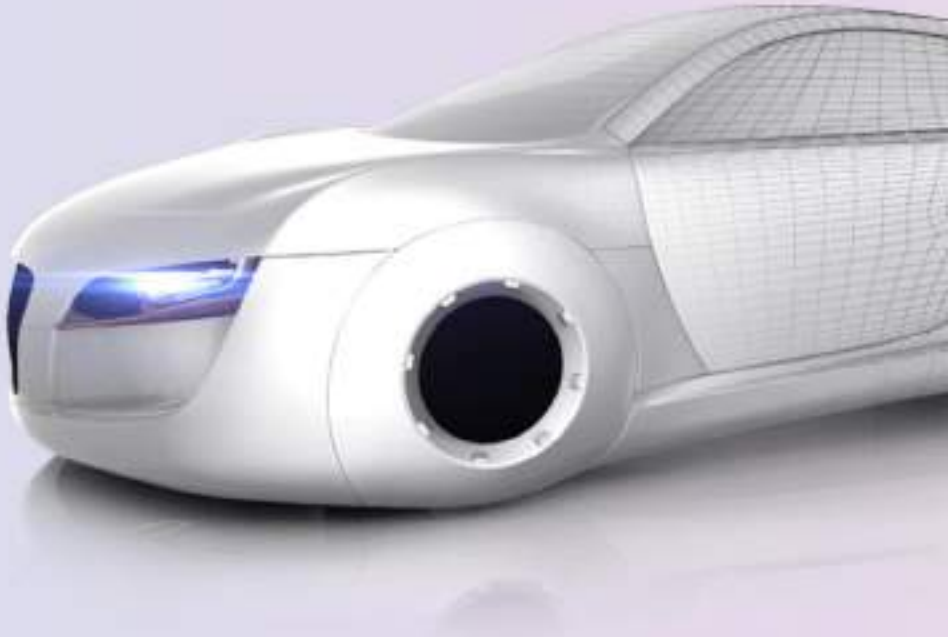
DUBAI WORLD CONGRESS
FOR SELF-DRIVING TRANSPORT
OCT | 2019

Connected and Autonomous Vehicles



Current State, Future Possibilities and Policy Challenges for Dubai

Jonathan Spear
Director, **Atkins Acuity**

An Ethical Dilemma

You are driving down a winding coastal road when a family with three young children step out in front of you. With no distance and time to stop, you have two choices.

1. Swerve to avoid a collision, but resulting in your car crashing off the road and your likely death or very serious injury as it plunges down a cliff
2. Stay on the road which will save your life, but you will hit – and probably kill – the whole family and have to live with the guilt

What do you do?

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Implications

The key issues and challenges for the introduction and mainstream deployment of Connected and Automated Vehicles are not necessarily just those of technology development, state of readiness and functionality for the vehicle and automotive equipment industry.

They are related to policy, regulation, standards and ethics set by governments, city and local authorities, transport agencies, service sector and civil society.

Whilst the main technology challenges will likely be “solved” in the next 5 - 10 years, the policy and regulatory issues are more intractable and the way forward will become clearer only over a longer timescale.

Connected and Autonomous Vehicles are Here

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Including Here in Dubai

25% of Total Trips Self-Driving by 2030

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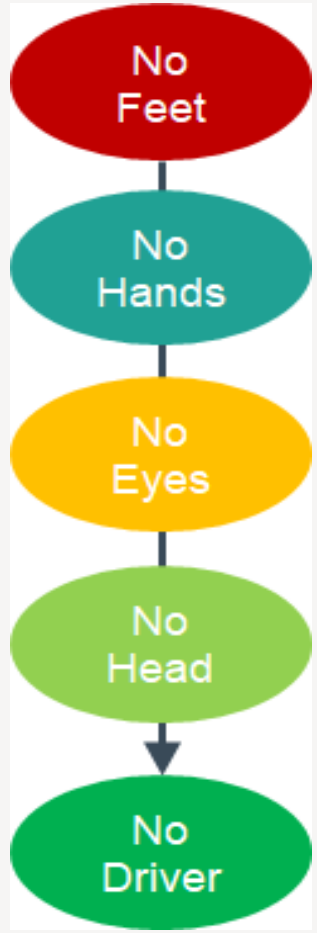
Levels of Automation

Level	Name	Narrative Description	Example	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Tasks	System Capability (Driving Modes)
Human Driver Monitors the Driving Environment							
0	No Automation (Driver Only)	Human driver controls all aspects of driving, even if enhanced by limited warning/intervention systems	Anti-Lock Braking, Blind Spot Warning	Human	Human	Human	N/A
1	Driver Assistance	System assists driver in steering or acceleration/deceleration with driver remaining in charge of all other dynamic driving tasks	Adaptive Cruise Control Parking Assistance Automatic Emergency Braking	Human and System	Human	Human	Some Driving Modes
2	Partial Automation	System undertakes both steering and acceleration/deceleration with driver performing all other dynamic driving tasks	Traffic Jam Assist (Likely 2015/2016 Onwards)	System	Human	Human	Some Driving Modes
Automated Driving System Monitors the Driving Environment							
3	Conditional Automation	System undertakes all aspects of dynamic driving tasks, but with driver able to intervene as requested	Expressway Auto-Drive	System	System	Human	Some Driving Modes
4	High Automation	System undertakes all aspects of dynamic driving tasks, and can continue to do so if driver does not respond to a request to intervene	Urban Automated Driving	System	System	System	Some Driving Modes
5	Full Automation	System undertakes all aspects of dynamic driving tasks under all roadway and environmental conditions (and vehicle does not therefore require a human driver)	Full End-to-End Journey Fully Driverless Vehicles	System	System	System	All Driving Modes



SAE International J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (2014)

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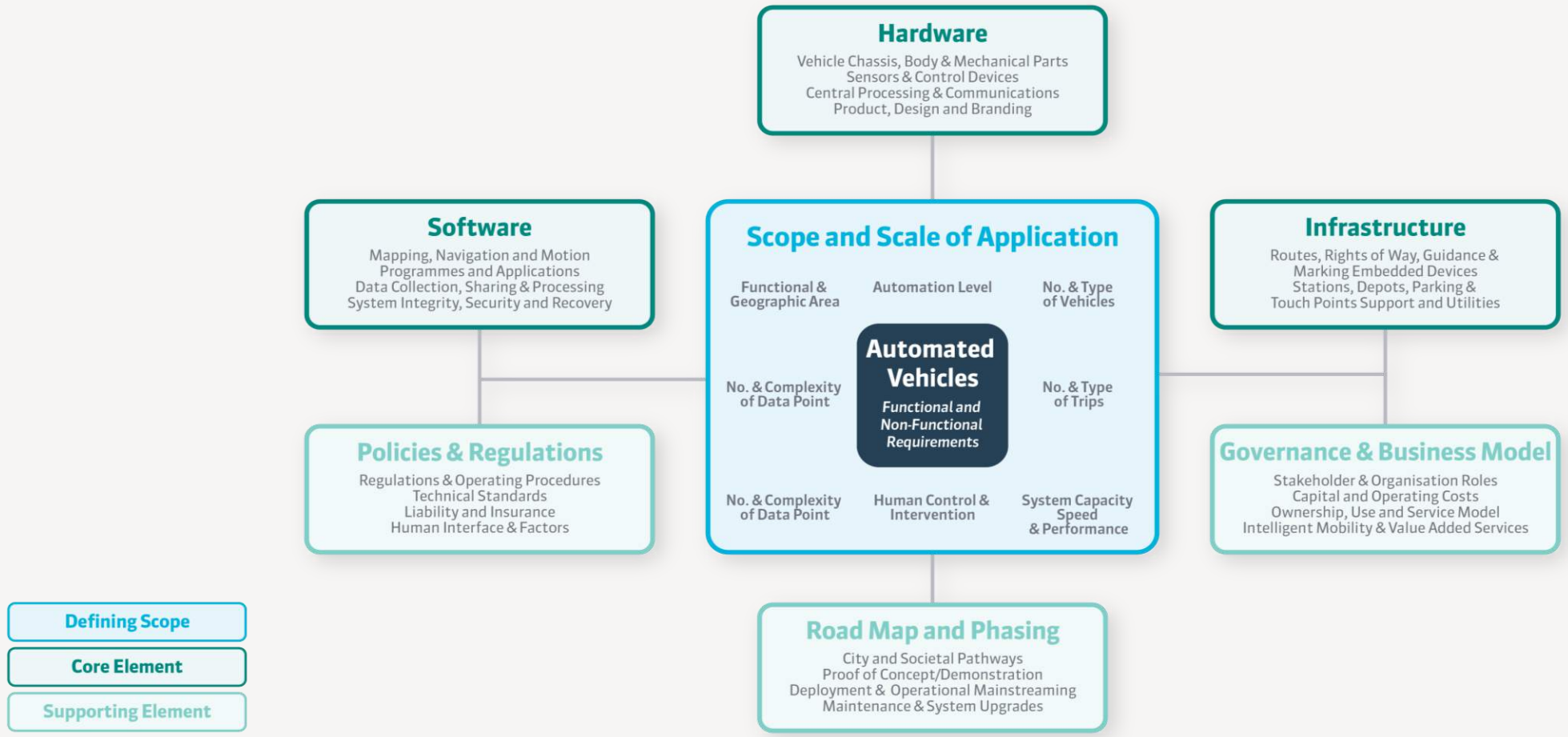
Self-Driving Transport Concept



