ADVI AUSTRALIAN DRIVERLESS VEHICLE INITIATIVE

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Australian Driverless Vehicle Initiative

Position Paper

Economics Impacts of Automated Vehicles on Jobs and Investment

30 September 2016

This paper represents the current position of the Australian Driverless Vehicle Initiative (ADVI) as a collaboration of its partners. It does not purport to reflect the position of individual partners nor commit them to a particular direction or technology position.

This policy position is subject to change as new information and knowledge arises, and as the ADVI partnership evolves. All assumptions are based on the best available information and no responsibility is taken for any errors or omissions. Any use of the information provided in this position paper is at the discretion of the reader.

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*This paper utilises the combined knowledge of a range of ADVI and Industry experts

Value Proposition

Automated vehicles[1] (AV's) can drive major economic outcomes in terms of public benefits (e.g. reduced traffic congestion / reduced road deaths) and private benefits (time savings / increased productivity). The scale and distribution of economic benefits will depend on how the introduction of automated vehicles is managed.

Prima Facie Economic Case

A strong prima facie economic case supporting the introduction of automated vehicles in Australia is based on the avoided costs of congestion and road deaths.

The future avoidable social costs of traffic congestion in Australian cities has been estimated by Infrastructure Australia at up to $53.3 billion per annum by 2031[2] with total vehicle usage (in vehicle kilometres) increasing by 35%. The annual economic loss of road crashes in Australia is estimated by the Department of Infrastructure and Regional Development to be $27 billion per annum. Since records have been kept in Australia (1925) over 187,000 road deaths have been recorded.

The total 'avoidable costs' of $80 billion is a baseline to which the economic benefits of jobs and investment can be added.

The UK has estimated £900 billion (AUD $1.6 trillion) in increased productivity and increased trade by 2025 as Advanced Driver Assistance Schemes (ADAS) and Automated Vehicle Technology (AVT) are progressively developed and utilised.[3]

Canadian research suggests that replacing conventional vehicles with self-driving vehicles would result in more than $65 billion ($AUD) in economic benefits for Canadians each year. This includes $25 billion in lives saved, $12 billion in avoided medical costs, $20 billion in wasted time in traffic and $8 billion in congestion avoidance[4].

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[1] It is assumed that in terms of vehicles 5% are fully automated @ 2026 / 30% @ 2035 / 60% @ 2045 / 100% @ 2060. Appendix One includes the key assumptions and indicates similarity with Canadian forecasts.

[2] Infrastructure Australia, Australian Infrastructure Plan 2016.

[3] Pathway to Driverless Cars (2016): Proposals to support Advanced Driver Assistance Systems and Automated Vehicle Technologies Centre for Connected and Autonomous Vehicles

[4] Automated Vehicles: The Coming of the next Disruptive Technology (2015), Gill, Kirk and Fleming
pp 20-37.

Understanding Economic Scenarios to Assess Employment and Investment Impacts

Two key economic scenarios emerge for consideration:

1. Minimum Public Intervention: Automated vehicles simply replace traditional vehicles over time in an unplanned fashion
2. New Mobility Ecosystem: Automated vehicles become the catalyst for economic change in the use and funding of roads, public transport freight and logistics and city building. With 'Vehicle-to-everything' (V2X) communication AV's can become part of an intelligent transport system.

The second scenario should be pursued. Maximising the economic benefits of Automated Vehicles would include:

- Ensuring that the transition to AV's did not result in increased traffic congestion.
- Transitioning from car ownership to sharing.
- Utilising AV's to maximise the efficiency of public transport.
- Implementing a regulated asset base for primary and secondary arterial roads to enable appropriate planning, investment and pricing[5].
- Devising a new approach to road freight movement and intermodal facilities to maximise efficiency.

