Prof. Philip Koopman

Autonomous Ground Vehicle Safety: Lessons To Learn

December 2023

www.Koopman.us

Carnegie Mellon University

PHILIP KOOPMAN

HOW SAFE IS SAFE ENOUGH?

Measuring and Predicting Autonomous Vehicle Safety

Overview

- ■ **2023 was a pivotal year for robotaxis**
  - ● Summer of hype
  - ● Winter of discontent
  - ● Will we see a glorious summer 2024?

- ■ **Top lessons for AV success**
  - ● More robust criteria to decide whether safe enough/good enough to deploy
  - ● Create more sustainable trust

"AV" = "Autonomous Vehicle" (no human driver needed)

https://on.gei.co/2r2rjzg

# Why Is AV Safety Complicated?

- ■ **Public expectations**
  - ● Expect super-human machine performance
  - ● Trust too easily given, backlash when broken
- ■ **Technical challenges**
  - ● Machine Learning safety is work in progress
  - ● Statistical approach vs. high severity rare events
- ■ **Still working on resolving a culture clash**
  - ● Autonomy researchers: it's all about the cool small-scale demo
  - ● Silicon Valley: move fast + break things
  - ● Automotive: blame driver for not mitigating equipment failures
  - ● Regulators: test-centric; weak digital safety expertise
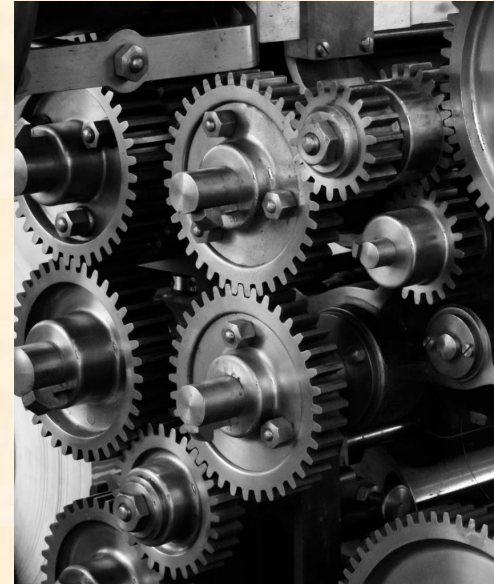
Robotaxis: "Safety Is Our #1 Priority"

WAYMO

Because Safety is Urgent™

Autonomous Driving Technology Can Save Lives and Improve Mobility

https://waymo.com/safety/

cruise

Safety first, always

https://getcruise.com/safety/

Motional

Safety Drives Us

Motional is developing safe autonomous vehicles.

https://motional.com/safety-philosophy

ZOOX

A new bar for safety

Safety isn't just part of what we do. It's why we're here.

https://zoox.com/safety/

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# Getting Past the AV Safety Rhetoric

- **Nobody knows when/if Autonomous Vehicles (AVs) will be safer than human drivers**
  - Current studies promising, but limited
  - Reduced fatality rates are aspirational
- **Some humans drive drunk**
  - On average they are still good and adaptable
- **But computers lack common sense**
  - Machine Learning is brittle to novelty
- **Computer drivers can be imperfect**
  - Net balance for computer drivers uncertain
  - Safety must be engineered, not assumed

[Dall-e]

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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

Forbes

https://bit.ly/46G07Gg
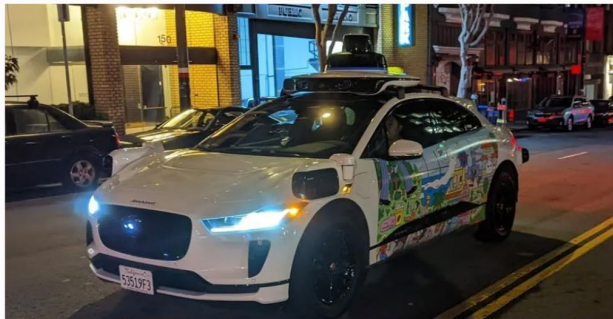
In January 2023, Waymo reached 1 million rider-only miles

