Intelligent Mobility

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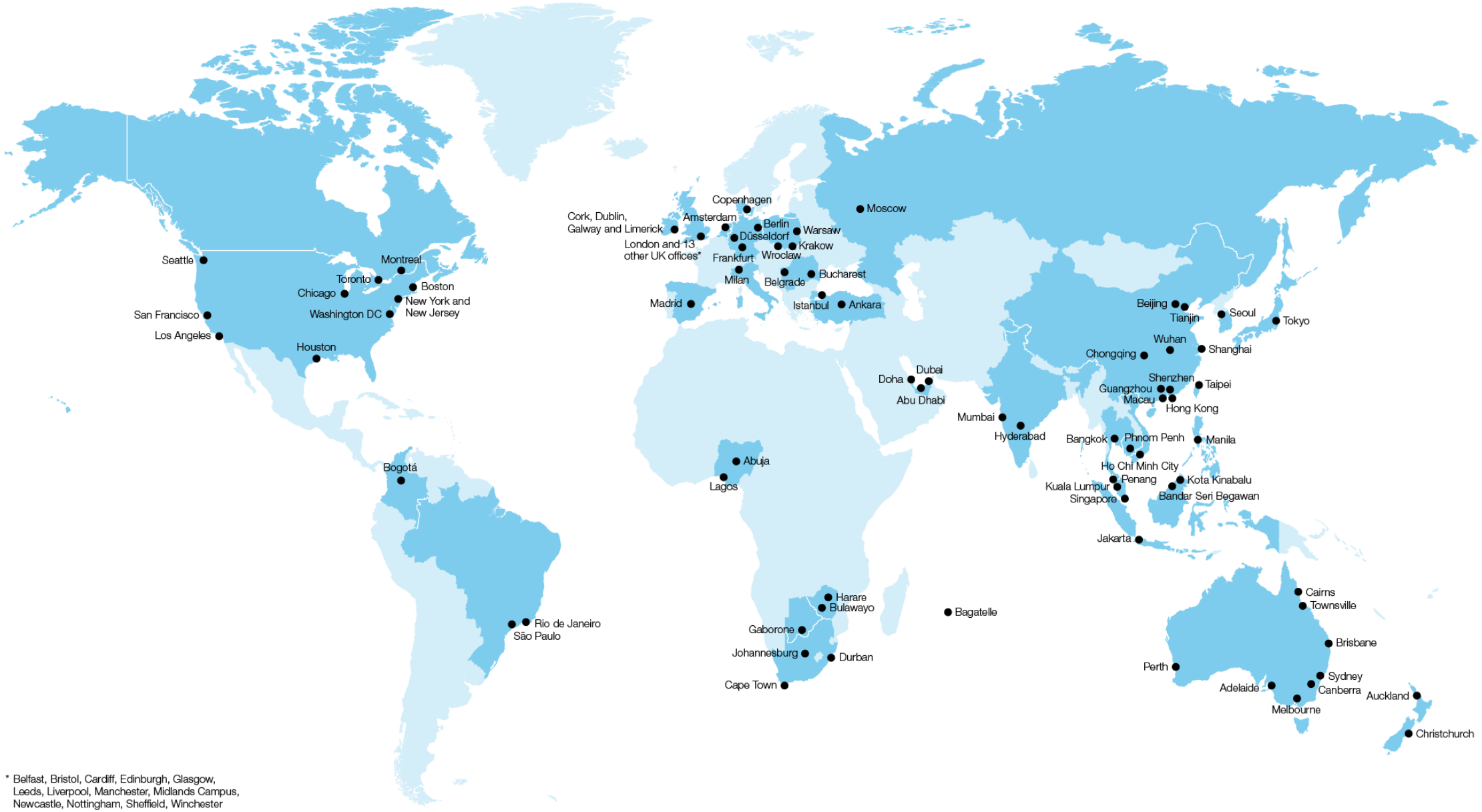
Agenda

- Introduction:
- The pace of change is increasing
- The Transport & Mobility Business
- Connected Automated Vehicles 101
- Views/Questions



* Belfast, Bristol, Cardiff, Edinburgh, Glasgow, Leeds, Liverpool, Manchester, Midlands Campus, Newcastle, Nottingham, Sheffield, Winchester