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Recent Trends in Technology Development

Category	Application	Example
1. Automotive Applications	Semi-Autonomous Electric Cars	Volvo V40, BMW i3, Nissan Leaf, Tesla Model S and X
	Driverless Test Cars	Google Prius, Mercedes F 015 Luxury in Motion, Venturer Wildcat, Uber Volvo
	Full Driverless Evolution	Mercedes Intelligent Drive, Audi Delphi Nissan Autonomous Drive
	Full Driverless Prototype	Waymo "Bubble" Car
2. Personalised and Public Transport Applications	Fully Self-Driving Electric Pods/Taxis	Lutz Pathfinder, 2getthere, Ultra, RobuCar, Next Future Mobility, GM EN-V
	Fully Self-Driving Passenger Shuttles/Buses	Navya Arma, RobuCity, EZ-10, Mercedes Future Bus
3. Autonomous Freight and Logistics Vehicles	Autonomous Warehouse/Building Operations	KARIS PRO System, RoboCourier, MultiShuttle Move, MOVEBOX
	Outside Logistics Operations	Altenwerder Harbour Container Terminal
	Self-Driving Road Freight Vehicles	Mercedes Future Truck 2025, Volvo Sartre Project, Otto/Uber ATG
	Last-Mile Delivery	Ford AutoDelivery, Starship Technologies
4. Driverless Mass Transit	Driverless Metro	Dubai Metro, Singapore NE Line, Vancouver Skytrain, VAL
	Automated People Mover	Hong Kong International Airport, Dubai International Airport, Disneyworld


Uber Self-Driving Taxi


Nissan Autonomous Drive


Waymo "Bubble" Car


GM EN-V


Navya Arma


Mercedes Future Bus


Ford AutoDelivery

Altenwarder

Otto Truck / Uber ATG


Dubai Metro


Changi Airport


Vancouver Skytrain

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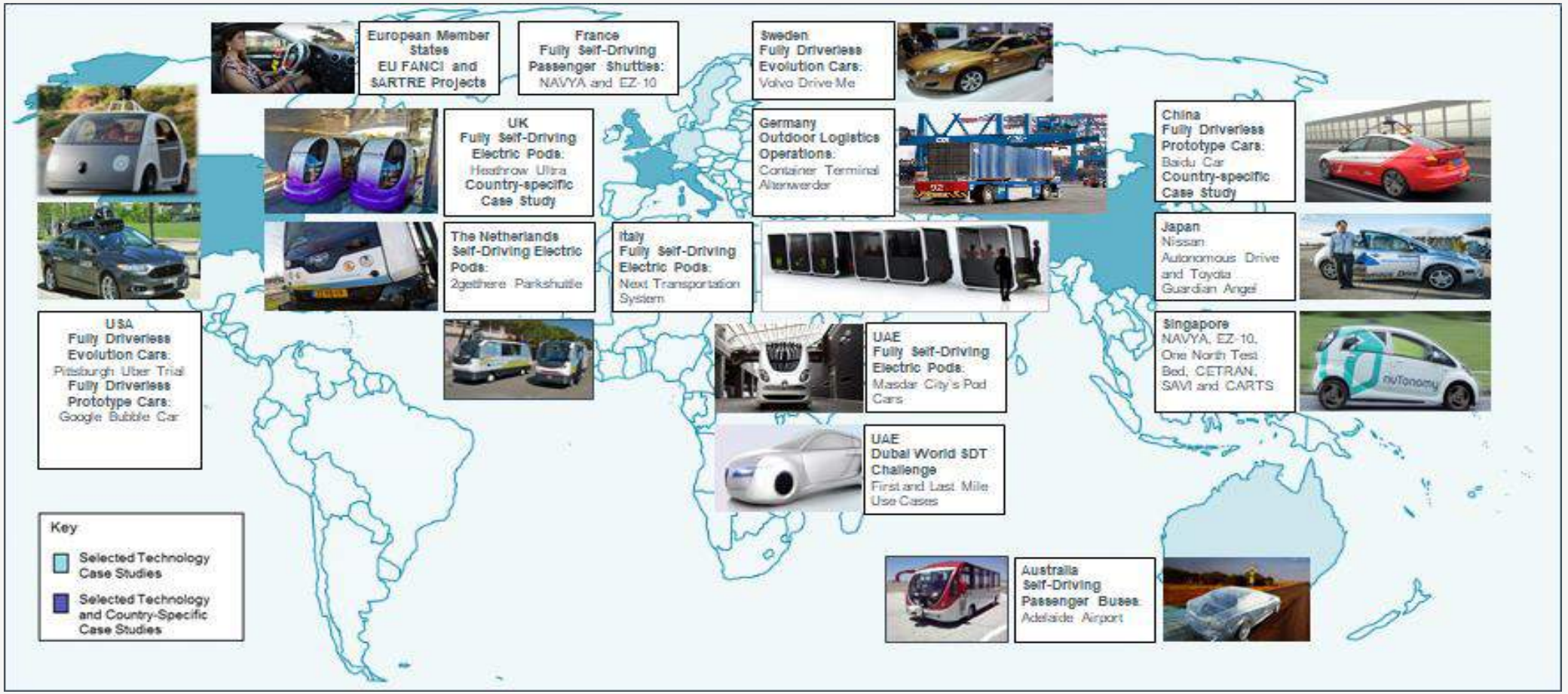
Global Competition



