Tunnel Safety with Innovative Vehicles

Dr Fathi Tarada
Mosen Ltd
Issues

• Autonomous & connected vehicles are now a reality
• Electric and hybrid cars are increasingly prevalent
• How safe are these vehicles in tunnels?
Agenda

• Autonomous & connected vehicles
  – General characteristics
  – Risks and accidents on open road
  – Specific risks in tunnels
  – Research findings

• Electric & hybrid cars
  – Battery fire incidents
  – Risks in tunnels
Autonomous vehicles

- Can sense their environment and navigate without human input, at least in certain traffic conditions and within specific time periods
- Cameras, radar, ultrasonic sensors and other data to automatically steer along the road, change lanes, brake and adjust speed

Tesla Autopilot
Connected vehicles

- Wireless connections to infrastructure and other vehicles (warnings, fleet learning)
Levels of Vehicle Automation

National Highway Traffic Safety Administration definitions:

Level 0 – No Automation
Level 1 – Function-specific Automation
Level 2 – Combined Function Automation
Level 3 – Limited Self-Driving Automation
Level 4 – Full Self-Driving Automation
Current Automation Level

• Tesla Autopilot: between Level 2 (cruise control + lane keeping) and Level 3 (driver fully cedes control of all safety-critical functions)

• Car senses when conditions require the driver to retake control & provides transition time for driver
## Expected Evolution

<table>
<thead>
<tr>
<th>Timeline</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2030+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>Blind spot monitoring</td>
<td>Lane departure warning</td>
<td>Lane keep assist (LKA)</td>
<td>Autonomous emergency braking</td>
<td>Intersection pilot</td>
<td>Emergency driver assistant</td>
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<tr>
<td><strong>Connectivity</strong></td>
<td></td>
<td></td>
<td>3D Cloud based navigation</td>
<td>Vehicle to vehicle, vehicle to device and vehicle to infrastructure communication</td>
<td>Certain driving situations e.g. remote parking and urban automated driving</td>
<td>Full end-to-end journey</td>
</tr>
<tr>
<td><strong>Autonomy</strong></td>
<td>Cruise control</td>
<td>Adaptive cruise control</td>
<td>Traffic jam assist</td>
<td>Highway autopilot</td>
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</tbody>
</table>
Automation Advantages

>90% of traffic accidents worldwide are due to driver error

Opportunity to reduce accidents and injuries: save >2,500 lives and 25,000 serious accidents per year in UK by 2030
Fatal Accident with Autonomous Car

- 7th May 2016
- Tesla Model S failed to identify a large white 18-wheel truck and trailer crossing the highway
- Car attempted to drive full speed under the trailer, with the bottom of the trailer impacting the windshield.
Fatal Accident with Autonomous Car
Risks for Autonomous Vehicles in Tunnels

• Lateral deviations due to incorrect steering -> collisions with tunnel walls
• Wireless signals attenuated
• GPS signals disrupted
• Special signage e.g. wig-wams, lane control signs
• May drive into smoke-filled areas
Tunnel Fire Scenario

- Escape door
- Distance
- Car in fire
- Safe area
- Very unsafe area
- Direction of longitudinal ventilation
- Driving direction
V2I and V2V warnings

EU’s Safe Tunnel Research Project
Closure Warnings

• Vehicle-mounted cameras to detect tunnel lane closure or redirection signs
• Tunnel operator may use V2I channel to direct vehicles or impose lower speed limits
Communication Protocols

• EU’s Safe Tunnel research project: GPRS (mobile telephone) network in tunnels
GPRS Network

Public mobile network

GPRS link

IP access

Control Centre
- Access & vehicle control
- Vehicle prognostic
- Vehicle tele-control
- Dissemination of emergency information

Vehicle monitoring during tunnel crossing

Vehicle monitoring release

Vehicles:
- Tunnel entrance area
- Tunnel entrance
- Tunnel
- Tunnel exit area
- Tunnel exit
Improved Wireless Communications

• EU’s SAFESPOT research project: improved V2I communications using the IEEE 802.11p protocol (enhanced Wi-Fi)
Decision-making during incidents

• Location of incident can be transmitted from tunnel detectors to vehicles
• Incident close to exit portal & at least one lane unblocked – proceed with driving out?
• Incident too remote from exit portal – stop, disembark and evacuate tunnel?
• Driver / operator intervention necessary
Wireless Installation Issues

• Short tunnels – broadcast antennae at the portals
• Long tunnels – leaky feeders
• High-speed data connections between tunnel incident detectors and V2I channels
• Equipment redundancy to achieve approved Safety Integrity Level
Way Forward for Autonomous Vehicles in Tunnels

• Significant investment required to make tunnels safe for autonomous vehicles
• In the meantime ...
• Ensure driver is in control while driving through tunnels
Electric and Hybrid Vehicles
Electric vehicles predicted to rise to 35% of global new car sales by 2040.
Air Quality Improvements – Electric-only Mode

• Small hybrid cars driven in electric-only mode -> 40% less CO\textsubscript{2} than equivalent petrol cars

• No nitrogen oxides or particulate matter discharged from tailpipe
Air Quality Improvements – Hybrid Mode

Proportional reduction (∝ electric power duration) expected in

- $\text{CO}_2$
- $\text{NO}_x$
- Particulate matter
Fire Risk with Lithium-Ion Batteries

• Flammable organic electrolyte
• Thermal runaway incidents
  – Overcharging
  – Charging/discharging too quickly
  – Damaging the battery during a crash or by impact with high-speed debris.
• Once ignited, such fires can be very difficult to extinguish, due to the risk of re-ignition
• Potential explosion risk
Tesla Model S lithium-ion battery pack

540 kg weight
Tesla Model S fire on 1st October 2013
Tesla Model S fire on 1st October 2013

- Cause: road debris on a highway in Washington, USA.
- Initial attempts to extinguish the fire with water unsuccessful - fire reignited underneath car.
- Firefighters had to use a jack to turn the car on its side, then cut holes in battery’s protective metal plate to apply water directly to the burning battery.
- Tesla has improved the impact protection around the battery.
Fire Tests by SP, Sweden

- Results presented by Andreas Sæter Bøe of SP, Norway
- Tata EV cars: 26 kWh Li-ion battery, 12 modules

Two tests:
- Drop from 20m height
- Exposure to propane burner
Test 1, Drop from 20 height

- Equivalent to 70 km/h impact to rear
Test 1

8 min after drop
Test 2, propane flame ignition

Extinguishing attempt 1: 100 litres (failed)

Extinguishing attempt 2: 550 litres (successful)
Test 2

Just before 2\textsuperscript{nd} attempt to extinguish fire
Lessons for Tunnels

- Identification of electric car?
- Isolation of battery?
- Graphite dry powder (class D) extinguishers?
- Difficult to turn vehicle on its side in a tunnel
- Leave the electric car to burn out? Long disruption of traffic, damage to facilities?
- Limited effect of fixed fire suppression?
Way Forward - Electric Vehicles in Tunnels

• Fire-fighting procedures to be tested and improved
• Database of best practice
• Improvements in impact protection
• Alternative battery technology (nickel-metal hydride)
• World Road Association: “technology watch”
Review

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