Over 12,800 people in more than 90 offices around the world

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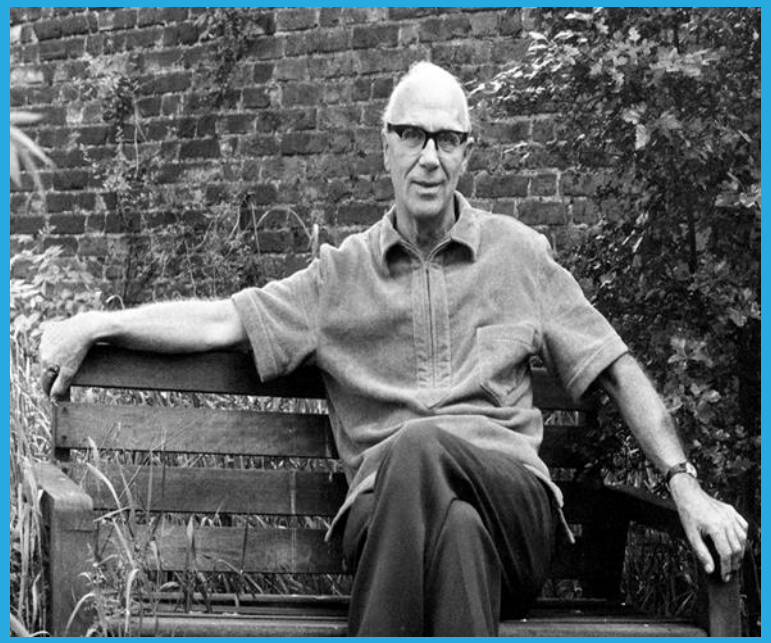
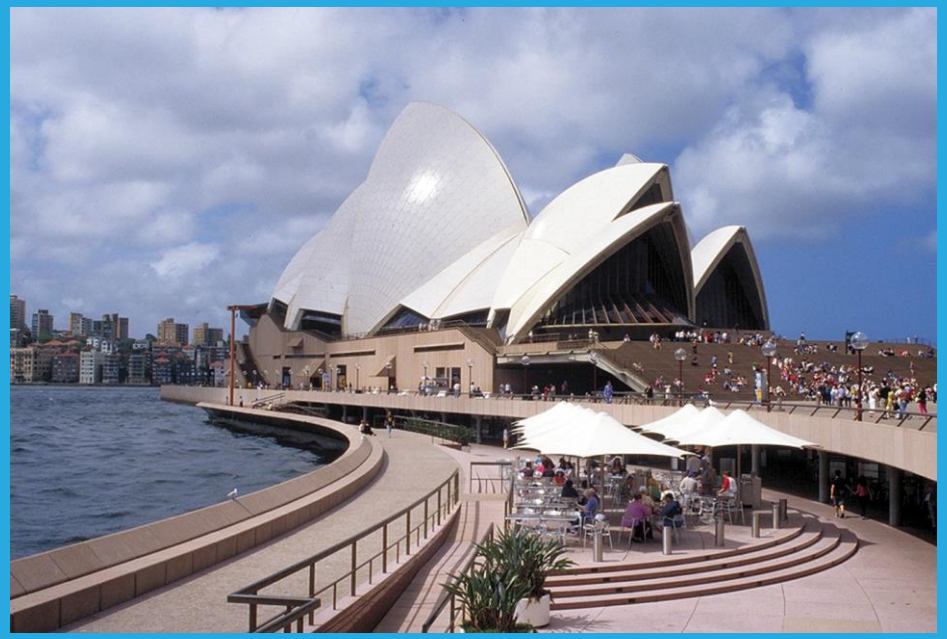
Our creative spark and intellectual independence has been there from the very beginning. These shared values, like the firm’s name, are essentially derived from the beliefs and convictions of the firm’s founder, the engineer and philosopher, Ove Arup in 1946.





10 years

2 billion smartphone users

SMART Devices?

50 billion user by 2020 myth or marketing?

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Connected Autonomous Vehicles = smartphone on wheels?

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Disrupting entire industries

Car Sales ?	**Social Services** ?	**Public Transportation** ?	**Insurance** ?
Real Estate ?	**Logistics** ?	**Entertainment** ?	**Retail** ?

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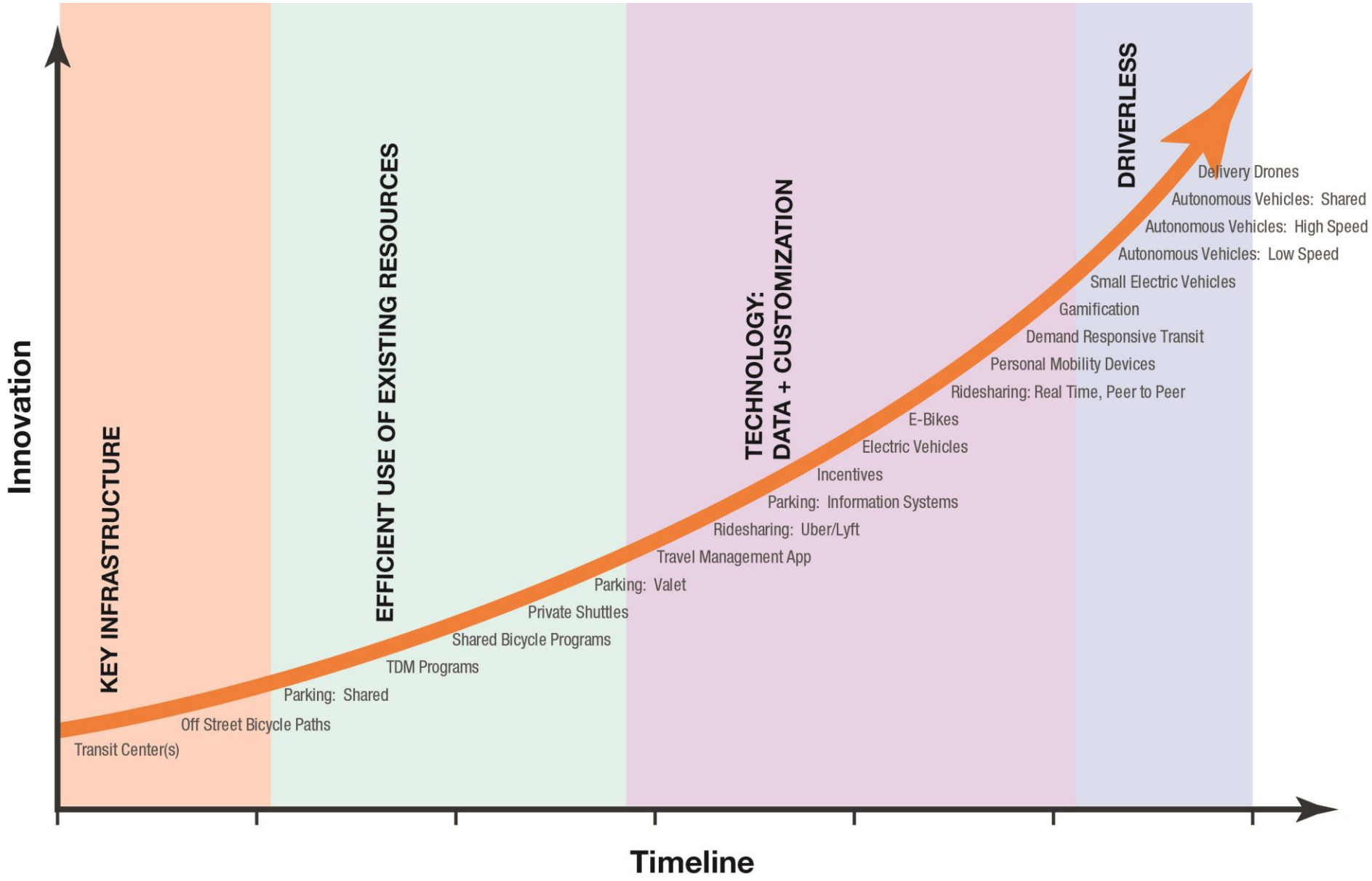
Intelligent Mobility Context

