roll out of similar infrastructure for AVs (e.g. Sharing mapping data)* |
| ***Governments role*** | Many Governments have struggled to decide the right posture to MaaS<br><br>This has limited its speed of development as MaaS ideally needs access to Governments PT data and payments infrastructure<br><br>Governments are struggling to decide<br>- The extent to which they can / should control or influence MaaS<br>- Data protocols (for provision and receipt of data0<br>- Whether a single or multiple MaaS platforms should be allowed | *Victoria should monitor the approach Government's take to MaaS as an example of shared digital infrastructure, to identify potential lessons learned relevant for AVs and ZEVs* |

Source: EV Global Outlook 2017; ICCT 2017; Statista

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emissions Vehicles
- Findings about Autonomous Vehicles
- **Findings about other New Mobility market models**
  - Rideshare
  - MaaS
  - **On demand public transport**
  - Dockless bike share
- Implications for Victoria

# On demand public transport: Summary

- Demand responsive transport (DRT or “paratransit”) has existed for many years
  - most typically serve special needs customers, or low density areas
  - bookings are typically made in advance by phone, or Internet
  - services generally quite high cost requiring government subsidy, limiting their widespread adoption
- New technology (i.e. smart phones & scheduling software) has enabled a range of new business models to emerge, sparking considerable innovation and trial. However, some early efforts (e.g. Bridj, Kutsuplus) have floundered, and widespread adoption has been much slower than (commercial) rideshare
- There is significant on-going experimentation with the models around the world, via pilots, or selective introduction into new bus contracts. Sydney has been a leader in piloting on-demand
- While commercial deployment has been slow, there are a range of reasons to believe it will gain increasing traction over time (assuming Governments are willing to subsidise services)
  - poor utilisation of many bus services across PT networks
  - significant areas of population underserved by public transport
  - high demand for first/last mile travel to rail stations, not able to be met with car parks or large buses
- It remains unclear whether the winning model will be small, flexible bus operations operating under contract from government, or rideshare providers operating with subsidies and stricter accreditation

# On demand public transport (or DRT) has existed for a long time around the world, based on phone or internet bookings

| Jurisdiction | Examples |
|---|---|
| **Telebus, Melbourne** | Operating since 1977 when there was just a single service. Now c.10 services operating semi-fixed routes which deviate upon user request. Tickets for the service which operates in fringe urban areas can be booked in advance or purchased when boarding the service. Cost recovery in 2007 was 47% (high for DRT) |
| **TELE-BUS, Poland** | A demand-responsive bus service designed to better customise the public transport offering to citizens living in low density areas of Kraków. Began in 2007, with 300 clients per month at the beginning of operation, and c.2k per month a year later. The publically funded program observed cost savings as the service replaced select existing bus services after several years of operation |
| **Ring a Link, Ireland** | Ring a Link seeks to offer affordable, convenient transport for rural residents of several counties in Ireland. The services run in business hours Monday to Saturday and is publically funded. Services are demand-responsive and are door-to-door |
| **PubliCar, Switzerland** | The service is a flexible, demand-responsive door-to-door minibus service which can be booked via call centres. Developed by the public transport operator, Post Auto, the service is targeted at areas of low population density as well as small towns or times of low demand e.g. at night. Cost recovery for the service which serves 20k-30k users per year is c.25% |
| **MyBus, UK** | Operated by Strathclyde Partnership for Transport, MyBus was launched in June 2010 and is designed to serve people with mobility difficulties or who live in rural areas. The service can be used by people with a temporary disability for up to four months or anyone who lives in parts of rural Strathclyde no served by regular public transport services |
| **AmicoBus, Italy** | The service which operates in Rome includes real-time location, web-based booking and door-to-door capabilities. Three different transport operators manage the service and guarantee coverage across several different areas |

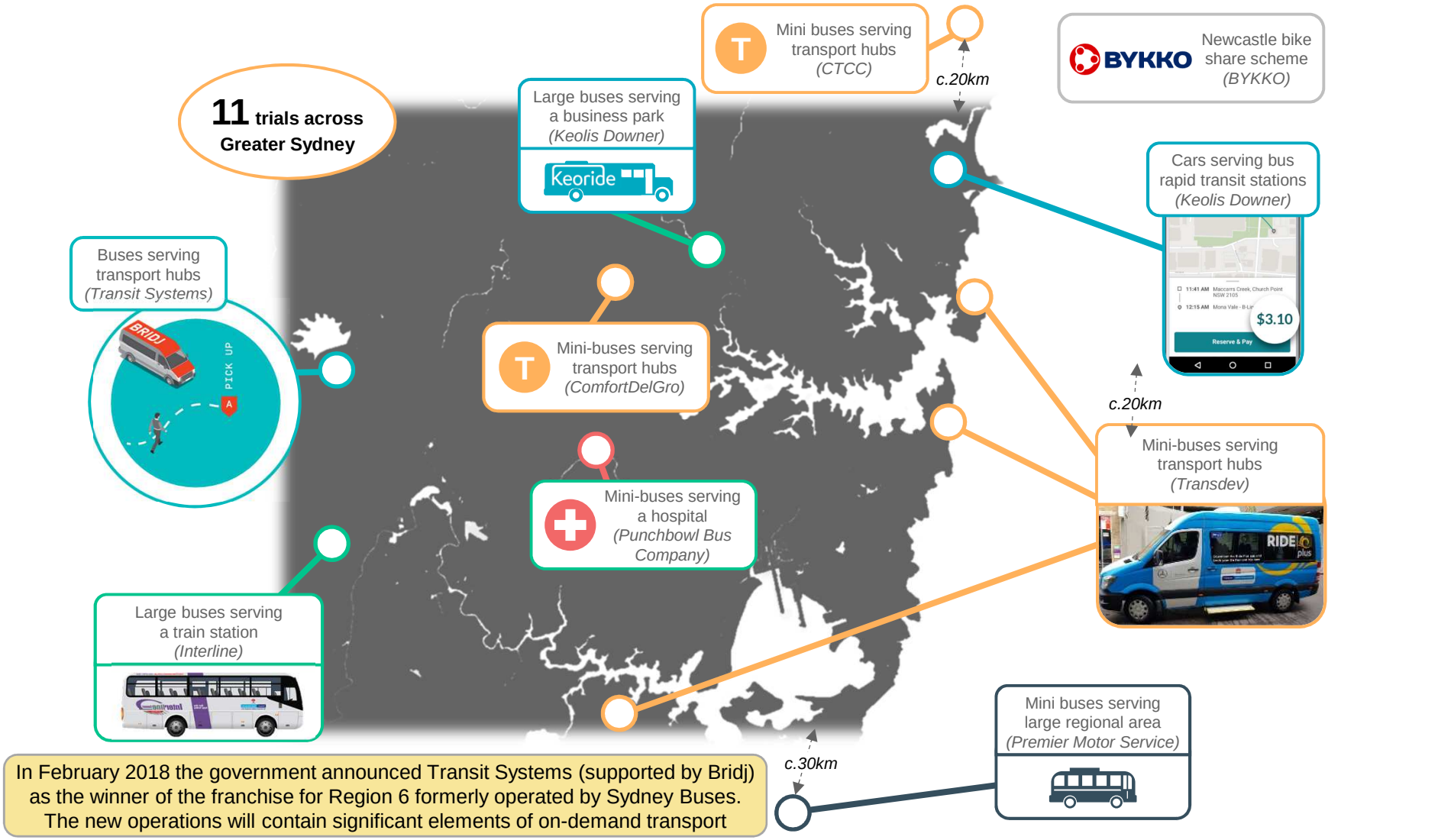
Source: L.E.K. research

# A range of innovative new business models have emerged, with some struggling to achieve commercial relevance or widespread uptake

| Jurisdiction | Examples |
|---|---|
| **Bridj, US** | An on-demand bus service with dynamically allocated passenger rendezvous points in selected areas with fares of $2 to $6. Launched in Boston, Kansas City and Washington between 2015 and 2016<br>Boston: Initial launch area for Bridj, and the most extensive implementation.<br>Kansas City: A collaboration with Kansas City Area Transportation Authority (KCATA), and Ford. One-year pilot which launched in March 2016 connecting two areas c.5km apart<br>Washington D.C.: Users charged a flat $5 fee for the journey between two specified areas<br>Bridj went into receivership in October 2016 but its assets were purchased by Transit Systems (Aust) |
| **Beeline, Singapore** | Launched in August 2015, Beeline is an experimental service led by government agencies (IDA, LTA) which partnered with private bus companies in order to provide an on-demand service. The routes are designed to better serve commuters who previously had difficulty making use of existing public transport |
| **Kutsuplus, Finland** | Now discontinued, Kutsuplus was an on-demand bus service which served around 100 square kilometres of Helsinki. The service was launched in 2013 with 10 buses, and later expanded to 15 before being shut down in December 2015 due to high costs |

Source: L.E.K. research

# NSW's on-demand trials are poised to provide deep learnings across a number of areas given the variety of services provided




Source: L.E.K. research and analysis; Transport for NSW

# NSW on-demand pilots utilise a number of drop off/pick up combinations, agreed on a case by case basis

| Drop off/pick up type | Description |
|---|---|
| **Total flexibility** | Within a defined boundary, on-demand pilots have access to pick up/drop off passengers anywhere |
| **Pre-determined fixed locations** | Virtual and existing bus stops on a fixed route where customers opt into a service at one of the defined locations |
| **Any point / address to a fixed point** | Pick up from any point, and drop off to a transport hub/key point of interest within the defined boundary |
| **Point determined by the operator** | Used to congregate demand, points are allocated by the operator and could include either the passengers home or fixed point such as a transport hub/key point of interest within the defined boundary |

Source: Transport for New South Wales; L.E.K. research and analysis

# While a number of technologies are being trialled across NSW in on-demand pilots, payments and customer searches are not yet integrated

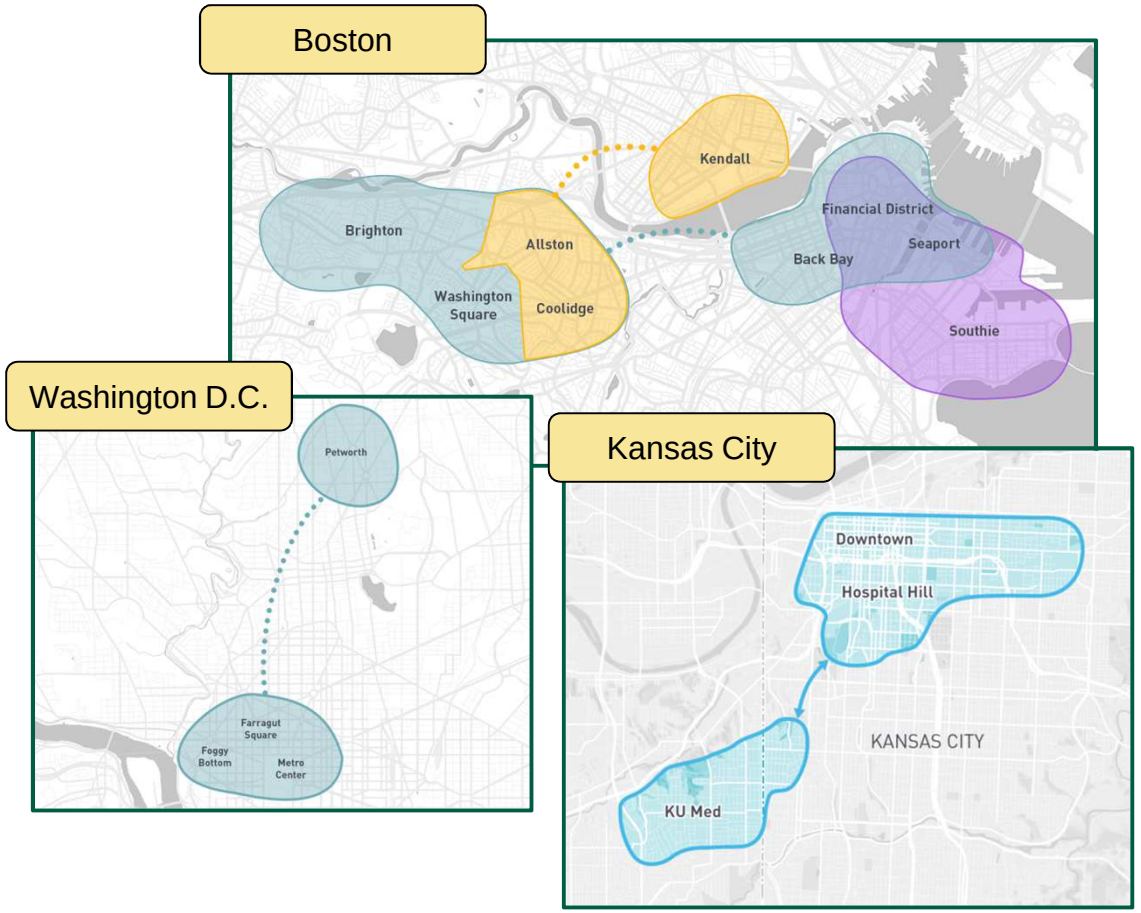
| Pilot | Keolis Downer - Northern beaches / Macq. Park (Keoride) | Transit Systems | Interline Connect | Punch Bowl Bus Company (POD) | Comfort Delgro (Our bus) | CTCC | TransDev | Premier Motor Service |
|---|---|---|---|---|---|---|---|---|
| **Technology** | Via Transportation | Bridj | Thoreb Australia | Dean Fribence | CDC | Unknown | Unknown | PODPI / Taxicaller |
| **Payments** | Not yet integrated – Opal pay coming soon | | | | | | | |
| **Customer search** | Not yet integrated into Government or private sector search apps | | | | | | | |

**Implications for Victoria: The NSW trials show that there are a range of different technology solutions available for on-demand transport, but integration of payments and search functionality will be required over time**

# BridjTransit was a demand-responsive bus service that operated in several large cities in the United States

## BridjTransit service

- BridjTransit was a demand-responsive bus service which serves passengers travelling between select areas
- Nearby users with proximate destinations received walking directions to a dynamically allocated rendezvous point for pick-up
- The service claimed to be c.40-60% more efficient than traditional transit methods due to its optimised pick-up and drop-off locations and operated in three US cities
  - Boston
  - Kansas City
  - Washington D.C.
- BridjTransit Boston serviced large parts of the Boston metropolitan area, while the Kansas City and Washington operations were focused on more select geographic parts of the cities




Source: Bridj

# The collapse of BridjTransit highlights the importance of integrating transit systems with public transport networks in a highly collaborative manner

| Case study: BridjTransit, Kansas City | |
|---|---|
| **Location** | • Kansas City's Bridj program provided demand-responsive transit to connect two fixed regions: the area surrounding Downtown Kansas City, and the area just beyond the state border around Kansas University Hospital<br>• Origins and destinations within these two areas were dynamically allocated based on user demand |
| **Problem / opportunity program sought to address** | • The program sought to connect the two areas by providing greater transport flexibility in a city where only c.1% of residents made use of public transport<br>• The intent of the program was to fill gaps in the current transportation offering in order to encourage residents to stop driving their own cars |
| **Role of Government / Partners** | • The Kansas City Area Transportation Authority operated the service. Ford had supplied 10 vehicles for the pilot program and urban technology company, Bridj handled the implementation as a whole |
| **Costs and Pricing Mode** | • KCATA spent US$1.3m on the pilot program<br>• Bridj was a for-profit company; in which the Kansas City operation was subsidised by the government<br>• In other regions such as Boston, typical fees for relatively short journeys were around $5. In Kansas City, the cost of each trip was $1.50 – payable through the mobile app |
| **Program success / failure and key outcomes** | • The program was supposed to show the world how the intersection between ride hailing and public transit can be successful, however the one year pilot trial failed to catch on and six months in, the vans had only provided less than 600 rides. |
| **Implications / Next steps** | • An attempted acquisition failed and the company entered bankruptcy<br>• Transit Systems bought the Bridj brand and technology and believes it can increase demand for Adelaide's bus services by improving connections between different regions |

**Key learnings:** It is believed that Bridj will be more successful in Australia because Transit Systems plans to integrate the 18-seat Hino Poncho buses with public transport networks, accepting (in Sydney) Opal cards

