31st ICTCT Conference
International Co-operation on Theories and Concepts in Traffic Safety

Road Safety and Automation

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Outline

- NTUA Dpt of Transportation - NRSO
- Introduction – Present traffic safety state
- Current technological state
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- Indirect safety implications
- Future challenges

NTUA - Dpt of Transportation Planning & Engineering - NRSO

NTUA History

- 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

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

MOBILITY AND TRANSPORT Road Safety | UNECE | ERF | TOGETHER FOR SAFER ROADS | Region of Attica

RESEARCH & INNOVATION Transport | World Health Organization Europe | IRF | Hellenic Institute of Transportation Engineers

International Transport Forum | CEDR Conférence Européenne des Directeurs des Routes Conference of European Directors of Roads | IRU | Hellenic Statistical Authority | TEE TECHNICAL CHAMBER OF GREECE

IRTAD International Traffic Safety Data and Analysis Group | FEHRL | ETSC European Transport Safety Council | Road Traffic Police | R.S.I. Road Safety Institute Panos Mylonas

Introduction & Present traffic safety state

What is it all about?

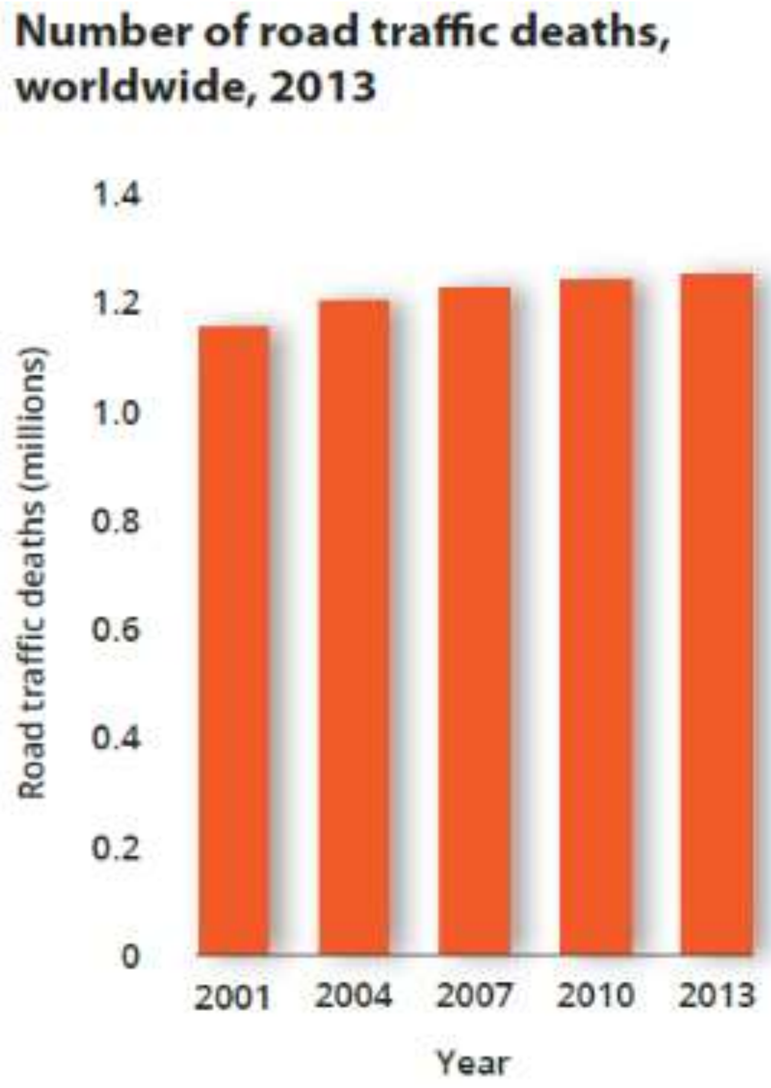
- In the past decade, **autonomous vehicles** (AVs), **connected vehicles** (CVs) and relative technology have been in the spotlight
- **Intensely researched** by both academia and industry
- Interest spurred by **computational advances,** both in processing power (CPUs) and methodology (Neural Networks)
- 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 oth
vehicles using internal sensor