The pace of change is increasing



Transport & Mobility Business

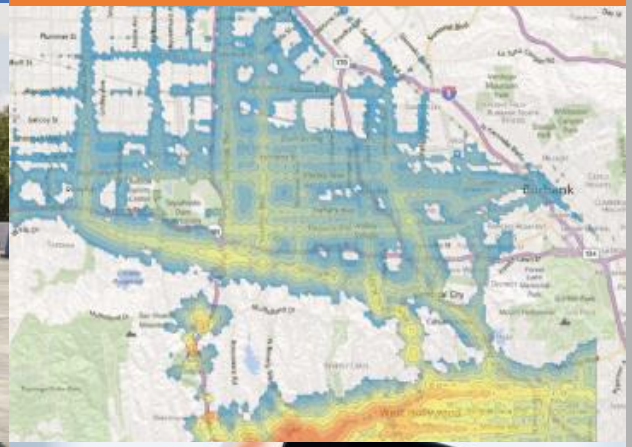
Mobility in the Global Context

- **Focus**
  - Innovation
  - Multi-Modality

- **Goals**
  - Visibility, thought leadership and differentiation
  - Monitoring trends, scouting opportunities, educating staff and clients
  - **New roles with new clients**
  - Clients become partners
  - Competitors become collaborators

Automated Vehicles

Data & Digital Tools



Intelligent Transportation Systems

Mobility as a Service

Transport & Mobility Business

Context against Road transport Management Principles

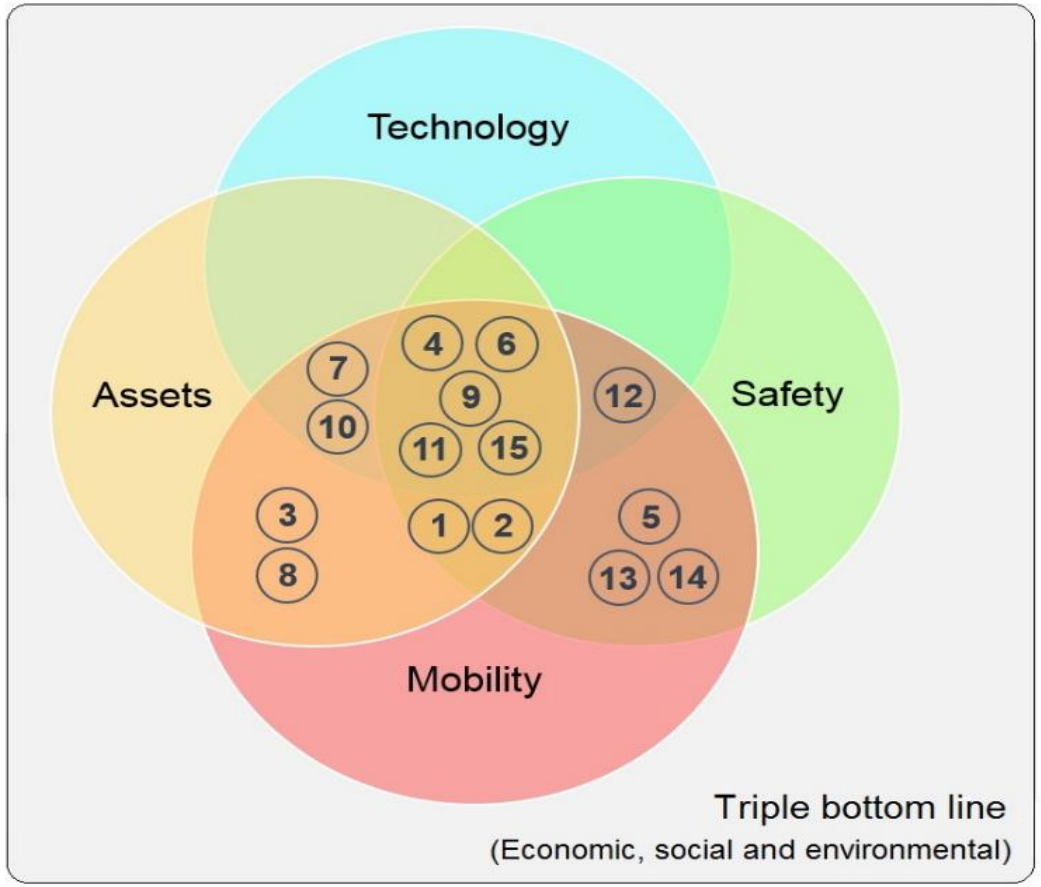
Goal A safe, efficient, reliable and sustainable road transport system

