Real-world safety assurance of connected and automated vehicles

or

A pragmatic view of the safety benefits of CAVs?

Joint workshop CAD & C-ITSec
9 June 2019, Paris

Loughborough University

Pete Thomas
Professor of Road and Vehicle Safety
Safe and Smart Mobility Research Cluster

The Queen's Anniversary Prizes
2007
Awarded to the Vehicle Safety Research Centre

Key challenges for CAVs

- How can we develop autonomous vehicles that work?
- How can we demonstrate they are good enough to reassure the public?
- How can we prove they will function correctly in all road conditions?
- 94% of crashes involve human error – how can we capture the expected safety benefits of CAVs?

More efficient travel

Cleaner world

Impact on jobs

Crashes will be obsolete

Crash avoidance technologies

Advanced Driver Assist Systems

- Anti-lock braking
- Electronic stability control
- Autonomous Emergency braking (City, inter-urban)
- Lane keeping/change
- …….

ABS – 2% reduction in accidents

ESC – 17% reduction in accidents

AEB city – 38% reduction in relevant accidents

LDW/LKA – 30% reduction in relevant accidents

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Increasing automation

Automation

Urban mobility

- Low speed, high automation
  - Pods and shuttles
  - Cyber cars
  - Automated buses

Private vehicles

- Higher speeds, progressively higher automation
  - Based on existing technologies (ABS, ESC, LDW, LKA, FCW, ACC etc.)
  - Movement to traffic jam assist, autopark, highway chauffeur, highway autopilot

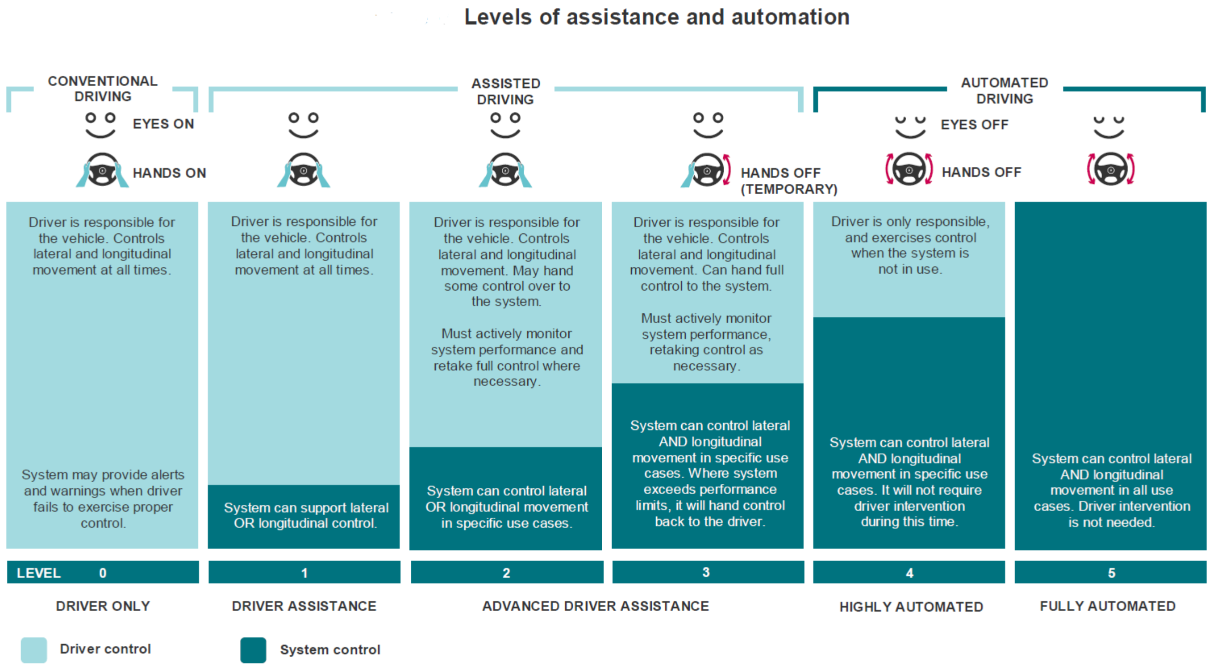
What are the differences?