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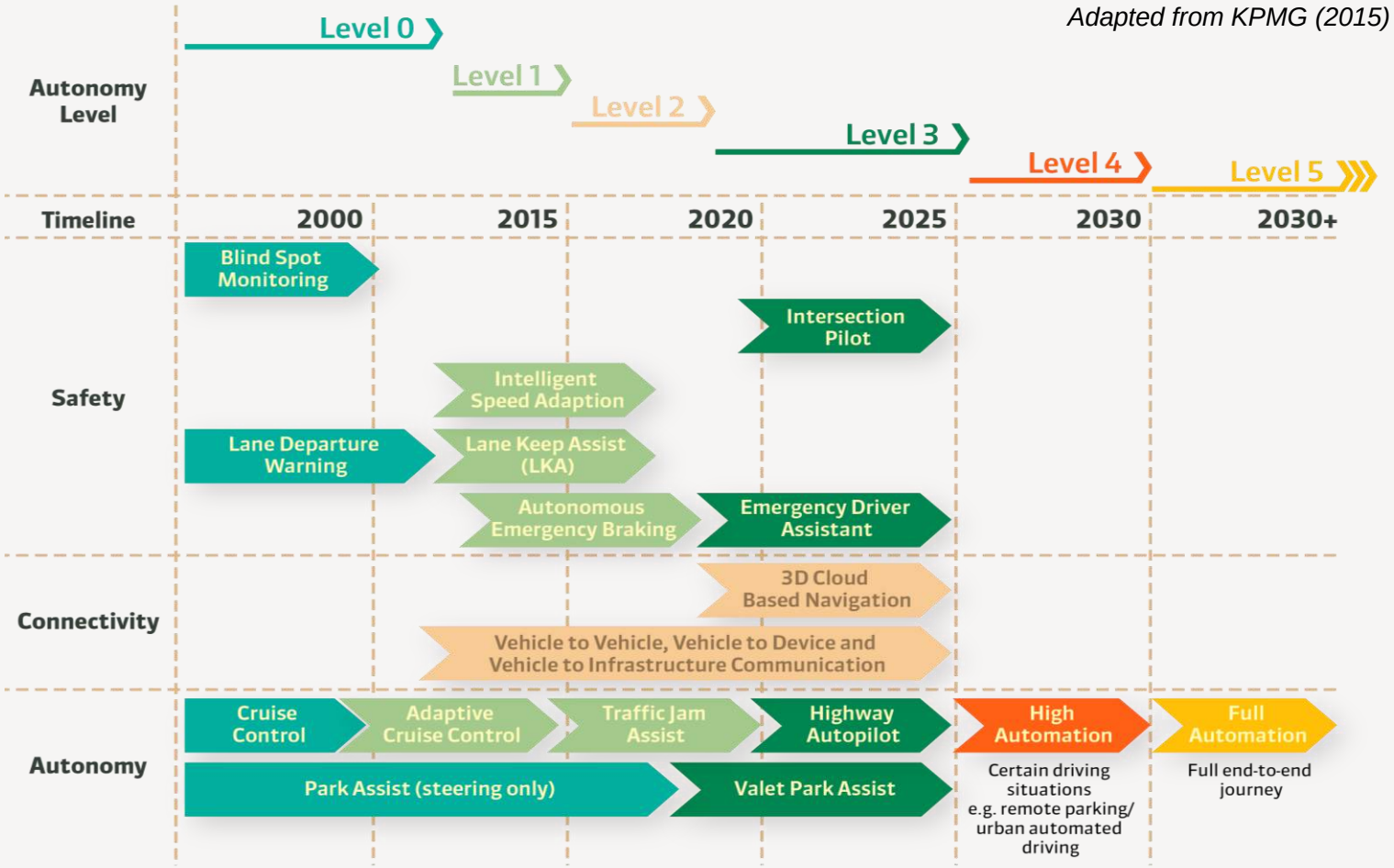
Potential Technology Road Map

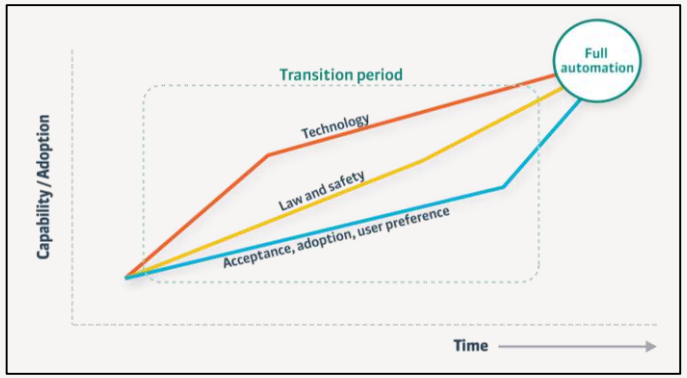
Adapted from KPMG (2015)



Factors

- Technology readiness
- Regulatory certification
- Commercial launch
- Cost and affordability
- Target early adopters
- Mainstream market
- Purchase rate vs turnover and legacy fleet

Technology ≠ Commercial availability and regulatory approval at affordable cost and consumer acceptance



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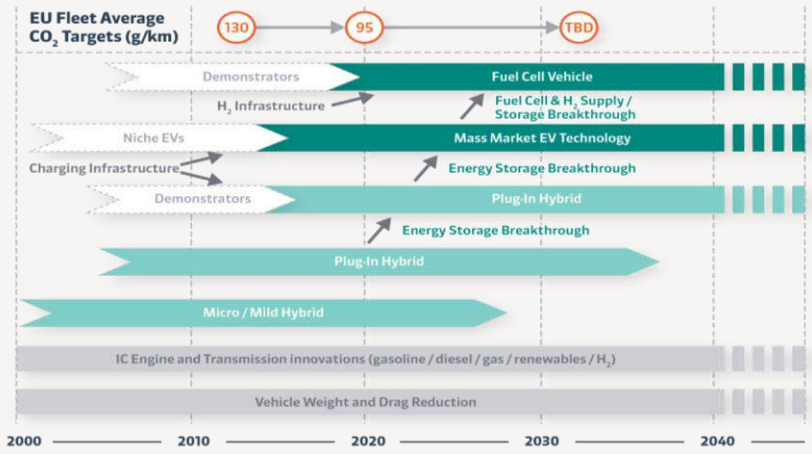
Wider Context – Electric Before Autonomous



Barriers

- High purchase cost
- Limited range and performance
- Lack of recharging infrastructure and range anxiety
- Lack of standards and regulations
- Lack of public awareness
- Limited brand association

Enablers

- Improving performance
- Government policy and regulation
- Financial incentives
- Non-financial incentives
- Infrastructure provision and funding
- Consumer information

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Wider Context - Shared Electric Connected and Autonomous