Objective To present the interconnectivity of multifaceted approaches in road transport management (RTM) to achieve the goal of enabling a safe, efficient, reliable and sustainable transport system

RTM Principles

1. Multi-modal network operations planning
2. Functional road classification
3. Well-connected transport network infrastructure
4. Traffic control devices and techniques
5. Traffic calming and local area traffic management
6. Traffic incident management
7. Lifecycle asset management
8. Integrated transport and land use planning
9. Parking strategy and management
10. Travel demand management
11. Safe System approach and principles
12. Electric, connected, autonomous vehicles
13. Transport sustainability and resilience
14. Human factors and road user behaviour
15. Stakeholder collaboration and engagement

RTM Landscape



Source – Austroads APR552 -17 Road Transport Management Framework and Principles

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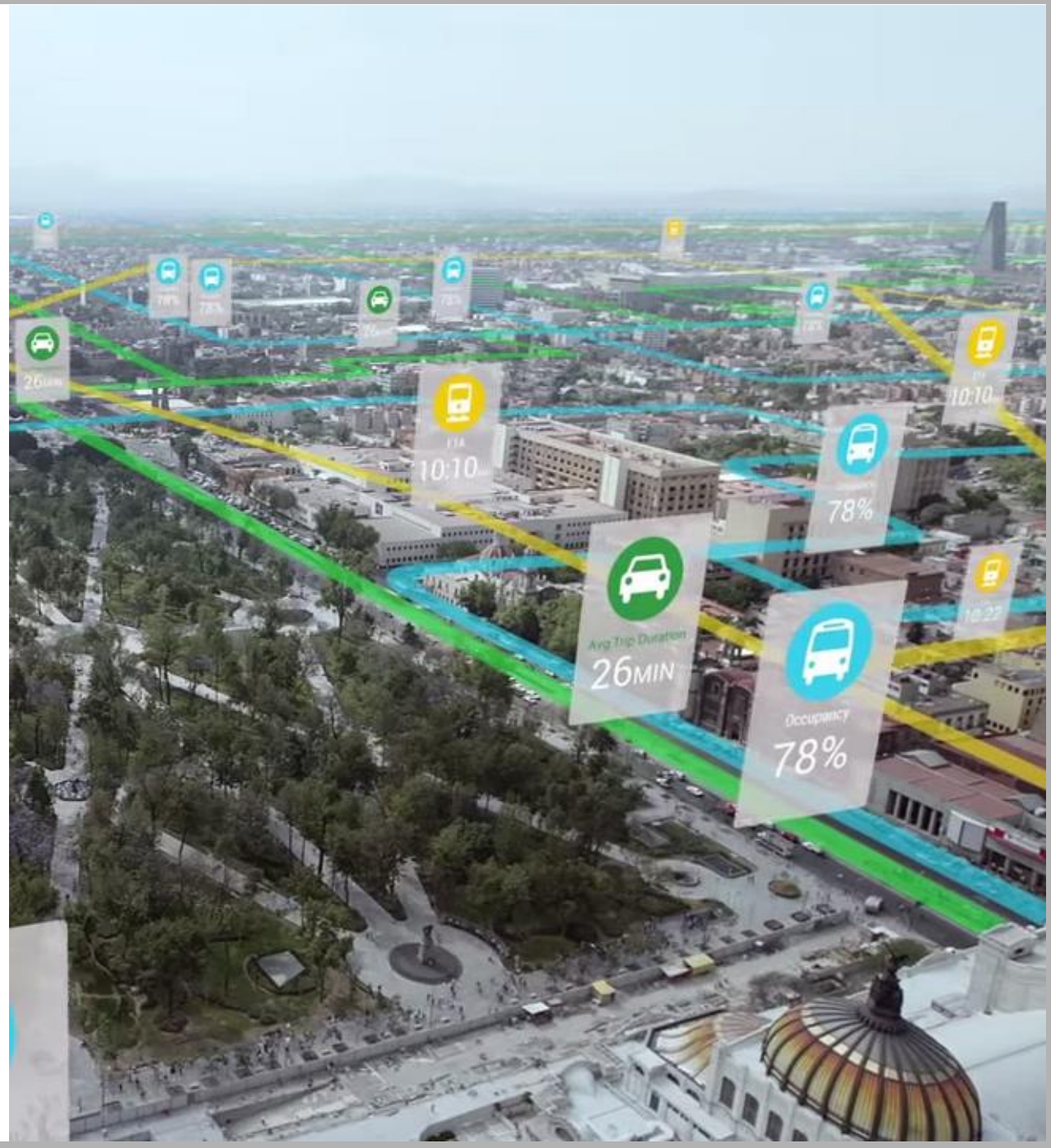
Focus Areas and Actions

- **Knowledge Management**
- Smart mobility news
- Transport + Digital initiative

- **Thought Leadership**
- Travel demand with autonomous vehicles
- Flexible/agile

- **External Partnerships and Events**
- Autonomous Driverless Vehicle Initiative
- International, national conferences
- Future Street
- OEMs & Tech



AV State of Play:

ACES
Autonomous
Connected
Energy Efficient & Emissions
Shared

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Variables

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Cities & Regions

- Will AVs **encourage sprawl**?
- What are the **social justice** implications?
- What **regulatory changes** are required?

Transport Agencies

- Will **streets** need to be redesigned? Who gets priority?
- What is the future of **public transport**?

Developers

- How should **parking** be designed? How much and where?
- Will AVs increase or reduce **congestion**?