Source: L.E.K. research

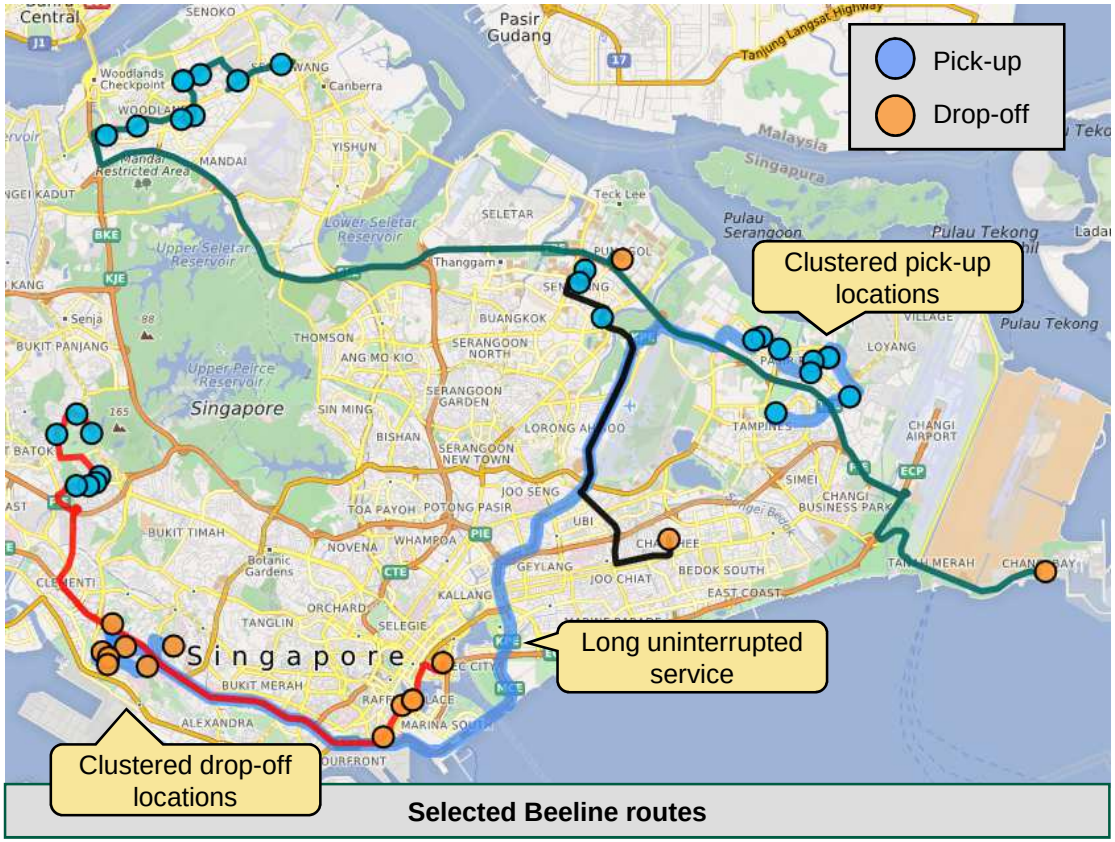
# Helsinki's innovative on-demand bus service, operated by the Helsinki Regional Transport Authority, failed due to high levels of cost to taxpayers

| Case study: Kutsuplus, Helsinki | |
|---|---|
| **Location** | • The service operated across the six municipalities of Helsinki capital region |
| **Problem / opportunity program sought to address** | • The program sought to increase the number of people using public transport instead of private vehicles and by changing the way that residents interacted with transport systems it was hoped that congestion could be reduced<br>• Kutsuplus offered the opportunity to provide a transportation method more efficient than private vehicle ownership and more flexible than existing public transportation options |
| **Role of Government / Partners** | • The program was a public-private partnership developed in collaboration between the Helsinki Regional Transport Authority (HSL), Split Finland Ltd., Aalto University and the Finnish Transport Agency<br>• The idea was created by The Department of Computer Sciences at Aalto University who then partnered with HSL, the Helsinki regional transport authority<br>• Both parties were involved in the testing phase as well as the coordination and implementation of the program |
| **Costs** | • The net cost was €7.9m to operate Kutsuplus from 2012-2015<br>• In 2015 the costs of a trip were as high as €15-20 |
| **Program success / failure and key outcomes** | • There was widespread commentary that the initiative had not been successful, although users of the service were highly satisfied<br>• Costs were very high; for instance, drivers were required to have a three-year fixed contract. Additionally utilisation wasn't at appropriate levels with public awareness relatively low<br>• The project did not have the chance to achieve the requisite scale to harness efficiencies that would have made the system more viable<br>• While the implementation of the service proved to be effective – with trips subsidised at around 80% , external economic conditions parlous, and Uber making a large-scale market entry at the same time – Kutsuplus was conceived in a difficult environment and suffered accordingly |
| **Implications / Next steps** | • The service was discontinued at the end of 2015 but serves to provide valuable insights into the implementation of a public-private demand-responsive transit solution implementation |

Source: L.E.K. research

# Beeline (Singapore) services multiple nearby stops at origin and destination, with few or no interruptions during the long journey in between

| Route | Origin | Destination | Approximate distance |
|---|---|---|---|
| B46 | Sembawang | Changi Naval Base | 40km |
| B47 | Choa Chu Kang | Changi Naval Base | 40km |
| B50 | Tampines West | Buona Vista | 25km |
| B51 | Tampines East | Buona Vista | 25km |
| B58 | Pasir Ris | Science Park | 35km |
| B59 | Kent Ridge | Pasir Ris | 35km |
| B60 | Bukit Panjang | Clean Tech Park | 15km |
| B61 | Bukit Batok | Anson Rd | 20km |
| B62 | Punggol | Buona Vista | 25km |
| B88A, B88B, B88C, B88D | Eng Kong | Beauty World MRT | 2-3km |
| B89 | Punggol | Chai Chee | 15km |
| B90 | Chai Chee | Sengkang | 15km |
| B91 | Sengkang | Chai Chee | 15km |
| B92 | Chai Chee | Punggol | 15km |




Selected Beeline routes

Source: OpenMapSurfer; Beeline; L.E.K. analysis

# Singapore Government's "Beeline" DRT model appears to be a more successful platform

| Case study: Singapore Beeline | |
|---|---|
| **Location** | • Beeline operates in metropolitan Singapore along routes which are not served well by conventional transport services<br>• Routes are typically 15-25 km and serve multiple nearby locations at origin and destination, with few or no stops during the middle of journeys |
| **Problem / opportunity program sought to address** | • The project seeks to improve customer experience by offering an affordable, flexible transport option to complement existing multi-modal transport options<br>• Users of public transport in certain areas face common challenges:<br>– existing routes not serving appropriate areas<br>– extensive queueing to catch a bus with no seats guaranteed<br>– changing routes several times on the same journey<br>• Importantly, beyond the immediate impact of service, Beeline was created for the purpose of providing a proof-of-concept for a new service model enabled by data analytics. It was conceived with the intention of encouraging other participants to provide their own offerings |
| **Program description** | • Beeline consists of a technological platform which links bus providers with customers in need. It caters to customers in the Singapore metro area who are not well served by other forms of transport, particularly commuters. The service offers adaptive and dynamic routes which are chosen based on crowdsourced suggestions<br>• The service operates in the mornings and evenings – targeting commuters<br>• Payment for the service is handled via smartphone, and users can track buses in real-time via the same application<br>• Passengers book seats on routes which have been defined by the system and services are dispatched when certain criteria are met e.g.: at least 20 people who are in need at a maximum of five pickup locations who can be reached within 15 minutes |

Source: L.E.K. research

# Since launch, the number of available routes has continued to build and operation of the buses themselves is commercially viable

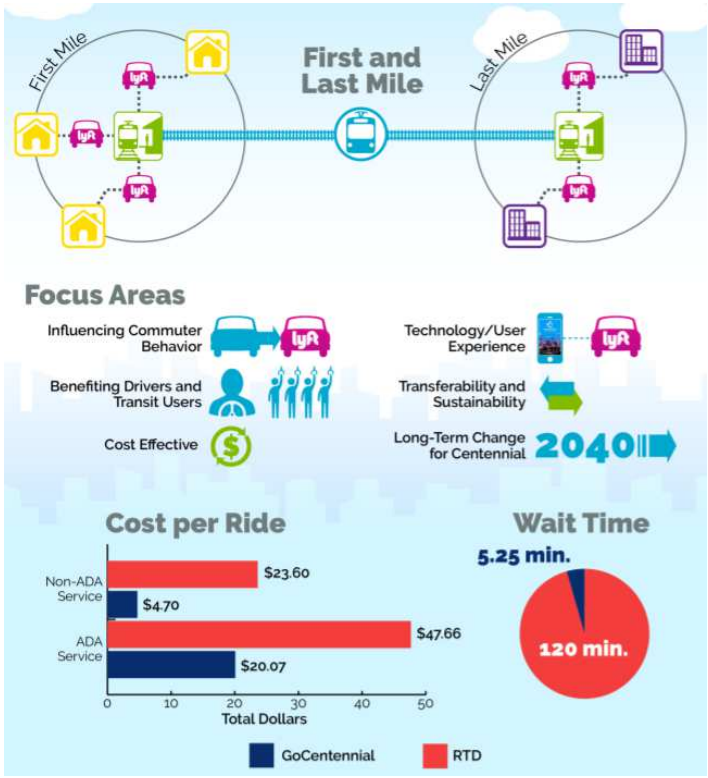
| Case study: Singapore Beeline | |
|---|---|
| **Role of Government / Partners** | • Beeline is a government-led project. The development of the technology on which the service relies was funded by the Infocomm Development Authority (IDA) and the Land Transport Authority (LTA) of Singapore. The scheme is one of many which seek to improve the lives of citizens by making use of data and technology<br>• The service is designed to make use of both data from the Beeline application as well as data collected from existing public transport systems. By combining the two sets, Beeline is better able to meet the needs of customers as well as ensure the pilot addresses appropriate areas<br>• Beeline makes use of private bus providers to actually drive the routes. The government agencies provide the data and the bus companies are then able to make decisions based on this information |
| **Pricing** | • The service is significantly cheaper than a taxi ride, with prices of S$4-6 over 2015-16<br>• Discounts are available for bulk bookings<br>• In order to promote the service, fares were reduced to S$2 in November |
| **Program timing** | • The service launched in August 2015 and is still operational |
| **Measures of volume involved** | • At launch, Beeline provided four bus routes and had modest patronage. Since then, the numbers of available routes, partner bus companies and passengers have all continued to build<br>• Within two months there had been 10,000 user suggestions for routes, with 300 tickets sold (2-3 per day on average)<br>• At July 2016 the Beeline app had been downloaded c.37,000 times and c.30,000 user suggestions had been made<br>• There are currently c.20 operational routes operated by c.10 buses<br>• An average of 15 routes per day are run by four bus companies. By the end of 2016, Beeline is looking to increase the number of bus companies to 10<br>• In the six months January to July 2016, c.5,500 tickets were sold to Changi Naval Base personnel |
| **Costs / subsidy** | • The technological components of the program are government funded and do not seek to be profitable<br>• Operation of the buses themselves is commercially viable, with prices set by the private bus companies |

Source: L.E.K. research

# Go Centennial launched a pilot program to address low ridership and transit dissatisfaction in Centennial, Colorado (1 of 2)

## *U.S. city partnership with Lyft*

- Launched in 2016, the City of Centennial launched the First and Last Mile program to address low ridership and transit dissatisfaction in Centennial, a key commuter suburb to and from Denver, Colorado
- Dry Creek Station, the one light rail station in Centennial, is not served by a fixed-route bus, and survey results indicate this as a key driver of low ridership
- RTD, the transit agency, provides a Call-and-Ride service to transport commuters to the station, but it is not well utilized because it requires advance sign up and exact cash upon pick up
- The First Mile and Last Mile program provided on-demand rides through Lyft and Via (for ramp access vehicles) for the 6-month pilot with the city paying for the first and last mile of transit to the station
- Lyft integrated with the Go Denver app and Via platform to create a convenient way to call rides on smartphones, and also created a call line for users without smartphones




Source: Go Centennial Report

# Go Centennial launched a pilot program to address low ridership and transit dissatisfaction in Centennial, Colorado (2 of 2)

***Successes and lessons learned from the pilot program***

- The pilot program met its mission to increase ridership on the light rail and to improve commuter experience
- The City of Centennial saw a 12% increase in ridership at the light rail station and understanding of latent rider demand in the city
- Commuters in centennial enjoyed wait times of 5 minutes vs. the previously scheduled intervals of up to 2 hours and lower transit costs with reduction in park and ride usage at station and average cost savings of $15-40
- The pilot program was successful overall, but there were a number of lessons to address before moving to full expansion including:
  - Integrating RTD agency's Call-and Ride service
  - Formalizing pick up and drop off locations
  - Better integrating call center with Lyft
  - Expanding duration, area, and hours of service
  - Better marketing service to commuters
  - More efficient accessible transport


Source: Go Centennial Report

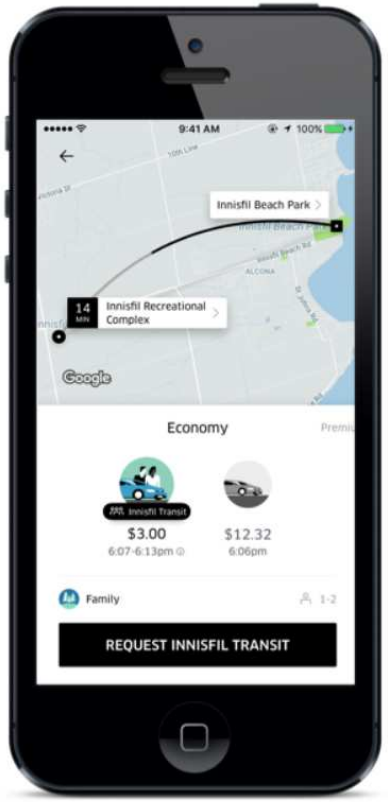
# The Town of Innisfil partnered with Uber to provide fixed rates to local transit hubs and discounts for local Uber rides

***First partnership with ride share service in Canada***

- The Town of Innisfil, 45 minutes from Toronto, partnered with Uber in May of 2017 to provide subsidized fares to and from transport and recreation hubs
- Innisfil ran a transit feasibility study in 2015 and found that at the high cost of AUD $270k annually for one route and AUD $615k annually for two routes, a new bus route was not feasible

  *"… Rather than place a bus on the road to serve just a few residents, we are moving ahead with a better service that can transport people from all across our town to wherever they need to go …"*

  *Gord Wauchope, Innisfil Mayor*
- Innisfil instead introduced a pilot program that cost AUD $100k to subsidize the difference between the cost of the Uber ride and the fixed rate as well as the discount of AUD $5 per ride for non-fixed Uber rates
- The pilot program is intended to reduce cost of transit for the commuter and connect commuters with local transit, while also providing a lower cost transit solution for the Town of Innisfil




Source: BBC, New York Times, Uber

# Section Summary: On demand public transport

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Road-related infrastructure*** | On demand public transport (in its smartphone enabled form) is very immature, with a number of cities conducting pilots, but virtually no widespread deployments (Sydney Buses region 6 will be one of the first signficaint deployments)<br><br>Early pilots have revealed that curbside infrastructure access is important to get right. In the Sydney pilots, operators required clarity about precise pick up and drop off locations (e.g. bus stops, shuttle stops etc.) | *Victoria should monitor the evolution of on demand public transport, for insights into how pick up and drop off locations may need to change with AVs* |
| ***Digital infrastructure*** | Initial on demand pilots have generally used bespoke applications for searching and booking rides. Payment has typically been by credit card<br><br>If on demand public transport takes off, greater integration or even common / standardized digital infrastructure may be required to normalize the customer experience<br><br>Governments will likely have a role to play in defining the standards or potentially providing this infrastructure, as well as integrating PT data and payment platforms | *Victoria should monitor the evolution of on demand public transport to see how Government's' involvement in the provision of digital infrastructure develops and potential implications for AVs and ZEVs* |

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emissions Vehicles
- Findings about Autonomous Vehicles
- **Findings about other New Mobility market models**
  - Rideshare
  - MaaS
  - On demand public transport
  - **Dockless bike share**
- Implications for Victoria

# Overview of bike sharing market

- There are over 1000 bike schemes across the world with more than 1m bikes in operation. The introduction of dockless bikes are growing the fleet numbers globally

- Key market players include:
  - **Docked Bikes**: These tend to be developed and operated in conjunction with city transport agencies
  - **Nextbike**: is a German run public bike-sharing operation operating more than 30k in Germany and other countries such as USA, UK, NZ, Poland, Croatia, Austria and Switzerland
  - **Dockless Bikes**: e.g.
    - MoBike
    - OFO
    - oBike

- The economics of bike sharing has little to do with the operations of the bike sharing schemes, and more to do with the data mining, advertising and interest earned on deposits
  - Product development of bike sharing schemes across the globe has invested in new channels of distribution to enable account registration, tracking via GPS and digital market
  - Sponsorship also plays a major role in the ongoing viability of schemes

- Bike sharing schemes globally are being disrupted by dockless bike sharing

- Dockless bikes have faced considerable criticism and vandalism, having been thrown into rivers and garbage, flooded pathways in busy pedestrian areas and led to many Governments introducing bike parking laws

Source: City Lab;

# The prevailing model (i.e. docked bike share), quickly becomes challenged by a new, more flexible model

## Evolution of bike share schemes

### 1st Gen

- ***Amsterdam*** (1964): 'White Bikes' were bikes painted white and scattered around the city. Scheme collapsed within days due to theft

### 2nd Gen

- ***Copenhagen*** (1995): 'ByCyklen' introduced heavy duty bikes designed for urban use. A coin deposit was used to unlock bikes, again theft was an issue due to the anonymity of the customer

### 3rd Gen

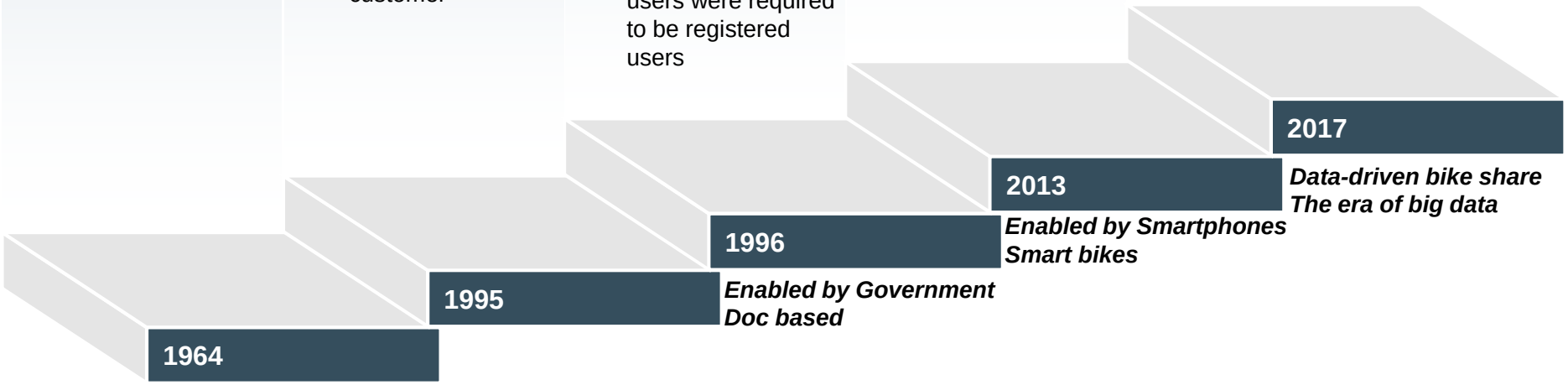
- ***Portsmouth University*** (1996): 'Smart' bikes introduced as a scheme called 'Bikeabout'.
- Required a magnetic stripe card to unlock the bikes for use, in turn reducing theft and vandalism as users were required to be registered users

