The Disruptive Impact of Connected & Autonomous Vehicles on Mobility

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Content

- Disruptive Mobility – Ricardo today
- Challenges in Today’s Urban Environment
- CAV Market Trends and the CAV Landscape
- CAV Security and Consumer Acceptance
- Real World CAV Solutions
- Future Mobility Vision
The Ricardo Global Automotive Group already participates worldwide in CAV solutions, across multiple market sectors

utilising the wide spectrum of skills and experience within the company

Ricardo continues to increase its investment in Connected & Automated Vehicle Research & Development
Ricardo – Global participation in disruptive mobility solutions
Bridging the gap between Tier 1 technology development and OEM demonstration and taking research from laboratory to production

Relevant Services

Market Sectors

After more than 100 years of transport evolution we are now in a period of.....

significant revolution and disruption
**Selected megatrends are likely to reshape the world in which we live and drive new requirements, behaviours and implications**

<table>
<thead>
<tr>
<th>Megatrends</th>
<th>Evidence/Cause</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Growth</td>
<td>7 billion to 9 billion by 2050 60% in Africa &amp; Asia</td>
<td>Demand for scarce resources Mobility &amp; energy demand Change in geo-economic power</td>
</tr>
<tr>
<td>Urbanization</td>
<td>Two-thirds of the world’s population reside in cities by 2030</td>
<td>Increasing number of megacities Urban people/goods mobility Overcrowding &amp; congestion</td>
</tr>
<tr>
<td>Increasing incomes &amp; wealth</td>
<td>60% of the world’s population “Middle Class” by 2030 – from 27% today</td>
<td>Improved access to education Better healthcare/ageing population More individual choice &amp; freedoms</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Exponential growth in volume and access to information</td>
<td>Interconnected global economy Growth of “intelligent” services New social interaction modes</td>
</tr>
<tr>
<td>Environmental awareness</td>
<td>Rise of The Green Agenda – Climate change, air quality, scarce resources</td>
<td>Growth of the “Circular Economy” Intolerance of environmental damage Growth of punitive regulation</td>
</tr>
<tr>
<td>Anti-Consumerism?</td>
<td>“Mindless consumerism” to improved work/life/ social balance?</td>
<td>New attitudes to economic growth Re-evaluation of wealth Challenging the role of “ownership”</td>
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Source: Arthur D. Little study “Mobility 2020”, Ricardo analysis
Challenges in Today’s Urban Environment

These Mega trends lead to key challenges to city transport systems from air quality and congestion to occupant and pedestrian safety

- **Emissions / Air Quality in cities**
  - Air Quality in cities & roadside exposure are dominated by road transport – accounting for 40% NOx (64% NO₂)
  - In 2012, 3 million people died as a result of air pollution exposure – 5.4% of all deaths worldwide
  - Deaths due to exposure to outdoor air pollution are twice that of road fatalities (~1.25 million / yr)
  - Air pollution, globally dominant environmental health risk

- **Congestion**
  - Congestion is a truly global problem, it links countries with a highly developed road network and those with little to no existing infrastructure
  - In the UK a recent study showed that people would be happier with a smoother journey over a fast journey

- **Safety**
  - Most crashes are caused by human error, and adding distractions from mobile devices pose further risks
  - Improving road safety is a key target for many Governments & OEMs throughout the world

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* Source: WHO
Challenges in Today’s Urban Environment

Connected and Autonomous Vehicles are part of the solution

City and commercial fleet challenges will help adoption of driver technologies such as autonomy and connectivity - leading to improved productivity and quality of life

Fuel Reduction for Fleets

Platooning 5-10%

Prevent traffic congestion

- Improved use of transport networks
- Reduce "unnecessary" trips and routes
- Self co-ordination of traffic (e.g. Platooning)

Some Benefits of Connected & Automated Driving

Increased traffic safety

- Automate mundane driving tasks
- Accident Prevention (advanced braking and collision avoidance)
- Accident reduction

Emissions Reduction

- Predictive Navigation / vehicle control with real-time data
- Advanced diagnostics and service functions to comply with strict emission regulations

Fuel Reduction for Fleets

Platooning 5-10%

- Driver Salary, $46,800
- Repairs & Maintenance, $15,000
- Insurance, $6,500
- Tires, $4,000
- Permits, Licenses & Tolls, $3,600
- Other, $4,100
- Fleet Maintenance $70k

Fuel Reduction for Fleets

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Sources:
1. Source: Ricardo
2. Source: Automated Vehicle Forum, April 2012, Booz Allen Hamilton (www.thetruckersreport)
The widespread introduction of CAV will enable a whole new transportation network – and disruptive new Mobility Services