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Understanding Automation

“Today, the automobile industry is on the cusp of a technological transformation that holds promise to catalyze an unprecedented advance in safety on U.S. roads and highways.”

Federal Automated Vehicles Policy, US DoT, 2016

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What is the “correct” terminology?

automated autonomous *Industry and policy use*

Automated[1] vehicle ***(AV)*** is the most commonly used term in the industry and in policy documentation. It is not definitive on the type of automation, and can be used for varying stages of human intervention in the driving process, from “driver assistance”, to “full automation”. ***Autonomous*** typically refers to full automation, where the vehicle can sense its environment and respond without human intervention.

self-driving driverless *Media and community use*

Self-driving or ***driverless*** cars ***(SDCs)*** are more often referred to in media or community. The issue with using this term interchangeably with AVs is that SDCs imply every vehicle is fully autonomous. Most vehicles in this category are only partially automated and require some driver intervention, negating the implied definition of *self-driving*. The poetic appeal of the term does excuse some confusion when communicating with the public, but should be used with discretion, and in context.

robotic *Infrequent, philosophical use*

Robotic cars is not commonly used term, except in reference to ethics and Asimov’s Laws of Robotics[2], which dictates the interaction between humans and machines.

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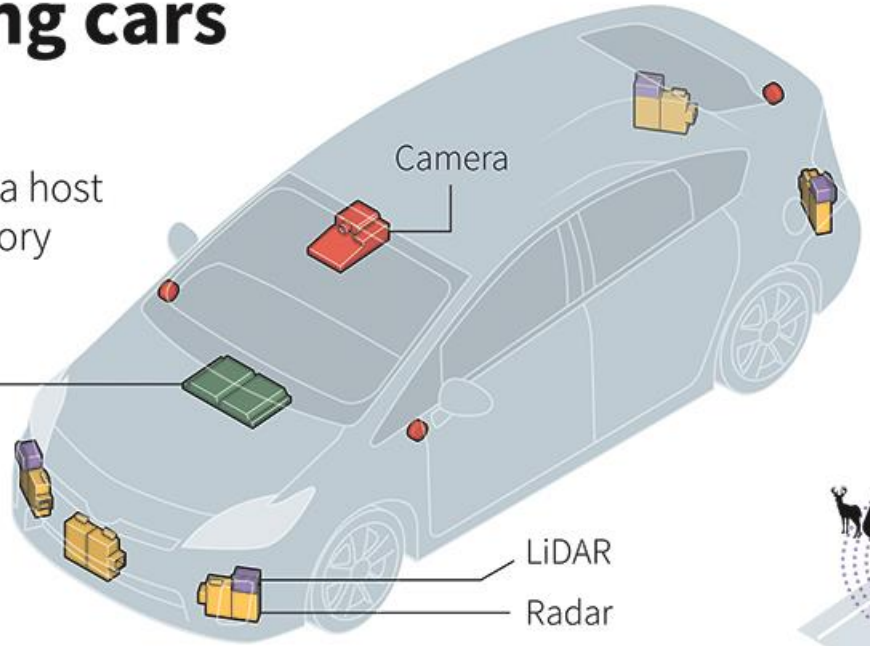
What is the technology of a fully automated vehicle?

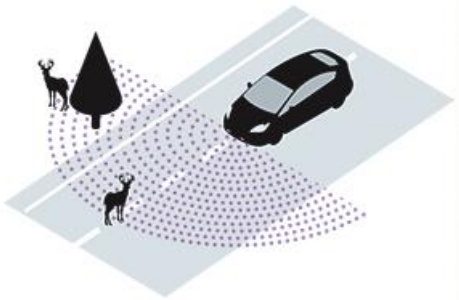
How self-driving cars see the road

Autonomous vehicles rely on a host of sensors to plot their trajectory and avoid accidents.

Multi-domain controller
Manages inputs from camera, radar, and LiDAR. With mapping and navigation data, it can confirm decisions in multiple ways.



Camera
Takes images of the road that are interpreted by a computer. Limited by what the camera can "see".



LiDAR
Light pulses are sent out and reflected off objects. Can define lines on the road and works in the dark.

Radar
Radio waves are sent out and bounced off objects. Can work in all weather but cannot differentiate objects

Source: Delphi

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What are the Potential Applications of Autonomous Tech?

TECHNOLOGY

Semi-autonomous features (Level 2)

Self-driving testing

Low-speed automated shuttles

Fully autonomous freeway driving (Level 4)

Automated bus corridors

Fully autonomous cars available (Level 5)

Self-driving taxis

Today

+10 years

IMPLICATIONS

Increased safety

Market positioning

New business models

Blurring public vs. private transit

Reduced travel costs

Possible Increased VMT

Inclusive mobility

Reduced car ownership

Reduced parking

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How will AVs be applied in cities & regions?

Near-term application

Testing + Development

- **Testing grounds**: Controlled-access development environment. (Examples: MCity, GoMentum Station)
- **Public roads**: Tests on public roads with engineers in the vehicle (Example companies: Waymo, nuTonomy, Delphi, GM/Cruise, Ford, Uber)

Driver Assist Features

- **Level 1**: Driver-assist systems available from most major auto manufacturers.
- **Level 2**: The driver is responsible for monitoring the driving environment.
- **Level 3**: Fully automated parking and summoning are Level 3 applications.

Low Speed Circulators

- **Automated circulators** provide mobility within designated zones and dense urban environments. (Examples include UK Autodrive, Easymile, Olli, Navya)
- **Segregated automated circulators** are faster but separated from pedestrian traffic. (Example: 2getthere ParkShuttle)

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What is the range of possible business models?