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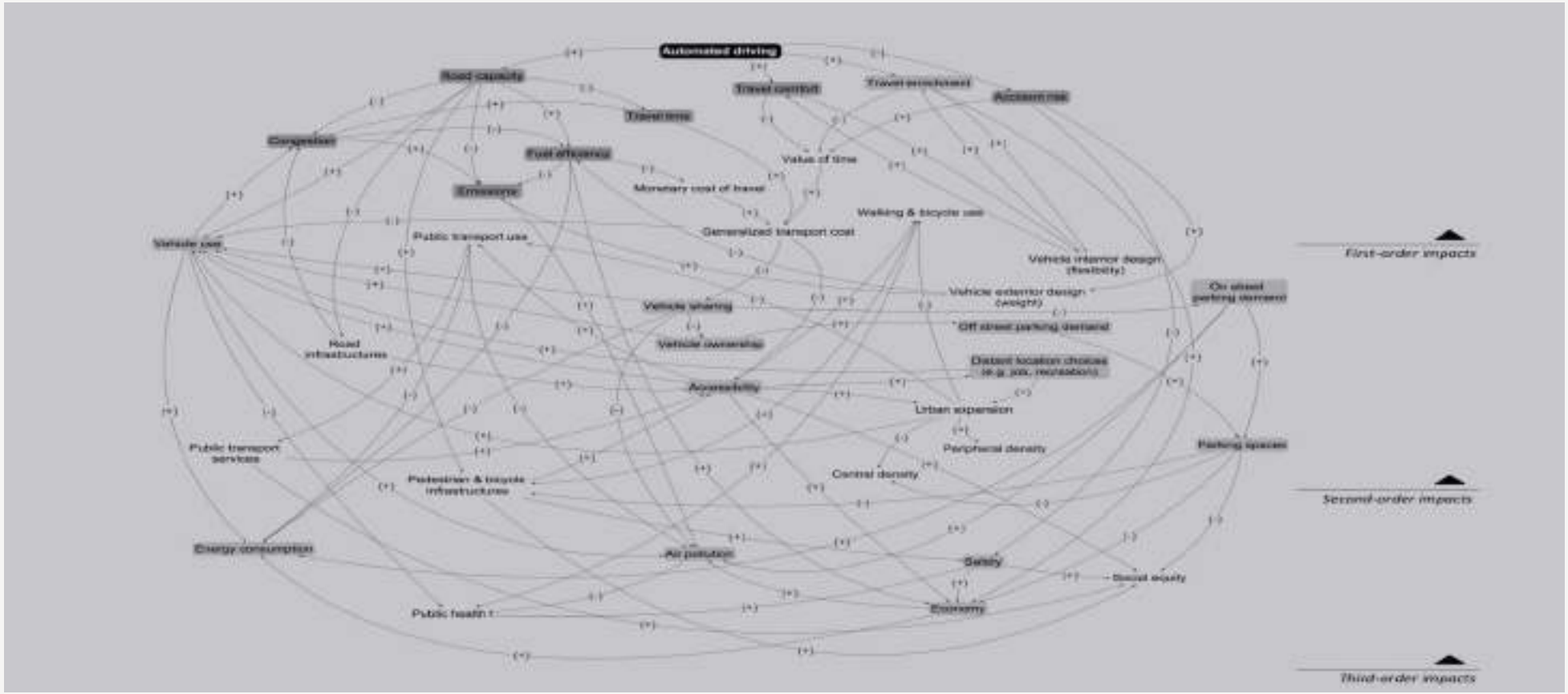
http://www.atkinsglobal.com/~/media/Files/A/Atkins-Corporate/uk-and-europe/uk-thought-leadership/reports/Journeys%20of%20the%20Future_300315.pdf

Ripple Model of First, Second and Third Order Impacts



Source: Delft Infrastructure and Mobility Initiative (2015)

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Alternative Views of Future Mobility

Clean and Shared (Eco City)

- Shift to cleaner transport (EVs)
- Optimised shared mobility, walk, bike
- Limited adoption of CAVs
- Expanded Public Transit and Transport Demand Management

Low income, dense urban areas in emerging economies experiencing rapid urbanisation with limited resources

Traffic and Congestion	↘
Road/Parking Space	→
Emissions	↓
Accidents	↘

Mumbai, Mexico City, Manila, Jakarta, Istanbul

Private Autonomy (Free City)

- Shift to cleaner transport (EVs)
- Mass adoption of CAVs
- Limited shared mobility (car/ride pool)
- Continued focus on private vehicle ownership and use

High income, low density urban areas with significant suburbs, self-regulation and weak governance/social control

Traffic and Congestion	↑
Road/Parking Space	→
Emissions	↓
Accidents	↓

Houston, Sydney, Kuala Lumpur, Dubai

Seamless Mobility (Techno City)

- Widespread adoption of SECAVs and blurring of private, shared and PT
- High-quality Public Transit as backbone
- Flexible CAVs for low demand corridors/periods, walk, bike, PMDs
- Travel Demand Management

High income, dense metropolitan areas with strong transport governance and regulation, and social control

Traffic and Congestion	↓
Road/Parking Space	↓
Emissions	↓
Accidents	↓

Singapore, London, Zurich, San Francisco

Adapted from McKinsey (2016), Boston Consulting Group (2016) and Spacescape/Alexander Stahle (2014)

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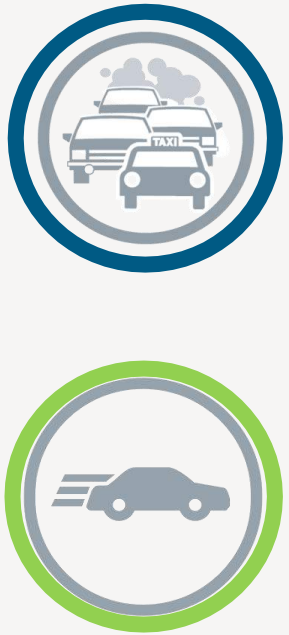
Managing the Future Demand for Travel

In an unconstrained market, CAV deployment could result in more intensive vehicle use and traffic even with smaller overall city fleets

- Increased vehicle access and convenience
- Trips by those ineligible to drive (e.g. seniors)
- Mode shift from public transport
- Reduced value of time and journey time
- Empty running of CAVs
- Commercial incentives to maximise utilisation



Cities therefore need to develop clear policies and strategies to ensure CAV deployment delivers enhanced mobility within available road network capacity

- Mass transit in high demand areas/periods
- Conversion of road capacity/parking
- Regulation of CAV pick-up and use of local roads
- Managing CAVs through UTC/ITS
- Dynamic pricing, direct or indirect
- Partnerships between operators and city managers

Selected simulation studies (e.g. Lisbon, Singapore) indicate VKM could rise by 5 – 30%

MaaS, TDM and other proactive strategies essential to deliver CAV benefits, but minimise potential disbenefits

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SDT Impacts on City and Infrastructure Development

- Increased road efficiency
- More efficient infrastructure
- Plot efficiency

Efficient infrastructure, developer savings & more opportunities/ revenue

Improved Bankability/ Investment

- Less environmental impact
- Increased safety
- Mobility and social inclusion

Improved citizen quality of life, liveable city and enhanced reputation

City Brand Proposition

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Improved Traffic Flow

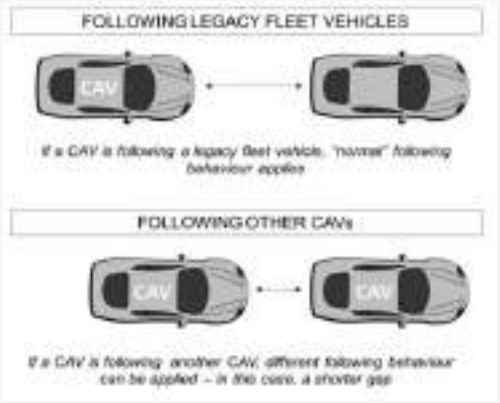
Traffic flow microsimulation:

- Different car-following behaviour
- Different lane changing and gap acceptance
- Different profiles of acceleration and deceleration
- Different levels of CAV penetration
- Road network:
- Strategic model (motorway, A-road, major intersection)
- Urban model (urban A-road, signalised junctions, priority junctions)

Scenario	Average delay (s)	
	(s)	%
Base	35.84	-
(1) 25% CAV	36.17	+0.9%
(2) 50% CAV	33.39	-6.8%
(3) 75% CAV	29.77	-16.9%
(4) 100% CAV	23.72	-33.8%
(5) Upper bound	21.38	-40.3%

A low penetration of low capability CAVs is unlikely to contribute positively to improved network performance

Key issue: to segregate or not (safety and performance)