Big-data and live updates as events unfold, enable new opportunities for business

- Move from vehicle-centric to a transportation network
  - Network of vehicles – different types of vehicle
  - Smart infrastructure – traffic lights, car parks, multimodal transport
  - Cloud computing – traffic / map data, system optimisation / control

- Needs to work with new industries – consumer electronics, cloud computing, services, non-traditional OEM’s
- New business models
- New ownerships models
- New behaviours
  and also an opportunity to resolve….
- New threats – to cybersecurity, safety, financial transactions
Connected vehicles – Smart Cities

Autonomous and connected vehicles are enablers for a complete urban mobility solution combining the physical & virtual worlds enabling cities to become smarter & connected

- E-mobility will require a new infrastructure:
  - Chargers
  - Car parks
  - Ride sharing
  - Ride handling

- The deployment of infrastructure is already subject to smart planning:
  - London Taxi becoming hybrids
  - eCar in Paris, Indianapolis, Singapore,..
  - eScooter in Paris, Barcelona,..

- A connected solution will remove some of the main hurdles:
  - Driving in circle to find a parking spot
  - Ride-Sharing / Car-Sharing
  - EV charger real-time availability
  - Traffic jam avoidance
CAV market trends and the CAV landscape

Connected Automated Vehicle (CAV) Landscape
Mobility Systems in context

- System architecture
- Safety / accident statistics & impacts
- Energy management
- Booking system
- Multimodal transport integration
- Payment system
- Connected car services
- Machine learning software
- Smart infrastructure management
- HMI, Human factors, user experience
- Vehicle fleet management
- Use of modelling & simulation
- User acceptance (societal)
- Business models
- Standards
- Legislation, regulation
- Technology strategy & roadmaps
- Certification / assurance
- Verification & validation methods
- Security / cybersecurity
- Functional safety
- Veriﬁcation & validation methods
- Insurance, liability
- Business models
- Standards
- Legislation, regulation
- Technology strategy & roadmaps
- Safety / accident statistics & impacts
- Energy management
- Booking system
- Multimodal transport integration
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- Connected car services
- Machine learning software
- Smart infrastructure management
- HMI, Human factors, user experience
- Vehicle fleet management
- Use of modelling & simulation
- User acceptance (societal)
- Connected, Automated Vehicle
- Localisation & Environmental perception
- Trajectory calculation & Path prediction (of others)
- Vehicle control & Cooperative vehicle control
- Vehicle connectivity (V2V, V2I, V2P, ...)
- Steering
- Acceleration
- Braking
- Base Vehicle
- Connected, Automated Vehicle
- Impact assessments
- Mobility System
- Engineering the Mobility System
- Security / cybersecurity
- Functional safety
- HMI, Human factors, user experience
- Use of modelling & simulation
- User acceptance (societal)
CAV security and Consumer acceptance

CAV will use differing levels of technology – its introduction governed by legislation & validation – driven by cost and consumer confidence

Complexity progression – SAE Level 0-5

and with this transition comes the need for resilience to threat
Resilience to threat - Legislation and Consumer Confidence

The 5StarS Program

- CAVs are increasingly exposed to malicious cybersecurity attacks. This has the potential to destroy the CAV market opportunity.

- Currently, there is no means for the consumer to make an informed buying decision, or for OEMs to differentiate their products.

- There is opportunity to create a marketplace for vehicle cybersecurity by:
  - Providing the insurance industry and consumers with a means of assessing risk.
  - Providing OEMs and suppliers with cybersecurity assurance services for CAVs to ensure consumers have confidence in their products.
The objective of 5StarS is to develop an agile assurance framework for assessing the cybersecurity of vehicles.
Drawing on existing industry expertise
Applying core skills to Connected & Automated Vehicle

Control & connectivity

- Control strategy development of longitudinal & lateral control
- Functional safety definition and review
- Cooperative control systems

- Core vehicle system functional engineering
- Demonstrator builds
- Conventional electrical systems integration & network management

Real World CAV solutions
Real World CAV solutions

Drawing on existing industry expertise
Connected & Automated Vehicle - tools and processes to support development

**Assurance & Certification**
- Independent safety assurance & certification
- Independent cyber-security assurance & certification

**Architecture**
- Systems architecture definition for functionality, functional safety & cyber-security
- Fail-operational architectures

**Verification & validation**
- Virtual testing, verification & validation
- V&V methodologies
- Performance metrics & attributes
- Test case management

**Energy management**
- Energy optimisation at vehicle / fleet / grid level
- Electronic horizon based control
The UK Government, under the Centre for Connected & Autonomous Vehicles (C-CAV), has identified a corridor of virtual and real-world test environments in the UK and is actively supporting trials of CAV technology within the UK.