The private sector economic benefits of automated vehicles include; time savings, increased productivity, increased personal safety, (reduced travel costs or increased productivity of travel time), increased accessibility for the old, young and disabled and increased travel amenity. The public sector economic benefits and costs include increased safety (reduced road deaths), reduced car and noise pollution, potentially 'managed' travel congestion, reduced costs of public transport (driverless buses, taxis boats), better transport rationing and pricing, more efficient freight, increased connectivity of mass transit with driverless bus interfaces (increased efficiency of public transit), reduced car ownership and more efficient use of the vehicle fleet.

Automated vehicles will have direct and indirect economic impacts and will generate a range of important economic multipliers. Direct economic impacts derive from the development of the vehicle. The indirect economic impacts derive from the use of the vehicle and enabling infrastructure.

[5] The Infrastructure Australia Plan (2016) recommended that major primary and secondary roads in Australia be deemed as a 'regulated asset' and transferred to a corporatized body. The rationale behind this was to create a consistent basis for road charging, congestion charging and to maintain the asset base. This strategy would create a national consistency and support national investment in roads to support the rollout of autonomous vehicles.

Direct Economic Impacts

Automated vehicles have different supply chain requirements to traditional vehicles. The key differences are the requirements for V2X devices, auto pilot software's, amenity software's (entertainment, information etc.) and communication systems. In addition automated vehicles will include 'learning' and 'mapping' software to enhance safety and efficiency. Some companies are automating traditional vehicles (e.g. Volvo, Mercedes Benz), others are building new vehicle types. Direct economic impacts will depend on the nature of emerging supply chains and the actual infrastructure requirements.

Indirect Economic Impacts

Environmental benefits are likely to be substantial. The range and scale of benefits depends on assumptions in relation to moving from vehicle ownership to sharing, shifting to electric vehicles and assumptions in relation to induced travel due to ease of travel. Combining these factors, Fagnant and Kockelman (2014)[6] found that each shared autonomous vehicle (SAVI) can replace around eleven conventional vehicles, but adds up to 10% more travel resulting overall in beneficial emissions impacts.

Indirect economic impacts include costs of new road traffic infrastructure, increased vehicles on road, changes to insurance and liability, the cost of enabling road and telecommunication systems, implications for public transport without a managed introduction of AV's, reduced car purchase, potentially reduced active transport[7] and potentially increased demand for car parking in the short term as vehicle usage increases prior to full automation.

Benefits include new technologies and requirements for driver learning, spin-off technologies for robotisation and automation and export supply to global markets for components such as devices. Cohda a South Australian company for example is the world leading supplier of V2X devices.

Social inclusion in terms of mobility for the elderly, young and disabled is likely to generate significant economic benefits. This will occur in ways such as access to services, personal safety, wider residential location opportunities and time savings.

Indirect economic benefits should include environmental and health benefits derived from increase in fuel efficiency plus an induced impact on the shift to electric vehicles. Additional benefits include urban design and place making[8]. In particular with full automation (SAE levels 3, 4, 5) major reductions car parking spaces in the long term, plus increased land use efficiency (15% to 20% claimed)[9] in newly developing areas can be identified as having significant indirect economic benefits.

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[6] The Travel and Environmental Implications of shared Autonomous Vehicles, using Agent Based Model Scenarios, Fragnant, D and Kockelman K (2014).
[7] Current international and domestic research suggests that the introduction of AV's will reduce levels of active transport.
[8] Making Better Places WSP Parsons Brinkerhoff, Farrells.
[9] Making Better Places estimates that 50% to 70% of the 5,000 hectares dedicated to car parking in London could be released.

Understanding Timing and Implementation

A key parameter underpinning the estimation of jobs and investment in AV's is the articulation of the components implementation of Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicle Testing (AVT), plus required enabling infrastructure and industry development programs. In order to understand timing in a consistent manner, the SAE Levels of Automation (Appendix One) have been adapted. These levels of automation need to be translated in Australia considering several pathways:

- The operational framework including traffic regulation (National Transport Commission) and insurance.
- Implementation timing of near to market technologies which will condition the market place acceptance of AV's. This includes high speed motorway assist, remote control parking and heavy vehicle platooning.
- Production of ADAS vehicles and market demand, noting prestige vehicle makers (MB / MBW / Tesla) indicate production by 2020.
- Timing and funding of enabling infrastructure including communications systems and roadways.
- City performance i.e. congestion, park costs, lack of parking etc.
- Introduction of an institutional framework to manage the implementation and operations of AVT.