ADAS

- Examples – ESC, AEB, LDW, LKA…
- They operate in tricky situations when the human cannot
- Rapid development of technologies and entry to market

Automation

- Replaces human for normal driving tasks
- ERTRAC roadmap highlights highway and parking technologies
- Defined for a specific environment
- SAE Levels 0 - 5



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Trials and normal operational use

- ADAS widespread in the vehicle fleet
- CAVs are in use on the public road in trials with regulatory exemptions and safety marshal
- CAVs are not permitted in service in most locations

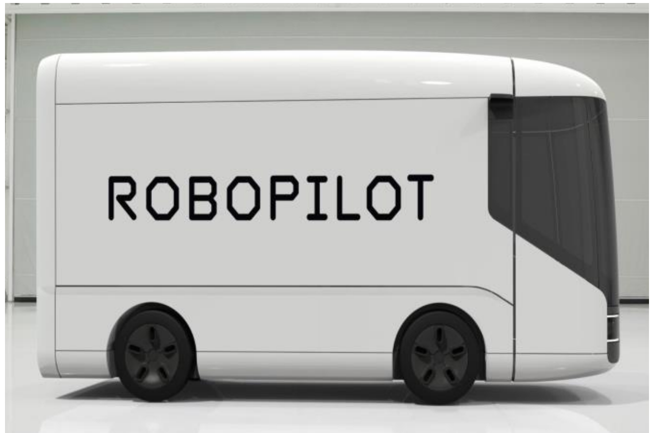
Field trials and evaluations

Evaluation

- System functionality under natural conditions
- Human factors and road user behaviour
- Impact on safety, environment and efficiency
- Events investigations

Demonstration

- Show CAV operation to public and stakeholders
- Business models
- Reassure public over safety and efficiency
- *but..............*



How do we prove CAVs operate correctly in all situations?

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- Physical testing
  - Off road
  - On road
  - 10^5 km +
- Simulation
  - Challenging
  - How to model environment, sensors, control systems?

What could possibly go wrong?

theguardian

Self-driving bus involved in crash less than two hours after Las Vegas launch

A truck driver is blamed for the accident, which passengers say could have been avoided if the autonomous vehicle had only reversed

Self-driving bus company says vehicle safe following crash – video

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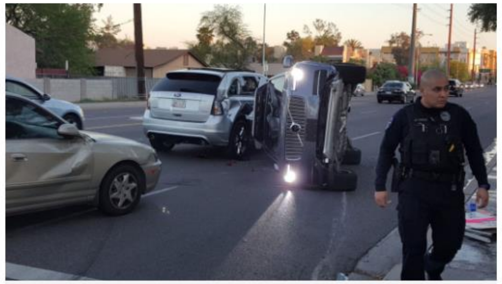
Uber halts driverless car tests after vehicle rolls over in Arizona smash

An investigation is underway after an autonomous SUV is involved in a three-vehicle crash during testing.



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Technology

Tesla and GM self-drive cars involved in road collisions

24 January 2018

The front of the Model S crumpled upon impact

"A Tesla Crash, but Not Just a Tesla Crash": NTSB Issues Final Report and Comments on Fatal Tesla Autopilot Crash

OCTOBER 3, 2017 AT 11:48 AM BY PETE BIGELOW | PHOTOGRAPHY BY NTSB/FLORIDA HIGHWAY PATROL/AP, NATIONAL TRANSPORTATION SAFETY BOARD, TESLA MOTORS

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Tesla's Autopilot woes continue with Laguna Beach police car crash

By JEFFREY COOK and ERIN DOOLEY Jun 2, 2018, 8:36 AM ET

The Guardian

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Uber

Uber crash shows 'catastrophic failure' of self-driving technology, experts say

Concerns raised about future testing as footage suggests fatal collision in Arizona was failing of system's most basic functions

Video released of fatal Uber self-driving crash

Sam Levin in San Francisco

Uber dashcam footage shows lead up to fatal self-driving crash – video

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El Capitan: two climbers die in fall from Yosemite rock face

Regulation – how is it developed?