### 4th Gen

- ***New York City***: City Bike's launched in 2013 with 332 stations and 6k bikes
- ***China***: Hangzhou Public Bicycle was funded $60m by the government to introduce 84k bicycles

### 5th Gen

- **Shanghai (2016):** Users grant permission to the platform to collect and share their movement data with third party providers
- The primary funding mechanism is data that can be used in mobility modelling and transport planning




Source: Polis 2017; L.E.K. research and analysis

# The economics of bike sharing has little to do with the operations of schemes, and more to do with data mining, advertising and interest earned on deposits

Due to the high value of assets required to create a reliable bike share scheme, bike share companies require significant investment from venture capitalists to become established. Returns on the investment are generated through four revenue streams

1. **Usage Charges**: Bike share schemes charge users for the time that they are using the bikes. Fees start at around $2/hour. Fees are typically not linked to the distance travelled, and are low in comparison to the asset maintenance and overheads

2. **Advertising:** There are two sources for advertising in the bike sharing ecosystem. The first is on the bikes themselves; baskets and panels in the frame allow adverts to be seen by a city even while the bike is not in operation. The second is within the app; revenue can be generated through pop-ups, side bars, or by allowing companies to pay for prominence on the in-app map

3. **Data:** In order to participate in bike sharing schemes, users must accept terms of service and privacy policies which allow the bike sharing schemes to share personal information with third parties. This data is a valuable tool in understanding movement, particularly short distance commutes that cannot be captured through the road network. The data can be sold to public and private sector organisations with a focus on mobility

4. **Deposits:** Many of the bike share schemes require a deposit or sign-up fee before riders can use the service. OBike requires a $69 deposit, and Reddy Go charges a $99 membership fee. This revenue can be used to purchase more assets, or simply used to earn interest

   - "Some of these companies have something like 100 million users in China - that is a lot of money to be sitting on.“ Dr Sandra Peter, from Sydney Business Insights at the University of Sydney's Business School

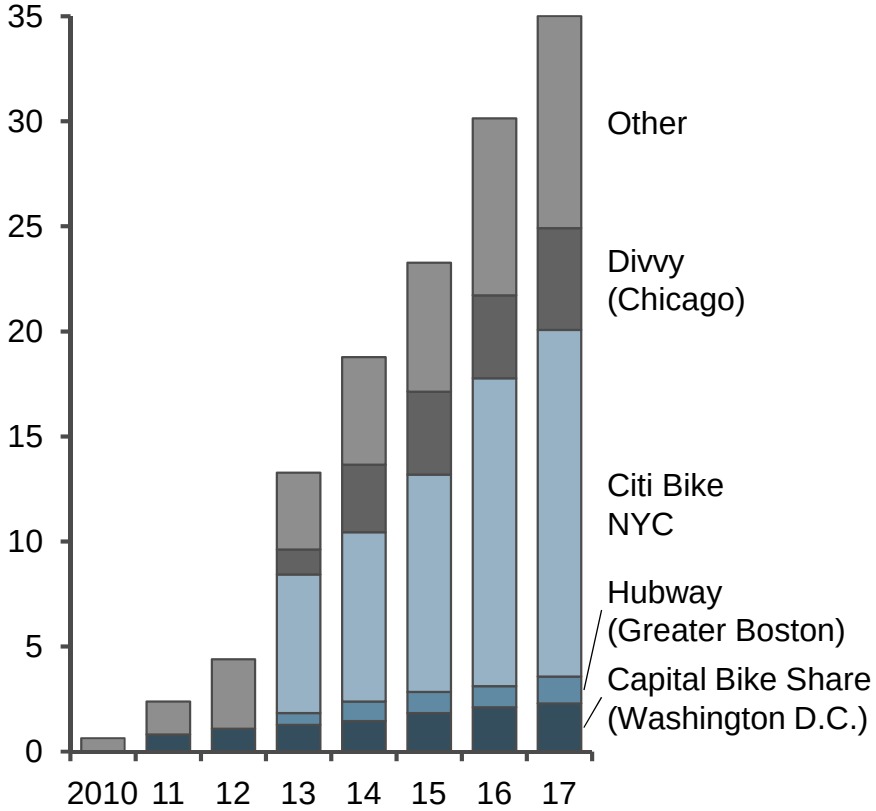
Source: Sydney Morning Herald; L.E.K. research and analysis

# Competitors will race to gain a leadership position, sacrificing yield for share in the near term

**Discounted fares are used to entice new customers and establish a customer base**

- In the bike share market, **discounted fares** are used to encourage users to overcome the initial hurdle, and to differentiate the product offering from other service providers
  - After its launch in Sydney, Ofo offered **free rides** for a month
  - Mobike charged a $1 deposit to ensure that payment methods had been correctly configured
  - Citi Bike rewarded users who referred a friend a free month of membership
- Among cities with station-based bike share systems, **32% have an income-based discount program.** Platforms are made available and attractive to all members of society to establish a large active user base. Discounts are offered using income thresholds or living in affordable housing as criteria

**Total bikeshare trips in the USA (2010-17)**
Millions of trips




Source: NACTO; Broadsheet Sydney; Timeout Sydney; Citibike

# Government backed docked bike share schemes have increasingly been replaced by privately funded dockless bike share schemes, such as in Singapore

## Docked

- Docked bike schemes are more commonly associated with government agencies. They provide the benefits of:
  - having bikes in specific locations, such as station entrances to reduce the first and last mile dilemma
  - reduced cluttering of pavements and public spaces with parked bikes, which can cause issues for mobility scooters
  - reduced vandalism and theft

## Dockless

- Dockless bike schemes are more commonly associated with private companies. They provide the benefits of:
  - an easier end of trip as the bikes can be parked at the rider's destination
  - lower initial investment as docking facilities are not required

## Singapore Case Study

- Governments are struggling to justify the expenditure on docked bike schemes due to the presence of dockless bike schemes
- In Singapore, the Land Transport Authority shelved plans for a government-backed docked bike scheme. 13 tenders had been received from firms wishing to partner with the LTA on the scheme, and more than 2,000 bicycles were planned to be included in four regions across the city alongside 210 docking stations
- However due to the influx of private dockless bikeshare companies, the forecasted revenue and utilisation reduced to a point that the LTA found the scheme to be unviable and cancelled the programme nine months before its launch
- *"The ongoing plans by the private dockless bike-sharing system operators have obviated the need for a government-run system backed by government grants," LTA said*
- Similar programmes in London and Taipei have required public sector funding for sustainability

Source: The Straits Times

# A "hands off" regulatory position can lead to community backlash over safety / nuisance with local councils having to step in to fill a regulatory void

## Issues with dockless bike schemes

- There are a number of issues with dockless bike schemes from the perspective of local councils
  - **Discarded bikes**
    Dockless bikes have been left in locations that clutter footpaths and hamper pedestrian access. In extreme cases the bikes are discarded in locations that makes them unusable, such as over cliffs and in rivers. In 2017 contractors working for oBike fished 42 bicycles out Melbourne's Yarra river
  - **Reduced utilisation of docked bike schemes**
    Brisbane's docked bike program cost $13 million to date, however utilisation of the public bike sharing scheme has decreased with the presence of dockless bike schemes
- There a number of solutions being trialed
  - The City of Sydney commissioned a study which found that it may have the "potential to buck the low usage trend" because of its higher density living and lower level of car ownership compared with Brisbane and Melbourne
  - Sydney Lord Mayor Clover Moore said well-run dockless bike services could supersede the need to roll out a docked system at "great cost to ratepayers and limited to a specific local area"

## Regulation of dockless bike schemes

- Following the end of a three-month trial on guidelines for share bikes, mayors from six Sydney councils called for "immediate action" from the state government on laws covering dockless share bikes
- The councils have also agreed to work together to propose new state regulation that can make commercial bike-share schemes "succeed without local communities bearing the costs". Operators are required to:
  - introduce geo-fencing for bikes, allowing them only to be parked in designated parking zones
  - have public liability insurance
  - move bikes in dangerous spots within three hours
  - offer incentives to customers to relocate bikes in built-up areas
  - send usage data, including origin and destination information to councils
- Chinese cities are also moving to regulate bike sharing services following the rush to entry by competing providers resulting in vast numbers of bicycles congesting and being abandoned in public spaces
- Melbourne will issue fines of $3000 per bike left uncollected
- Singapore has signed an MOU with 5 bike share schemes to reduce disamenity from dockless bike share

Source: news.com.au; Sydney Morning Herald; The Atlantic

# Section Summary: Dockless bike share

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Infrastructure requirements*** | Dockless bike share has quickly overtaken docked bike share in popularity due to a lower cost structure and better consumer proposition<br><br>While dockless bike share does not require additional infrastructure there have been unintended consequences from a "hands off" regulatory posture, in terms of public safety and urban amenity | *Victoria should monitor the development of dockless bike share for potential insights relevant to the roll out of AVs and EVs on infrastructure* |
| ***Public amenity*** | Governments are now responding to public amenity issues by imposing regulation and fines on bikeshare operators, and in some cases providing new infrastructure<br><br>Melbourne will fine bike share operators AUD $3k if they fail to collect a bike within 1-2 days of being notified of its location<br><br>Singapore has signed an MOU with bikeshare providers with protocols for removing badly parked bikes. Singapore is also introducing designated bike parking areas and trialing geofencing technology for bike parking | *Victoria should monitor the development of dockless bike share for potential insights relevant to the roll out of AVs and EVs on public amenity* |

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- **Implications for Victoria**
- Appendix

# The implications for Victoria have been distilled from the international scan to identify potential actions to address opportunities, barriers and risks

**Implications for VIC**

- The International Scan has highlighted that:
  - there is **a lot of activity** in key markets for each technology
  - there are **many examples and options** for potential Victorian government intervention depending on its broader policy outcomes for AVs and ZEVs
- This section **distils the potential implications for Victoria** from the findings through the International Scan. This is done for each technology in four steps
- **Firstly**, a number of **domains** are identified for each technology that present potential issues which could be addressed via **government intervention**
- **Secondly**, **objectives** are established for the potential interventions and these **interventions are classified** into three categories where it appears that Victoria:
  - **"should act"** – this is typically where significant **barriers** exist to the uptake of AVs or ZEVs
  - **"could act"** – where **opportunities** or **risks** exist where government intervention can accelerate or decelerate technology uptake, or influence achievement of the identified objectives for a potential intervention
  - **"does not need to act"** – this is typically where the private sector and consumers appear to effectively address potential issues without government intervention, or where further investigation of the issue appears necessary
- **Thirdly**, the potential **impact** of the intervention is qualitatively assessed on a scale of low to high by considering the strength of evidence from overseas markets and applying experience and judgment, and the level of **certainty** represented by shading to reflect the strength of evidence from overseas markets or maturity of technology involved
- **Finally**, we outline starting "postures" for potential interventions about key AV and ZEV-related assets that take into account where Victoria may be the "setter" of an approach or "taker" of approaches established overseas, and then describe examples of potential triggers to re-evaluate or change these postures as technologies and markets develop in Australia and around the world

# Implications for Victoria associated with Electric Vehicles (1/3)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on EV uptake | Key considerations |
|---|---|---|---|
| **Fleet – Vehicles** | | | |
| ***Providing financial incentives for EV uptake*** | Victoria could consider up-front financial incentives to help achieve ICE parity, accelerate uptake and reduce emissions | L — H | Given the speed at which EVs appear to be approaching cost-parity with ICEs, any incentives would need short time horizons, caps and regular review |
| ***Providing non-financial incentives for EV uptake*** | Victoria could consider special EV road access rights and privileges to accelerate uptake | L — H | Given the reduced attractiveness of special access as usage increases, these incentives would need regular review |
| ***Establishing vehicle $CO_2$ emission standards*** | Victoria could consider vehicle $CO_2$ standards to accelerate uptake | *Short term* *Long term* L — H | Australia's lack of vehicle emissions standards limits OEM interest in bringing low emission models to this market |
| ***Banning ICE vehicle sales*** | Victoria could consider a ban on ICE vehicle sales to accelerate uptake | *Short term* *Long term* L — H | This type of strong government intervention may have adverse impacts on mobility options, particularly for lower income groups |
| ***Purchasing EVs for government vehicles and public transport*** | Victoria could consider government procurement to accelerate uptake and assist to remove barriers | L — H | Material government demand for vehicles means procurement policies directly contribute to EV uptake and catalyse other investment in supporting infrastructure |
| **Infrastructure – Energy** | | | |
| ***Supporting investment in zero-emission generation*** | If zero "well to wheel" EV emissions are desired, then Victoria would need to facilitate greater investment in zero emissions electricity | *Tailpipe* *Wheel to well* L — H | Greater zero-emissions generation is causing challenges for energy system security around the world, and it is not clear whether "smart charging" / V2G will mature to promote system stability and ensure EVs are charged from zero emissions sources |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Electric Vehicles (2/3)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on EV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Energy (continued)** | | | |
| ***Supporting large-scale electricity network upgrades to support EVs*** | Victoria should further investigate grid impacts of EVs under a range of technology scenarios – we note this is part of Infrastructure Victoria's work program | *Unclear* L H | Given EV uptake and maturity of a number of EV technologies, there is material uncertainty about the appropriate energy infrastructure response for EVs to ensure energy system security |
| ***Supporting development of public charging in Metro areas*** | Victoria could consider to reduce "range anxiety" and barriers for some segments of the population for whom home charging is not an option | L H | The private sector generally appears effective in developing public charging infrastructure in Metro markets – it would appear that any financial support should be carefully targeted |
| ***Supporting development of public charging in Regional areas*** | Victoria should consider to ensure access and facilitate long-distance EV use | L H | Regional areas are unlikely to be prioritised in private sector rollouts beyond what has been seen from Australia's autoclubs, and public charging infrastructure could address a potential "range anxiety" barrier to uptake for certain users |
| ***Facilitating installation of home and business charging in selected locations*** | Victoria could consider to promote access to EV technology and reduce demand for public charging | L H | The case is strongest where this is limited to certain building types or locations that remove barriers to EV use for certain segments of the population (especially inner city, rented, and high-rise accommodation) |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Electric Vehicles (3/3)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on EV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Energy (continued)** | | | |
| ***Subsidising installation of home charging*** | Victoria could consider to promote access and reduce demand for public charging | L H | To date, consumers and the private sector generally appear to be effective in developing home charging infrastructure – it would appear that any financial support should be carefully targeted |
| ***Supporting adoption of Type 2 plug standard*** | Victoria could consider to promote investment certainty for consumers and the private sector | L H | Existing private sector activity and government interventions appear to have effectively addressed this issue |
| ***Supporting adoption of "fast charging" standard*** | Victoria could consider to promote investment certainty for consumers and the private sector, and enable optimal land use for public charging | L H | There is moderate uncertainty about which standard should be adopted. There is a greater case for supporting fast charging in public charging. Home fast charging may adversely impact energy system security. |
| ***Supporting adoption of "smart charging" and demand management*** | Victoria could consider to promote investment certainty and improve energy system security | *Unclear* L H | While "smart charging" and demand management have potential for improving energy system security, the standards and applications are not mature, presenting challenges for investment in the digital and physical infrastructure required to enable it |
| ***Supporting adoption of vehicle to grid (V2G) technology*** | Victoria could consider to promote investment certainty and improve energy system security | *Unclear* L H | While V2G has potential for improving energy system security, V2G standards and applications are not mature, presenting challenges for investment in the digital and physical infrastructure required to enable it |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Hydrogen Vehicles (1/2)

