Road Safety and Automation

P. Papantoniou, A. Ziakopoulos, G. Yannis
National Technical University of Athens

Porto, 25 October 2018
Outline

- NTUA Dpt of Transportation - NRSO
- Introduction – Present traffic safety state
- Current technological state
- Transition phase
- Direct safety impacts
- Indirect safety implications
- Future challenges
The National Technical University of Athens (NTUA) is a public-owned University and the largest Technological University of Greece.

NTUA and the School of Civil Engineering have contributed unceasingly to the country's scientific, technical and economic development since their foundation in 1837.

In 2018, the School of Civil Engineering of NTUA was ranked 11th in Europe among all Civil Engineering Schools and 31st worldwide.
NTUA Road Safety Observatory – Centre of Research Excellence

20+ members Scientific Team:
• Internationally recognized Professors
• 8 Senior Transportation Engineers (4 PostDoc)
• 6 Transportation Engineers PhD Candidates
• 2 Information Systems Engineers

With experience in Greece and Internationally (since early 90s):
• 75 road safety research projects (Greek 30, International 45), mostly through highly competitive procedures and several international cooperations
• More than 500 scientific publications (> 150 in Journals), widely cited worldwide
• More than 60 scientific committees
• International collaborations: European Commission, UN/ECE, OECD/ITF, WHO, World Bank, EIB, CEDR, ERF, UITP, ETSC, WCTR, TRB, decades of Universities and road safety research centers
Panagiotis Papantoniou, Road Safety and Automation

NTUA Road Safety Observatory

An international reference road safety information system, with most updated data and knowledge, with:
- more than 3,000 visits per month,
- tens of items and social media posts/tweets annually

www.nrso.ntua.gr
Introduction & Present traffic safety state
What is it all about?

• In the past decade, autonomous vehicles (AVs), connected vehicles (CVs) and relative technology have been in the spotlight

• Intensely researched by both academia and industry

• Interest spurred by computational advances, both in processing power (CPUs) and methodology (Neural Networks)

• Competition and breakthroughs from the involvement of non-traditional automotive industry players
Questions regarding traffic safety

• Will there be an **impressive reduction in accidents** when full automation is reached?

• Could vehicles be **freely repurposed** when there is no need for human hands-on driving?

• What do we have to **change from the current state** to reach safe automation?

• Where does the **fault or liability** lie in the event of an accident?

• What will happen during the **transition phase** - human drivers sharing the road with autonomous vehicles?
Present traffic safety state

• Despite progress, **traffic safety** remains a major issue worldwide

• Road traffic deaths have globally **plateaued** at 1.25 million a year – further improvement seems difficult

• Ambitious targets remain (e.g. Sweden’s **Vision Zero**)

• Accidents are estimated to be caused mainly by **human error** (65%-95% of total)

• AVs aim to **eliminate** that error: no distraction, emotions, fatigue, poor/clouded judgment, cognitive impairments, instant reactions, greatly improved perception (no need for line-of-sight)

Source: WHO, 2015
Autonomous vehicles

• Autonomous vehicles (AVs) are vehicles operated by an artificial intelligence (AI) in place of a human driver.

• AVs use an array of sensors and auxiliary devices to collect information of the surroundings of the vehicle.

• AI receives input and provides all driving related controls and decision making that substitutes traditional drivers.

• Intercommunication of vehicles with other vehicles or elements of the road environment
  – vehicle-to-vehicle communication (V2V)
  – vehicle-to-infrastructure communication (V2I)
Connected vehicles

• Connected vehicles (CVs) are conventional vehicles, (still operated by a human driver), but are also enhanced via various telematics-electronic devices and upgrades

• Intercommunication of vehicles through V2X schemes as well

• Drivers receive more enriched information about the driving environment than they normally would (expected benefits when implemented in a wide scale)

• Certain technologies currently available
Connected Automation

**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors.

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure.

**Connected Automated Vehicle**
Leverages autonomous and connected vehicle capabilities.
5 Levels of automation (additional to baseline) have been introduced (SAE, 2016)

As levels increase, vehicles become more independent but require more sophisticated equipment to operate.

