Collaborative Sciences Center for ROAD SAFETY

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Sharing the Road with Robots: How Safe Is "Safe Enough?"

Michael Clamann, PhD, CHFP

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Level 0

Photo: Village Roadshow

Level 1

Photo: Motortrend

Level 2

Photo: Tesla

Photo: The New Yorker

Photo: Volvo

Summary of Levels of Driving Automation for On-Road Vehicles

This table summarizes SAE International's levels of *driving* automation for on-road vehicles. Information Report J3016 provides full definitions for these levels and for the italicized terms used therein. The levels are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. "System" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

The table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASt) and approximately correspond to those described by the US National Highway Traffic Safety Administration (NHTSA) in its "Preliminary Statement of Policy Concerning Automated Vehicles" of May 30, 2013.

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***Human driver* monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
***Automated driving system* ("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	-	

Autonomous vs. Semi-Autonomous

Satisfactory technology

vs.

Effective human-centered design

Overview of the technology

Photo: Udacity

AUTOMATED DRIVING SYSTEMS 2.0

A Vision for Safety

Current Test Settings

- Closed test tracks with professional drivers
  - Mcity
- On road data collection with professional drivers
  - Google, Uber
- On road data collection with consumers under controlled conditions
  - Volvo (DriveMe)
- On road data collection with consumers who agree to terms and conditions
  - Tesla

3 trillion miles driven annually in the US

Can we Drive our Way to Safety?

- Test-driving alone cannot provide sufficient evidence for demonstrating autonomous vehicle safety (Kalra & Paddock, 2016)
  - Autonomous vehicles would have to be driven hundreds of millions (or billions) of miles to demonstrate their reliability in terms of fatalities and injuries
  - Existing fleets would take tens and sometimes hundreds of years to drive these miles

> "If you are driving a Tesla equipped with Autopilot hardware, you are 3.7 times less likely to be involved in a fatal accident."
>
> - The Tesla Team

Approaches to AV testing (UMTRI, 2017)

- Naturalistic Field Operational Tests
- Test Matrix
- Worst-Case Scenario
- Simulation

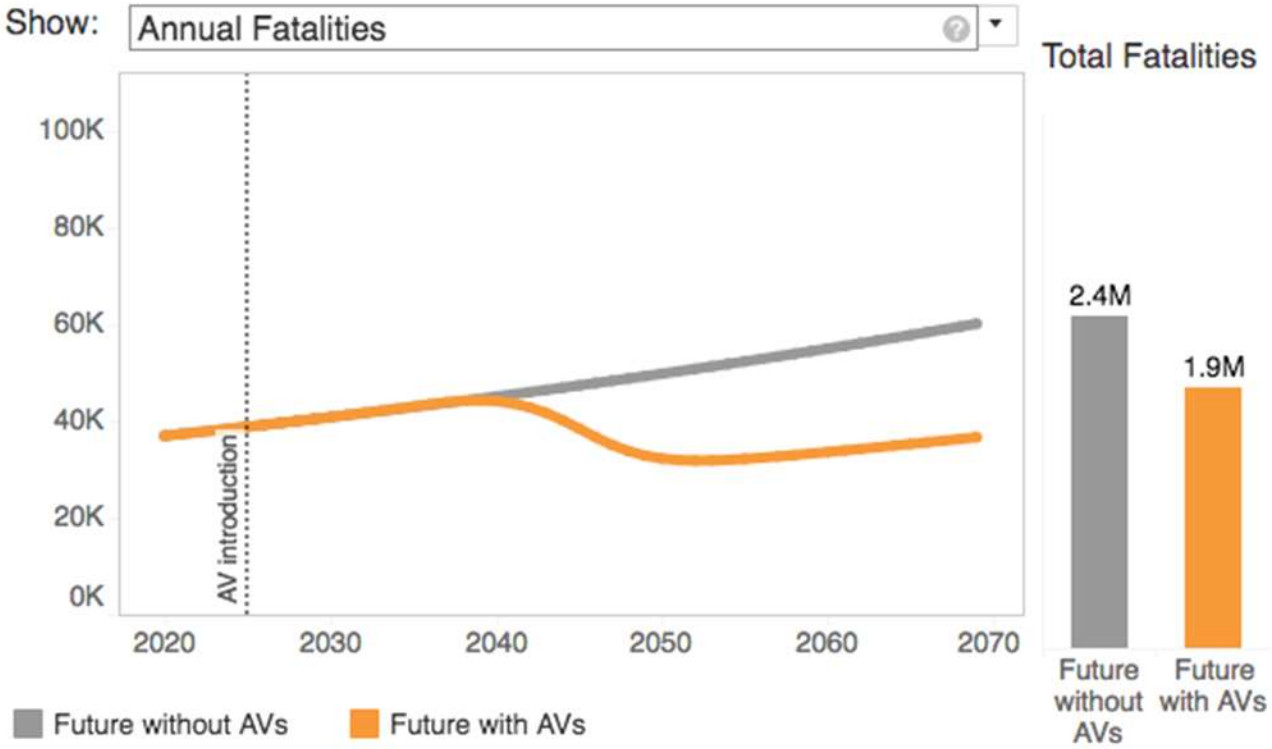
How will driving change?