Personal Mobility

Owned AVs

Shared AVs (SAVs)

Transit

On Demand Services

Automated High-Capacity Transit

Logistics

Automated Delivery Drones

Autonomous Freight

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Some of the many companies working on AVs

VEHICLE STARTUPS

olli
EASY MILE
RDM GROUP
nauya
TESLA

OEMs

GM
NISSAN
Ford
TOYOTA
VOLVO
JAGUAR
LAND ROVER

MOBILITY SERVICES

UBER
lyft
WAYMO

TECH COMPANIES

NVIDIA
Alibaba Group 阿里巴巴集团
nuTonomy
OXBOTICA
Baidu 百度

SPECIFIC COMPONENTS COMPANIES

DELPHI
Velodyne
NAUTO
QUALCOMM
MOBILEYE
Our Vision. Your Safety.™

UNIVERSITIES

TEXAS
The University of Texas at Austin
TU Delft
Carnegie Mellon University
UNIVERSITY OF CAMBRIDGE
UNIVERSITY OF LEEDS
Massachusetts Institute of Technology
Berkeley
UNIVERSITY OF CALIFORNIA
UNIVERSITY OF OXFORD
UNIVERSITY OF MICHIGAN
ETH zürich
Stanford University
The Open University

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Mobility as a Service (MaaS) is also a developing market

FORD SMART MOBILITY

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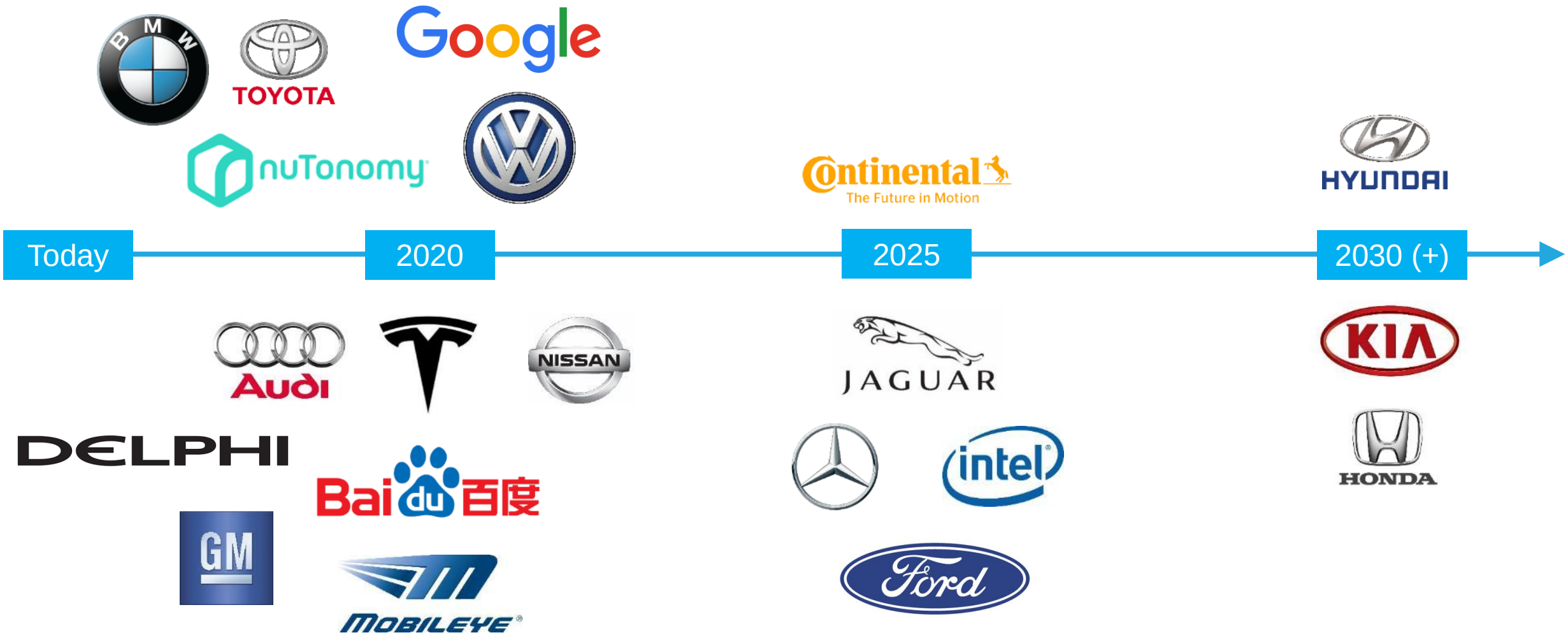
When will AVs be ready for consumers?