Connected Automated Vehicle

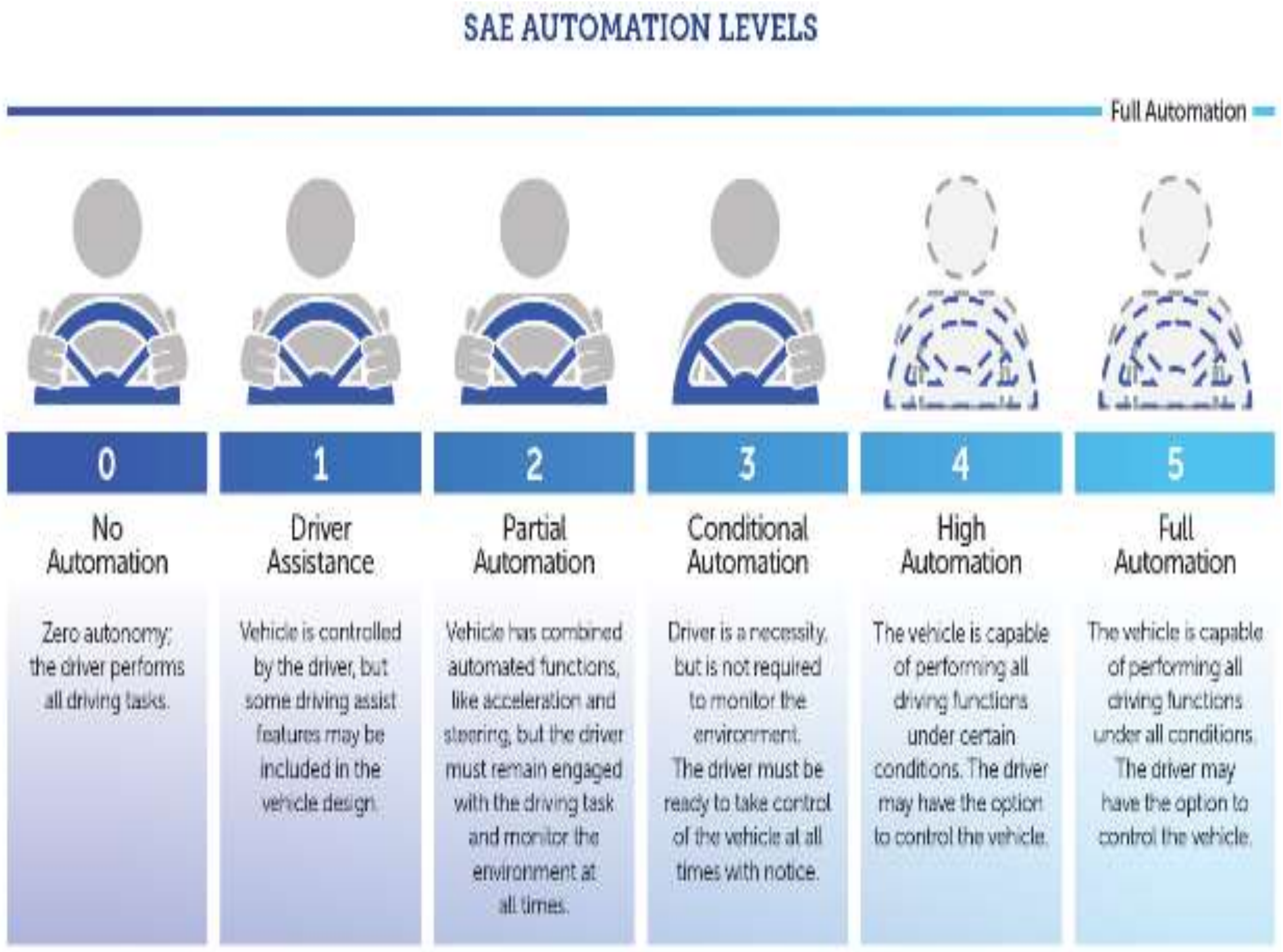
Leverages autonomous and connected vehicle capabilities

Connected Vehicle

Communicates with nearby vehicles and infrastructure

Automation Levels

- **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)** :