1. How fast will road travel grow?
   1.0% annually
2. When will AVs be introduced?
   2025
3. How many years until full diffusion?
   40
4. At the time of full adoption, what fraction of road travel be autonomous?
   80%

How will safety evolve?

Compared to today's drivers:

5. How safe will non-AVs ultimately b…
   just as safe (1.12)
6. How safe will AVs be at introductio…
   half as safe (1.68)
7. How safe will AVs ultimately be?
   twice as safe (0.56)
8. Will the change in the AV fatality rate occur quickly or slowly?
   slowly



In this scenario, autonomous vehicles will be introduced into the marketplace in **2025**, when they are **half as safe** as current drivers. They will be fully adopted in **2065**, when they account for **80%** of miles traveled in the United States. Over this period, their safety **changes slowly**, so that by **2048** they are **twice as safe** as current drivers. Additionally, road travel will increase **1.0% annually** and non-AVs will be **just as safe** as current drivers by 2070.

As shown in the bar graph, a future without AVs would have **2.38 million** fatalities by 2070, while a future with AVs would have **1.87 million** fatalities. Over this time, AVs will have **saved 0.50 million** lives, compared to a future without AVs.

Ethical perspectives

- Utilitarianism
  - Greatest good (happiness/utility/well-being) for greatest number.
  - Cost/Risk Benefit Analysis

> "It would be morally wrong to withhold functionalities that improve safety simply in order to avoid criticisms or for fear of being involved in lawsuits."
>
> -Elon Musk, Tesla

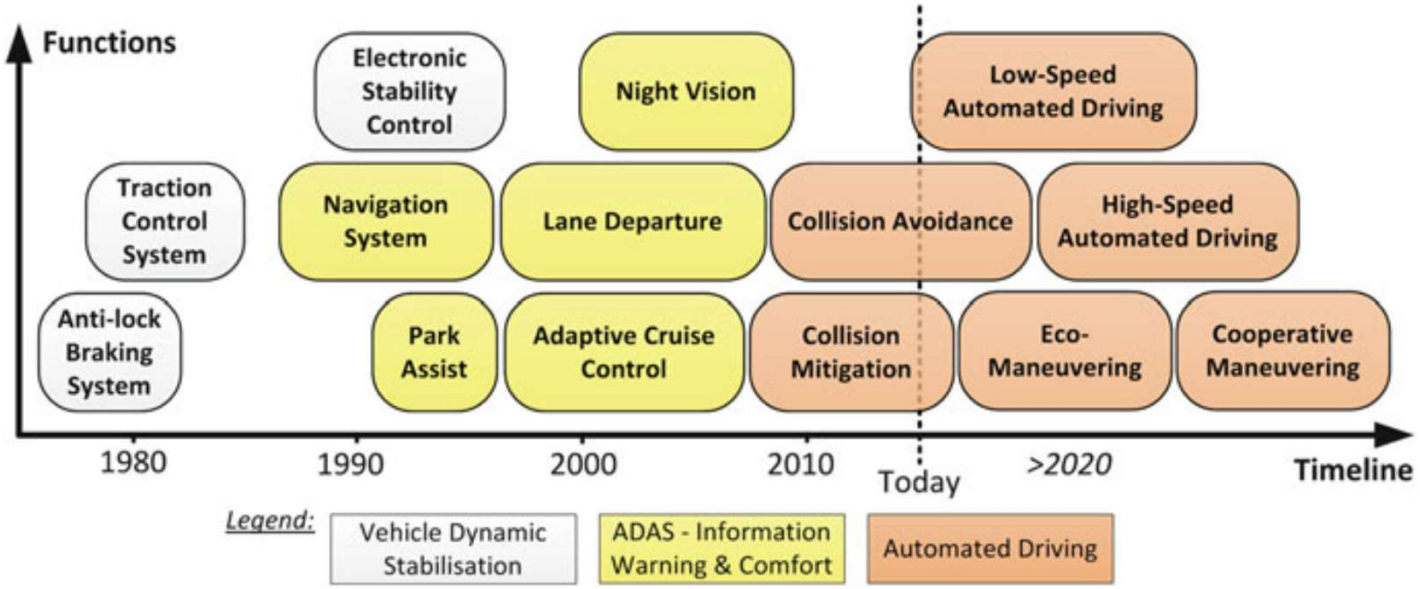
- Respect for Persons
  - Every individual deserves equal respect and should be treated as a moral agent.
  - Autonomy

> "Society tolerates a lot of human error, but we expect machines to be much better than us."
>
> -Gil Pratt, Toyota

NSPE Code of Ethics for Engineers

- Engineers, in the fulfillment of their professional duties, shall:
  - Hold paramount the safety, health, and welfare of the public.
  - Perform services only in areas of their competence.
  - Issue public statements only in an objective and truthful manner.
  - Act for each employer or client as faithful agents or trustees.
  - Avoid deceptive acts.
  - Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Evolution of advanced vehicle functions



(Martin, Tschabuschnig, Bridal, & Watzenig, 2017)

How safe *is* “safe enough”?