**Implications for VIC**

| | Categorisation and key policy levers identified | Qualitative impact on HFCV uptake | Key considerations |
|---|---|---|---|
| **Fleet – Vehicles** | | | |
| ***Providing incentives for HFCV uptake*** | Victoria could consider financial and non-financial incentives for HFCV uptake |  | Given the relative immaturity of hydrogen industry and lack of refuelling infrastructure this would be a low priority until other elements are in place. Not observed internationally outside of Japan |
| ***Providing subsidies for hydrogen fuel cost*** | Victoria could consider subsidising fuel costs to make HFCVs ownership more attractive |  | Access to hydrogen refuelling appears to be a greater barrier than cost. This could be considered if other elements are in place |
| ***Establishing vehicle $CO_2$ emission standards*** | Victoria could consider vehicle $CO_2$ standards to accelerate uptake |  | Australia's lack of vehicle emissions standards limits OEM interest in bringing low emission models to this market |
| ***Aligning on quality standards for hydrogen fuel*** | Victoria could consider aligning to ISO 14687-2 purity standard to promote alignment |  | OEMs already appear to have aligned on the ISO 14687-2 standard, but formal adoption may provide some limited improvement in investment certainty for the Victorian private sector and consumers. The development of higher EU standards should be monitored |
| ***Purchasing EVs for government vehicles and public transport*** | Victoria could consider government procurement to accelerate uptake and assist to remove barriers |  | In contrast to EVs, the lack of economic vehicles and re-fuelling suggests this would achieve little until the other industry elements are in place |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Hydrogen Vehicles (2/2)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on HFCV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Energy (continued)** | | | |
| ***Supporting development of zero-emissions hydrogen industry*** | If HFCV uptake is desired Victoria could support the development of zero-emissions hydrogen generation, and hydrogen industry more broadly |  | This is a key barrier to overcome, and other markets have also not yet developed mature zero-emissions hydrogen industries for HFCVs or otherwise |
| ***Supporting development of hydrogen refuelling infrastructure*** | If HFCV uptake is desired, Victoria should consider seeding investment in hydrogen re-fuelling infrastructure |  | Governments have supported initial investment to kick start the sector, and are seeking greater private sector responsibility for subsequent development hydrogen refuelling infrastructure. However, there is limited evidence of private sector investment in hydrogen refuelling infrastructure in regional areas, where there may be a greater need for government support |
| ***Aligning on standards for hydrogen refuelling infrastructure*** | Victoria could consider adopting ISO standards relating to the production, storage, transport, measurement and use of hydrogen |  | The private sector and OEMs already appear to have aligned around these standards, but formal adoption may provide some limited improvement in investment certainty for the Victorian private sector and consumers |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Autonomous Vehicles (1/4)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on AV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Transport** | | | |
| ***Investment in general road infrastructure*** | Victoria should not consider without evidence of a fundamental incompatibility of Victorian roads with AVs | L — H | The international scan suggests that OEMs and governments expect AVs will "take the network as they find it". There may be a case for some specific investments to accelerate maturity, and for optimisation. |
| ***Increased investment in road maintenance*** | Victoria should monitor the impact that AVs will have on road maintenance | *Long term Short term* L — H | It is possible that road standards may need to be higher to accommodate AVs, at least in the short term, and that increased traffic volumes may lead to greater maintenance. While this point remains uncertain, Victoria may need to budget for higher levels of recurrent road maintenance spending |
| ***Providing information on planned disruptions*** | Victoria should consider providing regular updates to maps for planned disruptions to the network | *Long term* L — H | Given government involvement in road provision, there may be a need for government to provide information on planned disruptions to enable effective use of AVs in the presence of roadworks. It is unclear exactly how & what role government or private sector will take. |
| ***Changing investments in car parking infrastructure*** | Victoria should consider how demand for car parking will change in the future when investing in and making rules about parking infrastructure | L — H | Whilst change to parking demand with AVs (and rideshare and ride pooling) appear likely, the timing and extent of impact on and demand for parking infrastructure remains unclear. Beyond building in flexibility into parking infrastructure, the Victorian Government should consider parking infrastructure in the context of other policy issues and Victoria as a significant parking asset owner |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Autonomous Vehicles (2/4)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on AV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Transport (continued)** | | | |
| ***Modification to curb-side access infrastructure*** | Victoria should consider this to promote transport system efficiency, particularly to support shared AV ownership models | L — H | Trends in rideshare indicates the likely increased need for access infrastructure to cope with increased drop-off. This would be particularly so for shared AV ownership models. |
| ***Investing in improved line markings*** | Victoria could consider this to promote better compatibility with AV sensor technology for accelerating AV maturity | *Long term* *Short term* L — H | Improving and widening line markings was the key example of changes to road networks that are occurring now for AVs. As sensor and AV technology matures, this may not be required |
| ***Standardising signs*** | Victoria could consider this to promote better compatibility with AV sensor technology for accelerating AV maturity | *Long term* *Short term* L — H | This is also seen as a challenge in other markets, including the US. As sensor and AV technology matures, this may not be required |
| ***Modifying slip lanes*** | Victoria could consider this to promote better compatibility with AV sensor technology and algorithms for accelerating AV maturity | *Unclear* L — H | It is unclear whether improved technology will overcome potential need to modify slip lanes to promote traffic flow in environments with platooning, or where automated driving systems struggle to interface with other traffic |
| ***Road space allocation for AV vehicles and dedicated lanes*** | Victoria could consider this to optimise AV operations although the weight of evidence is that dedicated lanes will not be required to roll out AVs | *Unclear* L — H | As there does not appear to be a need for investment to make Victorian roads AV-ready, any design changes should focus on transport system efficiency and optimising AV usage, such as for platooning and its implications for slip lanes |
| ***Certifying roads as AV compatible*** | Victoria could consider this to promote readiness of the public and focus investment and testing activity | *Unclear* L — H | It is not yet clear if this will be necessary beyond trials. It is more likely to be applicable in more remote locations where road conditions are more variable |

**Legend:** Should act | Could act | Does not need to act | L High certainty level | L Medium certainty level | L Low certainty level

# Implications for Victoria associated with Autonomous Vehicles (3/4)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on AV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Communications** | | | |
| ***Support for sensor standards*** | Victoria should not consider without evidence of market failure | L ▼ H | In-vehicle sensor development appears to be driven by the private sector and OEMs without obvious need for coordination or other potential sources of market failure |
| ***Support for mapping*** | Victoria could consider investing in mapping to remove the potential short-term barrier of mapping data, potentially focused on regional areas | L ▼ H | The private sector generally appears to address its own mapping needs |
| ***Choice of 5G spectrum and standards*** | Victoria should not consider further action without evidence of market failure | L ▼ H | Australia already appears to have made spectrum decisions and appears sufficiently aligned to other markets |
| ***Support for 5G investment*** | Victoria could consider supporting investment in greater 5G coverage to support connections to AVs | L ▼ H | It appears clear that AVs will not require 5G connectivity for operation, but it may be an important enabler for more efficient transport system operations and shared ownership. There may be a stronger case for support in regional areas, but this remains unclear |
| ***Choice of DSRC spectrum and standards*** | Victoria should not consider further action without evidence of market failure | L ▼ H | Australia already appears to have made spectrum decisions and appears sufficiently aligned to other markets, and there appears to be limited role for government intervention other than potentially leveraging it for C-ITS applications |

**Legend:** Should act | Could act | Does not need to act | L H High certainty level | L H Medium certainty level | L H Low certainty level

# Implications for Victoria associated with Autonomous Vehicles (4/4)

**Implications for VIC**

| Domain and potential intervention | Categorisation and key policy levers identified | Qualitative impact on AV uptake | Key considerations |
|---|---|---|---|
| **Infrastructure – Communications (continued)** | | | |
| ***Investment in connected intelligent transport system infrastructure (C-ITS)*** | Victoria should only consider C-ITS investment in the near term within the broader network management / smart cities approach | *Unclear* L — H | The full realisation of the benefits of AVs from a network outcome perspective will likely require some form of C-ITS enabled network management capability, but it is not at a stage of maturity to make significant investments for AVs |
| ***Promoting transport data brokerage*** | Victoria could consider promoting transport data brokerage as a solution to the data integration challenges involved in the provision of data for V2X applications | *Unclear* L — H | The Victorian Government should periodically evaluate the need for a central organisation serving as a 'data broker' to consolidate and share real time transport data feeds within a single environment by considering the barriers to information flows across the transport value chain and responses adopted in international markets |
| **Fleet – Vehicles** | | | |
| ***Promoting Victoria as a trial location*** | Victoria could consider any of these options to promote readiness of the public and any AV adaptation required by OEMs to suit Victorian conditions | L — H | While each of these interventions could have merit, the objectives, benefits and investments in trials would need to be clearly articulated, as part of Victoria's broader policy objectives |
| ***Clarifying and streamlining obligations for trial participants*** | | L — H | |
| ***Supporting investment in trial locations*** | | L — H | |

**Legend:** Should act | Could act | Does not need to act | L — High certainty level | L — Medium certainty level | L — Low certainty level

# Example triggers to re-assess posture – Electric Vehicles (1/2)

**Implications for VIC**

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Fleet – Vehicles** | | | |
| ***Government vehicles and public transport*** | Government fleet and assets used to provide services under government contracts. Rules determining procurement policies for government assets, and influencing private investment to align with contracts | Shift to EVs will occur through normal procurement cycles where there is a business case to do so – no obvious need for intervention to set specific rules/targets, unless there is a strong desire to accelerate uptake | Decision to accelerate adoption via signalling or "pump priming". Earlier than expected commercial case for adoption. Broader national policy to accelerate adoption. Lack of grid readiness favours delayed adoption |
| **Infrastructure – Energy** | | | |
| ***Zero-emissions generation*** | Small number of high value/long-lived (private sector) assets. Direct influence over government investment, as well as rules enabling private sector investment, within NEM parameters | Current policy settings appear to be delivering new privately funded zero-emissions generation capacity – limited reason for government intervention | Insufficient (or higher than expected) private sector investment in zero-emissions generation. Increase in vehicle emissions, favouring acceleration of EV adoption |
| ***Electricity Network*** | Very small number of entities making high value investments under regulatory regime – substantial influence over government investment and support for private investment within NEM parameters | Case for substantial investment unclear. Investigate grid impacts further and decide need for active intervention | Material uptake of "fast charging" by home users. Lack of planning from network owners. Load profile causing network issues in international markets with more EVs |
| ***Public charging*** | Assets all privately owned. Substantial influence over new government investment, as well as rules enabling private sector investment environment | Charging infrastructure not considered a significant barrier to take up. Private sector roll outs occurring in markets with higher EV uptake, and in Australia: Limited/ no case for intervention other than "pump priming" | Charging infrastructure lags EV adoption. Clear case for targeted intervention (e.g. country or inner city with no off street parking). Desire to "prime pump" |

# Example triggers to re-assess posture – Electric Vehicles (2/2)

Implications for VIC

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Infrastructure – Energy (continued)** | | | |
| ***Home charging*** | Very widespread investments in local / private assets – substantial influence over rules enabling private investment | Barriers to EV home charging similar to other utilities – potential to address through similar approaches (tenant rights, infrastructure access, building requirements) | Evidence of low EV uptake amongst segments of the population with challenges for home charging once EVs hold a material share of car parc (e.g. >10%) |
| ***Plug type*** | Victoria will be a "taker" of plug technology from overseas / OEMs – could set rules to reinforce market outcomes, but unlikely to set initial direction | Australia has already converged on Type 2 plugs without government intervention – no obvious reason for government intervention | Development overseas or in Australia that suggests Type 2 plugs not the default standard |
| ***Fast charging standard*** | Victoria will be a "taker" of fast charging technology from overseas / OEMs – could set rules to reinforce market outcomes, but unlikely to set initial direction | Market should be expected to converge on fast charging standard in same manner as plugs without government intervention – no obvious reason for government intervention | Multiple, incompatible public charging networks emerging<br>Government investment in public charging |
| ***Smart charging / demand management standard*** | Victoria will be a "taker" of smart charging / demand management technology from overseas / OEMs for vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction | Need and benefits unclear at present maturity – once standards become clearer to specify as rules, there may not be a strong need for government intervention | Clear standard choices available but not adopted by market, and substantial investment in electricity network required for EVs due to consumer EV charging patterns |
| ***Vehicle to Grid standard*** | Victoria will be a "taker" of V2G technology from overseas / OEMs for vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction | Need and benefits unclear at present maturity – once standards become clearer to specify as rules, there may not be a strong need for government intervention | Successful utilisation of V2G overseas<br>V2G demonstrated to be low-cost means of providing greater energy system security relative to alternatives |

# Example triggers to re-assess posture – Hydrogen Vehicles

**Implications for VIC**

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Fleet – Vehicles** | | | |
| ***Government vehicles and public transport*** | Government assets and assets used to provide services under contracts with government – control over rules determining procurement policies for government assets, and influencing private investment to align with contracts | Shift to HFCVs will be expected through normal procurement cycles where there is a business case to do so – no obvious need for government intervention to set specific rules, unless strong desire for rapid uptake | Less consumer choice available than in comparable markets requiring market development<br>Other policy reason to achieve rapid uptake of HFCVs for these assets |
| ***Quality standards for hydrogen fuel*** | Victoria will be a "taker" of fuel standards from overseas / OEMs for vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction | Need and benefits unclear at present maturity – once standards become clearer to specify as rules, there may not be a strong need for government intervention | Less consumer choice available than in comparable markets. Evidence that standards are holding back market development. |
| **Infrastructure - Energy** | | | |
| ***Zero-emissions hydrogen generation*** | Relatively small numbers of high value investments – substantial influence over government investment, as well as rules enabling private sector investment environment. | Insufficient demand for hydrogen from HFCVs – limited reason for government intervention without greater demand | Substantial uptake of HFCVs in overseas markets<br>Increase in emissions caused by increasing HFCV uptake<br>Broader policy ambitions for Hydrogen sector |
| ***Hydrogen refuelling infrastructure*** | Widespread investments in local assets – substantial influence over government investment, as well as rules impacting private sector investment requirements | Insufficient demand for hydrogen from HFCVs – limited reason for government intervention without greater demand | Substantial acceleration of uptake of HFCVs in overseas markets<br>Hydrogen refuelling infrastructure lagging comparable markets<br>Poor balance of public safety vs. cost of infrastructure |

# Example triggers to re-assess posture – Autonomous Vehicles (1/3)

**Implications for VIC**

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Infrastructure - Transport** | | | |
| ***General road infrastructure*** | Very large, mostly public assets – government investment possible, as well as rules about private sector standards | No change in investment or rules beyond specifics below | Change in OEM approach. Clearer optimisation cases. Greater international investment changing the nature of general road infrastructure. Desire to accelerate pilots |
| ***Road maintenance*** | Very large, mostly public assets – government investment possible, as well as rules about private sector standards | Investment and rules same or better standard as now | Change in approach internationally. Greater evidence that higher standards will be required |
| ***Parking infrastructure*** | Large numbers of public and private assets – government investment possible, as well as rules about private sector standards | Examine more closely prior to major investments. Build optionality into design | Clearer evidence of rideshare impact on car park assets<br>Greater clarity over AV impacts and "parking" requirements (e.g. recharge) |
| ***Curbside access infrastructure*** | Very large numbers of small, mostly public assets – government investment possible, as well as rules about private sector standards | Don't mandate investment / rule changes for AVs alone. Build in optionality where possible | Clearer evidence of impacts from rideshare. Greater confidence in potential AV impacts |
| ***Line markings*** | Very large numbers of small, mostly public assets – government investment possible, as well as rules about private sector standards | Investment / rules in line with leading jurisdictions with mature, publicly available AV tech | Evidence from international markets that enhancement is required. Desire to accelerate pilots |
| ***Road signs*** | Very large numbers of small, mostly public assets – government investment possible, as well as rules about private sector standards | Investment / rules in line with leading jurisdictions with mature, publicly available AV tech | Evidence from international markets that enhancement is required. Desire to accelerate pilots |
| ***Slip lanes*** | Large numbers of small, mostly public assets – government investment possible, as well as rules about private sector standards | Investment / rules in line with leading jurisdictions with mature, publicly available AV tech | Evidence from international markets that enhancement is required or desirable (e.g. due to platooning or smoother traffic flow). Desire to accelerate pilots |

# Example triggers to re-assess posture – Autonomous Vehicles (2/3)

Implications for VIC

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Infrastructure – Transport (continued)** | | | |
| ***AV lanes*** | Very large, mostly public assets – government investment possible, as well as rules about private sector standards | Unlikely to be required | Evidence that some level of segregation will be required<br>Required to reduce the impact of platooning on other road users |
| ***Certification*** | Very large, mostly public assets – rules about assets in Victoria possible | Not currently anticipated | Emerges as common international practice |
| **Infrastructure - Communications** | | | |
| ***Sensors*** | Victoria will be a "taker" of sensor technology from Australia / overseas / OEMs – could set rules to reinforce market outcomes, but unlikely to set initial direction | No rules or investment - overseas market and technological evolution driven | Variation in sensor technologies implemented in vehicles, resulting in significant variations in safety outcomes |
| ***Mapping*** | Small numbers of large private digital assets – government investment possible, as well as rules enabling private sector investment environment | No rules or investment – leave to private sector. | Inability to use AVs in regions due to lack of mapping<br>Evidence from other markets that private sector is not fulfilling role |
| ***5G*** | Victoria will be a "taker" of 5G technology from Australia / overseas / OEMs in vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction<br><br>Small number of large private assets outside of vehicles – government investment possible | No obvious reason for State government intervention | De-specification of Australian vehicles vs. overseas equivalents<br>Poor 5G coverage in regions and inability to use AVs without coverage |
| ***DSRC*** | Victoria will be a "taker" of DSRC technology from Australia / overseas / OEMs in vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction | No rules or investment - overseas market and technological evolution driven | De-specification of Australian vehicles vs. overseas equivalents |

# Example triggers to re-assess posture– Autonomous Vehicles (3/3)

**Implications for VIC**

| Assets / asset characteristics | Nature of assets, and level of Victorian government control and influence | Initial posture | Trigger to re-evaluate posture |
|---|---|---|---|
| **Infrastructure - Communications** | | | |
| ***C-ITS*** | Victoria will be a "taker" of C-ITS technology from overseas / OEMs in vehicles – could set rules to reinforce market outcomes, but unlikely to set initial direction | No rules or investment – neither vehicles, nor infrastructure | Substantial proportion of vehicle fleet with C-ITS capability (>10%)<br>C-ITS infrastructure lagging comparable markets |
| ***Data brokerage*** | Moderate numbers of large public and private digital assets – strong control over investment and rules for public assets, moderate control over rules for private assets where owner has presence in Victoria | No rules or investment in digital infrastructure, but monitor trends overseas | Evidence of need for cross- network transport system data<br>Requirements for greater standardisation of digital infrastructure and messaging for the transportation sector<br>Reduction in data integration costs<br>Increasing needs for data governance or privacy protection |

