The “wicked problems” of connected and autonomous vehicles (CAVs)

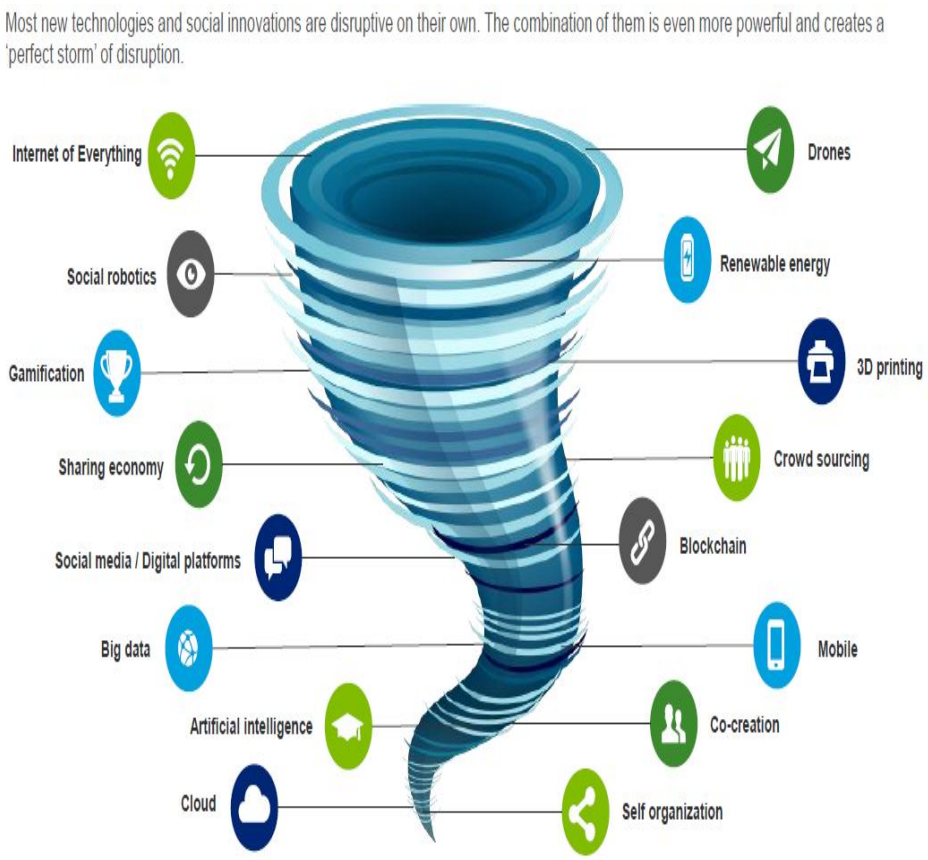
The development of Connected and Autonomous Vehicles (CAVs) is generating “Wicked Problems”.
The phrase “wicked problems” is attributed to an article by the American philosopher and systems analyst, Charles Churchman 1967 who defined such problems as difficult or impossible to solve because of “Incomplete, contradictory and changing requirements that are often difficult to recognise”.

As a researcher and policy maker I’d suggest that the wickedness of a problem increases when it is controversial and emotive.

This presentation provides an introduction to rapidly developing Connected and Autonomous vehicles including:

- **The incremental disruption and changes that CAVs will bring**
- **The five stages of automation from Level 0 manual driving to full automation**
- **The broader impacts of CAVs including challenges for Government, Car Makers, Customers and Behaviour Change**

Wider context of Automated cars – Accelerating Artificial Intelligence(AI)



The analogy between the Cambrian explosion of biological life through eyesight "technology" and the imminent explosion of robotics through visual perception improvements is hard to miss

Today there is a similar explosion in the diversification of the application of robotics

A number of base technologies are key to CAV's exponential improvements in:

1. Power storage and efficiency
2. Computational power
3. Sensor technology "eyesight"
4. Data storage capacity
5. Communications bandwidths
6. Algorithms

All these improvements are developing self awareness in today's brainless conventional cars.

- Evolutionary robotics is breathing life and visual perception into inanimate automated vehicles.
- Coordinated delivery by industry, technology providers and government will be crucial.