Levels are descriptive rather than normative and technical rather than legal:
- No particular order of market production is implied
- Minimum capabilities for each Level

Source: NHTSA, 2017
Current technological state
Connected Vehicle Progress

**Level 1** driver assistance available system (ADAS):
- Cruise control (since 1960s)
- Electronic stability control (since 1990s)
- Lane keeping/departure warning systems (LK/LDW) (since 2000s)
- Adaptive Cruise Control (ACC), Intelligent Speed Adaptation (ISA), Autonomous Emergency Braking (AEB) & Collision Warning systems **more recently**
- Several parking assistance systems **in use**

<table>
<thead>
<tr>
<th>Category / Domain</th>
<th>System / Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception - Information</td>
<td>Surround view</td>
</tr>
<tr>
<td></td>
<td>Parking assist</td>
</tr>
<tr>
<td>Collision avoidance</td>
<td>Collision warning – avoidance</td>
</tr>
<tr>
<td></td>
<td>Cross traffic warning</td>
</tr>
<tr>
<td></td>
<td>Autonomous emergency braking</td>
</tr>
<tr>
<td></td>
<td>Pedestrian detection</td>
</tr>
<tr>
<td>Navigation control</td>
<td>Intelligent speed adaptation</td>
</tr>
<tr>
<td></td>
<td>Lane departure warning</td>
</tr>
<tr>
<td></td>
<td>Adaptive cruise control</td>
</tr>
<tr>
<td></td>
<td>Traffic sign recognition</td>
</tr>
<tr>
<td>Safety augmentation</td>
<td>Seatbelt reminders</td>
</tr>
<tr>
<td></td>
<td>Electronic stability control</td>
</tr>
<tr>
<td></td>
<td>Alcohol interlock systems</td>
</tr>
<tr>
<td>Post-crash aid</td>
<td>E-call</td>
</tr>
<tr>
<td></td>
<td>In-vehicle event data recorders</td>
</tr>
</tbody>
</table>

Panagiotis Papantoniou, Road Safety and Automation
Automated Vehicle Progress (1/2)

Two main fronts:

- **‘Sensor-based’ technology**
  - Focus on devices to observe the road environment and navigate independently from driver

- **‘Connectivity-based’ technology**
  - Focus on devices to observe the road environment and navigate independently from driver

- **Systemic fusion** – convergence phase:
  - The latest approach to shrink costs and reach 100% functionality

Source: OECD, 2015
Automated Vehicle Progress (2/2)

Previous CV systems adapted for AVs
- ‘Never leaving factory’
  - Updating remotely (like a PC)

- Industry constantly creating prototypes:
  - Waymo, Tesla, Volvo between Levels 2 and 4, many others closely following
  - Original Equipment Manufacturers began to orient towards higher Level automation, independently developing singular systems

- Road authorities closely monitoring and struggling to keep up
  - Roadmap documents, implementation predictions (see right)

Source: ERTRAC, 2015

Panagiotis Papantoniou, Road Safety and Automation
Findings from the literature for CV traffic safety

- **Crash avoidance technologies** have considerable potential for preventing crashes of all severities (applying to more than a million crashes in the US annually). LK/LDW systems show similar but smaller effects.

- **Cooperative Intelligent Transport Systems** have been assessed from Field Operational Tests (FOTs) in EU, USA, Australia and Japan.

- **AEB** systems were effective in preventing 38%-44% of rear-end collisions.

- **ISA** reductions in fatalities estimated between 19-28% (even higher depending on regulations)

  - All effects **highly dependent** on penetration rate and exposure parameters (e.g. see right).

Source: Malone, 2014

Panagiotis Papantoniou, Road Safety and Automation
Safety lessons from incidents to date

- **Majority** of AV crashes attributed to either their operation by a human at the time crash or as fault of another vehicle (13 of 14 incidents for Waymo/Google cars)
  - **PDO crash** for Waymo/Google (2016):
    AV in autonomous mode, falsely ‘believed’ it was going to be granted priority
  - **Fatal crash** for Tesla (2016):
    AV in autonomous mode; sensors failed to detect a trailer
  - **Injury crash** for Waymo/Google (2018):
    AV not in autonomous mode, another car collided into AV
  - **Fatal crash** for Uber (2018):
    AV in autonomous mode, sensors detected pedestrian but AEB was disabled

- **Strong publicity**: Nonetheless, 89.2% of participants in a survey answered they would surrender navigation to an AV
Transition phase
Transition phase characteristics

- For decades autonomous vehicles and human drivers will likely **share the roads**
- Autonomous vehicles operations are inherently **different from human driven** vehicles and have the potential to offer several important benefits
- Should Avs do well to imitate some human habits?
  - to provide a sense of **familiarity** with the technology and reassure passengers
  - to interact with **traffic**
  - to **handle situations** where human intuition can be more useful
Traffic safety during the transition phase

- **Zero fatalities** cannot be expected
  - Safety levels might decline temporarily, at least for human drivers

- **Mixed traffic**
  - Several road users will not know what to expect; increased risk

- **Penetration rate – adequate exposure**
  - Critical for measurable differences

- **Vulnerable Road Users**
  - Need to take into account increased conflicts and interactions with pedestrians, cyclists, mobility impaired people etc.
Transition phase – things to consider

