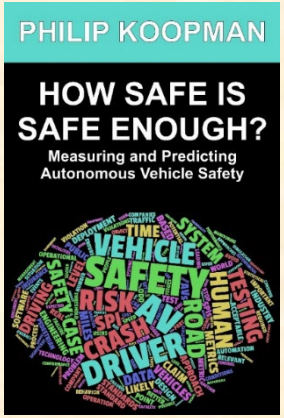
Prof. Philip Koopman

Beyond Net Risk for Autonomous Vehicles

May 9, 2024

Carnegie Mellon University

www.Koopman.us



What Do We Mean By Safe?

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- Rhetoric:
  - “Safety is our #1 priority”
  - “Robotaxis won’t make stupid driving mistakes”
- Acceptable net risk:
  - Positive Risk Balance
  - Risk is managed via insurance
- Requirements beyond net risk:
  - Avoid risk inequities
  - Avoid negligent driving behavior
  - Expectation of safety via engineering rigor

[Dall-e]

Robotaxis: “Safety Is Our #1 Priority”

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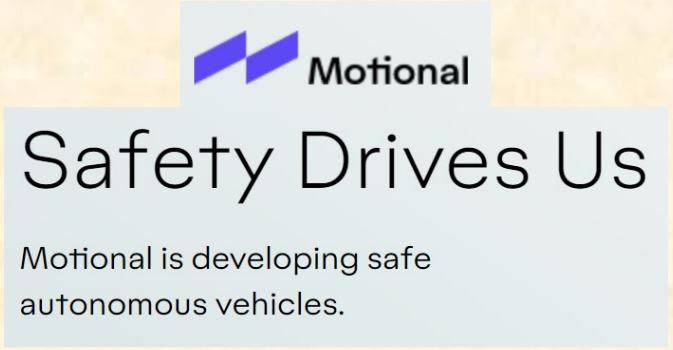
https://waymo.com/safety/

https://getcruise.com/safety/



https://motional.com/safety-philosophy

https://zoox.com/safety/

Early 2023: Driverless 1 Million Miles

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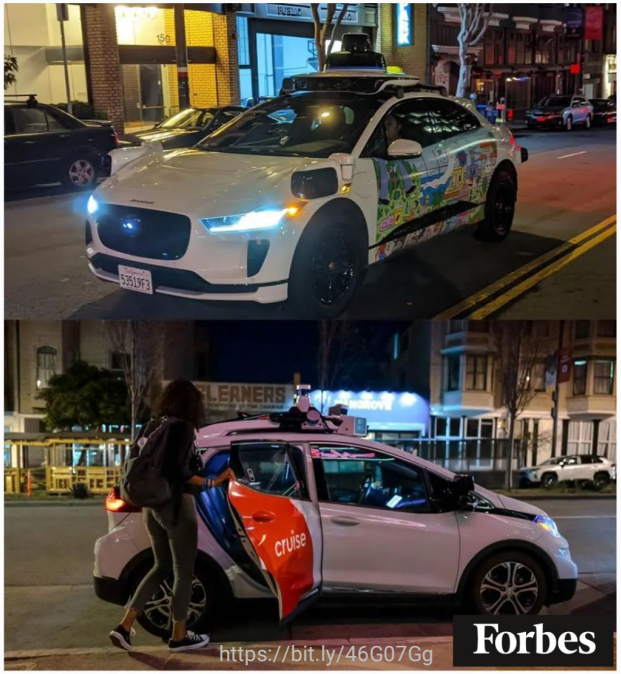
Waymo And Cruise have Both Hit 1M Miles With No Driver, But Waymo Publishes Detailed Safety Data

