WAYMO

Carefully managing risk as we scale

Trent Victor, PhD

Director of Safety Research and Best Practices

Our safety philosophy

Reduce traffic injuries and fatalities by driving safely and responsibly and **carefully manage risk** as we scale our operations.

Our experience

Tens of millions

miles on public roads

Tens of billions

miles in simulation

25+ cities

across the USA

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01

1+ million

passenger trips without a human behind the wheel

02

24/7

across multiple cities

03

SF & PHX

tens of thousands of rides per week in each

04

LA & ATX

emerging rider-only territories

05

10+ million

rider-only miles

Snapshot: Waymo's operations today

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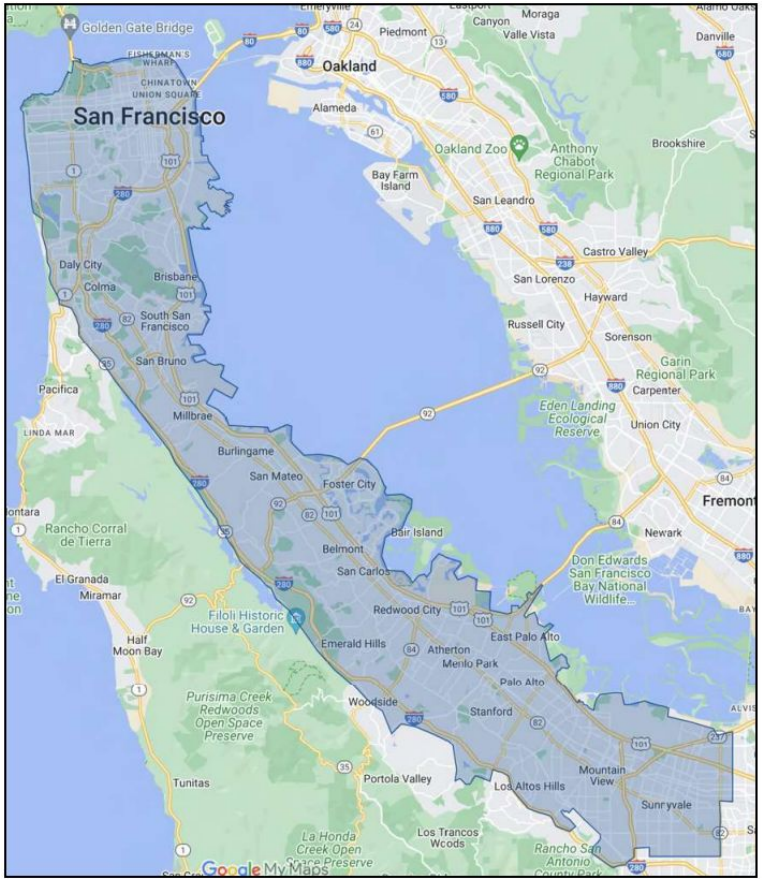
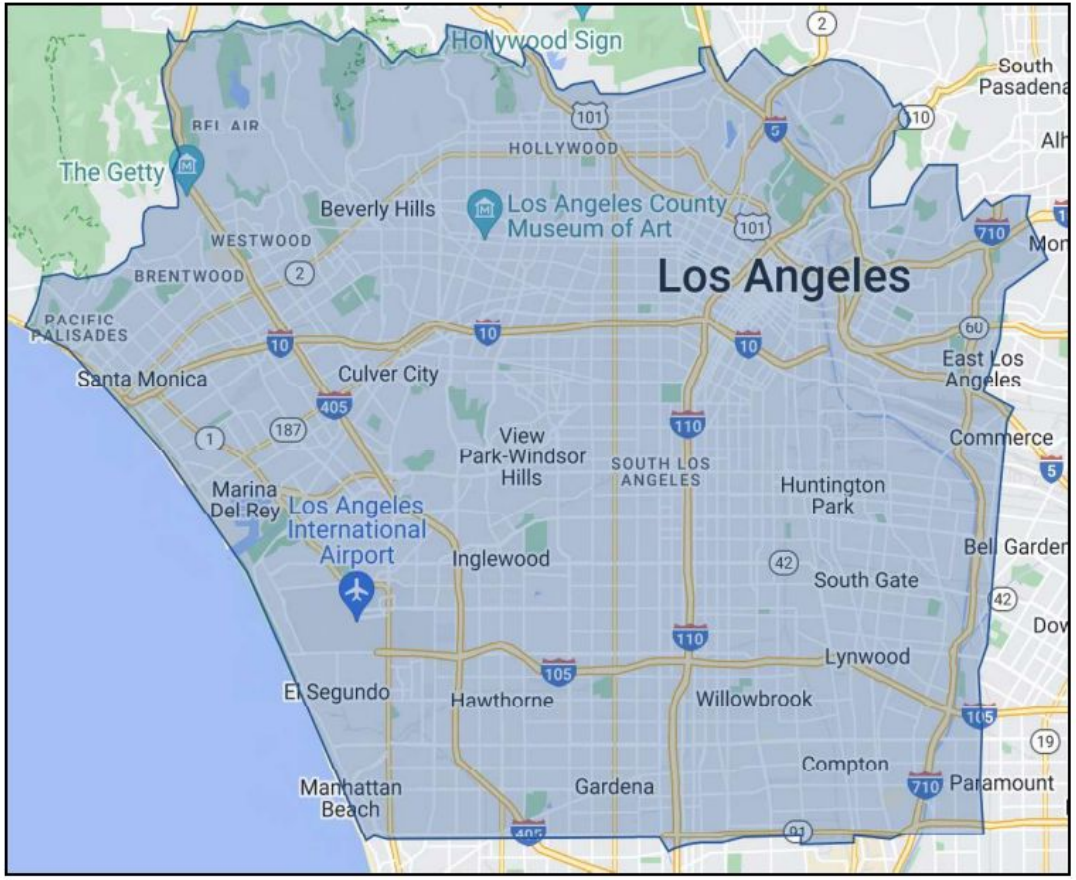
Commercial service in