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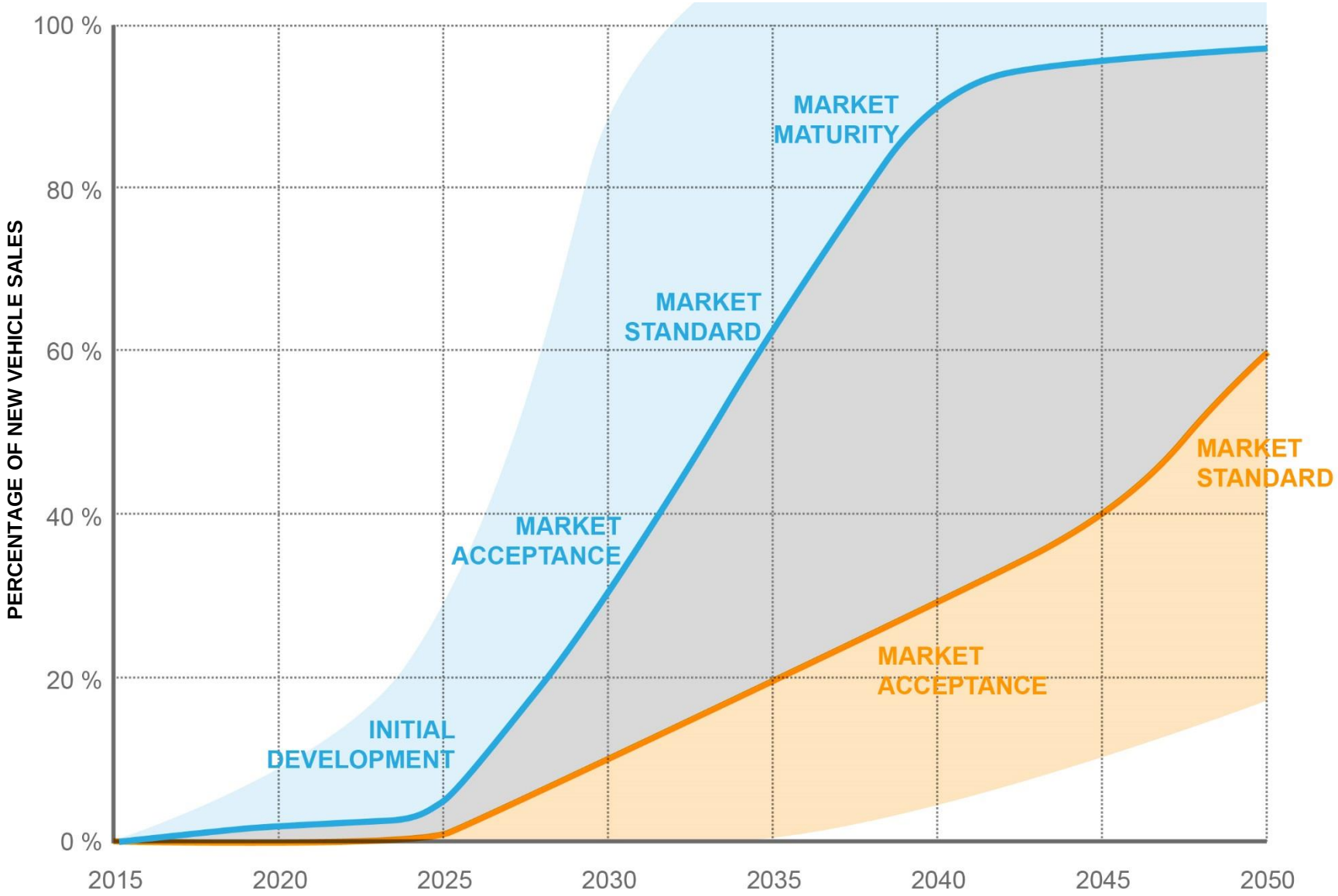
When do AVs become commonplace?



Revolutionary

- Technology breakthroughs
- Regulatory resolutions
- Shared model, at much lower cost than ownership
- Rapid adoption

Evolutionary

- Slower technology development and rollout
- Owned AV model with cost premium
- Slower adoption

Fully Autonomous Vehicle (L4/5) uptake predictions based on high disruption scenarios, indicates possible percentage of new car sales 2016 to 2050.

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The future is highly uncertain

TIMING	**3 to 13** years until L5 AVs available for purchase
SAFETY	**+40% to +90%** increase in safety
CAPACITY	**0% to +45%** increase in roadway capacity
DEMAND	**+5% to +40%** increase in VMT
ENERGY/EMISSIONS	**-50% to + 100%** change in GHGs

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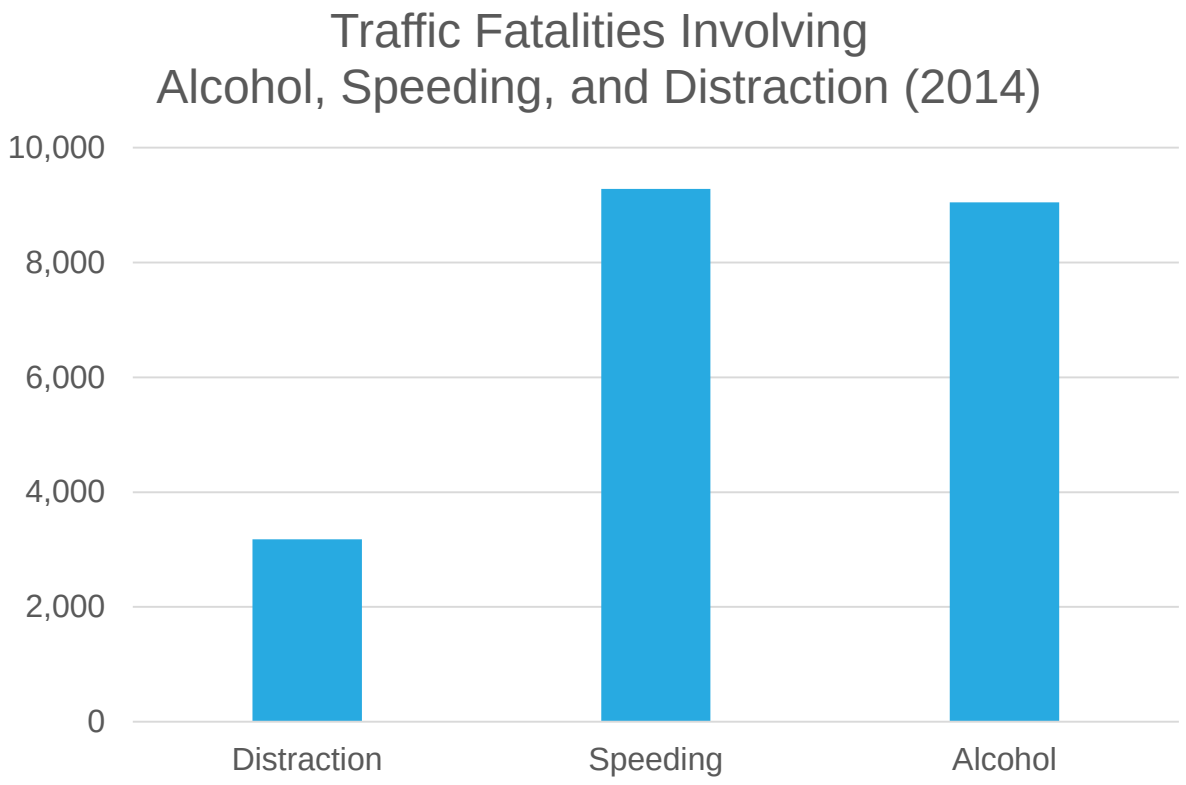
AVs will be 40% to 90% safer than human drivers.