Brad Templeton · Feb 28, 2023, 12:00pm EST



In January 2023, Waymo reached 1 million rider-only miles

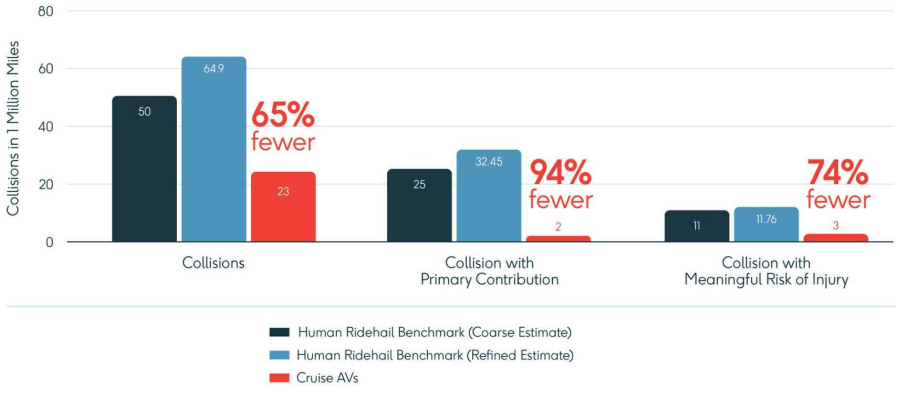
- No reported injuries
- Only 2 collisions that met the criteria for inclusion in NHTSA's CISS
- 18 minor contact events
- 55% of all events were the result of a human driver hitting a stationary Waymo vehicle
- Human drivers violated road rules and/or behaved dangerously in every vehicle-to-vehicle event
- 10% of all events happened at night
- No intersection-related events
- No events involving vulnerable road users

Waymo: Feb. 2023.
https://bit.ly/3N5F6xF

Waymo passenger injury August 2, 2023:
https://bit.ly/47Z9pyb

Updated Human Ridehail Benchmark vs Cruise AVs in 1M

Collision Counts in San Francisco



Both emphasize "at fault" crashes

Cruise: Sept. 2023.
https://bit.ly/47W1DVR

Summer of Robotaxi Hype: July 2023

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Humans are terrible drivers

42,795 Americans were killed in car crashes last year

You might be a good driver, but many of us aren't.
People cause millions of accidents every year in the US.
Cruise driverless cars are designed to save lives.
Our cars were involved in 92% fewer collisions as the primary contributor.* They also never drive distracted, drowsy or drunk.

Kyle Vogt
@kvogt
Follow

We ran this full-page ad in @nytimes and several local papers today.

Human drivers aren't good enough. America can do better, and it is time we fully embrace AVs.

Last edited 11:45 AM · Jul 13, 2023 · 956K Views

https://twitter.com/kvogt/status/1679517290847694848

Human Error → Robot Error

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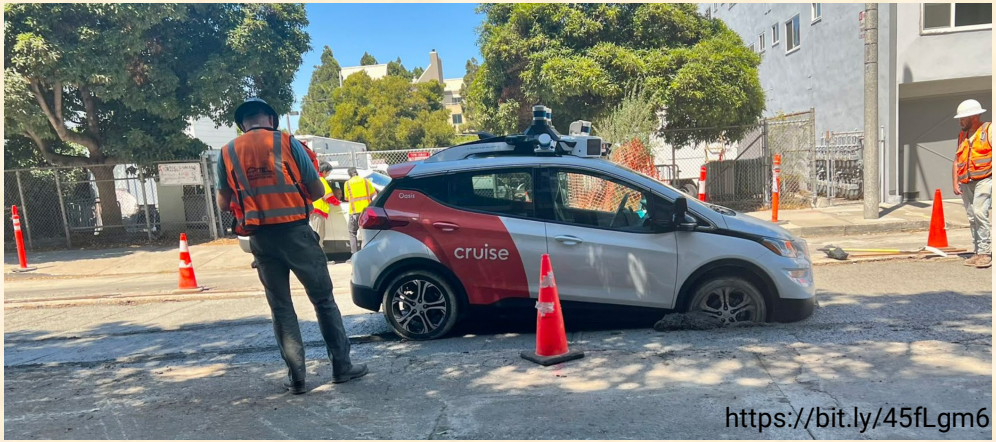
Aug. 2023: Injury crash with fire truck.
CA DMV asked Cruise to cut active fleet size in half.

March 2023
Are software defects the new drunk driving?

August 2023



What Does Safe Even Mean?

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- Is it statistical parity with (sometimes drunk) human drivers?