Growing service in

Territories approved by the recent CPUC permit





Pioneering Engagement in Standardization for the ADS Industry

ISO

SAE INTERNATIONAL

Automated Vehicle Safety Consortium
A Program of SAE ITC

IEEE
Advancing Technology for Humanity

bsi.

Actively collaborating in over 20 working groups or committees

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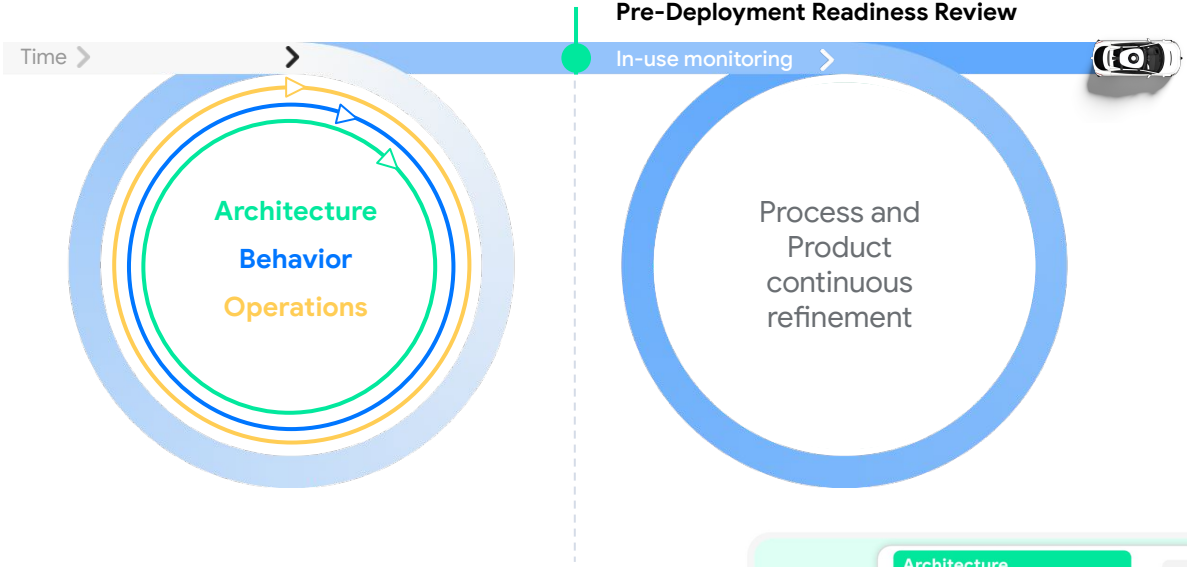
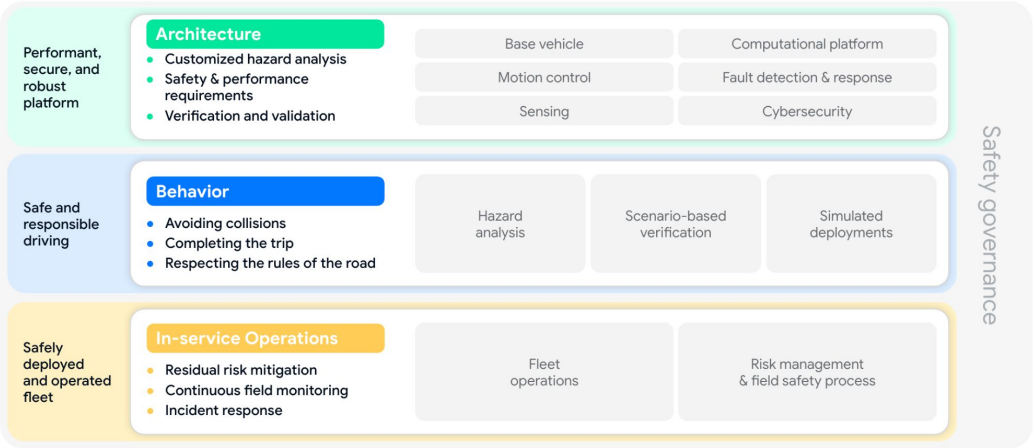
Waymo's Safety Determination Lifecycle