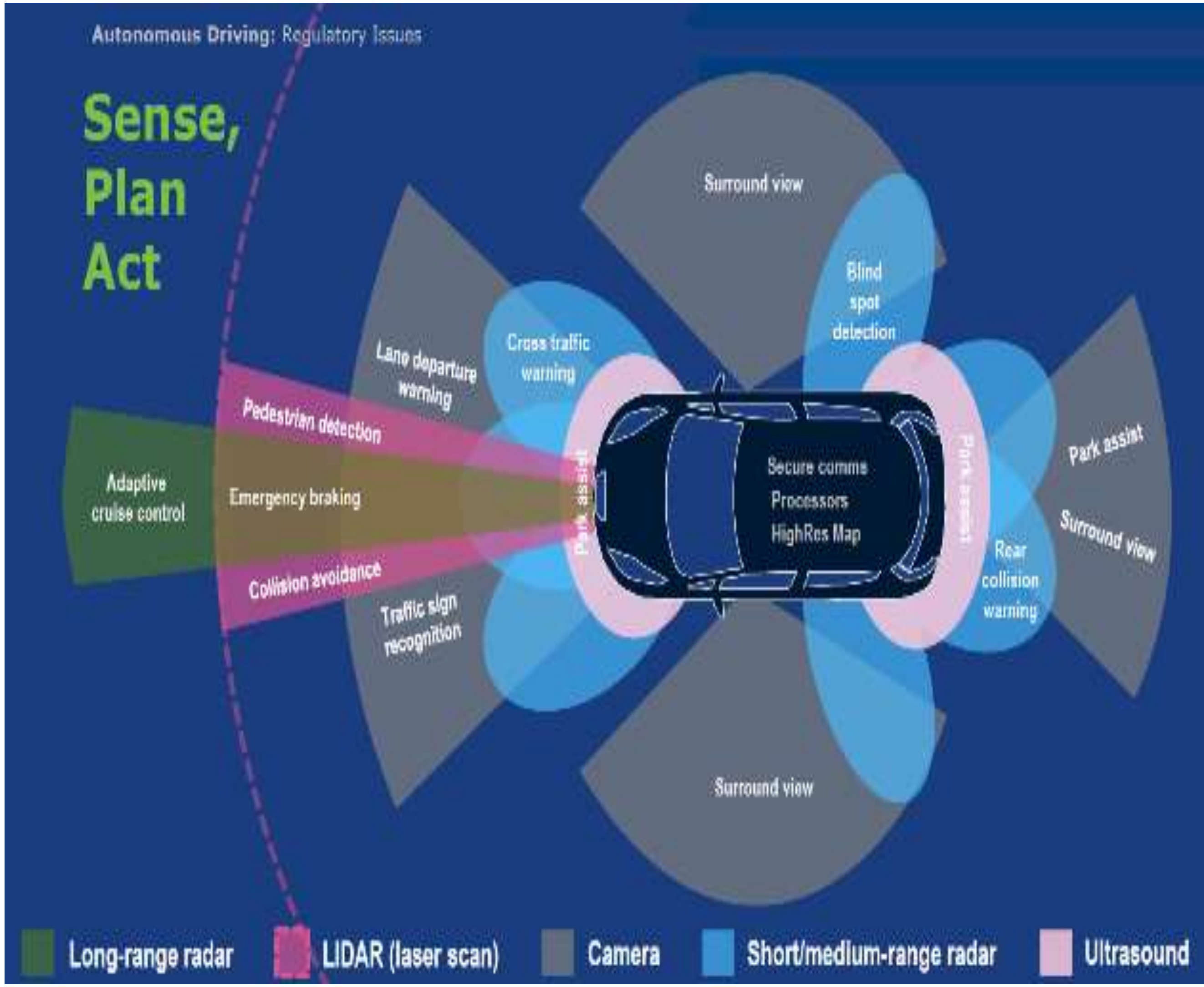
- Cruise control (since **1960s**)
- Electronic stability control (since **1990s**)
- Lane keeping/departure warning systems (LK/LDW) (since **2000s**)
- Adaptive Cruise Control (ACC), Intelligent Speed Adaptation (ISA), Autonomous Emergency Braking (AEB) & Collision Warning systems **more recently**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