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
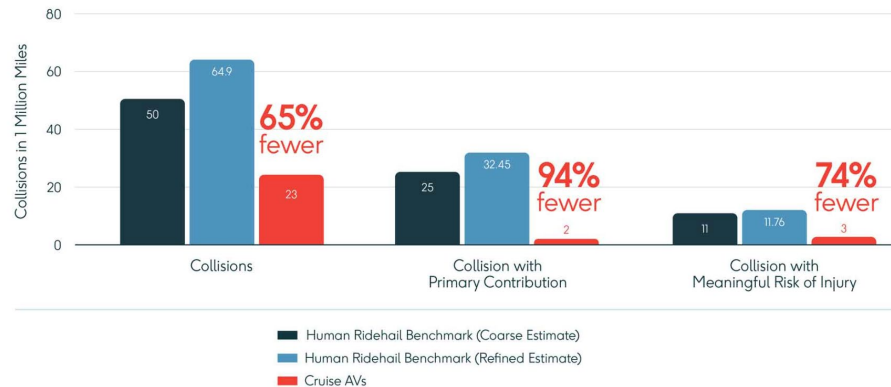
No events involving vulnerable road users

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

65% fewer

94% fewer

74% fewer

Collisions — 50, 64.9, 23
Collision with Primary Contribution — 25, 32.45, 2
Collision with Meaningful Risk of Injury — 11, 11.76, 3

Collisions in 1 Million Miles

- Human Ridehail Benchmark (Coarse Estimate)
- Human Ridehail Benchmark (Refined Estimate)
- Cruise AVs

Both emphasize "at fault" crashes

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

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Are Robotaxis Safer?

- **Nobody knows when Autonomous Vehicles (AVs) will be safer than human drivers**
  - Press releases overstate company study results
  - Study limits: at-fault crashes; ride-hail driver baseline

- **Fatality safety rates take 300+ Million miles**
  - Currently about 5 million miles/company in S.F.
  - Current studies are predictions and extrapolations
  - Reduced fatality rates are still aspirational

- **Declaring safety "victory" at this point is like claiming a medal ... after the first mile in a marathon**

"Better than Human" Narrative Erodes

August 2023

https://bit.ly/3R1bGnx

August 2023

https://bit.ly/45fLgm6
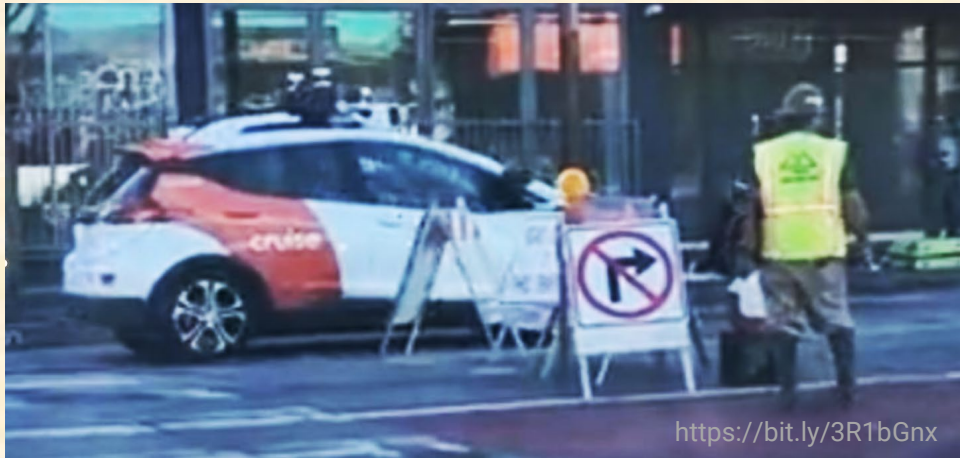
March 2023
Are software bugs the new drunk driving?