Current constraints include:

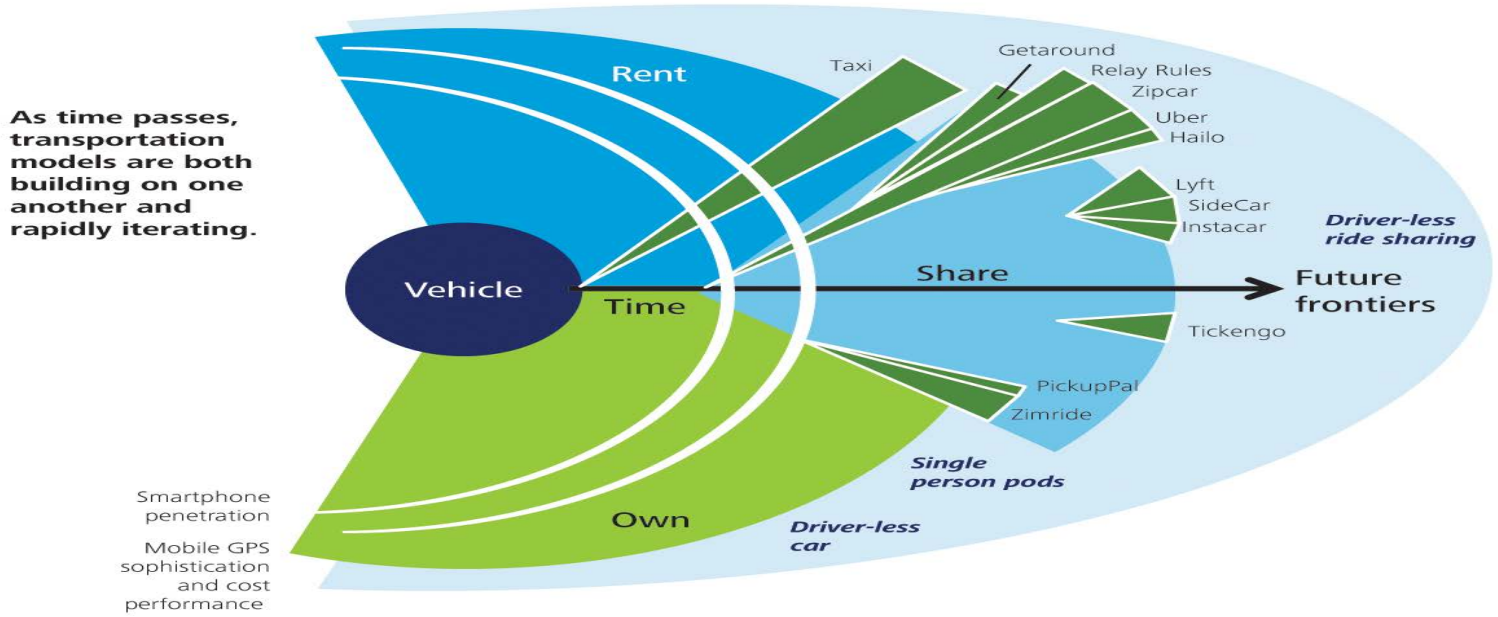
- CAV technology is too expensive for mass sales
- Its illegal to drive fully automated vehicles on the NSW road network.