AVs could make traffic fatalities a bad memory.

- Alcohol, drug use, driver distraction, and/or fatigue is a factor in **40%** of all traffic fatalities.
- Considering that some **90%** of all traffic fatalities can be tied back to human error, AVs could greatly diminish traffic fatalities and serious injuries.
- Of course, they could introduce new challenges, so the projected safety benefits remain uncertain.

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Industry is designing vehicles to minimize reliance on infrastructure.

However, a memo from Uber to the City of Pittsburgh may shed light on complementary infrastructure.

Self-Driving Uber requested:

- Dedicated lanes
- Designated passenger loading zones
- Optimized intersection signalization with DSRC equipment
- Bike lanes (to promote street calming)
- Designated staging areas
- Prioritizing snow removal

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A wealth of research in V2I and V2V applications has produced steps for infrastructure upgrade.

Light adoption

- No design changes
- Standard road markings and signs
- Regular maintenance
- Materials (e.g. reflective thermoplastic paint)

Supportive Actions

- Communications infrastructure
  - High speed data backbone
  - Wireless communications
- Embedded road condition sensors
- Differential GPS service
- Detailed, updated 3D mapping
- Broadcast sign and traffic signal locations
- Broadcast traffic signal messages
- Real time / predictive traffic management

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Big Questions

“Incredibly, we might actually get a chance at a do-over—of our cities, our fossil fuel dependence, and the social contract with labor—thanks to the impending advent of autonomous cars. Yes, their arrival is inevitable, but how they will impact us is yet to be determined.”

Robin Chase, Zipcar co-founder and former CEO

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What can we say with some confidence?

- **Autonomous vehicles will be safer** than human-driven vehicles, likely to a significant degree.
- **Vehicle miles/kilometers traveled will likely go up**, unless a fundamental shift in travel dramatically increases ridesharing and decreases trip making. However, new “driving” populations (elderly, children, disabled, etc.) will induce demand, possibly balancing any shifts.
- **Shared autonomous vehicles will likely be cheaper** than car ownership today.
- **Full autonomy will have capacity significant benefits**, but the long road to 100% AVs could see only small capacity benefits or even capacity losses. There’s also a possibility human factors, such as acceleration/deceleration preferences, will balance capacity gains.
- The need for **proximate parking will eventually become effectively obsolete**.
- **Demand for curbside service will increase** and challenge street-level safety and delay, as long as bike lanes are unprotected and on-street parking is ubiquitous.
- **Government at all levels will see big shifts** in parking, curb management, labor, cyber security, and budget.

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What trends remain highly uncertain?

- **Public Transit/Transport**
  - Will transit ridership change in response to automation? Will response differ by geography? By income?
  - How will transit agencies and labor unions respond to automation? What cities or nations will be leaders and why?
- **Goods Movement.**
  - With the increasing popularity of online shopping, goods delivery will continue to shift from store to door. How will this shift impact the network?
  - What freight technologies will stick? Drones? Highway platooning? Sidewalk robots? Automated trucks?
- **Infrastructure.**
  - Is an infrastructure upgrade necessary for AVs to reach the market?
  - What infrastructure is complementary? Will such infrastructure still be complementary in 10 years? 20 years? 30?
  - How big of a concern is smart infrastructure obsolescence?
- **Ownership.**
  - Will ownership become obsolete everywhere or just in major cities? What business models will dominate in suburbs, towns, and rural communities? What about developing countries?
- **Land Use Patterns.**
  - Will easier traveling make even greater sprawl more feasible?
  - What new land use patterns will follow AVs? Compare to parking lots for cars, ports for ships, or even skyscrapers with elevators.

What trends remain highly uncertain? (cont'd)

- **Road user interactions.**
  - Will pedestrians, bicyclists, and human drivers behave erratically, knowing AVs will move cautiously? What would be the network impacts of such behavior?
- **Motion sickness and other human factors.**
  - Will motion sickness make some users uninterested in AVs?
  - Because passengers tend to prefer more gradual acceleration, deceleration, and turning compared to drivers, will AVs be programmed to behave more gently? What could be the network impacts of such preferences?
  - Will trust in automation and fear over loss of control be major impediments to market penetration?
  - Will safety concerns lessen ridesharing in self-driving taxis?
- **Policy – local, regional, national, and even international.**
  - Will governments impose pricing mechanisms on AVs? Will subsidies be available?
  - Will standardized data sharing and communications be widespread?
  - What safety-based regulations can still encourage innovation? How will such regulations impact network performance?