https://bit.ly/CarMuniCrash March 2023

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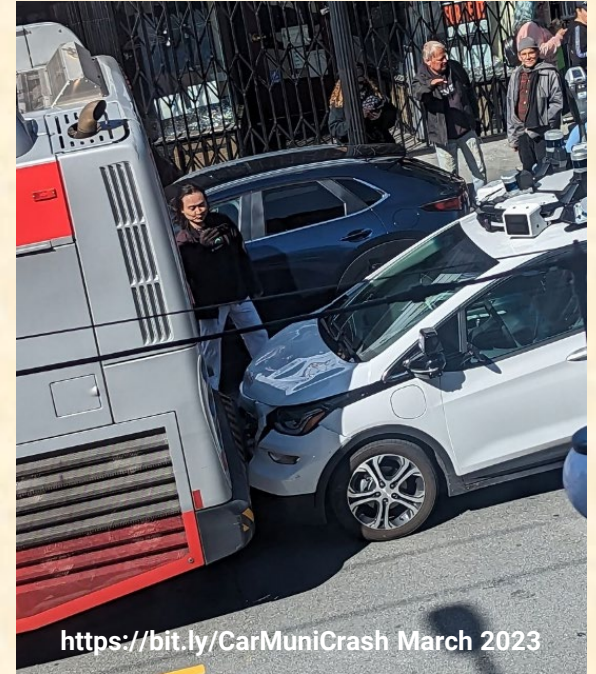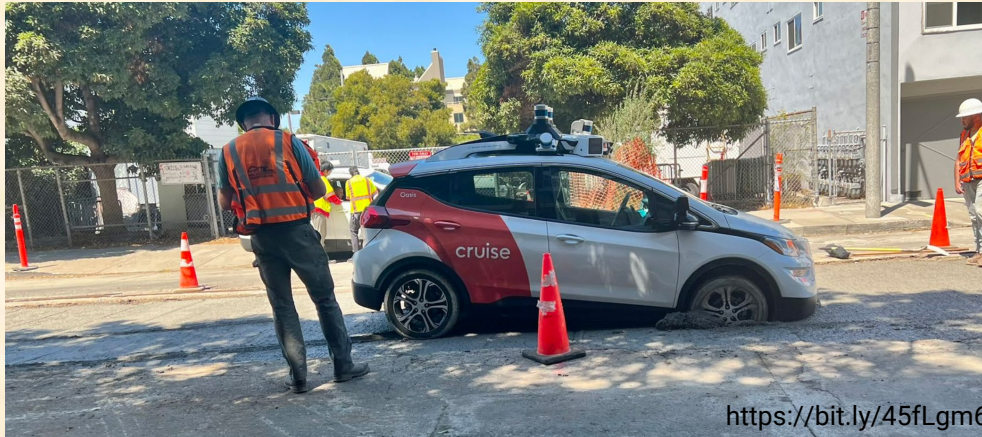
AV driving that interferes with emergency response

Emergency Response (SFFD) Impact Incidents by Type (Jan 1 – Sept 27, 2023)

https://bit.ly/41cwJGl

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Summer Into Fall

- **July "Coning":**
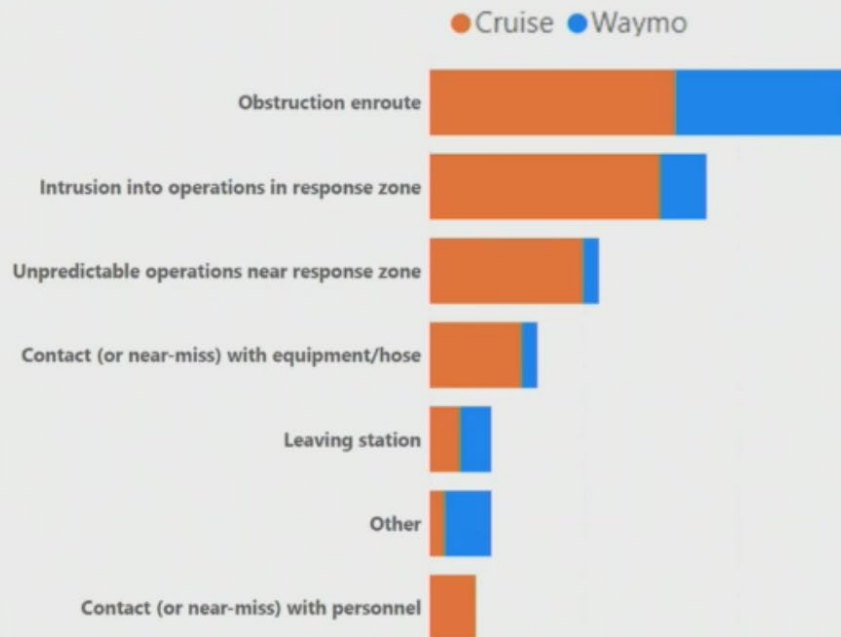 - Putting a traffic cone on the hood of a robotaxi as a form of protest

- **August 10:**
  - California PUC approves expanded robotaxi services

CityLab Perspective
Bloomberg

Why Robotaxis Can Make Cities Safer
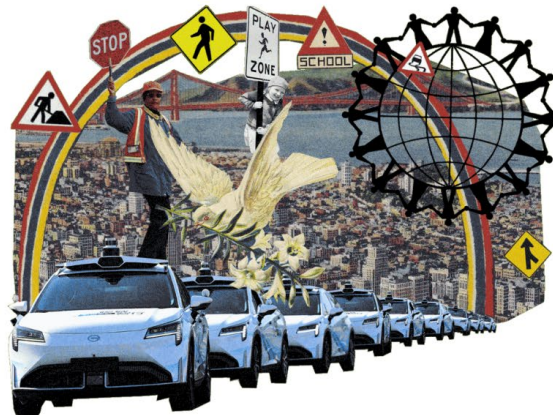
An urban policy analyst at the Manhattan Institute argues in favor of expanding autonomous ride-hailing in San Francisco and beyond.