Disruptive Innovation: from manual to autonomous vehicles

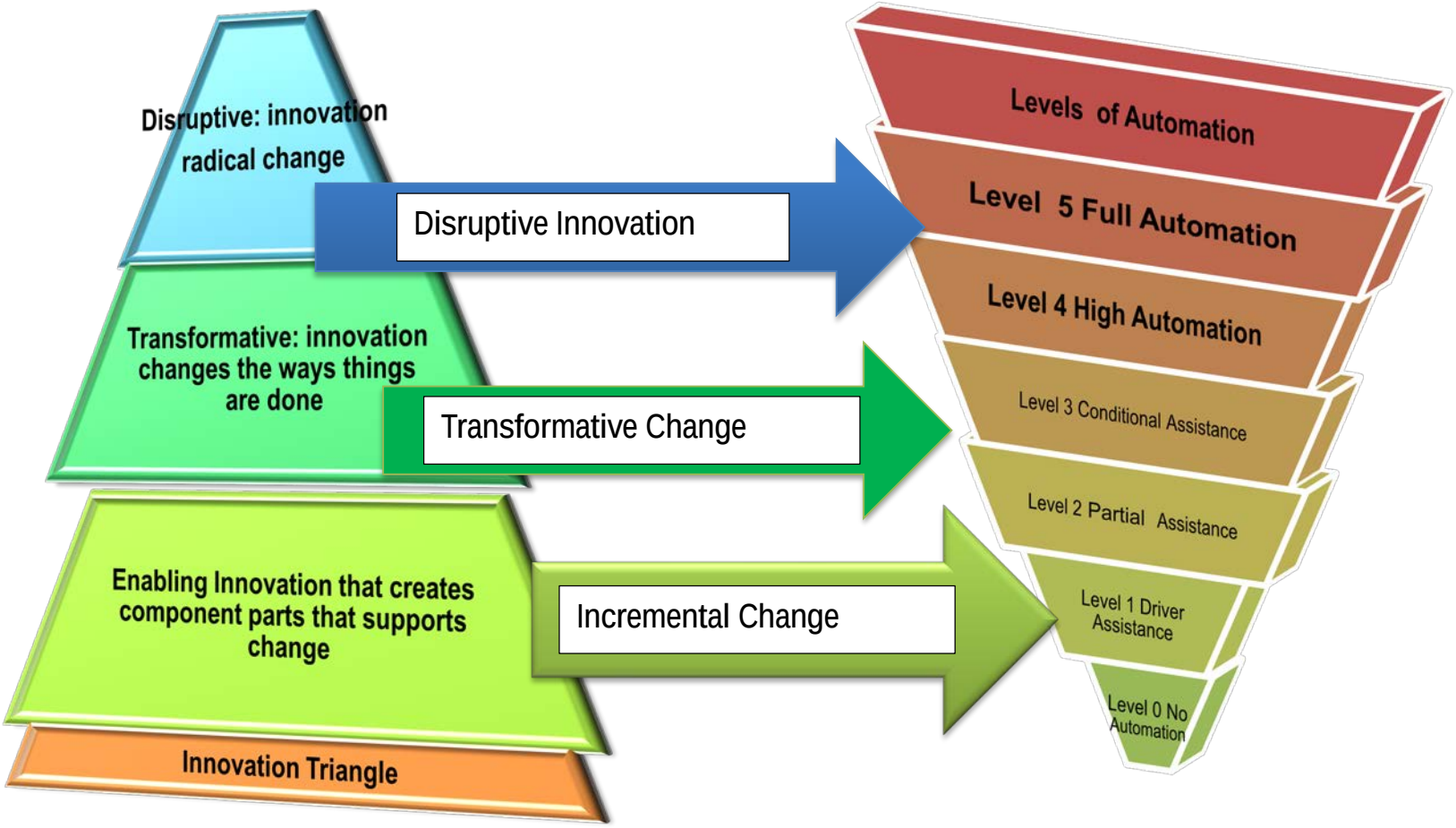
Our world is speeding up we have robotic construction, augmented reality and connected and automated vehicles and artificial intelligence.

- Few cities are preparing for Connected and Automated Vehicles CAVs
- Rather than cities just waiting for CAVs to arrive they should be preparing Smart plans to use CAV's to improve liveability, workability and sustainability.
- Dislodging our substantial transport systems by forceful technological change may benefit some and alienate others.

"Disruptive innovation' theory Clayton Christensen of Harvard Business School, "The Innovators Dilemma"; process initially starts at the bottom of a market and then moves relentlessly 'up market', displacing established models.



Incremental change and disruptive innovation



Levels of Automation and infrastructure change

The levels of automation has been defined by the Society of Automotive Engineers SAE 2014 into the following levels of automation ranging from level 0 to full driving automation level 5.