- **Non-linear progression** through AV Levels
  - Perceivable gap between Levels 3 and 4 of automation: industry will develop **independent AVs** over ‘grey area’
  - Level 3 technologies are proving too **difficult to engineer** for meaningful safety impacts mitigation

- **Pending barriers**
  - **Conventional road safety improvements** will help AVs as well, and they are not done yet
  - **More FOTs** for observation replications
  - Sensor capabilities, ADAS and HMIs need to be **upgraded and standardized**
  - **Additional concepts** possible (e.g. smart tires)

Source: Schoettle, 2017
Transition phase – Authority activities and enforcement

• **Enforcement agencies need increased readiness**
  – In an AV crash police should be able to **determine**:
    1. Involved AV capabilities
    2. Whether the AV was operating in automated mode
    3. Whether the AV was operating inside or outside its operational design domain
  – **Visual identification** has been proposed for AVs

• **Road Authorities** have started to mobilize:
  – Australian, AUSTROADS (2017)
  – European Parliament (2016)
  – Germany, Department for Transport (2016)
  – UK, Department for Transport (2015)
  – US, NHTSA (2013)
Direct and indirect safety impacts
Direct AV impacts on safety

- Too complex to describe casually!
- For AV penetration rates of 10%, 50% and 90%, Fagnant and Kockelman (2015) project 1.100, 9.600 and 21.700 lives saved/year (for USA)
- Behavioral adaptations for human drivers as well from AV interaction
- Personal driving styles will be suppressed (perhaps ‘manufacturer styles’?)
- Best case scenario: a virtuous circle of increased safety-trust-safety – Currently many unknown parameters

Source: Innamaa et al, 2017
Human factors issues

• Behavioural adaptation **more imminent with CV**
  – Positive effects (e.g. increased speed reduction and sign compliance rates in Japan with C-ITS)
  – Must tackle rebound effects (driver overreliance on a system and not paying attention)

• **Forward (in)compatibility** must be avoided
  – Absence of important human cues and mannerisms

• Need to anticipate **unconventional road user behavior**. Examples:
  – School zones
  – Wheelchairs
  – Skateboarders
Application issues

• Temporal and spatial headways **will be minimized**

• **Gradual increase** for AADT and vehicle-kilometers travelled (VKT) from increased demand.

• No need for drivers; **new AV users** (children, elderly, people with impairments)

• **Repurposing of vehicles** (leisure or business-oriented),
  – Changing passenger orientation will pose safety challenges

• **Infrastructure adaptation possible**
  – Possible roadside equipment needs (e.g. reflective signs, infrastructure collision warning systems etc.)
Indirect implications – Mechanical safety

• VKT increases will lead to more material fatigue – **mechanical faults**; chance for sophisticated equipment failures

• **Black box area**: AV occupants will be out of touch with the technology they use

• **Vehicle redesign traps**
  – Should avoid overeager ‘lighter’ designs due to increased AV traffic safety

• **Cybersecurity issues**
  – Anticipation of malicious acts; steps to denying hackers vehicle control are critical

• Traffic safety **measured differently** (Time To Collision etc.)
Indirect implications – Additional domains

• Legislation issues
  – Currently laws and regulations assume human drivers
  – AV systems are not persons, thus not liable
  – ‘Control’ and ‘Proper Control’ are undefined
  – Industry has begun to lobby for their AV products to find a robust legal framework

• Economic impacts
  – Potential large savings from traffic safety improvements
  – Services like e-call will reduce delays and minimize costs even after crash
  – Cost reductions are not universal: Safety benefits for a Park and Ride public transport AV scheme in Greece were not feasible, for instance
  – AV/CV circulation will reduce crash externalities
Future challenges
Future Challenges (1/2)

• **Legal framework for road safety**
  – Traffic rules and the regularly framework need to be adapted
  – Safety requirements have to be agreed

• **Public acceptance is critical**
  – A gradual trust-building exercise
  – Possibility of virtuous cycle of safety-trust-more safety
  – A challenge to prove AV-dominated roads are safer
  – However, penetration rates and VKT will affect AV traffic safety outcomes
Future Challenges (2/2)

• Significant initiatives from industry so far
  – A lot of ground to cover for smooth transition and integration
  – A consensus on how to determine whether an automated system is roadworthy is required at the very least (adhesion to standards or self-policing demonstrations)

• Data processing
  – How data privacy and cyber security will be addressed?

• Liability issues
  – The manufacturer or the driver?
31st ICTCT Conference
International Co-operation on Theories and Concepts in Traffic Safety

Road Safety and Automation

P. Papantoniou, A. Ziakopoulos, G. Yannis
National Technical University of Athens

Porto, 25 October 2018