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

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

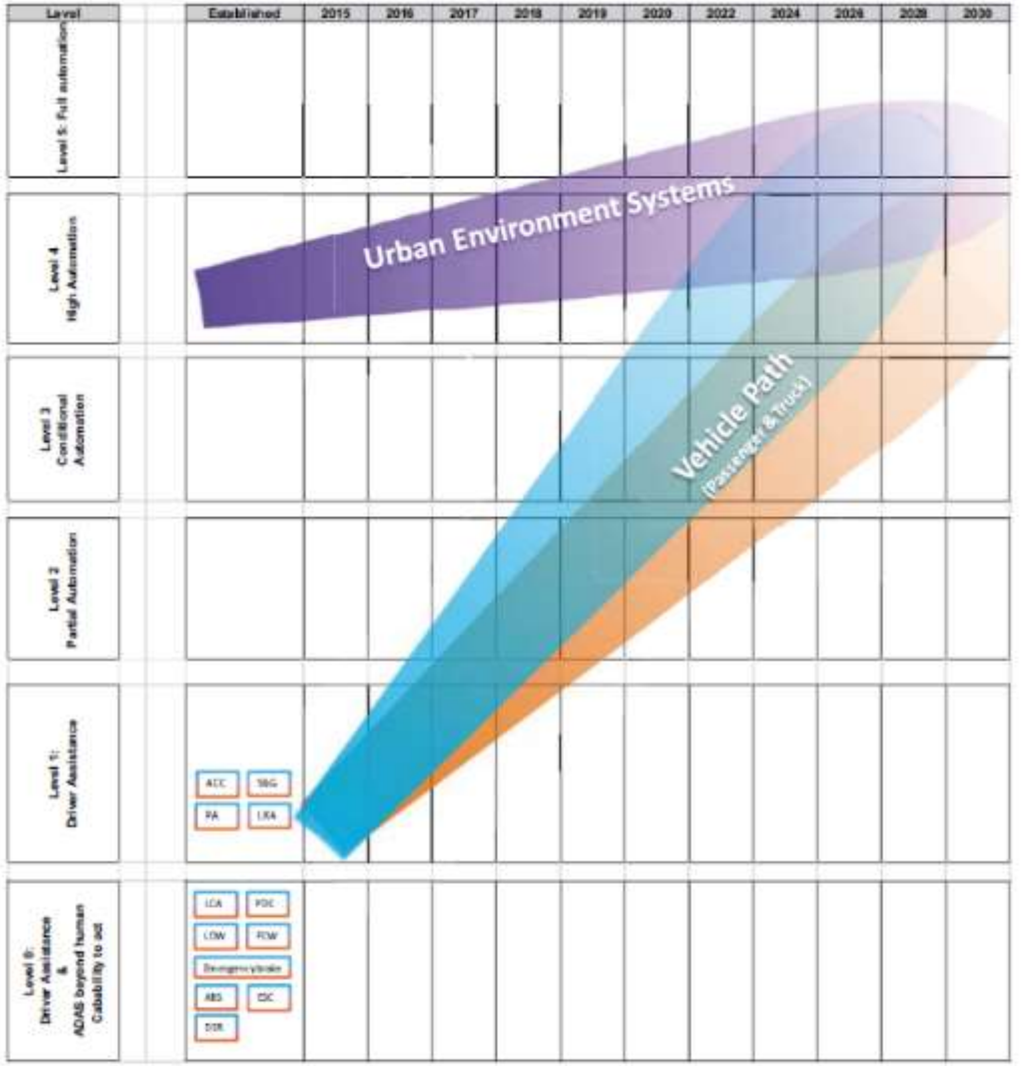


Source: OECD, 2015

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)