- EU – Brussels – EC Whole Vehicle Type Approval
- Global – Geneva – WP 29 – Global Technical Regulations
  - Safety and security of vehicle automation and connectivity:
    - Framework
    - Functional requirements
    - New assessments and test methods
    - Cyber security (and software updates)
    - Data Storage System for Automated Driving (currently)
  - ADAS:
    - Remote control manoeuvring
    - Automatically commanded steering systems
  - Dynamics (Steering, Braking etc.):
    - Advance Emergency Braking Systems
    - Anti-lock Braking System for motorcycles
    - Electronic Stability Control

Why is this important?

- Automated systems cannot be used in production vehicles unless they comply with regs
- Regulation primarily addresses safety
- Exemptions are possible but
  - Lack of relevant regulation is a barrier to deployment and sales

Current regulatory concepts

Multi Tier Measurement

Audit

Function Safety Strategy. FMEAs…

Design, development, testing, manufacturing processes

Testing → / ← Refine

Virtual Testing

Road/scenario DB
Driver models
Vehicle models

Testing
Knowns
- Objects
- Movement
- Vehicle drives as per model

Perception limited

Measurements
- Against test criteria of knowns

Testing → / ← Refine

Tracks Testing

Specific scenarios testing

Testing
Knowns
- Objects
- Movement
- Real vehicle motion

Perception edge case possible

Measurements
- Against test criteria of knowns
- Perception consistency

Testing → / ← Refine

Real World Testing

Safety driver controlled use, wide verity of scenarios with diversity of conditions

Testing
- Few external knowns
- Disengagements
- Testers notes

Measurements
- Perception consistency
- Planning accuracy
- Driving accuracy

Testing → / ← Refine

In Service

Significant increase in miles driven. Limited or no driver interventions

Measurements
- Perception consistency
- Planning accuracy
- Driving accuracy
- Near misses
- Accident reports

Deploy → / ← Refine

What is safety?

- Management of the introduction of new technologies to avoid the introduction of new risks

- Use of new technologies to reduce existing road risks ->reducing casualties below existing numbers

- How do we decide on a reference safety level?
  - same risks than current vehicles?
  - as safe as a human?
  - no crashes under any circumstances?

What are the limitations of new systems?

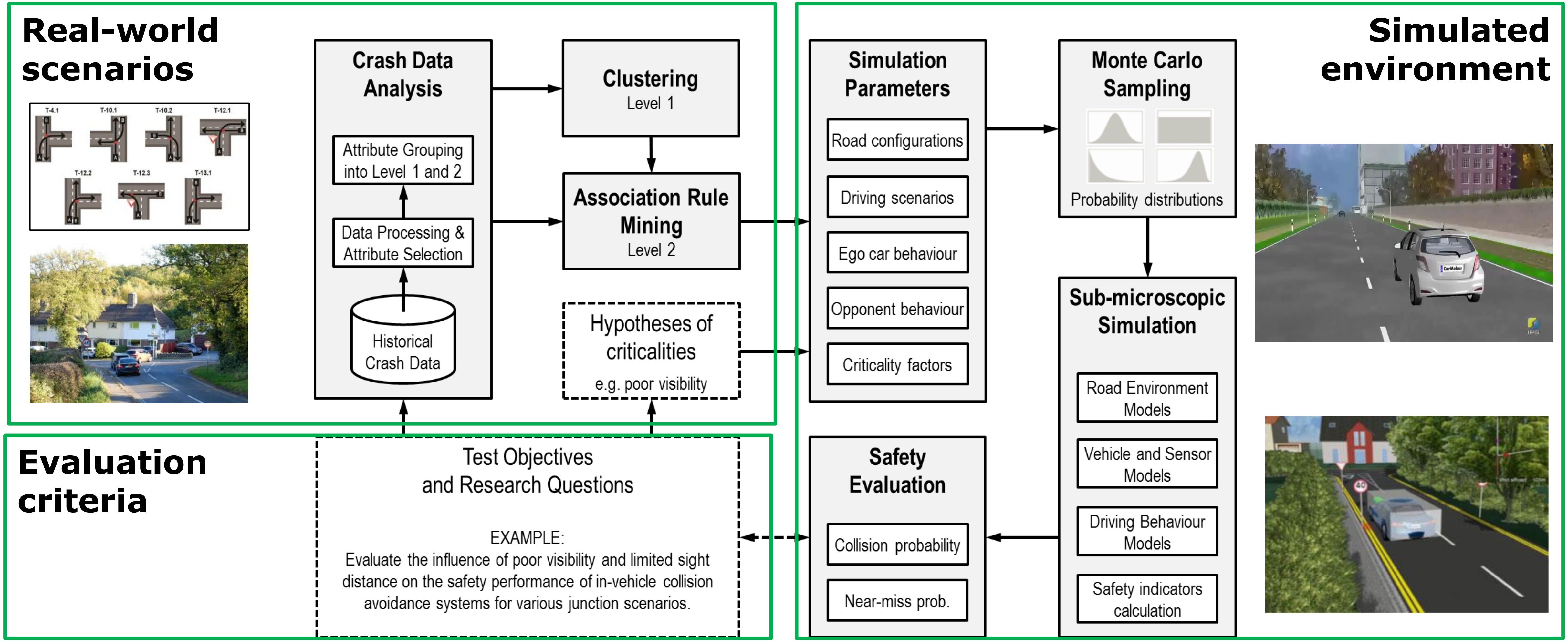
- How do they compare to human drivers?