Levels of automation					
Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
No automation Humans are required to manually interact with all parts of the vehicle for its operation	Driver assistance Augmented Steering Throttle and Automatic Braking systems	Partial automation Driver required at all times. Partially enabled vehicle with automatic steering, accelerating, and braking in controlled pilot zone areas	Conditional automation Drivers will rely on automatic pilot with limited manual control; interactions with infrastructure will be become critical.	High automation Driver only needed in emergency situations with critical conditions on public roads	Full automation No driver autonomous systems take over manual driving functions Challenges and uncertainty are inevitable.
Potential future infrastructure systems requirements					
No Change	Design Changes Planning and design of future CAV infrastructur e required	Modified road layout in controlled pilot areas	Modifications to infrastructure vehicles regulations and road rules will need to change.	Changed road regulations, licensing modifications to signals intersections, road markings	Radical changes to legal and insurance and modifications to transport networks

Levels of Automation

Level 1: Driver Assistance

Key catalyst points for driver and partial assistance systems are highlighted. The table summarises the development cycles, costs and market saturation deployment. Litman 2018.

Past lessons learnt clearly demonstrate the long development cycles for adoption of driver assistance systems.

Market deployment of Driver Assistance Systems

Technology	Deployment Cycle	Typical Cost Premium	Market Saturation share
Air Bags	25 years (1973- 98)	A few hundred dollars	100% due to federal mandate
Automatic transmission	50 years 9(1940s - 90s)	$1,500	90% US 50% worldwide
Navigation systems	30+years (1985-2015+)	$500 and rapidly declining	Uncertain, probably over 80%
Optional GPS Services	15 years	$250 annual fee	2-5%
Hybrid Vehicles	25+ years (1990-2015+)	$5,000	Uncertain, currently about 4%

Level 2 Partial Assistance
Level 3 Conditional Assistance

Level 2 Partial Assistance: Partial automation

Level 2 has introduced unifying partial assistance hardware and software systems to enable partial automation of vehicles through steering, acceleration, and braking

However driver involvement is still required to carry out tactical manoeuvres such as responding to traffic signals or changing lanes, as well as scanning for hazards, monitoring the surroundings, traffic, weather and road conditions.

Level 3 Conditional Assistance – Considered unsafe model

The key catalyst points for conditional assistance will enable vehicles to automatically undertake most aspects of driving, including monitoring the environment

Many in the CAV industry believe that a staged transition from automatic to manual control is not only **technologically challenging but also unsafe. The Driver not being required to monitor the environment is considered a flawed concept.**

When failure of systems is detected only 7 seconds is allowed for driver to to manual control. A MINIMUM OF 35 SECONDS IS REQUIRED. When a driver takes their eyes of the road for 2 seconds they lose situational awareness

The global car makers including Ford, Waymo (Google), Volvo, Toyota will not be developing level 3 vehicles. They aim to go from Level 2 to level 4.

Level 4 High Automation
Level 5 Full Automation

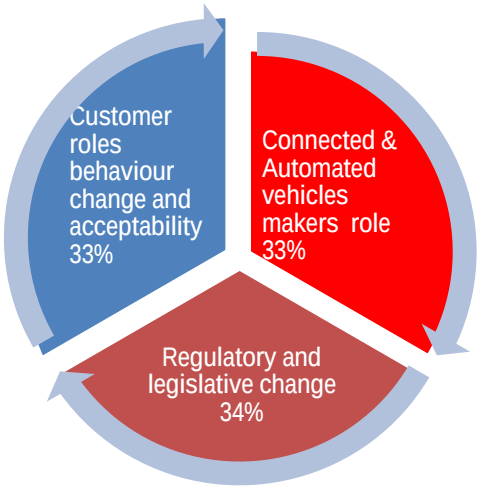
Level 4: High Automation

At Level 4 highly automated vehicles are able to operate without a human driver in limited situations, for example, in particular locations, routes or conditions. Examples of Level 4 passenger shuttle buses include the one being currently trialled at Sydney Olympic Park, and footpath – based delivery robots that started a 2 year trial in 2017. Several companies including Waymo and Uber have begun testing driverless taxi services (Bergen shuttling people around Phoenix, Arizona.