Department for Transport

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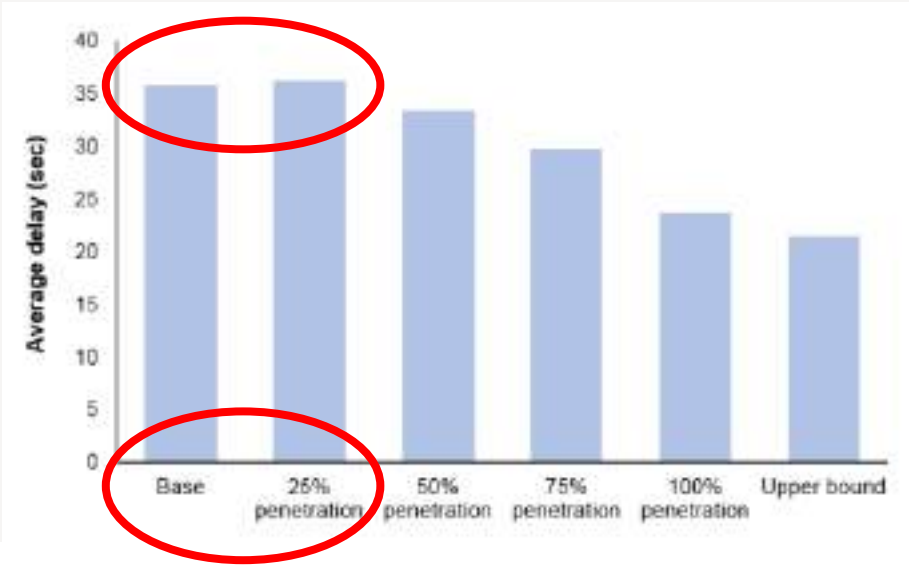

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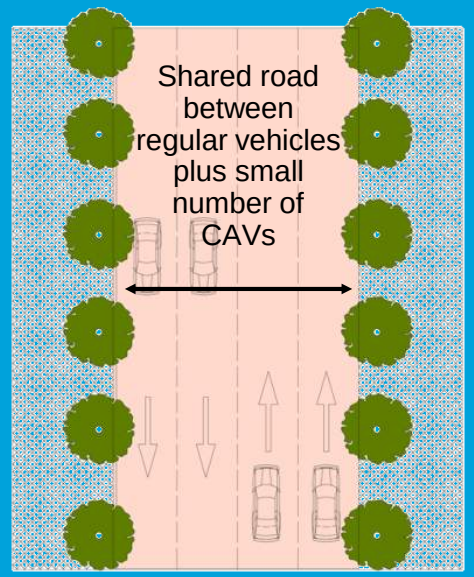
Improved Road Efficiency

Diversified use of roads

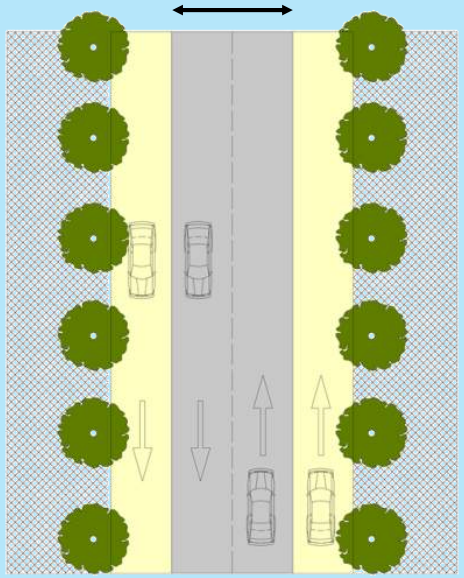
2020



Autonomous vehicles

Scenario 1
Segregated lanes for regular vehicles and autonomous vehicles

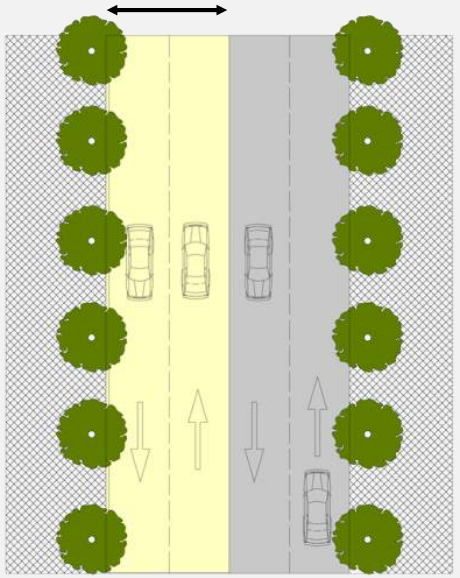
2030



With controlled cross overs at junctions

Scenario 2
Segregated but interchangeable direction autonomous vehicle lanes

2030



With controlled cross overs at junctions

CAVs potentially capable of stronger acceleration/deceleration, shorter merging/gap acceptance, vehicle following and more aspects of traffic behaviour, as well as reduction in lost/search mileage (e.g. for parking). Increasing adoption of (Shared) CAVs may allow substantial reduction in traffic flow and re-allocation of physical capacity to new uses, but with high conversion rate (50% plus) and with detailed modelling required to assess impacts

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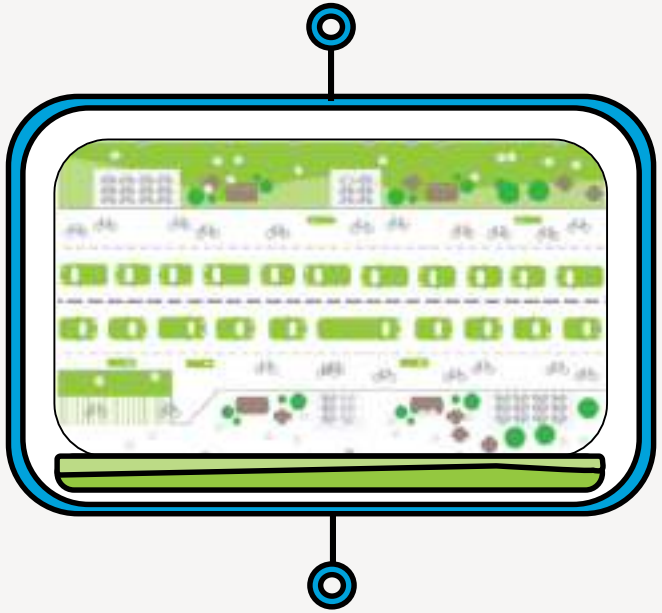
Changes to Road Design and Right of Way

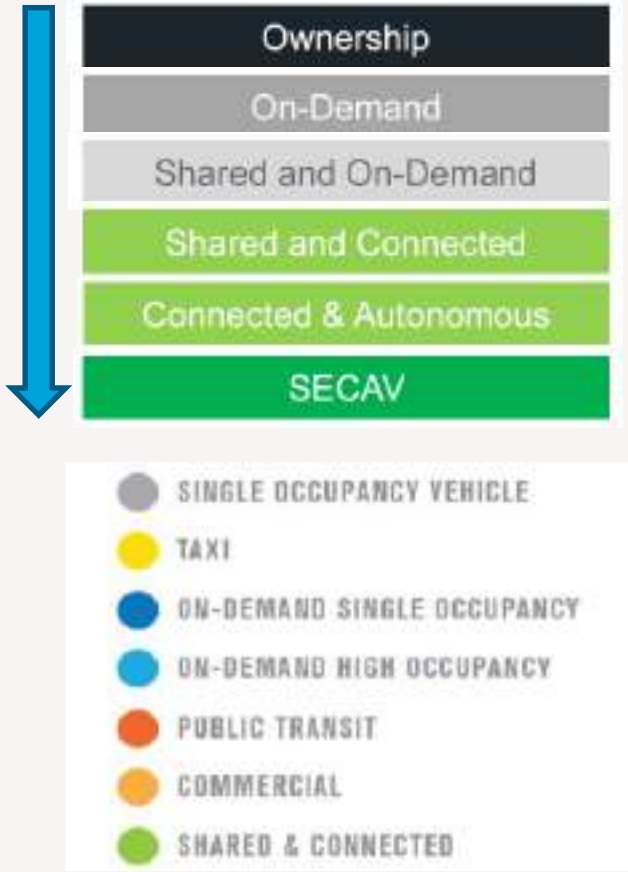
PRIVATE OWNERSHIP MODEL

- Vehicles operating in wide infrastructure independently with no connectivity.
- Congestion, pollution, collisions, waste, noise.
- Public space dominated by roads & parking.
- Lack of social equity
- Poor access to public transport