- In reality, it takes a lot more
  - #1: Positive Risk Balance (PRB)
  - #2: Avoiding risk transfer
  - #3: Avoiding negligent driving
  - #4: Safety standards conformance
  - #5: Specific risk mitigation / recalls
  - #6: Ethical & equity concerns
  - #7: Sustainable trust

August 2023
Nobody was hurt.
Does that make this safe?

#1: PRB – Which, Where, Who?

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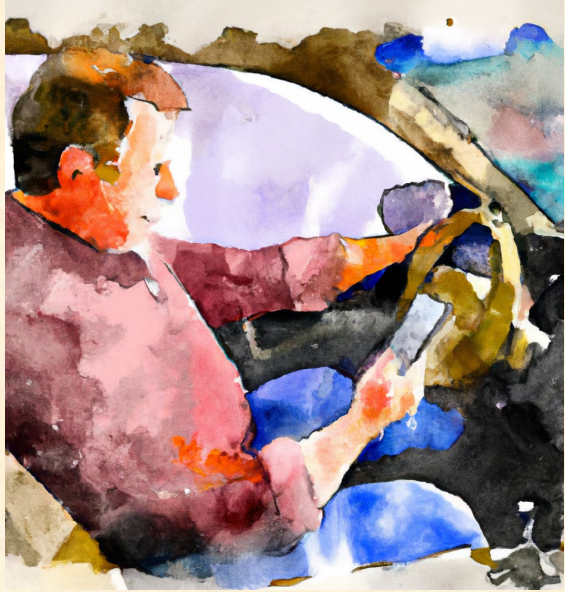
- Positive Risk Balance: safer than a human driver
- But which human driver?
  - 28% Alcohol/driving under influence fatalities
  - 26% speed-related, 9% distracted, 2% drowsy
  - 60 year old driver is ~3.5x better than 16 y.o.
- Where/Who?
  - 3.4x fatality per VMT variation by US state
  - Victim demographic (e.g., pedestrians)
- Which vehicle?
  - New cars have active safety – BUT <u>average</u> car age ~12 years



[Dall-e]

[DOT HS 813 060 & DOT HS 813 021] [AAA] [IIHS Fatality Fact Sheets State by State] [DOT HS 813 060]

#2: Avoid Risk Transfer

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- What if children at greater risk?
  - Or disabled pedestrians?
  - Or bicyclists? Etc.
- Caution – this particular article is controversial
  - Regardless, this is an important safety constraint
- Avoid increasing any group's risk
  - Extra effort decreasing risk to vulnerable groups

https://bit.ly/46Gehav

#3: Avoid Negligent Driving

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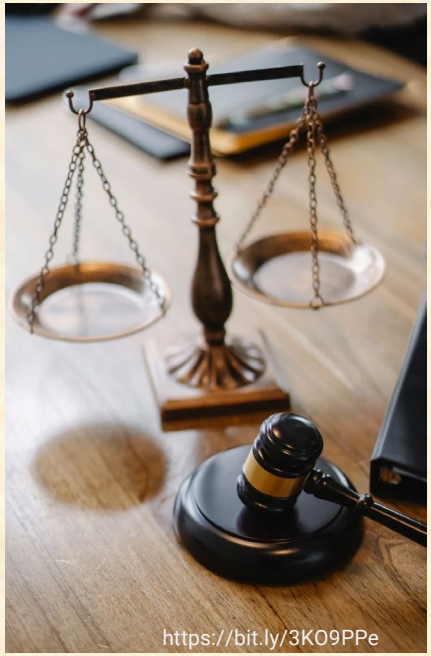
- "Negligent" robotaxi driving involves:
  - Establishing a duty of care to other road users
  - Was a loss event caused by breach of duty of care?
    - Would a human driver have been negligent?
  - Statistical safety arguments are irrelevant here
    - "Safe" drivers don't get free passes to run red lights
- October 2 Cruise pedestrian mishap:
  - Robotaxi arguably should have increased caution
    - Accelerated toward pedestrian in crosswalk
    - Other car hitting pedestrian was readily predictable
  - Robotaxi should not have moved with pedestrian under vehicle