The UK view is that the production and use of truly driverless cars will occur from the mid 2020's. Further, major ADAS technologies including motorway assist systems for travel on high speed roads and remote control parking are likely to come to market in the next two to four years[10].

Translating these factors into timeframes for the production of ADAS (up to SAE Level 2) then fully driverless AVT (SAE Levels 3, 4 and 5) is complex. The market penetration levels for AV's assessed in this position paper have been variously described as too 'sharp' and not 'aggressive enough', however on balance offer realistic scenarios on which to base implementation and industry development (Appendix One). They do however take into account the rate at which the car fleet is turned over (2% per annum max) and the potential in the short term for ADAS to be offered as an upgrade rather than as standard in all circumstances. Further it is anticipated a fully driverless AVT purchase would initially be a 'prestige' option until high speed motorway assist can be utilised with drivers able to delegate responsibility for part of the journey to the vehicle.

Internationally different approaches to the take up rates or market penetration of AVs have been pursued. These range from the Canadian example (see Appendix One) of estimating market share in relation to growth and change in the motor vehicle market only, to the McKinsey (2016) approach[11], which focuses on disruptive trends that will transform the auto industry into a key part of the mobility services industry. McKinsey (2016) have forecast that

[10] Pathway to Driverless Cars (2016) p. 6 and p. 8
[11] McKinsey + Company, A Road Map to the Future of the Auto Industry (2016)

the automotive revenue pool could increase by (30%) $US1.5 trillion including ride/car sharing, on demand services and data driven services. This compares with an estimate in the UK of the value of the intelligent mobility markets globally which is around $900 billion ($US 1.2 trillion)[12]. In the United States, $3.5 trillion is currently generated from traditional car sales and aftermarket.

Depending on the scenario adopted, the implications for jobs and investment are vastly different. McKinsey (2016) utilise two scenarios, high disruption and low disruption (see Appendix Two) to forecast the potential number of new cars which could be fully autonomous over time. In the high disruption scenario McKinsey forecast up to 15 percent of new cars sold could be autonomous by 2025. Significantly, McKinsey argue with support of a range of analysts that by 2030, 10% of vehicles sold will be shared vehicles accounting for 30% of kilometres driven.

Having regard to international research ADVI could adopt the following indicative take up rate scenarios to guide industry by development (see Appendix One).

Australian Autonomous Vehicle, Take Up Rates (%) (% New Vehicle Sales)		
	Scenario One - Minimum	**Scenario Two - Maximum**
2016 - 2021	0	0
2021 - 2026	2	5
2026 - 2036	15	30
2036 - 2045	30	60
2045 - 2055	60	90
2055 – 2065	100	100

[12] Modelling for Intelligent Mobility (2015) Transport Systems Catapult.

Jobs and Investment Forecasts

Utilising Scenario Two (Maximum Take Up Rate) for AV's which is more consistent with the McKinsey high disruption scenario timing and the UK modelling for intelligent mobility, suggests that on a per annum basis the global intelligent mobility market will be worth $US 1.2 trillion to $US 1.5 trillion by 2025. Australia's market share of global production was estimated by the Productivity Commission[13] to be 0.25% in 2013 and cars sold 1.3% of 85 million. Based on achieving 1% of the global intelligent mobility market, Australia would generate $15 billion in revenue and depending on the nature of the jobs (software, coding, component manufacturing etc.) this would generate approximately 7,500 direct jobs and 16,000 direct and indirect jobs requiring $1.5 billion - $2.0 billion annual investment based on traditional car manufacturing parameters[14]. An aggressive strategy for early investment in AV's in Australia would mirror the UK objective from the Transport Systems Catapult (p.3, 2015, Modelling for Intelligent Mobility), which is to: ***"Drive UK global leadership in Intelligent Mobility, promoting sustained economic growth and wellbeing through integrated efficient and sustainable transport systems."***

Estimating total job and investment outcomes from the introduction of AV's would include directly generating new employment and new investment through:

- Industry expenditure (as above).
- Government industry development expenditure.
- New infrastructure funded by both the public and private sector.