One death	277 million km	173 million miles
One serious injury	19 million km	12 million miles
One minor injury	1.6 million km	1 million miles

- Human drivers are very safe and resilient – how do automatic systems compare?
- How do we compare risks?

Virtual validation methodology

Goal: Enable virtual testing of automated driving systems in representative scenarios and environments



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Validation challenges

- Public wants assurance automated vehicles are safe
- ……..in every driving situation
- ………not 99% or 99.9999%
- Many, many permutations
  - Road characteristics
  - Environmental characteristics
  - Vehicle characteristics
  - Traffic characteristics
  - Interaction characteristics

Thatcham Research

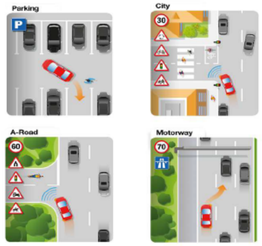
DRAFT

Assisted and *Automated* Driving Behavioural Competency Framework

Road Users

Motorised Vehicles

- Perform Low and High Speed Merge
- Detect and respond to encroaching oncoming vehicles
- Perform car following and stop and go
- Detect and respond to stopping or stopped vehicle
- Detect and respond to lane changes
- *Accommodate Emergency Vehicle priority*



Other Road Users

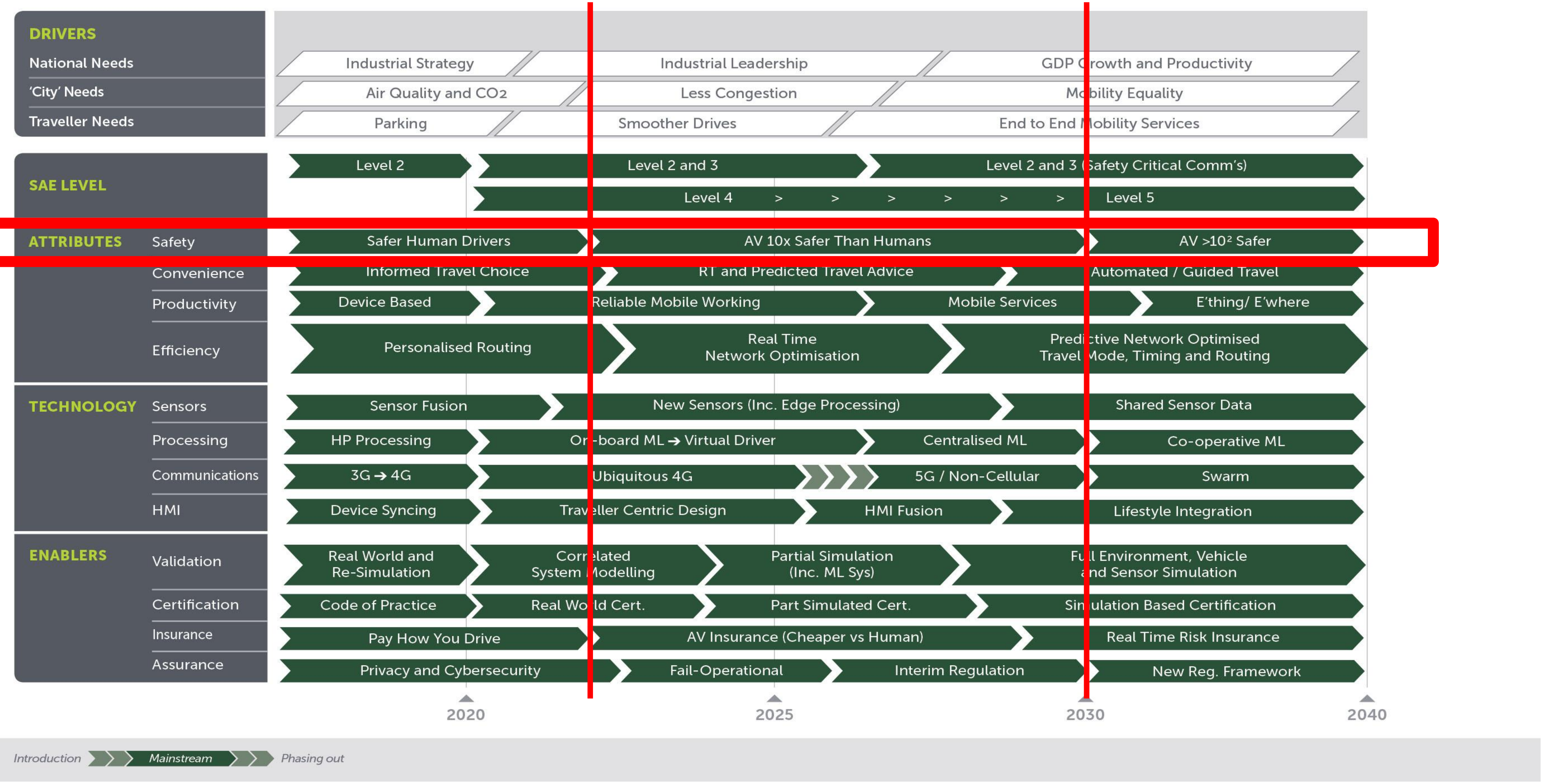
- Detect and respond to cyclists in and out of cycle ways
- Detect and respond to cyclist on roads including those inhibiting passing
- Detect and respond to pedestrians on pedestrian crossings – zebra/pelican
- Detect and respond to pedestrians crossing outside of pedestrian zones
- Provide safe distance and navigation of pedestrians and cyclists at side of road

Variability of real-world conditions

Urban | Rural | Highway | Weather | Lighting

Every possible real world scenario?

PRODUCT ROADMAP 2017: **INTELLIGENT CONNECTED VEHICLE**



Potential safety benefits of CAVs

Perfect CAVs mean that

- Crashes involving CAVs will be avoided

But

- Imperfect CAVs
- Mixed fleet
- Crashes not involving cars
- Communication with pedestrians, cyclists etc.