Ricardo is engaged and located in the heart of this area.

Ricardo will also have access to the growing controlled and real-world test environments that are being enabled by Meridian Mobility –

A mobility technology cluster designed to accelerate the development of connected and automated vehicles.
Real World CAV solutions

**Autonomous Vehicles – Definitions, Trails and certification**

Rollout via initial trials in restricted environments for both people & goods - Certification process is critical

SAE Automation Classification:

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Definition</th>
<th>Steering/Speed</th>
<th>Monitoring</th>
<th>Backup</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Human driver in control at all times</td>
<td>Human</td>
<td>Human</td>
<td>Human</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Either steering or speed control assistance</td>
<td>Human &amp; System</td>
<td>Human</td>
<td>Human</td>
<td>Some Modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>Steering and speed control assistance</td>
<td>System</td>
<td>Human</td>
<td>Human</td>
<td>Some Modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>Auto steering &amp; speed control - human backup</td>
<td>System</td>
<td>System</td>
<td>Human</td>
<td>Some Modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>Automated control - limited human intervention</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some Modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>Full automated driving without intervention</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All Modes</td>
</tr>
</tbody>
</table>

Closed Environment Trials
- Initial trials in “closed” or restricted access zones & at low speed

Mixed Environment Trials
- First use of fully autonomous capability in city “zones” restricting access to conventional vehicles

Restricted Inner City Zones
- First AV services in restricted inner city zones – convergence of public/private transport

Mixed Inner City Zones

Mixed Auto/Human

Automated Goods Supply

LGV Inner City Deliveries

LGV Inner Delivery Trials

HGV Platooning Trials
- HGV Platooning first semi-autonomous mode to be certified and implemented

HGV Platooning Rollout

= Functional Certification Achieved

2015 2020 2025 2030 2040 2050
Announced trials and demonstrations show that roll-out is critical to achieve standards and acceptance
Delivering Real World Mobility Solutions
An opportunity to combine innovative business solutions with large scale project delivery to enable significant and accelerated strategic change

Cooperative control platooning project
- Lead vehicle driven by trained professional driver, following vehicles have automated driving
- €6.4M EU co-funded FP7 project, seven partners
- Ricardo responsible for: Project lead & coordination, safety analysis based on IEC61508/26262, platoon control system incl. longitudinal and lateral control strategies
- Successful platoon demonstration on public roads

Real world operator platooning trial (UK)
- £8.1m UK Platooning Trials, real world trial as part of normal fleet operation in the UK (est 45,000km)
- To answer questions on benefits of platooning in the UK and to inform future policy
- Ricardo involvement in DAF RHD trucks, integrate platooning system components, requirements & architecture support, safety analysis, platooning software, trial ins. + support trial & data analysis

Steel mill slab yard automation
- Client using customer built slab carriers to transport 20t steel slabs from continuous casting machines to slab sorting fields & various processing facilities
- Client looking to replace ageing vehicles with newly designed automated vehicles which will operate in a new automated slab yard environment
- Ricardo proposal to develop new slab carrier vehicles and slab carrier automation

Dedicated short range communication (DSRC) demo
- Electronics Tier 1 client sought to develop a prototype automated vehicle to showcase technology
- Ricardo integrated and developed a demonstration of robust longitudinal and lateral controls for a lead-following automated vehicle
- Additionally, development of active safety features, including ‘digital-fence’ for both vehicles, navigation system health check & input plausibility checks

Production L3 Highway Pilot Support
- OEM developing L3 highway pilot system for passenger car mass production.
- Sensor fusion system being developed by EU supplier
- Ricardo support to ensure quality of supplier development focusing on R&D + development phase
- Ricardo supporting software, hardware, diagnostics, comms, functional safety & ECU mech design.

Safety management and assurance for “WEpods”
- First driverless vehicles on public road in the Netherlands
- Safety management & assurance support including: Writing the Safety Plan & Safety Case
- Helping the project team ‘do the right thing’ - Hazard identification sessions, Reviews of specifications & Use Cases, Gathering and Writing safety evidence
- Performing FMEA

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Future Mobility Vision

A Vision of Future Mobility

Fully co-operative, multi-modal on-demand systems – Public & Private transport converges
The Disruptive Impact of Connected & Autonomous Vehicles on Mobility

Delivering excellence through innovation and technology
Taking research from the laboratory to production and bridging the gap between Tier 1 technology development and OEM production engineering delivery

‘With Disruption Comes Opportunity’

Thank you