CAR SHARING CAV MODEL



- Fully optimised, maximum efficiency.
- Parking and road widths reduced.
- Pollution, noise, congestion minimised and major reduction in accidents and collisions.
- Repurposed infrastructure to shared space
- On street electric charge points



Source: San Francisco Smart City Challenge

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More Efficient Urban Infrastructure

- Improved public realm
- Reduced infrastructure land take land use area for other uses

increases

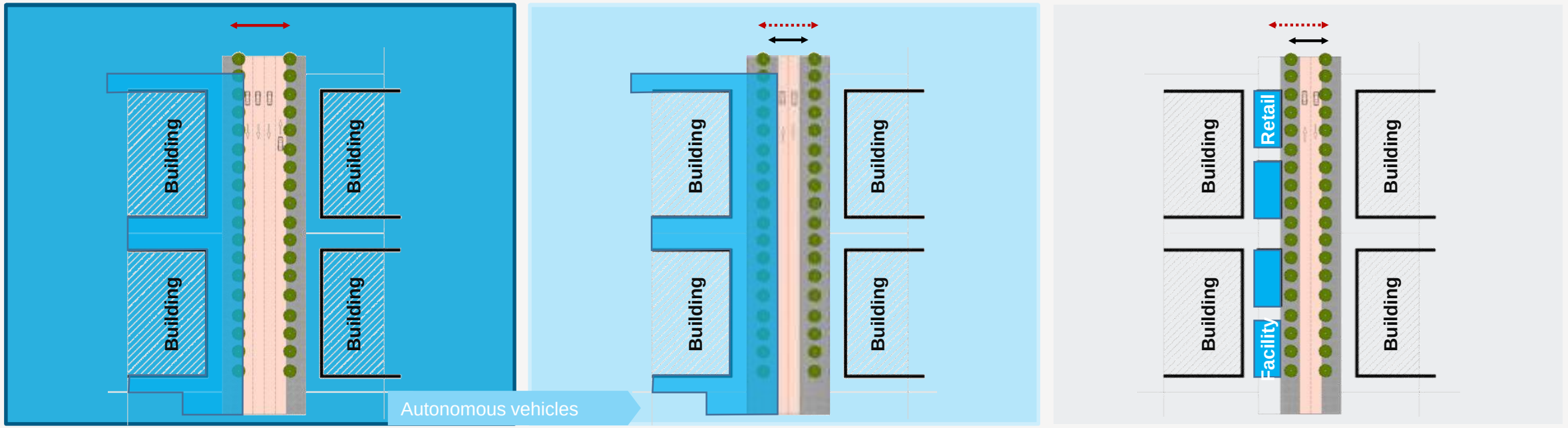
Scenario 1
Increase the public realm space for pedestrian use and street activities

Scenario 2
Increase the plot area for social housing or commercial revenue-raising uses

2020 Current carriage way to cater for current + future expansion

2040 Improved public realm

2040 Added functional and saleable area



Infrastructure enhanced by reduced street clutter from signage, road markings, traffic signals and traffic calming devices

Possible need to provide Electric Vehicle charging stations and access within and adjacent to buildings in interim

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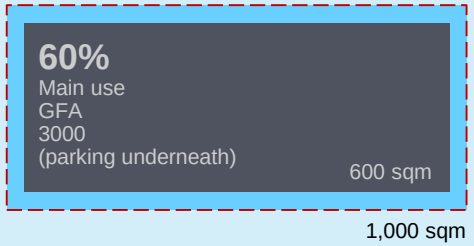
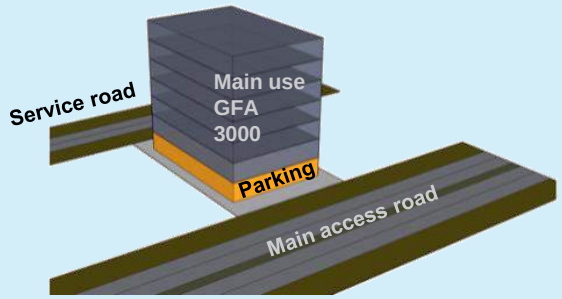
Increased Plot Efficiency

Increased land use area with revised strategy for plot planning & revised ground coverage strategy (vertical) in relation to removal of vehicle parking requirements

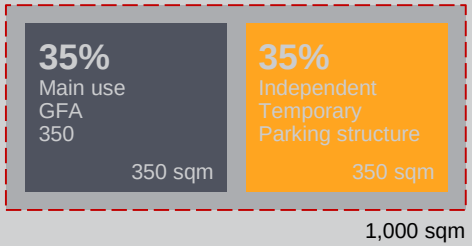
2020



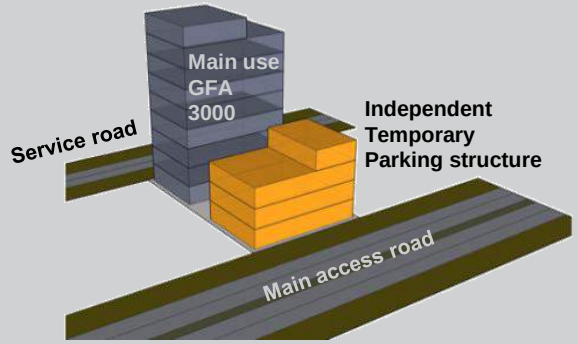
- 5 levels of main use
- 2 levels of parking



2020



- 8 levels of main use
- 3.5 levels of parking (temporary + detached structure)



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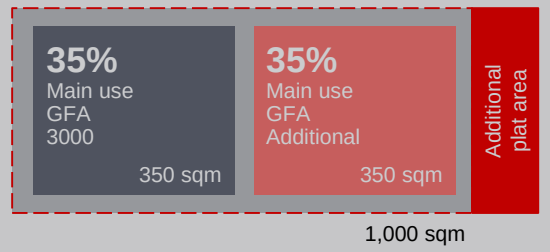
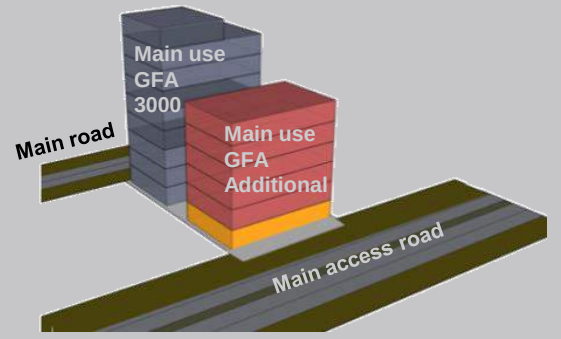


- 8 levels of main use
- 1 levels of parking



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Reduced Environmental Impact

- Increased land provision for quality public realm, landscaping and leisure
- Reduced emissions on street (assuming EVs) and air quality and noise benefits
- Elimination of street clutter from traffic signs, road markings, signals and parking
- Better interaction of motorised vehicles with pedestrians and cyclists
- Reduction in vehicle fleet size, traffic volumes and impacts (assuming TDM)

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Increased Safety (and Health)