Currently

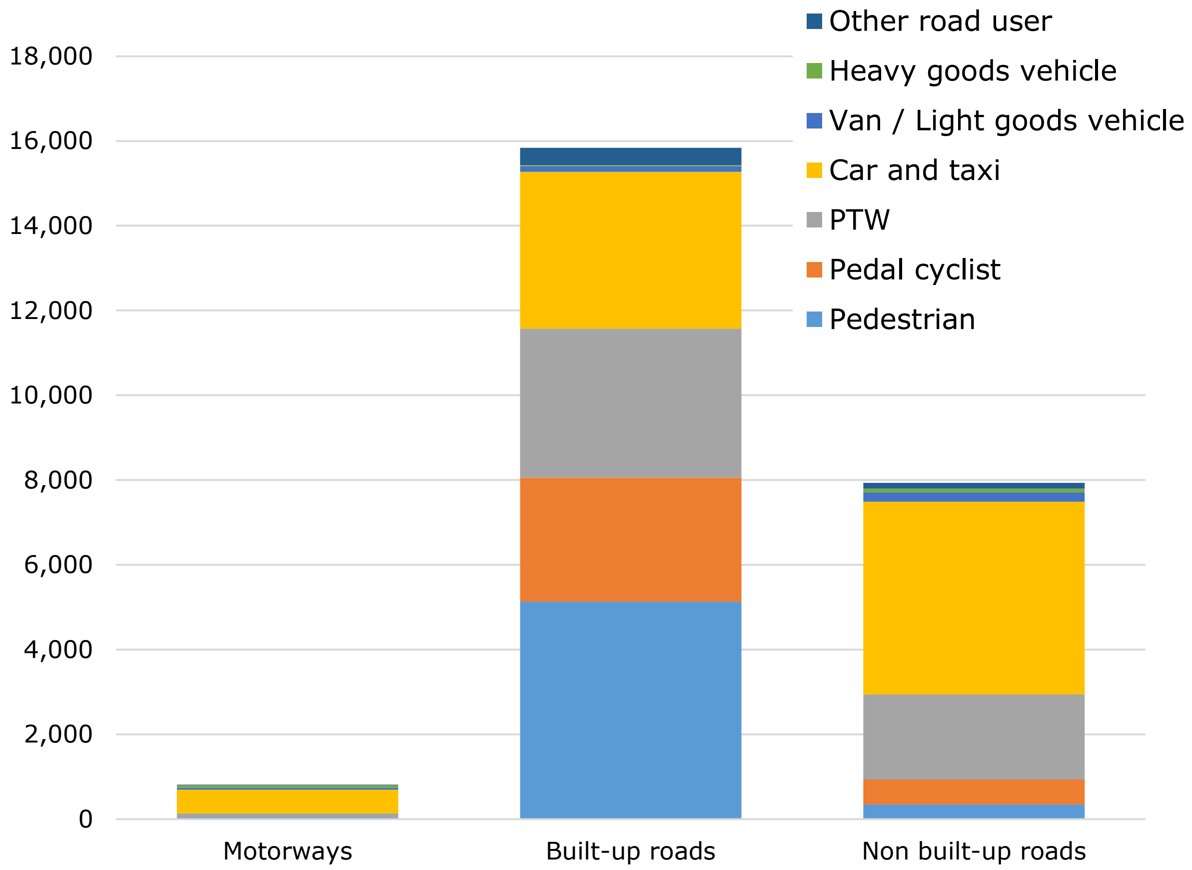
- CAVs can sometimes operate in simple scenarios
- We have little knowledge about the impact of CAVs on traffic and safety
- We have little more knowledge about ADAS and safety

What are the road safety challenges?

1. Urban safety technologies to prevent pedestrian, car occupant, PTW and cyclist crashes

2. Rural roads – car occupants and PTW riders

3. Improving highway safety, while valuable, does not address the most common groups of casualties.

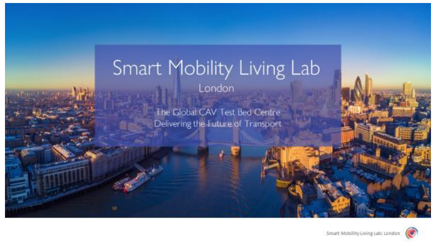


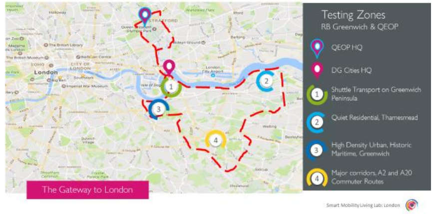
Killed and seriously injured casualties GB 2014

The UK real-world CAV test facility

Smart Mobility Living Lab:London

- New £17m CAV test bed located in London
- Test routes on Queen Elizabeth Olympic Park and Greenwich
- Instrumented and connected roads for CAV and Intelligent Mobility applications
- Partners Loughborough University, TRL, Cisco, Cubic, TfL, LLDC, DG Cities





Conclusions

- To support the deployment of automated vehicles a new regulatory pathway is needed
- The public expects safety levels to be much higher than that of human drivers
- Significant safety benefits in the near future will come from systems targeting vulnerable road users in urban areas

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