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emission Vehicles
- Findings about Autonomous Vehicles
- Findings about other New Mobility market models
- Implications for Victoria
- Appendix
  - **Selection of focus markets**
  - Non-infrastructure Autonomous Vehicle research and findings

# Principles for selecting focus markets

**Context**

- We wanted to prioritise 10-15 markets to ensure sufficient depth of research in the time available
- Prioritisation drove the areas of deeper research conducted into each potential technology
- Markets involve a combination of countries, cities and states that have substantial control over AV / ZEV related policy and legislation and therefore the focus of research

**Principles**

1. Examine the most advanced markets for different “technologies”
2. Examine markets with substantial share of global automotive supply or demand and influence
3. Where markets are not leaders for particular technologies, examine markets that give coverage of a number of technologies
4. Ensure markets are spread across different geographies (e.g. US, EU, Asia)
5. Include some markets that have similar characteristics and consumer behaviours as Victoria

# Process for shortlisting

**All countries**

**Long list of markets with substantial influence**

- Significant car manufacturing
- Significant car ownership

**Long list of markets with strong technology presence**

- EV
- AV
- Hydrogen

**Short list of most advanced jurisdictions in each technology**

- EV
- AV
- Hydrogen

+

**Shortlist by technology participation and socioeconomic similarity to Victoria**

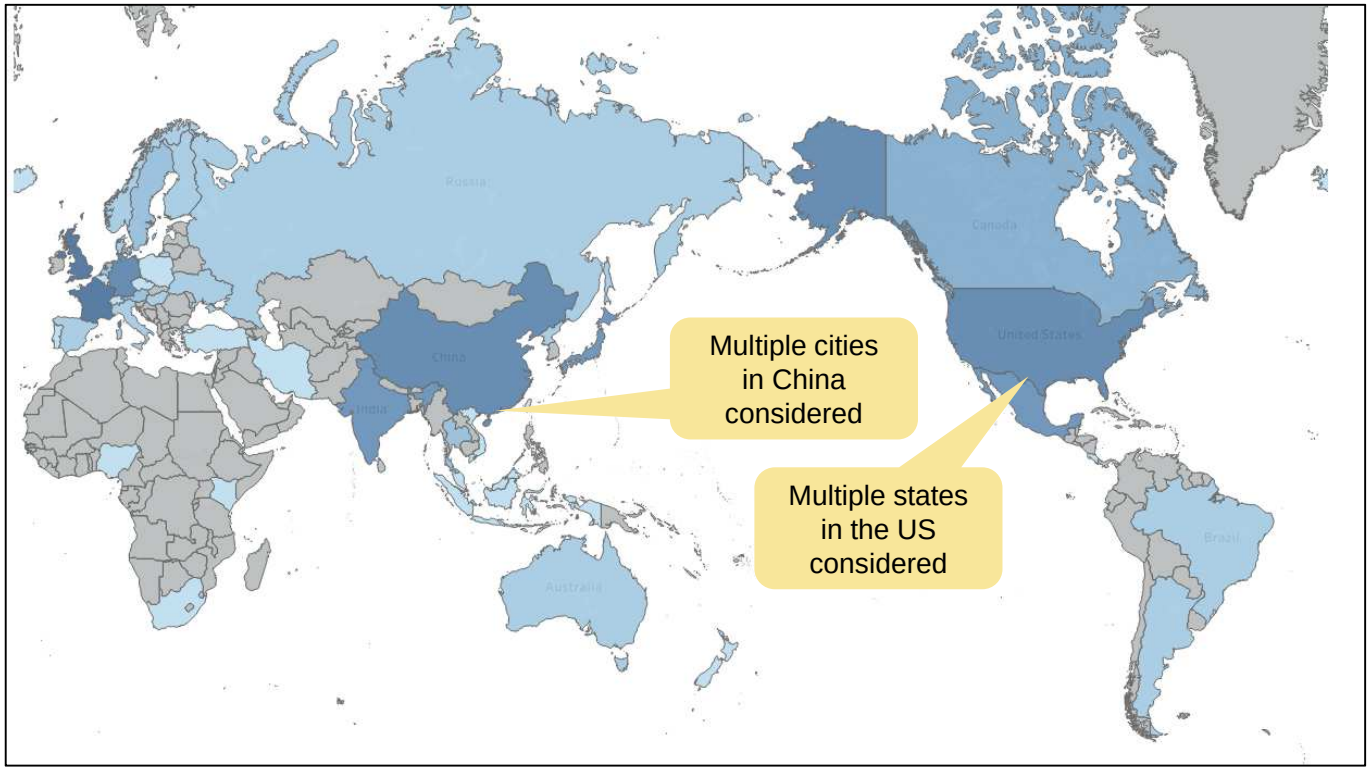
+

**Include some markets with interesting activities in new mobility (e.g. MaaS, applications of ride share)**

**A prioritised shortlist of 10-15 markets with focus on specific technologies in certain markets**

# 44 countries were included in the “long list” for prioritisation based on an initial set of indicators

## Number of positive indicators to derive “long list”




**Count of indicators by country*** 0 1 2 3 4 5 6 7

Indicators include:

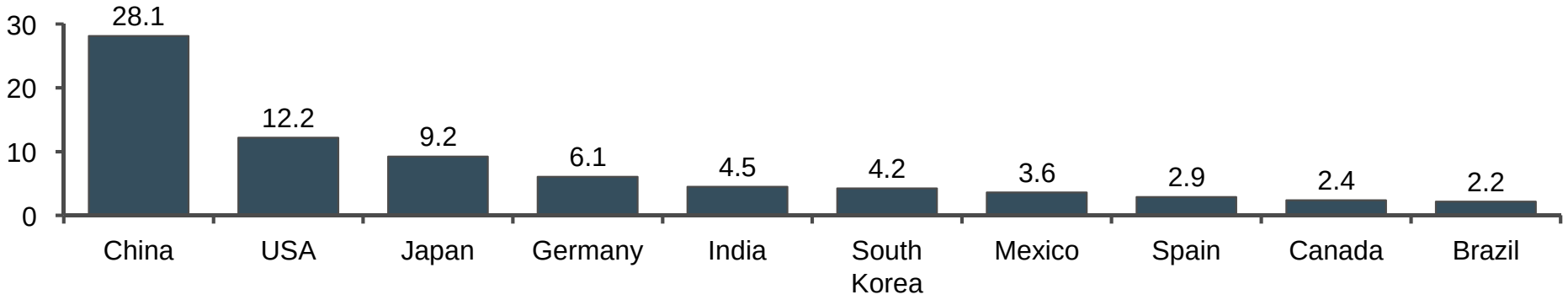
- Supply of vehicles
- Demand for vehicles
- Uptake of EVs
- AV trials
- Hydrogen infrastructure
- MaaS trials
- Early adopters of Uber
- Countries with significant established dockless bike share schemes

Note: * Highest score on indicator count is 7/8
Source: L.E.K. analysis

# Markets with substantial influence

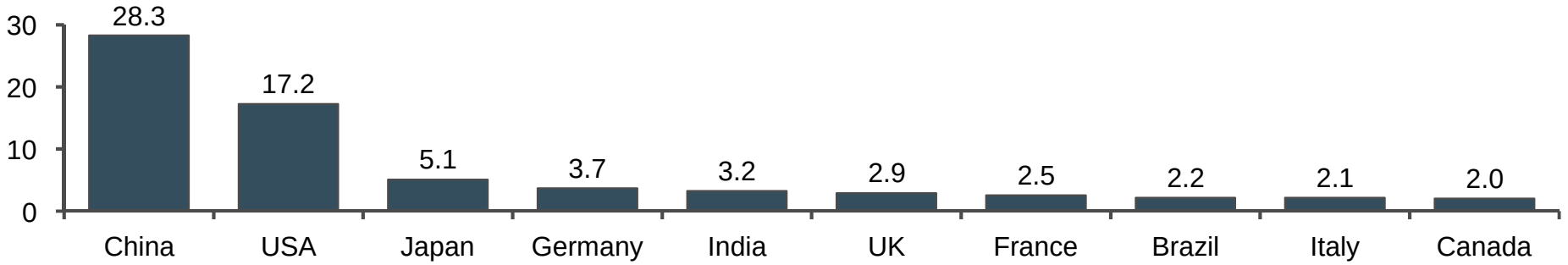
**Leading car manufacturing countries, top 10 ranked by production volume* (2016)**

Millions




**Leading markets for car sales, top 10 ranked by sales volume** (2017)**

Millions



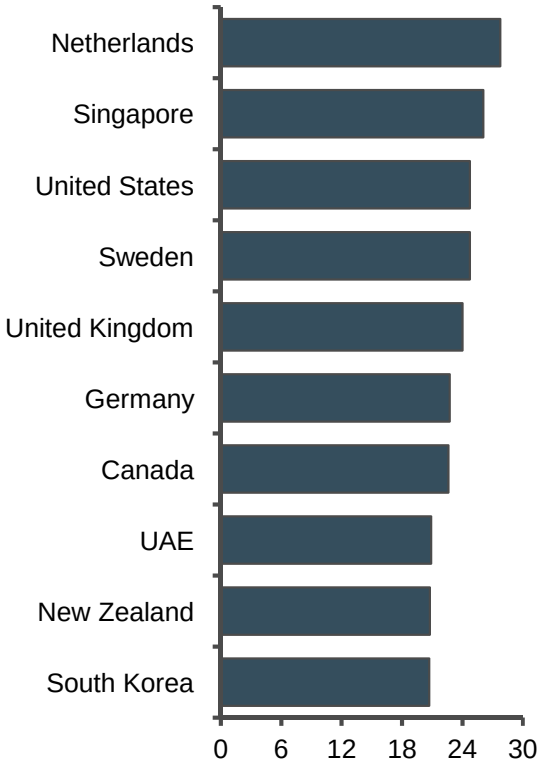

China, US, Japan and Germany all need to be included due to their influence over the global automotive market, with selective addition of the remaining six countries

Notes: * Includes both cars and commercial vehicles; ** Defined as cars plus light commercial vehicles
Source: SMMT, World Health Organisation; Focus2Move

# Key markets for Autonomous Vehicles

## Top rated markets for AV readiness

**Autonomous vehicle readiness level* (2017)**




**Examples of AV activity**

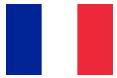
- Three-quarters of the population live in areas that are testing AV technology
- The Singapore Autonomous Vehicle Initiative was launched in 2014
- See state activity on the right
- Volvo has undertaken several AV initiatives, including a US$300 million joint-venture**
- Nissan is conducting AV trials in London
- Mercedes and BMW are both conducting trials on public roads
- In the last year, Ontario has issued seven permits to companies including Uber
- Has a specific AV function within its transport department
- Cars not required to contain drivers, NZTA supporting testing, and NZ aligning with AU
- K-City facility is the world's largest test bed for self-driving cars

## Other markets with substantial AV activity

**Japan**

- Nissan is commencing autonomous ride hailing service on roads in Japan in March 2018
- 11th on the AV readiness index

**France**



- PSA Group is working with start-ups *AIMotive* and *nuTonomy* — for AV trials on public roads
- 13th on the AV readiness index

**China**

- Both Beijing and Shanghai have allowed car companies (Baidu) to test AV technology on public roads
- 16th on the AV readiness index

**California**

- AV testing on public roads by multiple groups including Waymo, SAIC, BMW, and Tesla

**Arizona**

- Trials being conducted by various groups including Waymo, Ford and G.M

**Michigan**

- First US region to allow no driver or steering wheel

**Texas**

- One of 10 pilot sites by the US Dept. of Transport. Allows AV testing with no driver

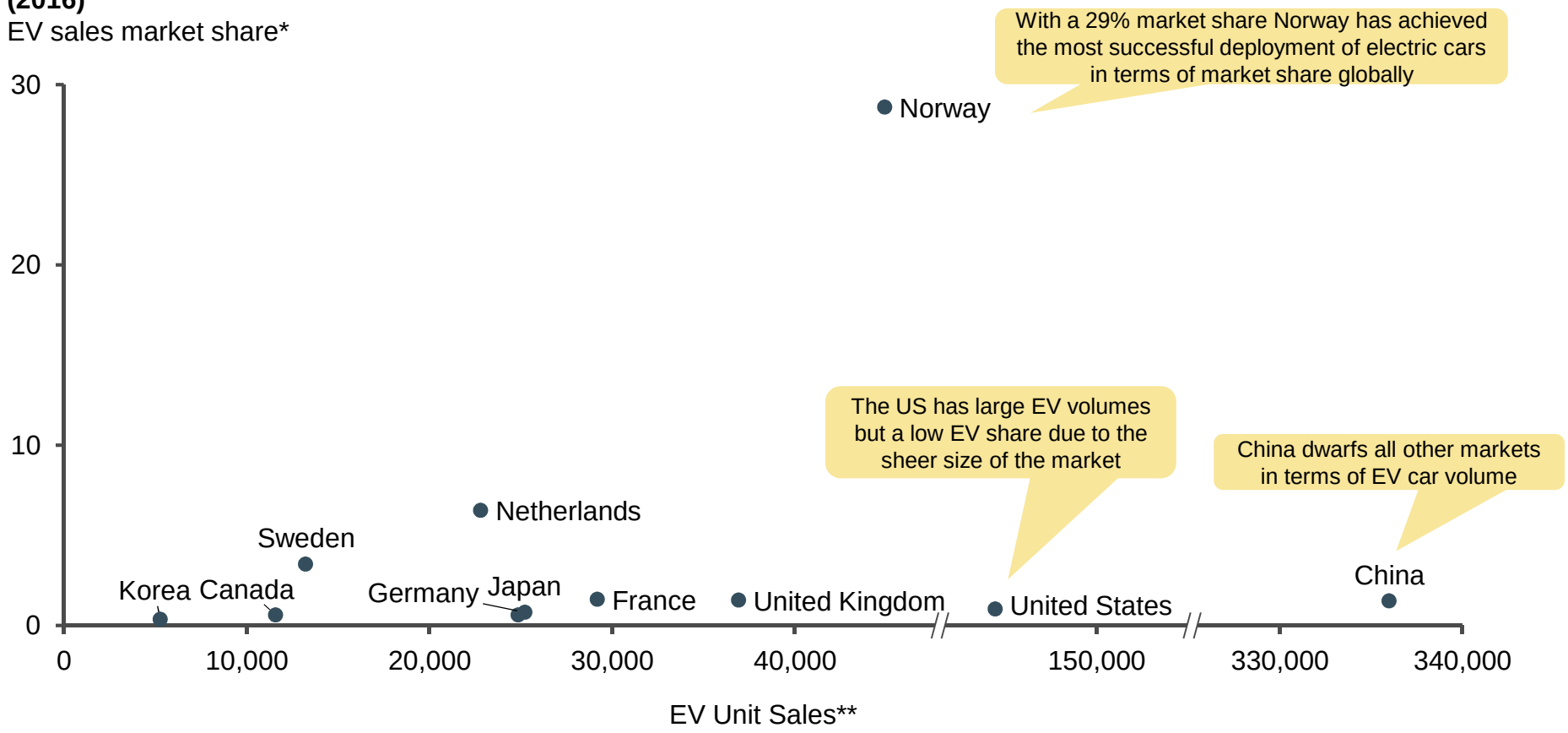
**The Netherlands, Singapore, and the US should be included in the short list for Autonomous Vehicle research**
**China, Japan, and Germany should also be included to their market influence and AV activity**
**South Korea should be a secondary focus market due to its material influence and AV activity**

Notes: * Considers i) policy & legislation, ii) technology & innovation, iii) infrastructure, and iv) consumer acceptance. Australia places 14th and China places 16th; ** With Uber
Source: KPMG Readiness Index; L.E.K. research

# Key markets for Electric Vehicles

PRELIMINARY

**Electric vehicle market share v sales volume, by geography (2016)**




Norway, China, and the US should be included in the short list, while other markets should be secondary markets for research

Notes: * Both battery electric and plug in hybrid, with market share defined as the number of new registrations of electric cars divided by the total number of new registrations at the country level;
** Number of new passenger car registrations by market (battery electric vehicles and plug in hybrid electric vehicles)

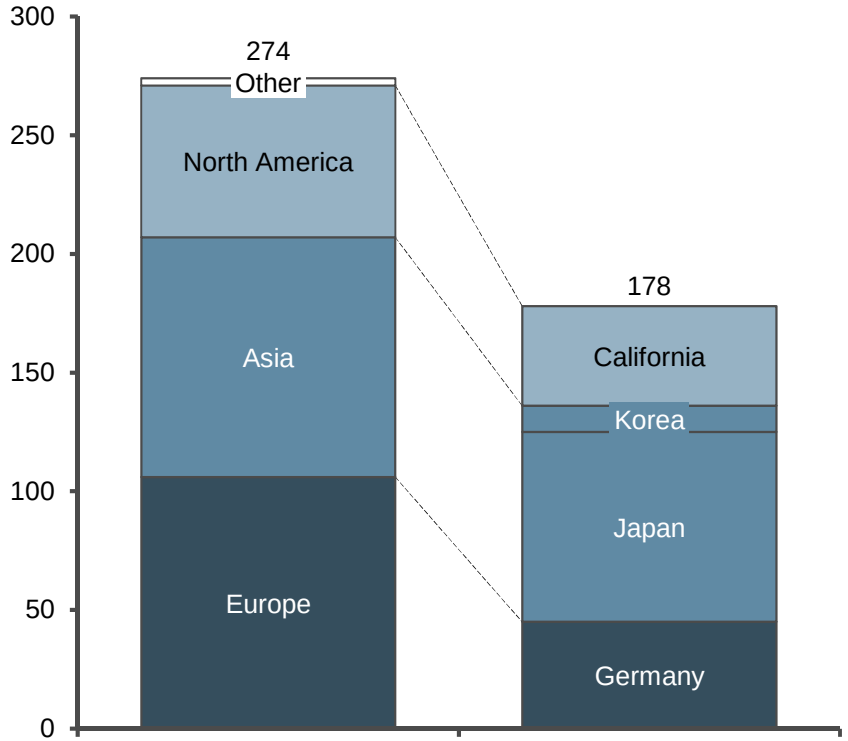
Source: International Energy Agency; Clean Technica; Business Financial Post; L.E.K. research



L.E.K.