#4: Standards Set Expectation of Safety

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SYSTEM SAFETY	ANSI/UL 4600		**Safety Beyond Dynamic Driving**
DYNAMIC DRIVING FUNCTION	ISO 21448	SaFAD/ISO TR 4804	**Environment & Edge Cases**
FUNCTIONAL SAFETY	ISO 26262		**Equipment Faults**
CYBER-SECURITY	SAE J3061	SAE 21434	**Computer Security**
VEHICLE SAFETY	FMVSS	NCAP	**Basic Vehicle Functions**

REQUIRED

HIGHLY AUTOMATED VEHICLE SAFETY CASE

ANSI/UL 4600

ROAD TESTING SAFETY

SAE J3018

#5: Fine-Grain Risk & Regulators

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- Want to avoid regulatory recalls
  - "Undue Risk" in the small – specific issues
  - Informed by test-centric standards
- Recalls are specific, not net risk
  - Rolling through stop signs
  - Phantom braking
  - Malfunctioning display console
  - Software safety & net risk are mostly beyond regulatory scope
- Regulators struggling to predict safety outcomes in advance
  - 2020 Proposal to require industry safety standards is inactive

Part 573 Safety Recall Report

#6: Ethical & Equity Concerns

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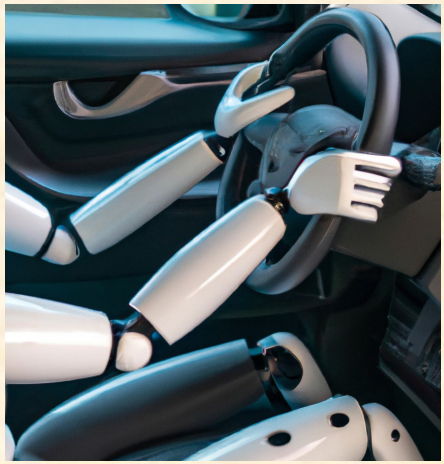
- Ride Hail made promises … with disappointing results
  - Why will this turn out any differently?
- Equity concerns:
  - Labor issues (e.g., displaced ride-hail/taxi drivers)
  - Will disabled community access really happen?
  - Cheap taxis undermine *safer* public transit
  - Municipal preemption / no local control of issues
- Ethical & related concerns
  - Testing risk imposed upon vulnerable people
  - Long-term aspirational safety incurs real short-term risk
  - No required independent safety technical oversight



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#7: Sustainable Trust

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- Trust-degrading rhetoric:
  - “Robotaxis won’t make stupid driving mistakes”
  - Relentless blame of human drivers
- Trust-degrading actions:
  - Lobbying for municipal preemption
  - Redacting & withholding information
- Toward increasing trust:
  - Talking with (not “at”) stakeholders
  - More transparency on incidents & corrective actions
  - Accepting proportional responsibility for loss events
  - Stating release criteria in advance & tracking metrics

Ford VSSA 2021 https://bit.ly/3njionT

Lessons for AV Industry Success

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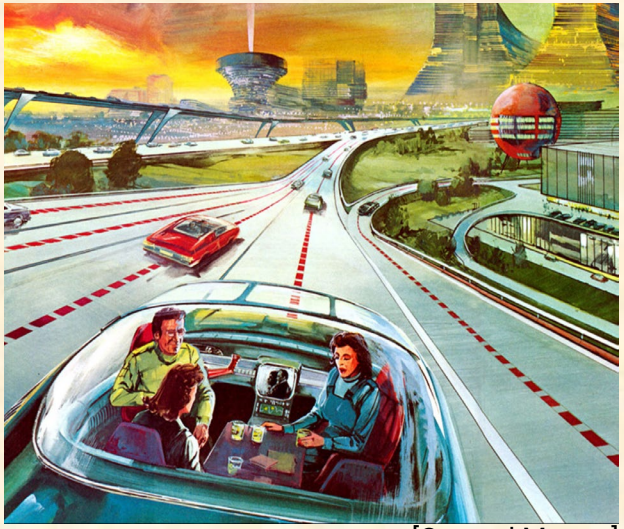
1. Net “better than human driver” only a starting point
2. Avoid risk transfer to vulnerable populations
3. Avoid negligent driving behavior
4. Conform to industry safety standards
5. Fine-grain regulatory control of risks
6. Address ethical & equity concerns
7. Build sustainable trust



[General Motors]

More talks here:
https://users.ece.cmu.edu/~koopman/