By Jordan McGillis   September 20, 2023

CityLab Perspective

Why Robotaxis Have No Place in the City

Two San Francisco activists explain why they're trying to halt the city's autonomous ride-hailing vehicles in their tracks.

September 20, 2023

By Aditya Bhumbla and Mingwei Samuel

Los Angeles Times

General Motors recalls all Cruise robotaxis after one dragged a pedestrian

GM

General Motors is updating the software of its Cruise robotaxi vehicles after one struck and dragged a pedestrian in San Francisco last month, according to documents posted by safety regulators Wednesday. (Paul Sancya / Associated Press)

BY TOM KRISHER | ASSOCIATED PRESS   NOV. 8, 2023 8:32 AM PT

- **October 2, 2023 crash**
  - Human-driven vehicle hits pedestrian
  - Cruise robotaxi dragged pedestrian *after* initial emergency stop was completed
  - Allegations of Cruise attempting cover-up
  - Oct. 24, CA DMV suspends Cruise permits

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What Happens Next?

- **Cruise will resolve its situation one way or another**
  - Spending cuts, single city operations, slower scale-up
    - Other outcomes are possible
  - Success will require hard pivot into safety

- **Other companies will continue to develop**
  - Heavy trucks, local deliveries
  - Low speed shuttles
  - Level 2+++ (almost fully self-driving)

- **The following lessons apply to all the companies**

Lessons To Learn

#1: Net "better than human driver" is just a start

- Difficult to prove up front
- Mishaps undermine credibility of claim

https://bit.ly/49POy27

■ Also need to also address:

#2: Negligent driving

#3: Risk transfer

#4: Recall issues

#5: Safety standards

#6: Ethical & equity concerns

#7: Sustainable trust

Aug. 2023:
Injury crash with fire truck.
Reduced pace of Cruise testing due to CA DMV request to cut fleet operations in half.

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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**
  - Pedestrian in crosswalk (even if in adjacent lane)
  - Other car hitting pedestrian was readily predictable
- **Robotaxi should not have moved with pedestrian under vehicle**

https://bit.ly/3KO9PPe

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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

CRUISE KNEW ITS SELF-DRIVING CARS HAD PROBLEMS RECOGNIZING CHILDREN — AND KEPT THEM ON THE STREETS

Sam Biddle   November 6 2023, 5:53 p.m.

The Intercept_

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#4: Fine-Grain Risk & Regulators

- **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

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Part 573 Safety Recall Report

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				HIGHLY AUTOMATED VEHICLE SAFETY CASE
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	ANSI/UL 4600
CYBER-SECURITY	SAE J3061	SAE 21434	Computer Security	ROAD TESTING SAFETY
VEHICLE SAFETY **REQUIRED**	FMVSS	NCAP	Basic Vehicle Functions	SAE J3018

#6: Ethical & Equity Concerns

- **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 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

[Dall-e]

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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
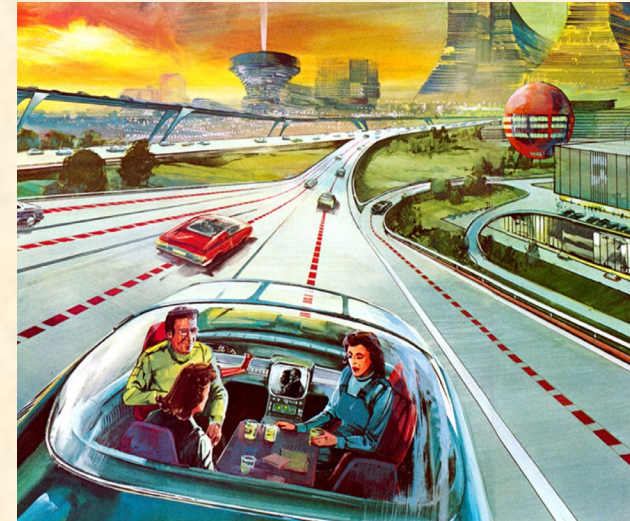 - ● Stating release criteria in advance & tracking metrics

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

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Lessons for AV Industry Success

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

[General Motors]

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