- Automated decision making has potential to reduce road accidents by up to 90%[1]
- CAVs programmed to detect pedestrians (V2P/V2C), regulate speed and avoid collisions
- Increased potential for shared use within urban precincts with more active modes and PMDs
- Reduced disruption, economic and social costs of accidents, and network recovery
- Simplification of traffic regulations, enforcement and freeing up Police and Civil Defence resources

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[1] Based on accidents caused or contributed by human error

Mobility and Social Inclusion

Personalised mobility and socially inclusive

Women and children

Old and physically challenged

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Car-Lite Development - Singapore

Marina Coastal Expressway (2016)
12 lanes of capacity regulated by ERP and static ITS systems with peak period congestion and fall in level of service

Marina Coastal Expressway (Illustrative 2040)
Lanes reduced from 12 to 4 by Shared CAV operations with no loss in level of service and a large part of land given back for landscaping, recreation and public use

Infrastructure Vision 2050 Challenge

HYPERLANE: GLOBAL SUPPLY CHAIN'S FINAL MILE

BAIYU CHEN &
ANTHONY BARRS

AEM

Redesigning the Concept of the Car (Level 5)

http://www.caradvice.com.au/394415/driverless-cars-levels-of-automation-and-the-barrier-of-human-factors/

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Turning Aspirations into Reality – Practicalities

Technology

- Component/Systems/Integration Development, Prototype and Commercialisation
- Technical Standards and Safety Assurance
- Human Factors, Key Interfaces and CAV Operational Parameters

Planning

- Car Ownership, Car Sharing and Ride Sharing Models – Future Trends in Access vs Ownership
- Social Attitudes to Take-Up, User Needs and Influence on Travel Behaviour
- Network Modelling and Traffic Simulation to Understand Impacts (at City and Local Levels)
- Adoption Curve and Conversion Rate to Achieve Impacts & Justify Infrastructure Changes

Policy

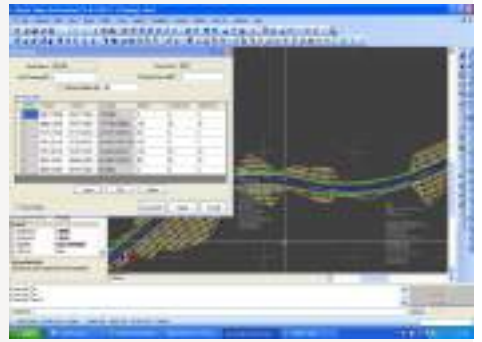
- Overall Policy Statement, Strategy, Programme and Timeline
- Regulatory Approach and Progressive Review and Reform of Regulations
- Transition Period – Length, End-State and Interim Management Strategies for Mixed Traffic
- Governance, Business Models, Private Sector Involvement and Related Issues for Insurance, and Data Management

Engineering and Design

- Highway Capacity Allocation, Design, Engineering, Operations and Asset Management
- Parking, Charging, Comms and Other Facilities
- Urban Planning, Design and Public Realm
- Implications for Traffic Impact/Transport Assessment and Development Control

Risks

- Cyber-Security and System Integrity
- Liability and insurance – shift from personal behaviour to consumer and product focus
- Burden of Regulation - Balance of Promoting Innovation and Deployment vs. Public Safety
- Managing Disruption on Driving-Related Jobs and Sectors and Unintended Consequences e.g. Organ Donation



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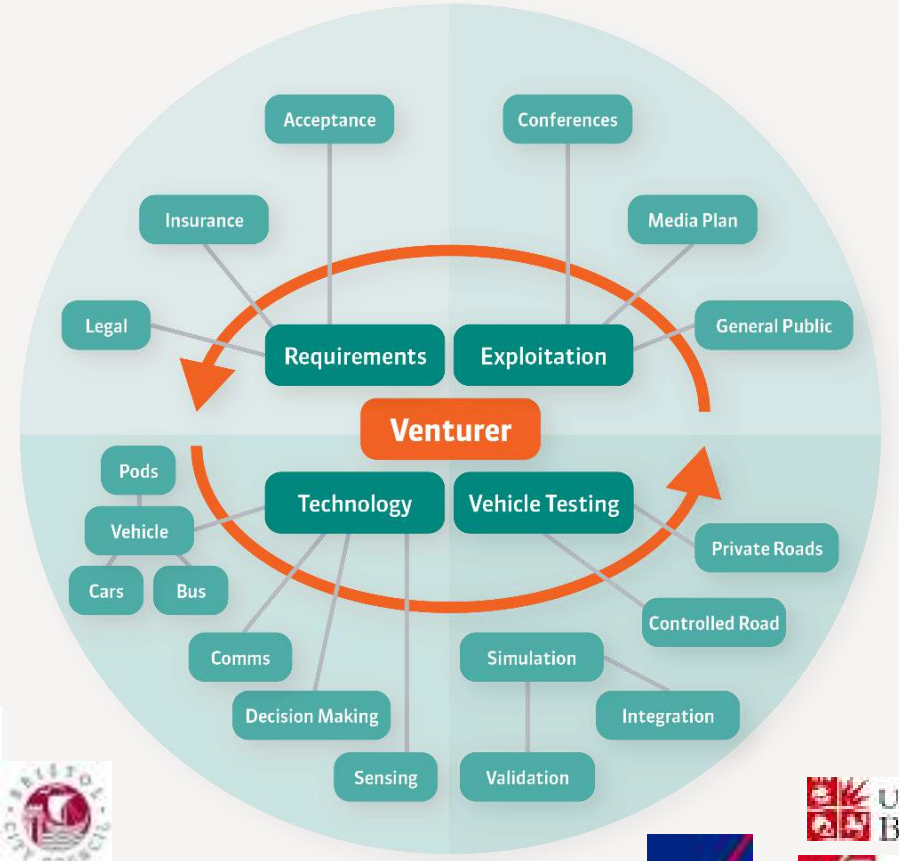
Immediate Focus on Testing

- Road & traffic scenarios of increasing complexity & risk in real-life situation
- Opinions & preferences of drivers, passengers, other road users
- Technical standards and regulations
- Vehicle technology linked to required infrastructure adaptations
- Public policy, regulation & liability
- Other in-vehicle services and use models



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VENTURER

flourish
empowerment through trusted secure mobility

Singapore's Evolving Car Lite Vision

Vision for AV Deployment

Reduce demand for car ownership
Reduce congestion at peak hours
Reduce reliance on manpower

Deployment Applications

Fixed & Scheduled Services
Point-to-Point Mobility on Demand
Freight & Utilities (e.g. Street Cleaning)

Committee on Autonomous Road Transport (CARTS)

Public, Private, Academic and International Experts
Working Groups on Vision and Deployment, Regulations and Implementation, & Industry Development
Singapore Autonomous Vehicle Initiative (SAVI) as Technical Platform

4. CETRAN @ CleanTech Park

Centre of Excellence for AV Research & Dedicated Test Track open 2017.