Pursuing a broader industry strategy could help mitigate the forecast 40,000 jobs[14]14 above to be lost in car manufacturing as a result of the withdrawal of this industry from Australia. It should be noted that if the average of $2 billion in assistance (1997 – 2012) to car manufacturers was invested in intelligent mobility, direct employment could be doubled from 7,500 persons to 15,000 persons. This would represent a significant impact on the forecast job losses and would generate a significant requirement for reskilling.

[13] Australia's Future Automotive Manufacturing Industry. Productivity Commission Inquiry Report (2014)

[14] This compares with the Productivity Commission estimates of up to 40,000 direct job losses due to the cessation of automobile manufacturing. It should be noted however to achieve this outcome required $30 billion of industry assistance from 1997 to 2012.

A New Industry Managing Change to Maximise Economic Prosperity

AV's present the opportunity for Australia to take leadership in the establishment of a new industry with key sectors developing and supplying the new 'Mobility Ecosystem' rather than unplanned introduction of AV vehicles. This proposed approach is based on growing:

- Advanced manufacturing.
- New legal and insurance service industries.
- Communications and information technology value chains and innovations.
- Integrated public and private transport systems.
- The use and efficiency of trunk public transport.
- Equitable mobility, pricing and new revenue collection technologies and systems.
- New city planning infrastructures.
- Reducing overall costs of mobility.
- Managing change to maximise active transport outcomes.

Dubai has taken this approach with the launch of its Dubai Autonomous Transportation Strategy which aims to transform 25 per cent of total transportation in Dubai to autonomous mode by 2030 saving AED $22 billion ($8 billion AUD) in annual economic costs. Based on avoidable costs alone an annual saving of $10 billion is realistic for Australia (and extremely conservative) and in terms of employment this would translate into around 20,000 jobs.[15] In 2015 BMW alone hired 400 IT professionals with another 500 experts in artificial intelligence to be added in 2016.

[15] The value of Australian automotive manufacturing (Monash Centre of Policy Studies) from an economic welfare perspective is around $21.5 billion automotive industry receives around $500 million annually in Government funding.

ADVI Position

Every country has a different pathway to deliver network connected and fully automated vehicles. The UK is at the forefront.

It is ADVI's position that the Commonwealth Government should prepare and explore mechanisms to fund and manage the introduction of autonomous vehicles on the following basis:

- To maximise employment outcomes targeting 20,000 new jobs by 2025.
- To maximise the social and economic benefits of introducing AV's in Australia.
- To maximise the technology spin-off industries in Australia.
- To put Australia in a competitive position to export mobility services expertise.
- To maximise the productivity of existing transport infrastructure.
- Create a new funding mechanism to replace the outdated system of shadow taxes, including; fuel excises, registration, licensing fees etc.
- To create the opportunity to develop a new industry based on the delivery of a best of breed 'mobility ecosystem'[16].
- Assess whether Australia should own or invest in AV system control to collect, filter and interpret data and to make ethical decisions in emergency situations.
- To encourage vehicles to become electric, connected and automated.

ADVI's position is for a 5 year funding and incentive package (i.e. to coincide with the introduction of an industry structure) focusing on research, development, demonstration and deployment similar to £100 million (AUD $177m) Intelligent Mobility Fund in the UK. This fund is match funded by industry.

ADVI recommends as an immediate action that an 'AV Accelerator Program' be initiated in Australia. This would ensure that by 2020 at the latest, near to market technologies such as high speed highway assist (with drivers in control), remote car parking (using a hand held device) and potentially truck platooning can occur, to ensure that as products come to market they can be sold and utilised.