Level 5 Full-Automation

Although the technology for Level 5 proto-type vehicles is still being refined the challenge for automakers and suppliers of Level 5 Fully Automated Vehicles will be the need for rigorous testing and validation of hardware and software systems.

Requirements, Opportunities and Principles



Requirements "What is needed"	Opportunities "What might change"	Principles "How to deliver to customers"
Government role regulations and policy How are government responding currently to CAV technology? To give an idea of the scale of the task for government, there are approximately 360 laws and regulations that need amending in NSW plus National regulations	Vehicle makers role How is industry approaching CAV technology? Why? The estimated value of investment by private industry into CAV technology deals approached $80 billion dollars (Kerry and Karsten, 2017). Most auto manufacturers have announced plans for CAVs and already offer and have released vehicles with increasing driver assistance systems	Customer role: behaviour change and acceptability What do we know about potential customers attitudes to the approaching CAV technology? Are they just being swept along? Are their views currently being represented and factored into CAV technology developments by industry and government?

What is needed? Government Regulations and policies

Road transport and safety legislation

The regulatory environment that manufacturers and users of autonomous vehicles must navigate is complex. In NSW the main legislation that will require review includes

- The Road Transport Act 2013
- The Roads Act 1993
- The Passenger Transport Regulation 2007
- The Crimes Act 1900

Many other jurisdictions are facing the need to review legislation to enable CAV vehicle trials that can provide valuable lessons for NSW.

Numerous laws in Australia implicitly assume that vehicles can only be driven by a human driver. This implicit assumption creates considerable uncertainty as to how these laws would apply when a vehicle is being driven by an automated driving system. The main questions that will require resolutions are:

- *Who is the driver of a fully automated vehicle that is operating on a public road without any passengers?*
- *Who is responsible for ensuring that a fully automated vehicle does not speed?*

Controlled trails in defined areas

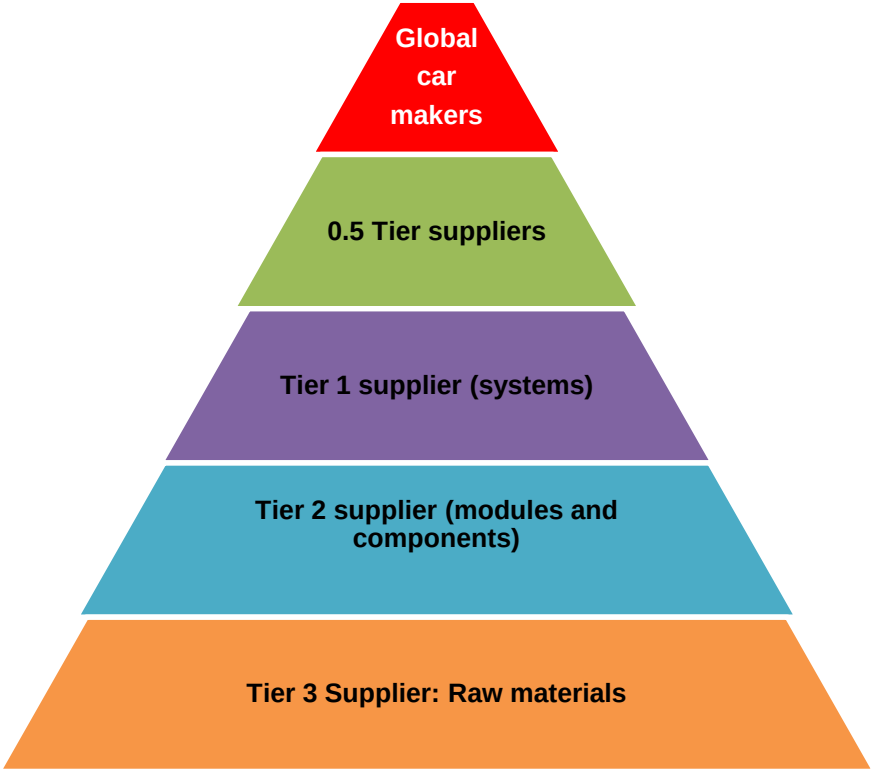
- Operating capability and limitations assessment
- Consistent interactions with infrastructure and signalling
- Autonomous vehicle operator learning and training
- Rapid data collection to inform insurance and liability matters
- Safe environment for ultra-innovative concepts