# Key markets for Hydrogen Vehicles

**Hydrogen refuelling stations in operation, by geography* (2018)**
Number




**There are 3 hydrogen cars publically available in select markets**

| Car | Make and Model | Description | Availability |
|---|---|---|---|
|  | Honda Clarity | The Honda FCX Clarity is based on the 2006 Honda FCX Concept and was the first hydrogen fuel cell vehicle available to retail customers | For sale in California<br><br>Testing in Europe |
|  | Hyundai ix35 FCEV | The current version and fourth generation is the 2012 ix35 FCEV | For sale in California, Canada, South Korea, Germany and selected European markets |
|  | Toyota Mirai | Toyota launched its first production fuel cell vehicle (FCV), the Mirai, in Japan at the end of 2014 | For sale in US, Japan, Germany, UK, Denmark, Belgium, Norway |

**Germany, Japan and the US should be included in the short list for Hydrogen research, and South Korea should be a secondary research focus**

Notes: * Non-exhaustive
Source: Fuel Cell Works; Fast Company; AFDC; Honda; Fuel Cells and Hydrogen Joint Undertaking website; Hyundai; Toyota

# New Mobility Initiatives exist that will provide interesting case studies in some markets, such as ride share, MaaS, on-demand and bikeshare (1/2)

PRELIMINARY

## Ride sharing

### USA

- USA is the home of Uber and rival firm Lyft and 30% of the population aged 14-65 has used a personal mobility app
- San Francisco is a leader in rideshare, with the taxi industry suffering a 65% decrease in rides since Uber arrival

### Ontario, Canada

- The town of Innisfil has replaced all forms of public transit with a subsidized Uber offering, which provides on-demand transit
- Passengers pay between $3 and $5 for set routes within Innisfil, such as to Town Hall and the GO train station, and the town pays $5 for all other rides within the town

### UK

- Ride hail is regulated by Transport for London (TfL) as part of private hire licensing – these regulations have been under review recently
- In September 2017, TfL made the decision not to renew Uber's London licence due to lack of corporate responsibility, which Uber is in the process of appealing

## MaaS

### Helsinki, Finland

- The company MaaS Global launched the Whim app for multi-transport ticketing across different modes and the ability to provide travel planning
- This was the world's first mobility service which allows users to book and pay for all mobility services in one app and for a monthly fee

### UK

- MaaS trials have commenced in Birmingham and other technology solutions providers such as Qixxit and Moovel are also targeting city-specific deployments in the UK market

### NZ

- NZTA are running a mobility marketplace pilot in two areas – one in Queenstown launched in August 2017, and the other in Auckland, launched in December 2017

Source: Company websites (Maas Global, Uber, Financial Post; Straitstimes; NZTA; ITDP; World Economic Forum; L.E.K. research

# New Mobility Initiatives exist that will provide interesting case studies in some markets, such as ride share, MaaS, on-demand and bikeshare (2/2)

PRELIMINARY

## Bike share

### UK

- Three of the largest dockless bike companies – Ofo, Mobike and Obike – have a strong presence in the UK
- As a response, Transport for London released a dockless bike share code of practice in September 2017
- A new report from the London Assembly Transport Committee has however called for tighter regulation to avoid an excessive number of unused bikes being left to clutter pavements and roads

### China

- China is emerging as a leader in dockless bike share uptake and has the highest number of bikes for share per capita (c.0.3)
- The city of Yichang has substantially improved bicycle conditions by adding 30 km of bike paths as part of a planned 220 km network
- A Yichang bike-sharing program was opened in early 2016 and is integrated with the BRT system

### Singapore

- As of January 2018, Singapore based oBike has rolled out c.14,000 dockless bikes, with more than a million active users
- Singapore initially planned to introduce a scheme using fixed docking stations, however it was revealed that London's bike-sharing scheme (which follows this model) is said to have cost the city more than $300 million between 2010 and 2016

## Demand responsive transport (DRT)

### NSW, Australia

- Transport for NSW is implementing 10+ on-demand trials to inform the development of future transport contracts which include on-demand services
- It is estimated that $10-20m of funding was provided for the trials (trials must be renewed every 6 months up to a maximum of 24 months)
- The trials commenced late 2017 and early 2018, with the remainder due to begin operations shortly

Source: Company websites (Maas Global, Uber, Ofo, Mobike, Obike; Financial Post; TfL; TfNSW; ITDP; World Economic Forum; L.E.K. research

## As an overlay to the quantitative analysis, we proposed some qualitative additions and deletions for a secondary level of focus – proposed inclusions

- **United Kingdom** has a moderate level of strength across all technologies and institutional similarities to Australia, and would be expected to be focus on how to balance alignment with Europe or the US
- **Canada** also shares moderate strength across technologies and institutional similarities to Australia, and would be expected to focus on how strongly it should align with its US neighbour
- **Dubai** appears to be particularly aggressive in pursuing autonomous vehicles, and how it positions itself despite no domestic auto industry and limited global influence as a market makes it a market worthy of further investigation
- **France** has moderate level activity across different technologies and influence through its domestic auto industry – while other markets are stronger across a number of indicators, further research into France will likely be beneficial
- **Sweden** is one of the stronger markets for AVs and EVs that suggests some further research would be beneficial**,** but it somewhat lacks automotive market scale and influence

# As an overlay to the quantitative analysis, we proposed some qualitative additions and deletions for a secondary level of focus – proposed exclusions

- **Spain** shows limited technological leadership, and its manufacturing strength is largely derived from local operations for US, German, Japanese, and French manufacturers

- **Italy** is one of the larger markets for new vehicles and also has a domestic manufacturing industry, but has demand of similar size as some of the larger US states and shows limited technological leadership

- The markets of **India, Mexico and Brazil** show limited technological leadership and substantially different characteristics to Australia / Victoria

  - The strength in supply of Mexico and Brazil is driven by offshoring by US auto manufacturers, which indicates limited additional insight over research about the US approach

  - India has different infrastructure issues relative to Australia (creating vs. upgrading) and appears to be hostile to AV development with testing / operating of AVs potentially or actually banned

# As a cross check we also sought to identify those with some geographic and transport similarity to Victoria (1/2)

| Market | Geography | Market comparability | | Customer behaviour | | | Overall |
|---|---|---|---|---|---|---|---|
| | | Urban pop. (%) | Traffic index rank* (/62) | Cars per capita (per 1000 persons) | Public transport modal share (%) | Smartphone penetration (%) | |
| **Australia – Victoria** | **ANZ** | **91** | **41**** | **750** | **7** | **80** | |
| Netherlands | Europe | 91 | 24 | 527 | 29 | 69 |  |
| Singapore | Asia | 100 | 51 | 149 | 44 | 77 |  |
| U.S. | North America | 82 | 43 | 797 | 10 / 4^ | 69 |  |
| Norway | Europe | 81 | 12 | 584 | 30 | 77 |  |
| China | Asia | 57 | 47 | 58 | 23 | 52 |  |
| Japan | Asia | 94 | 40 | 591 | 34 | 50 |  |
| Germany | Europe | 76 | 9 | 572 | 26 | 69 |  |

The top markets for specific technologies are relatively similar to Australia / Victoria across a number of dimensions, and China and Singapore are too important to exclude

Note: * Rank where 1 has the best overall traffic and 62 has the worst overall traffic; ^ Modal shares for California and Arizona; ** Traffic Index represents Australia
Source: L.E.K. research and analysis, World Bank, Numbeo, Journeys, Newzoo, EPOMM

# As a cross check we also sought to identify those with some geographic and transport similarity to Victoria (2/2)

| Market | Geography | Market comparability | | Customer behaviour | | | Overall |
|---|---|---|---|---|---|---|---|
| | | Urban pop. (%) | Traffic index* (/62) | Cars per capita (per 1000 persons) | Public transport modal share (%) | Smartphone penetration (%) | |
| **Australia – Victoria** | **ANZ** | **91** | **41**** | **750** | **7** | **80** | |
| Sweden | Europe | 86 | 6 | 520 | 43 | 72 | |
| United Kingdom | Europe | 83 | 32 | 519 | 44 | 69 | |
| Canada | North America | 82 | 39 | 607 | 24 | 70 | |
| Dubai | ME | 86 | 49 | 313 | 12 | 81 | |
| New Zealand | ANZ | 86 | 33 | 712 | 6 | 61 | |
| South Korea | Asia | 83 | 26 | 363 | 63 | 72 | |
| France | Europe | 80 | 27 | 580 | 62 | 65 | |
| India | Asia | 33 | 59 | 18 | 16 | 22 | |
| Mexico | South and Central America | 80 | 53 | 275 | 51 | 41 | |
| Brazil | South and Central America | 86 | 56 | 209 | 45 | 38 | |
| Spain | Europe | 80 | 19 | 593 | 26 | 67 | |
| Italy | Europe | 69 | 35 | 679 | 20 | 66 | |
| Finland | Europe | 84 | 10 | 612 | 30 | 77 | |

United Kingdom, Canada, and New Zealand are all quite similar to Australia / Victoria, and other markets besides India, Mexico and Brazil also exhibit reasonable similarity

Note: * Rank where 1 has the best overall traffic and 62 has the worst overall traffic; ** Traffic Index represents Australia
Source: L.E.K. research and analysis, World Bank, Numbeo, Journeys, Newzoo, EPOMM

# Focus markets chosen (with the understanding that the emphasis amongst these might change as the research program progresses)

| Market | Geography | AV | EV | Hydrogen | Other New Mobility |
|---|---|---|---|---|---|
| Australia – Victoria | ANZ | ✓✓ | ✓✓ | ✓✓ | ✓ |
| Netherlands | Europe | ✓✓ | ✓ | | |
| Singapore | Asia | ✓✓ | | | ✓ Bike Share |
| U.S.^ | North America | ✓✓ | ✓✓ | ✓✓ | ✓ Ride Share |
| Norway | Europe | | ✓✓ | | |
| China* | Asia | ✓✓ | ✓✓ | | |
| Japan | Asia | ✓✓ | ✓ | ✓✓ | |
| Germany | Europe | ✓✓ | ✓ | ✓✓ | |
| South Korea | Asia | ✓ | ✓ | ✓ | |
| United Kingdom | Europe | ✓ | ✓ | | ✓ MaaS, Ride & Bike |
| Canada | North America | ✓ | ✓ | | ✓ Ride Share |
| France | Europe | ✓ | ✓ | | |
| Helsinki, Finland | Europe | | | | ✓ MaaS |
| New Zealand | ANZ | | | | ✓ MaaS |
| Dubai | ME | ✓ | | | |
| Australia – Sydney | ANZ | | | | ✓ DRT |

**Key** ✓✓ Primary focus ✓ Secondary focus

Main research focus

Note: ^ Where different AV approaches are employed at the state level in the US, particular emphasis was placed on California and Arizona, and hydrogen was focused on California; * Likewise in China, particular emphasis was placed on Beijing and Shanghai areas

# Agenda

- Executive Summary
- Introduction & approach
- Findings about Zero Emission Vehicles
- Findings about Autonomous Vehicles
- Findings about other New Mobility market models
- Implications for Victoria
- Appendix
  - Selection of focus markets
  - **Non-infrastructure Autonomous Vehicle research and findings**

# Key issues explored for Connected and Autonomous Vehicles, with a focus on issues with the most significant impact on physical infrastructure

| Topics | Issues explored in focus markets |
|---|---|
| 1 Physical infrastructure upgrades and investments required for AVs | • Wholesale upgrades to road infrastructure<br>• Road infrastructure modification<br>• Parallel investment in smart infrastructure (C-ITS)<br>• Designated AV certification<br>• Parking related infrastructure and curb-side space |
| 2 Road usage and access for AVs | • Road space allocation, pricing infrastructure, and special access features<br>• Implications of planned disruptions for AV requirements<br>• Modifications to curb-side infrastructure to accommodate changed usage patterns<br>• Requirement for increased road maintenance |
| 3 ICT infrastructure and standards required for AVs | • Which communication technology (4G, 5G, LTE, DSRC, WiFi) will underpin AV rollout<br>• The choice of overall communication standards |
| 4 Mapping and positioning | • Satellite-based augmentation systems (SBAS) to assist with absolute AV positioning<br>• Approaches to 3D mapping for AV technology and positioning<br>• The extent of Government involvement in 3D mapping |
| 5 Public and user safety considerations for AVs | • Control of a vehicle under high SAE levels<br>• Non- driving tasks in fully automated vehicles<br>• Insurance frameworks<br>• Ethical decisions |
| 6 Data protection and sharing for AVs | • Data sharing and privacy protection<br>• CAV specific cybersecurity standards<br>• Software security and updates |
| 7 Policy support for AVs | • Primary objectives for Government leadership in AVs internationally<br>• Mechanisms used to support the deployment of AV technology<br>• Restrictions are placed on permits for AV trials |

Topics less aligned with infrastructure than topics discussed in the body of the report

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# Government and non-government bodies are beginning to revise existing and develop new vehicle and transport standards to include provisions for AV technology

| Organisation | Description |
|---|---|
| **United Nations Economic and Social Council** | The 1968 convention was established to develop standard traffic rules between contracting parties. It was updated in 2016 to remove the assumption of a human driver. The new legislation allows control of a vehicle to be passed on to an automated driving system, under the condition that a human driver can resume control. The convention was notably not signed by Australia, China and the USA. However Australia still follows the regulations closely |
| **United Nations Economic Commission for Europe (UNECE)** | The forum is a working party of the sustainable transport division of the UNECE. The forum works to regulate vehicle safety, environmental protection, energy efficiency, and theft-resistance. 68 countries are party to the forum including Australia. Until each component of a vehicle has been approved, including autonomous control systems, they can not be sold in the member countries |
| **European Commission** | In November 2016 the European Commission adopted a strategy on C-ITS. The strategy sets out two phases of implementation (Day 1 and Day 1.5) which include specific technologies to be addressed, including emergency brake lights, green light optimal speed advice, and vulnerable road user protection. The security of C-ITS communications and data privacy and protections are also discussed |
| **International Organization for Standardization** | The International Organization for Standardization creates standards and documentation for technology, ICT, and mechanical components which all have bearing on autonomous vehicles. ISO 26262 considers 'road vehicles – functional safety', ISO/TC 204 considers intelligent transport systems. Concern has arisen for how these standards account for new technologies such as machine learning. |
| **Society for Automotive Engineers International** | Similarly to ISO, SAE sets international standards. SAE's sole focus is on automotive vehicles. The SAE Levels of Autonomy have been adopted by international governments. J3016 concerns Taxonomy and Definitions related to On-Road Motor Vehicle Automated Driving Systems |
| **European Union** | In order to promote AV adoption and regulation, The Netherlands led a forum which brought together the 28 Transportation Ministers from the EU to create a declaration on cooperation in the field of connected and automated driving. The declaration lays a roadmap for the signatories to facilitate autonomous vehicle technology in Europe. |

Source: UN; UNECE; Automotive News Europe; EUR-Lex; Government of The Netherlands; ISO; SAE; Cornell University Library



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# There is not yet a consistent global view about “control” or liability for AVs (1/2)

| Region | Recognition of ADS as the driver? | Who is in control | Who is liable? | Implications for Victoria |
|---|---|---|---|---|
| **Vienna Convention** | No - the driver always remains human<br><br>No consideration of fully automated vehicles | The human driver remains responsible for the control of the vehicle.<br><br>At conditional levels of automation, a driver could perform other activities, so long as the activities do not prevent the driver from responding to takeover demands, and are consistent with the intended use of the automated driving function | The **driver** | *As Australia models its Road Rules off the Vienna convention, it may be expected Australia will need to make similar amendments as other countries modelling off the Vienna Convention* |
| **Australia** | No - the driver always remains human<br><br>No consideration of fully automated vehicles | The human driver remains responsible for the control of the vehicle | The **driver** | *Victoria will need to adapt to the Australian approach* |

Source: NTC – Changing driving laws to support automated vehicles discussion paper October 2017