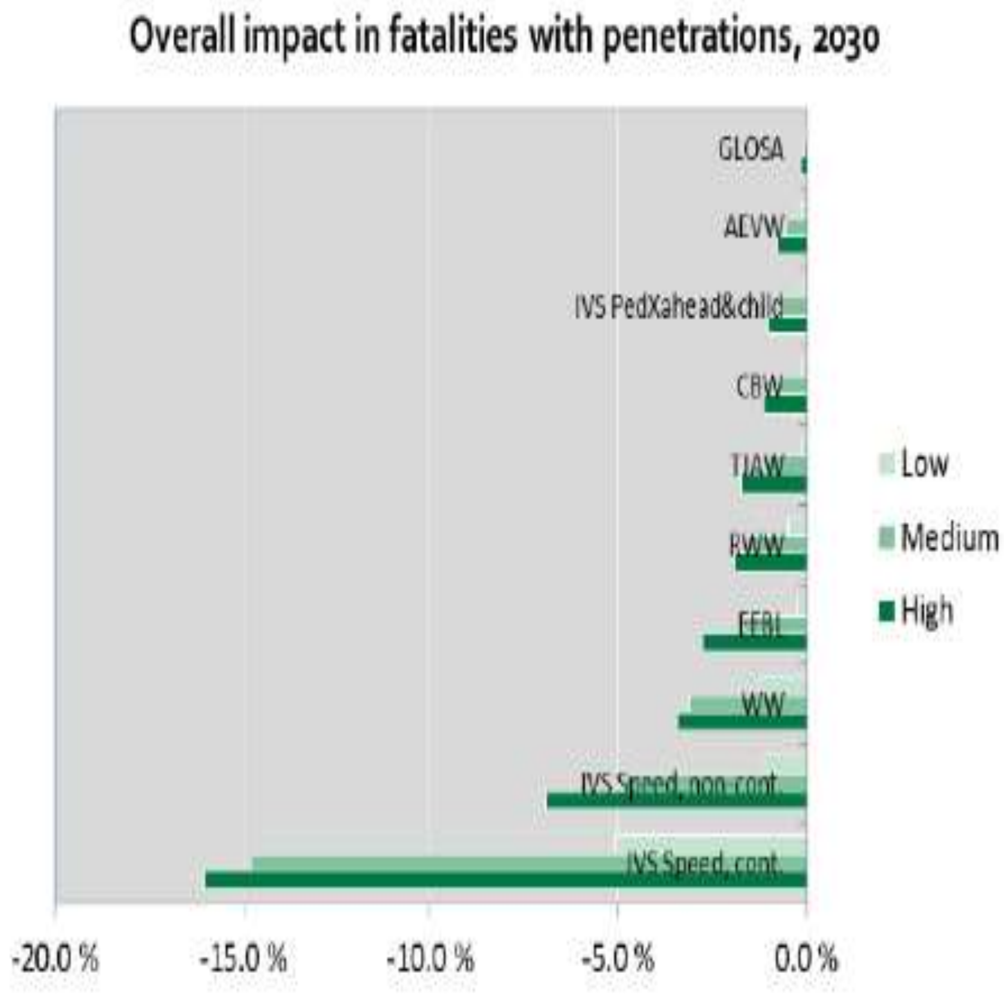


Source: ERTRAC, 2015

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

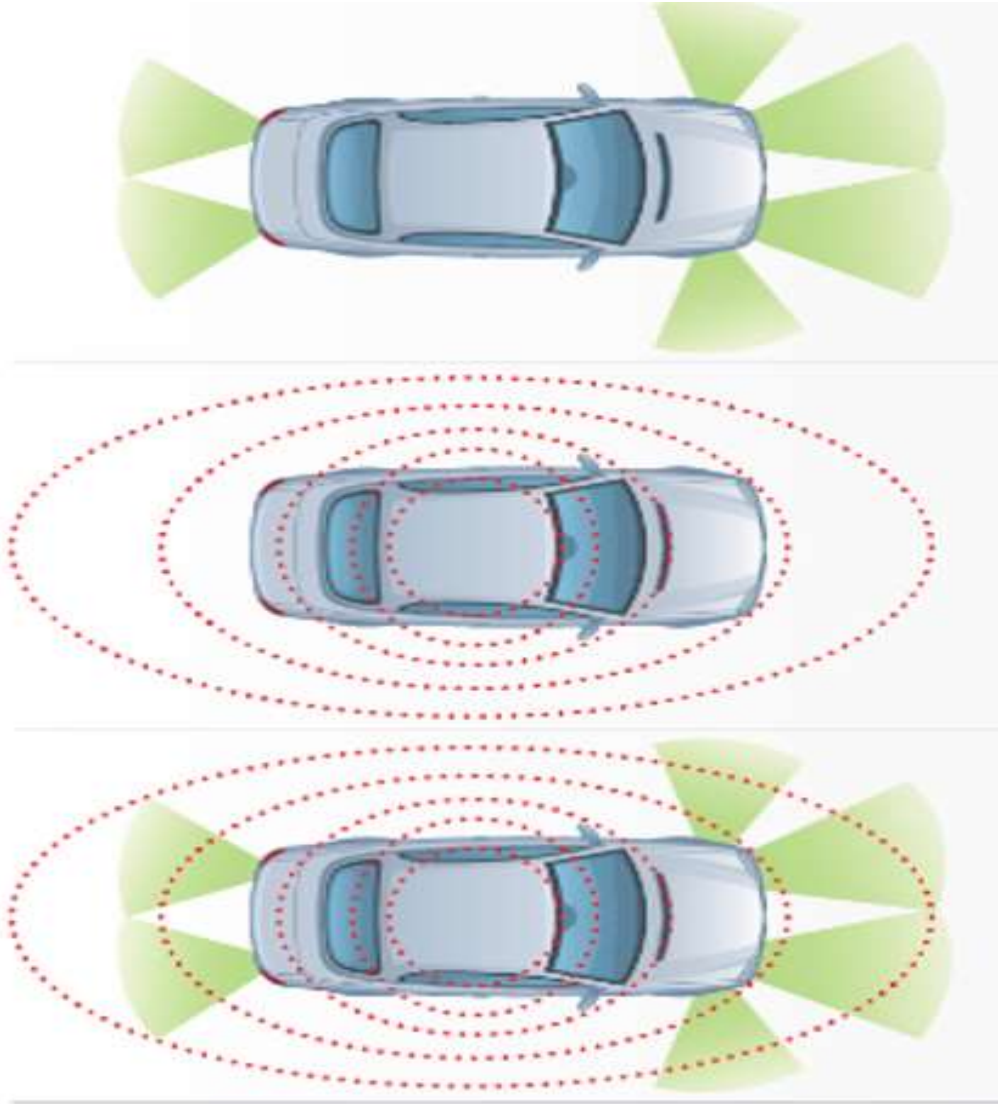
Safety lessons from incidents to date

- **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 **handling 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

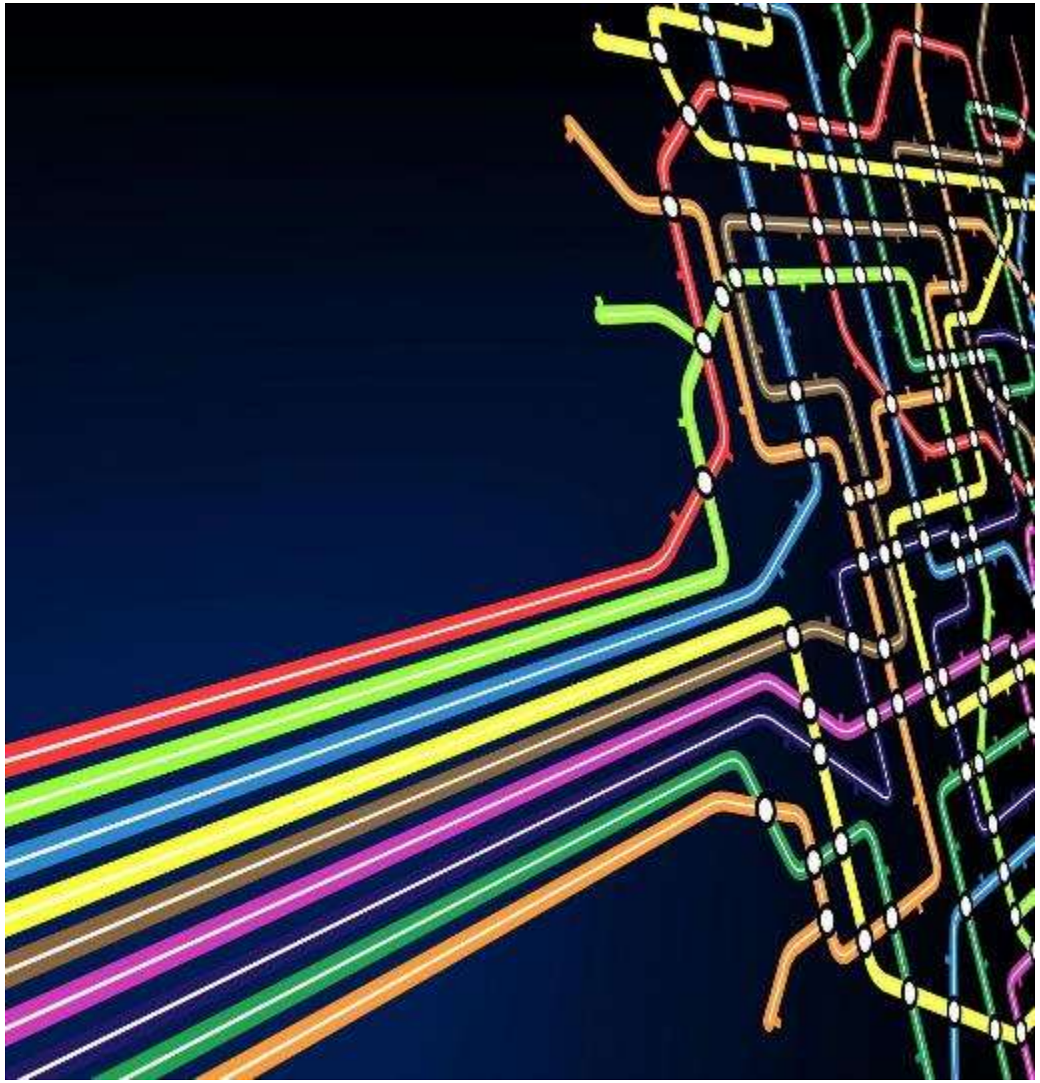
- **Non-linear progression** through AV Levels
  - Perceivable gap between Levels 3 and 4 of automation: industry will develop **independent AVs** over 'grey area'
  - Level 3 technologies are proving **too difficult to engineer** for meaningful safety impacts mitigation
- **Pending barriers**
  - **Conventional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