8. CleanTech Park

Proposed Trial of Self-Driving Hybrid Electric Buses Linking to Pioneer MRT

9. Punggol

LTA Considering Driverless Electric Shuttle to Connect to MRT and Demonstrate AV Alternative to Fixed LRT

11. SMRT-2gethere JV

2getthere Asia PTE to develop PRT, GRT and AV in Singapore, with partnership with NTU and JTC

12. TUM-CREATE

Design for Autonomous Mobility (DAM), Gemini & ecosystem for 2030

7. Tengah New Town

New Car-Lite "Forest Town" with AV Network for Internal Circulation and Connectivity

1. One North

AV Testing on Public Roads, including A*STAR, Delphi & nuTonomy Self-Driving Taxis

3. Gardens by the Bay

Autorider Electric Shuttle Connecting to Bayfront MRT

10. Changi Airport

Autonomous Airside Shuttle between T2 and New T4 as Alternative to Fixed APM

6. West Coast Highway

Trial of Platooning for Trucks with Port of Singapore

5. Jurong Island

Proposed Trial of Driverless Trucks with Potential Extension to New Tuas Port

2. Sentosa Resort & Island

AV systems Planned to Connect Harbourfront MRT with Resort, Beaches and Tourist Destinations

13. Blue SG EV Car Share

10-Year Concession in 2017 to kick-start public car sharing using Electric Vehicles with 1000 cars and 2000 charging stations

Options for Future Regulation

- Balance of regulation to encourage innovation whilst protecting safety
- Stepped rolling approach to reflect uncertainty and learn from experience
- Need for reforms to be supported by Regulatory Impact Assessment
- Regulations must reflect clear policy goals

Short Term (Level 3)

- Allowance and conditions of testing on public roads
- Narrow regulatory reforms for Conditional Automation (Level 3) e.g. Motorways Assist, Remote Parking, Platooning
- Clarification of vehicle and personal accident liability and insurance
- Setting expectations for future reform at the right time

Medium Term (Level 3 – 4)

- Definition of “Driver” and identification of Automated Driving legal entity
- Transition between Human and Automated control
- Reforms to traffic laws, regulation and enforcement
- Residual responsibilities of human beings (as passengers) during periods of automated drive

Long Term (Level 5)

- Continuation of human control of any driving function
- Future of issuing driving licenses
- Vehicle standards and design (International)
- Infrastructure standards and design (Inter-operable)

Adapted from Australian National Transport Council (2016)

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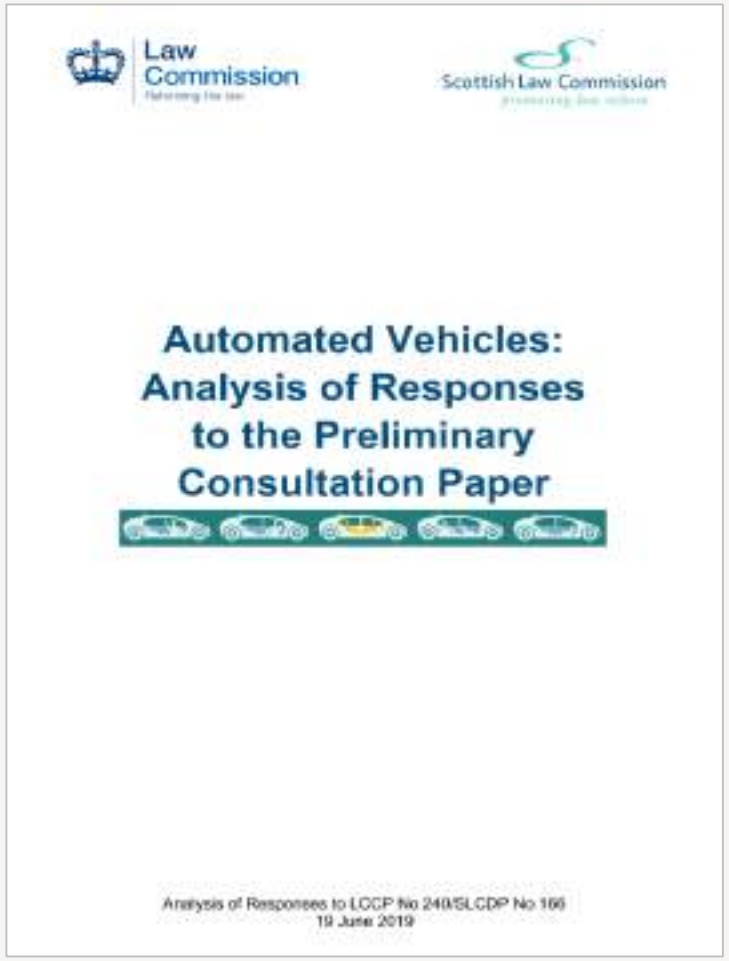
UK Regulatory Review 2018 - 2021



- Safety Assurance Scheme to complement current international Type Approval system, covering software, data and driver and operator training as well as automotive equipment
- Designation of Automated Driving System Entity in legal and practical terms, responsible for safe, legal and orderly vehicle operation in place of a human driver
- Transfer of vehicle operation from personal to corporate liability (e.g. product warranty) including software and data
- Definition of a “User in Charge” with defined responsibilities and duties whilst ADS is engaged (at least to Level 4)
- A “Digital Highway Code” with a Forum of Industry and Regulators to adapt road rules for AVs, define rights and responsibilities of other road users and resolve areas of uncertainty
- Re-emphasis of policy focus on pedestrians, cyclists and public transport as “desirable modes” with planning of streets and places focused on people rather than motor vehicles

It Will Not All be Plain Sailing

Land Transport Authority – We Keep Your World Moving

19 hrs ·

A self-driving vehicle belonging to nuTonomy was involved in a minor incident at Biopolis Drive in one-north at 9.28am today. The test vehicle was changing lane when it collided with a lorry at a low speed. There were no injuries. The Land Transport Authority and the Police are investigating the cause of the incident.

Crash investigation focuses on role of cameras, radar

Engineers offer theories on what went wrong

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Source: Land Transport Authority, Straits Times, Reuters

A Future Mobility Vision for Dubai 2050

- Nol has evolved from a stored-value PT smartcard to cloud-based MaaS with multiple modes and uses
- Manufacturers and distributors cease making and importing motor vehicles with manual controls (as well as Internal Combustion Engines) – the car becomes an automated “space for living”
- In line with other cities, Dubai stops issuing driving permits or licensing manual vehicles on public roads
- Careem-Samsung & nuTonomy-Toyota are the World’s largest providers of city automated transport services
- Congestion has been banished and streets remodeled, with Dubai being voted “Happiest city on Earth” for the third year running in the Global Happiness Survey

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Ethics, Law and Public Opinion May Mean a Different View Prevails

"The right of the citizen to travel upon the public highways and to transport his property thereon, either by carriage or by automobile, is not a mere privilege which a city may prohibit or permit at will, but a common right which he has under the right to life, liberty, and the pursuit of happiness."- Thompson v Smith 154 SE 579

"The right to travel is a part of the liberty of which the citizen cannot be deprived without due process of law under the 5th Amendment." - Kent v Dulles, 357 U.S. 116, 125.

UK IAM RoadSmart Survey (May 2016):

A Human Being should always be in Charge of the Vehicle: 65%

Once Driverless Cars are Available Driving should NOT be banned: 87%

The right to travel vs the privilege of driving?

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The Current CAV Debate (by Emoji)

- Enthusiasts (Optimists)

CAVs will be a force for good, a great deal for society and should be fully adopted as quickly as possible

What's there not to like?

- Sceptics (Pessimists)

CAVs are the latest manifestation of an automotive-centric paradigm which will and should never happen

Absolutely no way!

- Pragmatics (Realists)

CAVs will be generally a good thing under the right circumstances if properly planned based on research

Let's plan ahead

- Agnostics (Open-Minded)

It's all too difficult now so let's wait a while, see what happens and then decide

Yeah, whatever

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Another Game Changer?

The Future is Uncertain

"The Year 2000 will be the age of press-button transportation. Rocket belts will increase a man's stride to 30 feet, and bus-type helicopters will travel along crowded air skyways. There will be moving plastic-covered pavements, individual hoppicopters and 200 mph monorail trains operating in all large cities. The family car will be soundless, vibrationless and self-propelled themostatically. The engine will be smaller than a typewriter. Cars will travel overland on an 18 inch air cushion."

Weekend Magazine 1961

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Thank You

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