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# There is not yet a consistent global view about "control" or liability for AVs (2/2)

| Region | Recognition of ADS as the driver? | Who is in control | Who is liable? | Implications for Victoria |
|---|---|---|---|---|
| **US** | Yes – for conditional, high and full automation vehicles | The driver may be defined as whoever or whatever is doing the driving. Either the human or the HAV can be in 'control' of the vehicle | **No suggested approach** as to how to treat an ADS for the purposes of traffic laws and enforcements | *Australia may wish to define the role of the driver beyond the Vienna Convention definition.*<br><br>*If they do, Victoria may consider how to divide ADS liability between the human 'driver' and the manufacturer* |
| **California** | Yes – for conditional, high and full automation vehicles, with or without a driver | Both the human driver or the ADS can be in control of the vehicle | The **manufacturer** of the vehicle is responsible for the safe operation of the vehicle, including compliance with all traffic laws applying to the dynamic driving task when the ADS is engaged<br><br>Otherwise, the **human driver** is responsible when ADS is not engaged | |
| **Tennessee** | Yes – for high and full automation vehicles | Both the human driver or the ADS can be in control of the vehicle | The **ADS** is considered the driver for the purposes of determining liability for applicable traffic or motor vehicle laws | *As high and full automated vehicles enter public roads, this may create issues regarding accident liability* |
| **Germany** | Yes – for conditional and high automation vehicles<br><br>No consideration of fully automated vehicles | The human driver remains responsible for the control of the vehicle, but provides the legal basis for temporary, full transfer of the driver's control to the ADS. | Both the **driver and the vehicle owner** remain liable even if the vehicle is in automated driving mode<br><br>The manufacturer is not liable even if the vehicle is in automated driving mode | *Australia may wish to define the roll of the driver beyond the Vienna Convention definition.*<br><br>*If it does, Victoria may need to decide how to divide ADS liability between the human 'driver' and the manufacturer* |

Source: NTC – Changing driving laws to support automated vehicles discussion paper October 2017; NHTSA 2016; KPMG

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# There are existing non-driving tasks that ADS will not be able to perform. New obligations may need to be defined, but there is not yet one clear approach

## Existing non-dynamic driving tasks

Obligations may need to be assigned to other entities, such as a "fallback-ready user"

*NON-EXHAUSTIVE*

| Topic | ADS issue | Possible approaches and examples | Policy implications |
|---|---|---|---|
| **Parking where fees are payable** | *An ADS cannot put money into a parking meter* | • Conditional automation - the fallback-ready user could be assigned this task.<br>• High or full automation – an occupant of the vehicle<br>• If the parking fee is not paid, the registered operator would receive an infringement notice | *Victoria may need to determine these matters itself* |
| **Using portable warning triangles to warn road users when a load falls on the road** | *An ADS may not know when a load has fallen, and cannot place warning triangles* | • Conditional automation - the fallback-ready user could be assigned this task.<br>• High or full automation that includes manual controls – an occupant of the vehicle could be responsible for this task if they were able to stop the vehicle. | |
| **Wearing of seatbelts by passengers under 16 years old** | *An ADS does not know the age of a passenger* | • The parent or guardian or any adult passenger in the vehicle<br>• In the **US, Tennessee** has expressly excluded the ADS and the ADS owner from these responsibilities and assigned them to parents and guardians or the person accompanying the person under 16 | |
| **Duties of a driver involved in a crash, including stopping at a crash, providing details and calling the police** | *An ADS may not be able to identify another driver involved in the crash or a police officer* | • Conditional automation - the fallback-ready user could be assigned this task.<br>• High or full automation that includes manual controls – an occupant of the vehicle could be responsible for this task if they were able to stop the vehicle.<br>• In **the US**, the legislation of some states provides that various reporting obligations of a driver are satisfied if the ADS operated vehicle remains at the scene of an accident and the vehicle or its owner or operator contacts law enforcement authorities. | |

Source: NTC – Changing driving laws to support automated vehicles discussion paper October 2017



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# Autonomous vehicles also generate new tasks which need to be addressed

## New non-dynamic driving tasks

In addition to existing non-dynamic driving tasks that will require updating for the definition of the 'driver', automated vehicles present new non-dynamic tasks including maintenance and fallback-ready drivers

| Topic | Example approaches | Implications for Victoria |
|---|---|---|
| **Maintenance and software updates** | **Californian** regulations require that the registered owner of the autonomous vehicle shall be responsible for ensuring the vehicle is operated using the manufacturer's most recent updates | *Regulations will need to be developed to address these new tasks* |
| **Readiness to drive and take back control** | **The UN** World Forum for the Harmonization of Vehicle Regulations has indicated its intention to develop additional safety requirements on vehicles with conditional automation. This includes deactivating the system automatically only after requesting the driver takes over with a sufficient lead-time, and driver availability recognition to ensure the driver is in the position to take over when requested by the system<br><br>In **the US**, the NHTSA's 2016 automated vehicle policy provides guidance to manufacturers. It states that OEMs and other entities should have a documented process for transitioning to a minimal risk condition when a problem is encountered, and that fall back actions should be administered in a manner that will facilitate safe operations of the vehicle and minimize erratic driving behaviour<br><br>The proposed **Californian** regulations include a specific requirement that a fallback-ready user in a vehicle with conditional automation has the correct licence.<br><br>Recent amendments to the **German Road Traffic** Act to allow vehicles with conditional and high automation to operate allow the driver to avert their attention from the traffic. However, the driver must remain aware in order to regain control of the vehicle without undue delay either when prompted by the system or when the driver recognises (or must recognise) that the preconditions for the automated driving mode are no longer fulfilled | |

Source: NTC – Changing driving laws to support automated vehicles discussion paper October 2017



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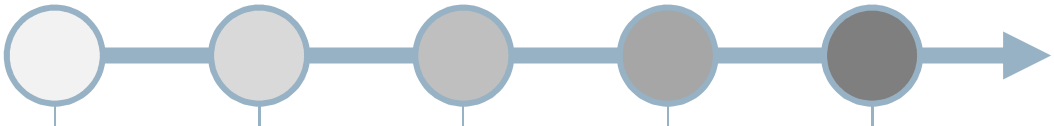
# Internationally, insurance requirements vary considerably. Some US states have identified specific insurance requirements for AV trials

## Insurance Requirements for AV Trial Operators in US States



### Georgia

- imposes a "super-insurance" requirement to cover caps at 250% normal levels

### Michigan

- A motor vehicle manufacturer shall insure each vehicle in a participating fleet in the amount of $10m USD

### California

- $5m USD insurance requirement from the manufacturer via 3rd party insurance; a surety bond issued by an admitted surety insurer; or a certificate of self-insurance

### Nevada

- Requires an autonomous vehicle network company to maintain insurance for the payment of tort liabilities arising from the operation of a fully autonomous vehicles, in order of $1.5m US

### Arizona

- The vehicle owner shall submit proof of financial responsibility, in an amount and on a form established by the Director of the Arizona Department of Transportation

**In the USA, various insurance requirements have been introduced on a state by state basis:**

- In Georgia, the state legislation states that until December 31, 2019, motor vehicle liability coverage is required equivalent to 250 percent of current indemnity and liability insurance codes
- Arizona has cultivated a liberal legal environment for AV trials, becoming a favoured partner for the industry. Arizona has minimum insurance liability rules in which "the vehicle owner shall submit proof of financial responsibility"
- In Michigan, the automated driving system is considered the driver of the vehicle, and so a car manufacturer is liable for incidents in which the automated driving system is at fault

**Implications for Victoria: Although a range of insurance regimes exist internationally, experts agree that legislation should provide for adequate insurance cover to protect against physical and property damage**

Source: Georgia State Government; DMV; SWLaw; Michigan State Government; Nevada State Government; California State Government; Arizona State Government

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# There is as yet no clear approach to ethical issues associated with AVs

| Issue | Issue Description | Implications for Victoria |
|---|---|---|
| **OEM-led opinions** | **Mercedes** appears to have decided to prioritise the life of the car occupant over that of those in other vehicles, pedestrians, or cyclists<br>*"…If you know you can save at least one person, at least save that one. Save the one in the car…"*<br>*Manager of Driver Assistance, Mercedes Benz*<br><br>When **Waymo** trialed their self-driving cars in Phoenix in Oct 2017, they chose not to include any specific moral value in this situation, rather ensuring the car 'goes for the smaller object'. Head of the Google self-driving car program Chris Urmson has also said the cars are designed to avoid vulnerable road users (cyclists and pedestrians) before other vehicles, and lastly things that don't move<br>*"It's not possible to make a moral judgement of the worth of one individual person"*<br>*Chris Urmson, Google Self-driving car head*<br><br>**Tesla** have taken an opinion not to intervene in a collision that a human is actively causing by not enforcing their automatic emergency breaking (AEB) systems when a human is deliberately pushing the accelerator. While designed not to second-guess drivers choices in an emergency, it has lead to a number of Tesla's being driven into garage walls at full speed | *Victoria may wish to investigate the varying approaches to ethical issues being adopted by OEMs to understand whether there is any need for intervention* |
| **Jurisdiction-lead opinions** | **Germany**'s Ethics Commission released a report in 2017 on automated and connected driving. It outlined 20 rules for autonomous vehicles, including:<br>1. In hazardous situations that prove unavoidable the protection of human life remains the top priority<br>2. In the event of unavoidable accident situations, any distinction based on personal features (age, gender, physical or mental constitution) is strictly prohibited<br>3. The accountability shifts from the motorist to the manufacturers and operators of the technological systems and to the bodies responsible for making infrastructure, policy and legal decisions | *Victoria may wish to investigate the varying approaches to ethical issues being proposed by other government bodies to understand whether there is any need for intervention* |

Source: Ethics Commission of Germany; Sydney Morning Herald; CEPS EU;

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# Summary: Public and user safety considerations for AVs (1/2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Assigning responsibility for control of a vehicle under high SAE levels*** | • **The driver is always in control and liable** under the Vienna Convention, which Australian road rules are broadly aligned with<br>• **Both** the **human driver and the ADS may be in control** in California, but a human is always liable, whether it be the **manufacturer or the owner of the vehicle**<br>• **The ADS manufacturer is treated as in control and liable for traffic offences** in fully automated vehicles in Tennessee<br>• A special additional safety requirement for deactivating autonomous modes is an option being considered by the UN World Forum to clarify responsibilities for AVs | *The lack of a consistent global view about "control" or liability for AVs means Australia will need to decide which approaches to adopt for control and liability*<br><br>*Assigning shared responsibility for control may result in legal complexity and unintended consequences at the intersection of personal / government liability for vehicle use or manufacturer liability for product defects*<br><br>*Compulsory third party insurance schemes will need to be reviewed to ensure they are fit for purpose where AVs are involved* |
| ***Assigning responsibility for non- driving tasks in fully automated vehicles*** | • There has been limited reform of responsibility for non-dynamic driving tasks that are currently undertaken by physical human driver to account for the impact of AVs<br><br>• The US is considering whether a **fallback-driver, owner of the vehicle or manufacturer** should be assigned responsibility for a range of non-dynamic tasks | *The National Transport Commission are currently conducting a review to address Australian laws relating to ownership, use and interaction with motor vehicles to assess whether responsibilities for non-dynamic driving tasks are appropriately assigned*<br><br>*New obligations may need to be defined to ensure public safety when AVs are more prevalent* |



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# Summary: Public and user safety considerations for AVs (2/2)

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Adopting insurance frameworks for AVs*** | • There is considerable international variation in approaches to insurance for current vehicles<br>• There are a range of approaches being adopted internationally for AV trials that show the importance of local legislative environments to solution design | *It is unlikely that many international approaches to addressing insurance for AVs will be easily "retrofitted" into Australian compulsory third party schemes and the broader Australian legal system* |
| ***Ensuring AVs make ethical decisions*** | • Leading OEMs are setting out principles for how their vehicles resolve ethical dilemmas<br>• The Government may mandate certain types of decision making by AVs, similar to the manner used by the Ethics Commission in Germany | *Given the leadership of OEMs and respected institutions on ethical AV decision making, it is unclear what the basis for Australian government intervention would be* |



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# Data & Confidentiality: General or AV specific approaches can be taken to balance privacy concerns with benefits from sharing AV usage data

| Data protection approach | Examples | Implications for Victoria |
|---|---|---|
| **Privacy by design** | A 'privacy by design' approach can limit the personal data collection while still allowing data to be collected for research and development purposes. **The Netherlands** collects traffic data through their smart traffic light exchange (TLEX). The traffic lights connect to all makes of car and the information is used to improve traffic flow and prioritise certain types of traffic (e.g. emergency vehicles)<br><br>The General Data Protection Regulation was passed as a directly binding and applicable regulation to protect data and privacy of the **EU** individuals. Coming into affect in May 2018, the regulation will include 'privacy by design' requirements, requiring data controllers to put technical and organisational measures, such as pseudonymisation, in place to minimise processing of personal data | *Victoria may wish to create guidelines for the use of personal data by CAVs.*<br><br>*If considering guidelines, Victoria should consider the impacts of protecting privacy on the ability to share data or use it for transport optimisation* |
| **CAV specific guidelines** | In 2017, **Germany**'s Ethics Commission issued guidelines requiring:<br>• CAV owners, CAV users and parties present in the vehicle's surroundings may decide whether and how their vehicle data is shared and used<br>• Manufacturers should suppress data collection in factory settings<br>• Independent testing institutes should monitor vehicles' data usage under the principle of transparency | |
| **Consent requirements** | **Chinese** Cybersecurity Law (CSL 2017) requires consent to be granted before personal information is collected, shared or exported from the country. 16 standards relating to cybersecurity and privacy are being drafted, including 'General Requirements on Vehicles Data Privacy and Cybersecurity Protection' | |
| **Privacy plan** | In Sept 2017 **the US** House of Representatives passed the Self Drive Act that requires OEMs to develop a privacy plan disclosing how data concerning vehicle owners and occupants is collected, used and stored. Specifically the plans must address:<br>• data minimisation, de-identification, and retention<br>• sharing with third party entities<br>• data deletion upon transfer of ownership<br>A privacy plan is not required if the data is anonymised or encrypted | |

Source: The Recorder; German Ethics Commission; Platform Beter Benutten; NTC; eConsultancy



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# Industry and government organisations are conducting research into and creating CAV-specific cybersecurity policies, but no consensus has emerged

| Approach to cyber security | Examples | Implications for Victoria |
|---|---|---|
| **Standards and legal frameworks** | **SAE International** drafted J3016 in 2016, 'Cybersecurity guidebook for cyber-physical vehicle systems'. The standard addresses incorporating cybersecurity into cyber-physical vehicle systems, tools and methods for designing cyber-physical vehicle systems and foundation for further standards development activities in vehicle cybersecurity<br><br>Vehicle connectivity will become part of the **EU** legal framework from April 2018, when all new vehicles will have to be fitted with a system called eCall. To in-build cybersecurity measures into the CAVs, eCall sends an automatic message to the emergency services containing the location of a vehicle involved in an accident using an in-built GPS location device | *AV-specific cybersecurity standards will likely be used in preference to more general cybersecurity standards and approaches* |
| **Principles and guidelines** | In 2017, the **Chinese** government issued guidelines for the Establishment of National Standards System of Telematics Industry which aims to set national standards for China's CAVs. 20 of the 95 standards to be created include cyber-security. The standards suggested include overall technical requirements for cybersecurity, cyber risk assessments and data security protection<br><br>In August 2017, **the UK** Department of Transport and Centre for the Protection of National Infrastructure introduced 'Key principles of vehicle cybersecurity for CAVs'. The list of principles addresses car makers and the supply chain, and highlights that security issues need to be dealt with from the board/management level | |
| **Research** | In **the US**, the NHTSA are currently conducting research into CAV cyber-security, including anomaly-based intrusion detection systems, firmware updates and reference parser development for V2V communication interfaces<br><br>Developments are also being made at a state level in **Ohio**, where the Vehicle Research and Test Centre are investigating risks in todays existing technology, and setting guiding principles for cybersecurity approaches in the future. | |

Source: Australian Government – cyber security; China Law Insight; House of Representatives Standing Committee on Industry, Innovation, Science and Resources – Social issues relating to land-based autonomous vehicles in Australia; SAE International, NHTSA, On Board Security



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# Cybersecurity: Australia has tasked a number of government organisations with AV specific cybersecurity investigations

| Level of government | Approach to cybersecurity | Implications for Victoria |
|---|---|---|
| **Federal** | The **Cyber Security Growth Centre**, as part of the Department of Defence, are looking at technologies around privacy, trust and security in relation to CAVs, and are creating a framework for issues of cybersecurity relating to a 10-15 year implementation of AVs | *Australian government agencies already appear to have a settled approach to addressing CAV cybersecurity issues*<br><br>*Victoria should monitor the approach being considered by the Commonwealth and decide if further intervention is required* |
| | Working under the Department of the Prime Minister and Cabinet, the 2017 report 'Social issues relating to land-based autonomous vehicles in Australia' has recommended the **National Cyber Security Strategy** look into automation vulnerabilities of CAVs | |
| | The Department of Infrastructure, Regional Development and Cities is engaging with the **UNECE World Forum for the Harmonisation of Vehicle Standards** to create guidelines regarding CAV cybersecurity | |
| **State** | Collaborative work is underway with state and territory governments to develop a security management plan for connected and automated vehicles, focusing on the security of wireless communications between vehicles, and with roadside infrastructure | |

Source: Australian Government – cyber security

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# Software security and updates: A key cybersecurity issue for AVs is the threat of attack during software updates

| Issue | Options | International Action | Implications for Victoria |
|---|---|---|---|
| CAV software can be updated either over-the-air (OTA) or in person using hardware | **Tesla** can deliver software updates using OTA technology, which allows Tesla to both add new features (e.g. voice command) and update existing software (e.g. blind spot sensors, bug fixes). While this approach is a quick and cheap, it runs the risk of a fleet-wide cyber attack.<br><br>**Chrysler** posted out a USB stick with a safety update to 1.4m vehicle owners in the US as way of a recall after hackers remotely accessed the Jeep fleet in the US in 2015. Chrysler found it hard to track which owners had implemented the software upgrade and when | **The UNECE Task Force on Cyber Security and OTA issues** are amidst ongoing investigations for a best practice | *OEMs appear likely to determine which technologies are used for updates*<br><br>*If over-the-air methods are widely adopted, there may be a need to create new methods for vehicle users to track whether critical updates have been applied to a vehicle* |
| Choice of security method to ensure OTA updates do not maliciously interfere with vehicles | International standards regarding security signatures levels differ. **The US** currently have standards for security management policies that require the security signature at the application layer. Meanwhile **the EU** enforce their security signature at the network layer.<br><br>The US requirements are considered to have tighter privacy regulations because it requires different security levels for each application. | **The World Forum Harmonisation Task Group** are currently investigating implementing a universal approach to security management. | *Until Australia decide which security signature standards to comply with, Victoria may be exposed to vehicles from OEMs with conflicting standards* |