Performance aspect	Human	AV			CV	CAV
		Radar	*Lidar*	*Camera*	*DSRC*	*CV+AV*
Object detection	Good	Good	Good	Fair	n/a	Good
Object classification	Good	Poor	Fair	Good	n/a	Good
Distance estimation	Fair	Good	Good	Fair	Good	Good
Edge detection	Good	Poor	Good	Good	n/a	Good
Lane tracking	Good	Poor	Poor	Good	n/a	Good
Visibility range	Good	Good	Fair	Fair	Good	Good
Poor weather performance	Fair	Good	Fair	Poor	Good	Good
Dark or low illumination performance	Poor	Good	Good	Fair	n/a	Good
Ability to communicate with other traffic and infrastructure	Poor	n/a	n/a	n/a	Good	Good

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

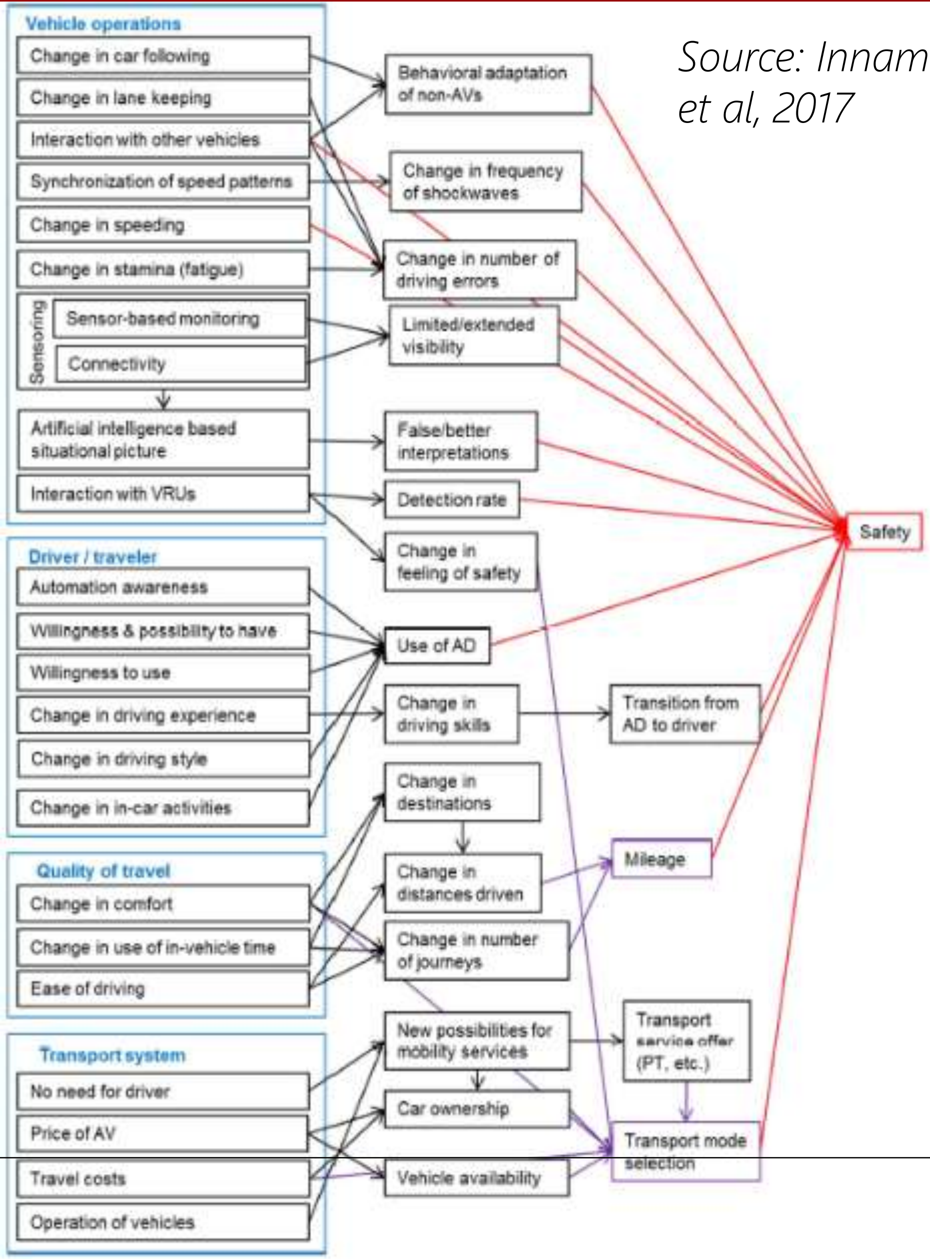


- **Road Authorities** have started to mobilize:
  - Australian, AUSTROADS (2017)
  - European Parliament (2016)
  - Germany, Department for Transport (2016)
  - UK, Department for Transport (2015)
  - US, NHTSA (2013)

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



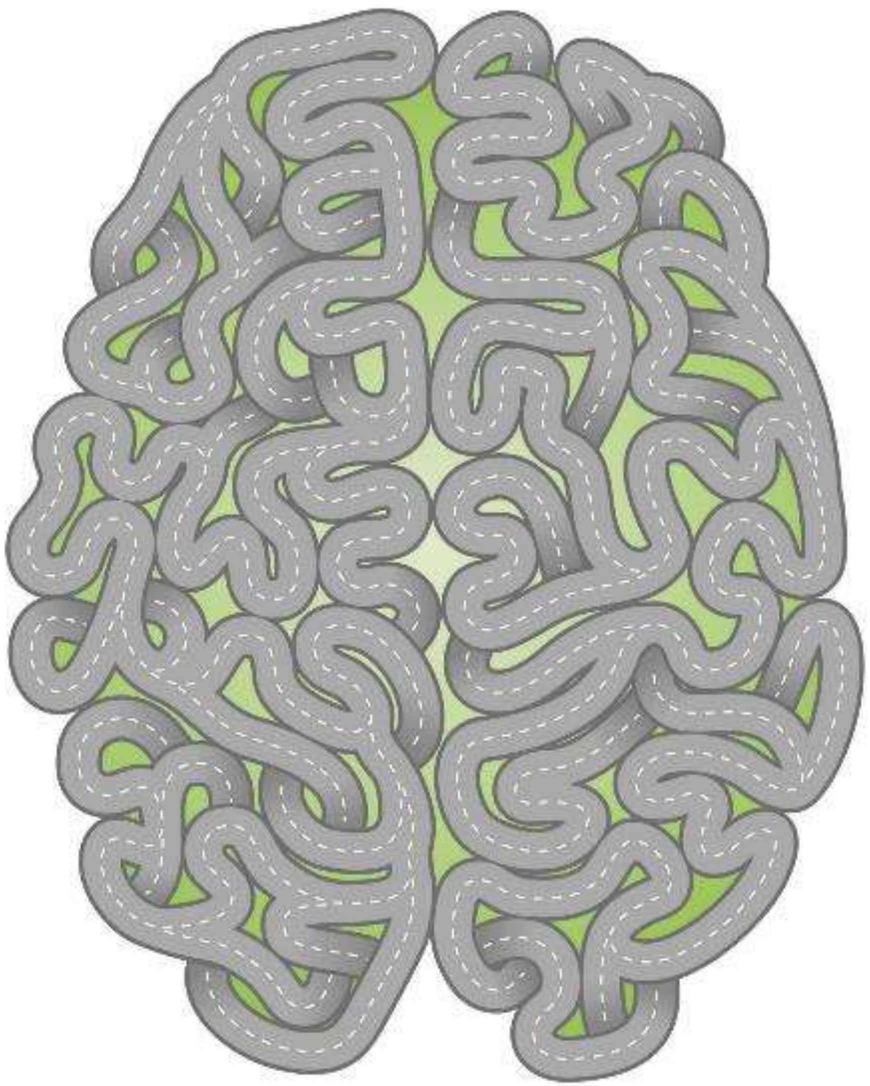
Source: Innamaa et al, 2017

Human factors issues

- Behavioural adaptation **more imminent with CV**
  - Positive effects (e.g. increased speed reductions 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?

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