The key concept is an AV 'rollout' program off-budget similar to NBN[17] with an institutional structure similar to NBN in order:

- To manage the operational characteristics, ownership funding and maintenance of the AV operating system
- To ensure that patents required to develop the AV operating system are developed and owned in Australia.

[16] The productivity Commission recently prepared a similar paper on removing barriers the growth of key service sectors in the Australian economy.
[17] The RC has also developed a leading edge industry structure for the National Disability Insurance Scheme.

APPENDIX ONE: Key Assumptions - AV Market Penetration

International Level Definitions (Attached)

- AV Initiation Phase 1: Level 0/1 Automation but licensed drivers are in control of the vehicle 2016 – 2021.
- AV Phase 2: Level 0/1/2 Automation with licensed drivers at the wheel but with minimal attention 2021-2026 (5% AV market share). Tesla, Mercedes Benz and BMW have reported production of fully automated vehicles by 2021.
- AV Phase 3: level 0/1/2/3 Automation widely available, automated taxis (Taxi bots) and buses. Licensed driver not required in all situations (e.g. elderly, disabled, 12-18 year olds etc.), 2026-2035 (30% AV market share).
- AV Phase 4: Level 5 Automation – all vehicles sold with level 5 capability and 90% of all future vehicles required to be fully automated by 2045 (60% to 100% AV Market Share).
- AV Phase 5: Level 3/4/5 AV vehicles modified for level 5 operation by 2060 (100% market share). Fully automated private vehicles saturation.

Please note the inherent statistics driving the assumptions are based on:

- 13.5 million passenger vehicles / 2015.
- 2% per annum growth.
- Most legal and insurance issues clear by 2021 / all clear by 2026.
- Major AV enabling infrastructures have capex plans in place for a 10 year roll out as per NBN by 2026.
- New institutional framework for fully automated traffic movement in place by 2021. This is likely to be similar in some ways similar to the NBN as primary and major secondary roads around Australia are classified as a Regulated Asset Base and controlled, maintained, priced and upgraded for AV's by a new corporatized national authority.

Canadian Forecasts

Fully Self-Driving Vehicle Implementation (share of the market in percent)			
	New Car Sales	All Vehicles	
2020s	2-5	1-4	Available, expensive option
2030s	20-40	10-30	Available, moderate cost
2040s	40-60	30-50	Available, minimal cost
2050s	80-100	50-80	Standard on most cars
2060s	80-100	80-100	Saturation
Source: Automated Vehicles: Implications for the Insurance Industry in Canada (2015)			

SUMMARY OF SAE INTERNATIONAL'S LEVELS OF DRIVING AUTOMATION FOR ON-ROAD VEHICLES

Issued January 2014, **SAE international's J3016** provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains. It defines more than a **dozen key terms**, including those italicized below, and provides **full descriptions and examples** for each level.

The report's **six levels of driving automation** span from *no automation* to *full automation*. A **key distinction** is between level 2, where the *human driver* performs part of the *dynamic driving task*, and level 3, where the *automated driving system* performs the entire *dynamic driving task*.

These levels are **descriptive** rather than normative and **technical** rather than legal. They imply **no particular order** of market introduction. Elements indicate **minimum** rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at **different levels** depending upon the feature(s) that are engaged.

System refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*. **Excluded** are **warning and momentary intervention systems**, which do not automate any part of the *dynamic driving task* on a sustained basis and therefore do not change the *human driver's* role in performing the *dynamic driving* task.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Key definitions in J3016 include (among others):

Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

Driving mode is a type of driving scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

Request to intervene is notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

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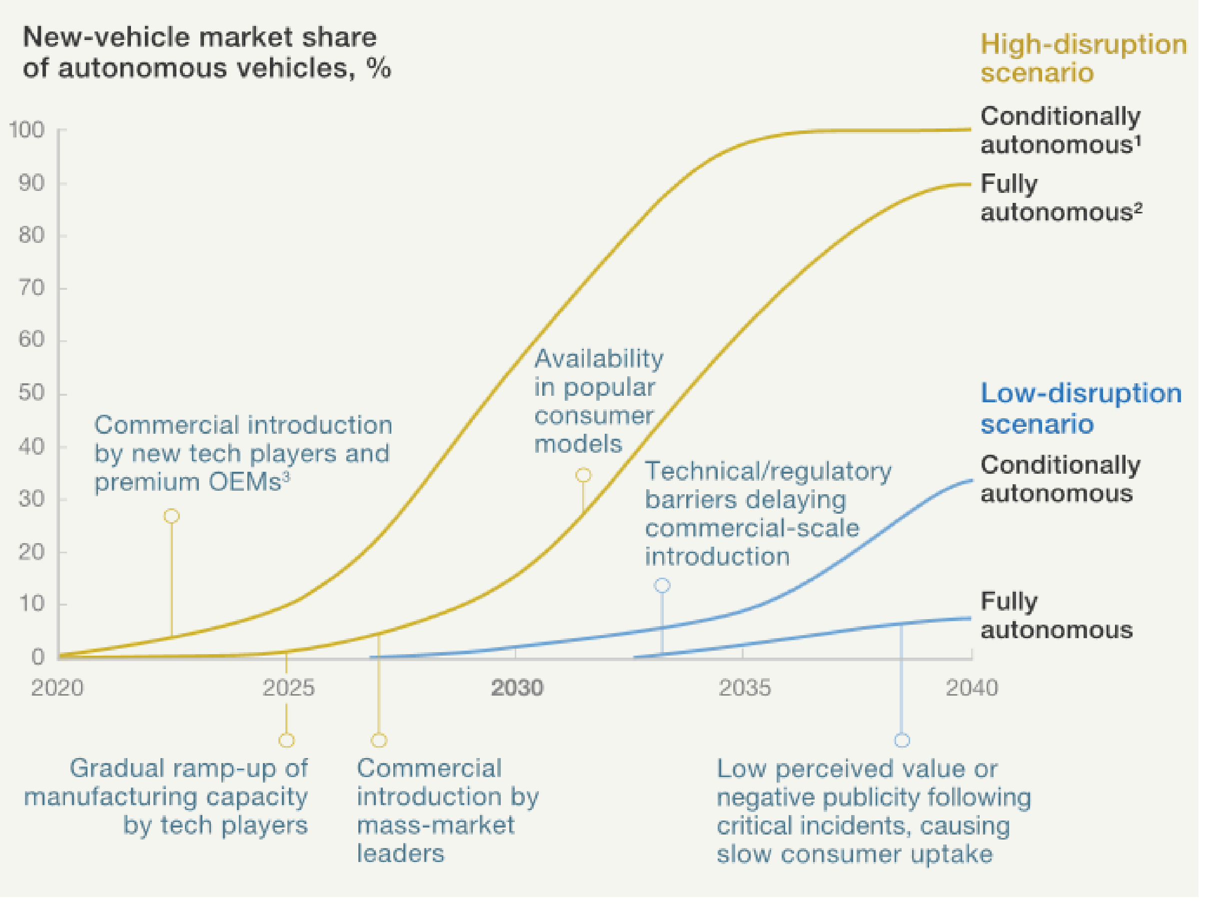
Source: SAE International and J3016

APPENDIX TWO

How many new cars may be fully autonomous by 2030?



Factors in disruption scenarios	High disruption	Low disruption
Regulatory challenges	Fast	Gradual
Safe, reliable technical solutions	Comprehensive	Incomplete
Consumer acceptance, willingness to pay	Enthusiastic	Limited

[1]Conditionally autonomous car: the driver may take occasional control.
[2]Fully autonomous car: the vehicle is in full control.
[3]Original-equipment manufacturers.

Source: McKinsey & Company (2016)