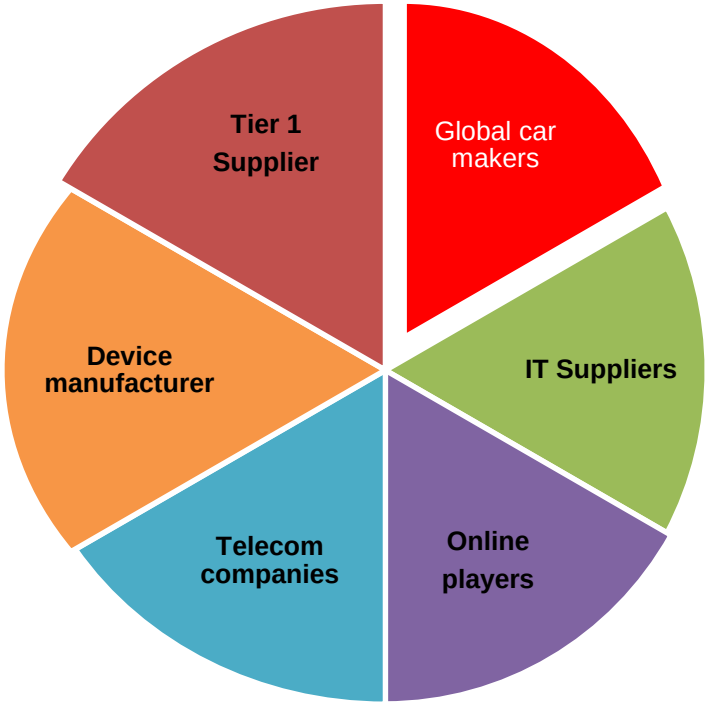
Road network and infrastructure testing

- Cross-border and long-distance trialling and testing
- Altering environmental conditions and road surfaces
- Varying road infrastructure and signalling
- Interactions with human-driven road vehicles
- Road hazard and roadworks awareness testing
- Moving hazard and unforeseen scenario perception testing

Opportunities: How will vehicles makers roles change?

Currently the car industry is shaped like a pyramid with the global carmakers at the top supporting several tiers of suppliers including raw materials and components, IT systems and production partners. In the future as the values of vehicle components change the shape of the pyramid structure changes to a hub and spoke integrated network with Global Car Makers still playing a pivotal role now surrounded by equally powerful interconnected hardware and software companies and suppliers.





Customer assessments and conclusions

Customer Assessments	
Positive outcomes	**Negative outcomes**
Will reduce automobile accidents, although this is contested	Cities will become more congested as more vehicles join the road
Providing transport to the elderly, disabled and kids; improving mobility for millions	That kids will get off their bikes and be driven, driverless, to school resulting in lack of exercise and obesity problems
Increases road capacity and traffic flow	More people will have access to cars and will be use more frequently driving further adding to congestion
Free our cities and towns of parking demands	Far from ending traffic congestion, CAV's will make it worse
Cleaner and greener	CAV's won't make our cities more liveable and connected, but more fragmented and sprawling, duller and more isolated
Free us from even owning a car at all, with driverless taxis and car share vehicles providing our mobility	Spatial inequality will increase the rich will cluster in city centres and the poor will be warehoused in the cheaper exurban fringe
Self driving cars have benefits, however will cause urban sprawl	CAV growth will need multiple legislation changes

Conclusions

As this review has highlighted there is a wide spectrum of views

- The predicted reductions of accidents by 95% by CAV's is contested
- Level 3 CAV's are considered unsafe; major auto makers are refusing to develop them
- New CAV developments will be a challenge for government regulators
- The 28% of employment by drivers will be severely impacted by job losses caused by CAVs
- Future behaviour change as to whether Autonomous vehicles will be acceptable and whether drivers will change from private car ownership to shared ownership is unknown

The focus needs to change from a car centric approach to a wider review of the impacts of CAV technology on our cities and our future lifestyles