Source: Tesla; Chrysler; AustRoads; OnBoard Security

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# Summary: Data protection and sharing for AVs

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***Balancing data sharing to drive innovation with privacy protection*** | • The new European General Data Protection Regulation (GDPR) establishes broad-reaching obligations for companies (including OEMs) and will apply to AVs, requiring companies to implement "privacy by design" and actively manage AV user private data<br>• Some jurisdictions are adopting AV-specific data protection laws<br>• The US is requiring OEMs to create a 'privacy plan' disclosing how they plan to protect user privacy | *There are existing Australian and international protections for data created when using AVs*<br><br>*A range of AV-specific approaches are being developed in overseas markets and could be adopted to address any shortcomings in existing Australian laws* |
| ***Development of CAV specific cybersecurity standards*** | • AV-specific cybersecurity standards are being developed, with the SAE providing the leading standards for cybersecurity regulations through J3016 issued in 2016<br>• Some jurisdictions adopt the general SAE standards in guidelines and for principles about AVs, including in NTC discussion papers in Australia<br>• Specific approaches to cybersecurity for different kinds of communications can be implemented, with the EU instituting cybersecurity measures that apply to communications about AV locations | *AV-specific cybersecurity standards will likely be used in preference to more general cybersecurity standards and approaches*<br><br>*Australian government agencies already appear to have a settled approach to addressing CAV cybersecurity issues* |
| ***Software security and updates*** | • Requiring software updates to be applied "physically" is one approach to prevent malicious interference used in trials by Chrysler<br>• Applying updates "over the air' is another approach that is utilised by Tesla, but there are a range of different international standards to secure the content of the updates | *OEMs and industry bodies appear likely to determine which technologies are used for updates and security*<br><br>*Use of OTA may create some security and public safety issues that need to be addressed* |



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# Leading markets for AV activity have a range of reasons that underpin their objectives for AV leadership

| | |
|---|---|
| ***Attracting manufacturing and industry*** | *By creating an environment conducive to OEMs, jobs can be generated and innovation can be fostered through AV trials. This extends from their manufacture, to testing facilities and academic facilities* |
| ***Attracting new technology*** | *The benefits of autonomous vehicles in safety, road efficiency, and increased access to mobility are widely sought after. AV leadership in trials is seen as a ticket to early access to these benefits* |
| ***Public assurance*** | *Given that the technology is seen as inevitable, public awareness through trial leadership can assure people, in order to facilitate a comfortable transition to new methods of transportation* |

## United Kingdom

- The UK government has expressed a desire to lead in AV technology. Subsequently, it has been active in supporting trials and reviewing its codes of practice in order to remove barriers for OEMs
- The government provided financial and regulatory support for three autonomous vehicle projects. Conditions of support were that the projects had to be public facing and produce media and research to showcase the technology to both local and international communities
- The stated objective of members of parliament was to make UK roads safer; autonomous vehicles were seen as a key step in this initiative. However, in order to overcome public concern, low-speed trials were used as a way to allow the public to interact with AVs to establish familiarity and confidence with the technology

## Singapore

- Conversely, Singapore is not coveting autonomous private vehicles. They are aiming to use autonomous technology to improve their public transport system. They hope that the public transportation landscape will be extended to include autonomous buses, mini-buses, and pods, which will connect passengers to the MRT train network
- Staffing requirements for public transport are difficult, particularly with few people qualified to drive due to restrictions on vehicle ownership
- Additionally, Singapore wishes to be viewed as a high tech state. Autonomous vehicle trials attract significant international interest and press coverage which supports the image that Singapore hopes to portray

**Implications for Victoria: Leading jurisdictions have clear objectives for AV trials that cross a broad range of economic and public safety outcomes**

Source: L.E.K. interviews; L.E.K. research



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# Case study: The UK aims to become a leader in CAVs to promote doing business in the UK, UK industry, public acceptance, and to deliver safety benefits

## Objectives

The United Kingdom government has issued support to AV trials for three avenues of public benefit

- **Promote industry:** 1.7m cars were produced in the UK in 2017, this was a decrease in 3.0% compared to 2016. In order to provide a boost to local manufacturing, the government has expressed a desire for the UK to be seen as a leader in CAV technology
- **Public assurance:** in order for the benefits of CAVs to come to fruition, the government acknowledges that public opinion is as essential as technology in determining the uptake of CAVs. Public engagements in trials was identified as a method for changing public sentiment
- **Transport benefits:** Law commissioner Nicholas Paines QS acknowledged that "British roads are already among the safest in the world and automated vehicles have the potential to make them even safer"

## Mechanisms

The government has used four systems to showcase the UK as an attractive venue for CAV OEMs

- **Public facing trials:** ARUP, who led the UK Autodrive project were tasked with having public facing programmes, publishing white papers, and engaging with stakeholders
- **Research and development funding:** In November 2016 the government announced £100 million for CAV infrastructure, with a pledge to match industry contributions to approved projects
- **Training facilities:** the government has provided financial support to the MIRA proving ground to develop its CAV facilities
- **Policy:** the UK released a code of practice for AV trials in 2015. The government is active in updating the regulations along with advancing technologies, and the COP is currently under review

## UK Autodrive

The UK Autodrive is a consortium of businesses, local authorities, and academic institutions conducting public AV trials in two English cities

- The UK Autodrive is a three year CAV trial (supported by the UK's innovation agency) which allowed the British Public to engage with autonomous vehicles. Trials were conducted in Milton Keynes and Coventry. Initial trials were conducted with an operator stationed in each pod. As confidence in the technology is established it is expected that members of the public will be invited to call up and use the pods
- The programme included interaction with community groups, particularly those with an initial objection to the technology, such as the blind and partially sighted community
- The project led to the creation of six public reports addressing topics of public interest such as cybersecurity and ethics

**Implications for Victoria: Leading jurisdictions have clear objectives for AV trials that cross a broad range of economic and public safety outcomes**

Source: L.E.K. interviews; Arup experience; UK Autodrive; UK Gov; SMMT; Techcrunch



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# Internationally, governments have been assisting AV trials via three primary support mechanisms: financial incentives, facilities and regulation

***Government support mechanisms***

A

**Financial incentives**

- Research and development
- Uptake of AVs
- Sharing of AVs

There is significant overlap between financial incentives between ZEVs and AVs as it is likely that the technologies will coincide. However the government benefits of autonomous vehicles are not as easily quantifiable due to the infancy of the technology and the dependence of benefits on sharing/occupancy models.

Therefore direct financial incentives at purchase has not been trialled specifically for autonomous vehicles

B

**Presence of testing facilities**

- Research institutions
- Off-road test tracks

Proximity to existing design and manufacturing facilities is likely to influence the roll-out timeline of technologies in different jurisdictions.

For example, Uber was launched in San Francisco first, prior to an international release. Governments can offset the geographic factors with policy and testing incentives.

C

**Conducive regulatory environment**

- Permit process
- Regulations on safety drivers

There are support systems within governments' control and environmental factors, both of which are taken into consideration by autonomous vehicle manufacturers when testing and releasing their technology.

Governments can support the introduction of autonomous vehicles by creating an environment conducive to technology testing and implementation

Source: L.E.K. interviews; NAVYA



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# Government R&D support is relatively common in markets with established automotive or technology industries

A

| Financial incentive | Description | Implications for Victoria |
|---|---|---|
| **R&D grants** | The **US** Department of Energy and Department of Transportation have issued solicitations that promote research, development, and demonstration efforts, for AUD $42m and $13m respectively<br><br>The **South Australian** government launched an AUD $10m grant funding round aimed at accelerating the development and rollout of CAVs in 2016<br><br>The **German** Ministry for Traffic and Digital Infrastructure made AUD $155m available as subsidies for AV projects, in its 2016 program 'Automatiastion and Inter-connection in the area of road traffic'<br><br>The province of Gelderland in the **Netherlands** provided AUD $5.5m to launch the WEPod project in 2016, an autonomous vehicle trial at Wageningen Univeristy<br><br>The **British** Government matched industry funding for autonomous vehicle research projects | *R&D grants appear to be the preferred international means of financial incentive for AV uptake* |
| **Partnerships** | **Japan** formed a partnership between Mitsubishi Electric, Here and the government to develop dynamic mapping capabilities, for which the government funded. Funding for the project came from a pledge from the Prime Minister to commit US$16.3 million per year to develop technologies necessary for AVs<br><br>In a partnership between **Singapore's** Land Transport Authority and Nanyang Technological University an AUD $3.5m facility called the Centre of Excellence for Testing and Research of autonomous vehicles in 2017 | |

Source: L.E.K. interviews; National Center for Transit Research; The Guardian; KWM; Economic Times; Clayton UTZ; Government of Japan, AutoDrive UK; L.E.K. research

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# Government support has helped create testing facilities that encouraged manufacturers to bring their technology to new jurisdictions

B

Before permits are issued to CAV manufacturers for testing on public roads the technology must be proven including safety assurances. In order to test the technology off-road facilities are required.

Typically the facilities include varied road features, from different road surfaces and lighting to crossings and traffic lights. Existing car testing facilities can be used, but specific CAV proving grounds with features such as bike lanes are beneficial in testing full autonomous capabilities.

| Testing ground incentive | Description | Implications for Victoria |
|---|---|---|
| **Government designated testing ground** | In 2017, **the US** Department of Transport announced the designation of 10 official autonomous vehicle proving grounds across the US to encourage testing and information sharing. DOT offered no financial support in their solicitation of proposals. The benefits of becoming a designated proving ground are the designation itself and becoming part of a Community of Practice around safe testing and development | *At the present stage of AV development, the mechanisms that appear the most effective to promote AV testing and use are targeted at manufacturers, given lack of widespread ownership and availability* |
| **Privately funded testing grounds** | The **UK's** MIRA proving ground is located in the Midlands and offers specialised ITS training facilities designed to replicated both European and US environments. Horiba MIRA is a private organisation with c. AUD $195m of test equipment, however it is central to the UK Government's Enterprise Zone programme. The Government has supported its expansion through approving further developments<br><br>**New Zealand** is home to the Southern Hemisphere Proving Ground. The privately-funded ground provides winter conditions to test vehicles in extreme conditions. The pitch to CAV companies is to 'reduce development lead-times by adding an additional winter season to the testing calendar'. The company is working closely with the New Zealand government to facilitate autonomous vehicles | |

Source: DOT; DOE; HKLaw; Mcity University of Michigan; MIRA; Coventry Telegraph; Driven; Southern Hemisphere Proving Ground; L.E.K. research

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# Clear processes and reforms to enable trials are attractive to OEMs, and are common and effective in leading AV markets

C

One of the primary attraction for AV manufacturers testing their technology in a new jurisdiction is the conditions on the permits they must acquire before conducting trials.

- **Permit availability:** Countries with clearly defined processes attract more trials, even with restrictions on when and where the trials may take place. However factors such as weather, proximity to manufacturing location, and the presence of off-road training facilities have also played a role in trial location
- **Safety driver:** The progression from occupied vehicles to unmanned trials has occurred after confidence in a system has been established. This may boost or hinder public acceptance, depending on the outcome of trials
- **Liability:** Most jurisdictions place liability for incidents on manufacturer or permit holder while the vehicle is operating in autonomous mode

| Permit requirement | Description | Implications for Victoria |
|---|---|---|
| **Discretion in granting permits** | **Victoria** reserves the right to decide whether a human driver is required for each trial permit. Conditions may be placed on the time and geography of the trial, alongside prior testing before trials take place. The permit holder is taken to be driving the vehicle while it is in autonomous mode. **NSW** can impose similar conditions to Victoria, but a safety driver must be present at all times | *Australian state governments do not have a unified approach to trial permits. If desired Victoria could seek to more closely align its protocols with other states to attract greater trial activity to Australia* |
| **Strict permit requirements** | **California** enforces strict regulation on AV trials. The DMV has three autonomous vehicle permit options: testing with a driver, driverless testing and deployment. The manufacturer is bound 'under penalty of perjury' to comply with permit conditions under the laws of the state<br><br>**South Australia** requires all trial details to be submitted in the permit, and mandates that details of the trial must be published online one month prior to commencement | |
| **No permit requirements** | **Western Australia** has proceeded to host a number of autonomous vehicle trials without any specific legislation<br><br>**New Zealand** legislation does not explicitly state the need for a human driver, therefore there are fewer legal barriers to autonomous vehicle testing | |

Source: King&Wood Mallesons; Victoria Parliament; Ministry of Transport NZ



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# Requirements to share trial results are common, but vary in nature balancing promotion with the expected benefits of trials with commercial sensitivity

## Reporting and Data Considerations for AVs

Disclosure requirements vary between jurisdictions. While some jurisdictions opt for full disclosure requirements to assist policy makers, others are concerned that such strict disclosure requirements will discourage manufacturers, due to the commercial sensitivity of product development.

| Issue | Issue Description | Implications for Victoria |
|---|---|---|
| **Drive data reporting** includes reporting on vehicle performance, location or trial and driver details | **Victoria** have the most stringent rules for AV trials in Australia, with VicRoads requiring real-time monitoring of the performance and location of the vehicle. South Australia imposes less stringent laws, requiring no reporting except for a final report to Parliament<br><br>From May 2018, AVs undergoing trials in **China** must automatically store drive data (e.g. vehicle control mode, location, speed, environmental awareness, vehicle lighting, internal and external video, remote control instructions etc.) every 6 months<br><br>**Singapore** requires trials to keep records of sensor data and video footage, as the minister who granted the trial permit can require access to the data at any time. However, the trial participant can request that data is not made public, and the minister must proactively ensure this<br><br>In **New Zealand**, the Transport agency would be 'grateful' to receive a summary of trial data, but no strict regulations are in place | *Drive data reporting is beneficial for government awareness. Victoria's stringent reporting rules may risk discouraging AV trials in the State* |
| **Disengagement reporting** includes reporting on the deactivation of the autonomous mode when a failure of the autonomous technology is detected | In **Australia**, the NTC guidelines require serious incidents and to be reported within 24 hours, while near misses and disengagements must be reported on a monthly basis. Australia also has state-based requirements, which differ by state but all require similar incident and accident reporting<br><br>**California** requires a declaration of disengagements, collisions, and the number of miles driven by AVs on an annual basis per OEM, to be published on their website. However, as different OEMs define 'disengagement' differently, levels of reporting can vary. Difficulties come in defining disengagements at the start or finish of a test run, and what is classified as testing for 'an entire year'. Tesla have avoided reporting all together by claiming all test drives were done in simulation instead of on Californian roads<br><br>Meanwhile, **Arizona** do not have reporting requirements on disengagements or incidents. Hence, Arizona has become a hot-spot for CAV testing by leading companies including Uber, Lyft, Waymo and Google | *The level of disengagement reporting required by a jurisdiction can have an impact on the advancement of CAV testing in that jurisdiction* |

Source: King&Wood Mallesons; The Ministry of Public Security of the People's Republic of China; NY Times; NTC; NZ Ministry of Transport; CleanTechnia



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# Summary: Policy support for AVs

| Issues | Choices / Approaches | Implications |
|---|---|---|
| ***What are the primary objectives for Government leadership in AVs internationally*** | CAV trials are seen as a way to **promote manufacturing and industry** and create jobs, to **attract new technology** and for **public assurance**<br><br>There is a significant debate around whether CAVs will increase of reduce **congestion**. **Singapore** aims to use AV technology to improve their **public transport system**<br><br>Depending on the licencing system, AVs may **increase access to mobility** for individuals who are unable to drive | *Leading jurisdictions have clear objectives for AV trials that cross a broad range of economic and public safety outcomes*<br><br>*Trials and regulations about AVs use present an opportunity for improving social access*<br><br>*No clear policy responses have emerged at this stage to negate negative outcomes – road charging and usage rules are thought to be the most prospective approach* |
| ***Which mechanisms are being used to support the deployment of AV technology*** | A **conducive regulatory environment** is one of the strongest drawcards to attracting OEMs<br><br>The **presence of testing facilities** has been a significant drawcard to manufacturers, particularly due to the need to prove safety capabilities before public trials<br><br>**Financial incentives** have been provided to support R&D efforts | *At the present stage of AV development, the mechanisms that appear the most effective to promote AV testing and use through attracting trial activity are targeted at manufacturers, given lack of widespread ownership and availability Victorian could consider closer alignment with other state regimes to attract trial activity* |
| ***The extent to which restrictions are placed on permits for AV trials*** | The **process for granting permits** is **still in development** in many jurisdictions<br><br>Most jurisdictions **place liability for incidents** on **manufacturer or permit holder**<br><br>The **progression from occupied vehicles to unmanned trials** has occurred after confidence in a system has been established | *Given the wide variety of approaches observed internationally, Victoria can set its own standards for trials. There may be some benefit in closer alignment with other states if there is a desire to attract more trial activity in Australia* |

Source: L.E.K. interviews; L.E.K. research



L.E.K.