Prior to deployment of a **new SW release** across the fleet a highly **cross functional** group of stakeholders **reviews performance** according to **pre-specified targets and execution guidelines for each methodology**. A recommendation to Waymo's **Safety Board** leads to final **approval.**



Waymo's Approach to a Safety Case

SAFETY CASE STRUCTURE

GOAL
(Overarching statement)

The top-level goal of **Absence of Unreasonable Risk.**

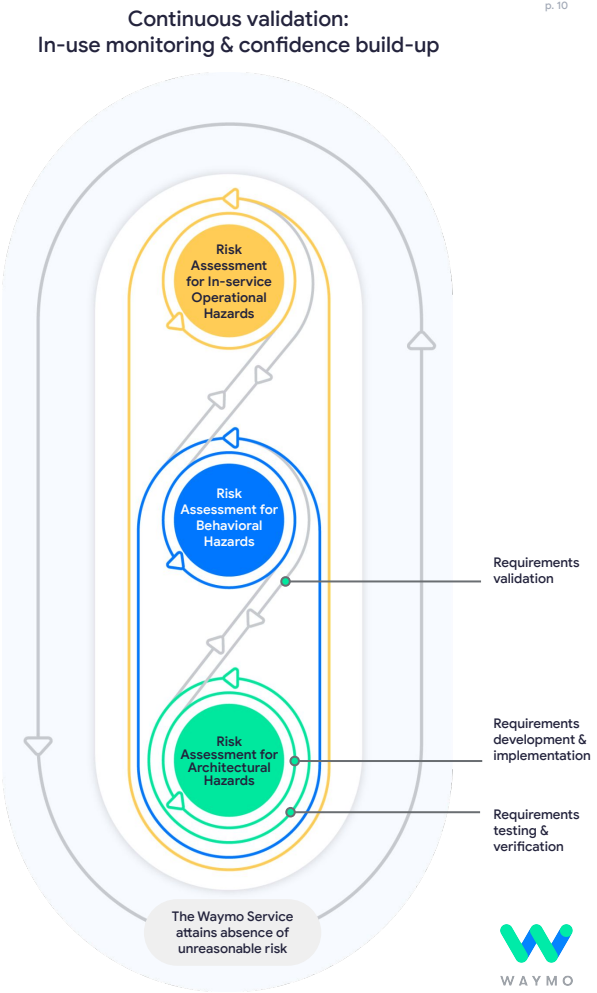
LOGICAL ARGUMENT
(Decomposing the statement)

See: "Building a Credible Case for Safety: Waymo's Approach for the Determination of Absence of Unreasonable Risk. (March 2023)"

EVIDENCE
(Compelling proof)

- waymo.com/safety
- waymo.com/research
- waymo.com/blog

Waymo's approach to safety relies on **multiple complementary methods** that examine both **aggregate-level and event-level performance** of our Automated Driving System



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Acceptance Criteria Enabling Event-Level Reasoning

Acceptance Criteria Enabling Aggregate-Level Reasoning	Included	Not Included
Included	 An appropriate balance coming from the inclusion of both event level and aggregate level indicators helps ensure that the risks for a given scenario category are being captured. It also enables the evaluation of single undesirable behaviors that a developer needs to consider to show that residual risk is as low as reasonably possible.	 An argumentation based only on aggregate criteria may not capture some risk posed by the ADS in individual scenarios/situations. Furthermore, confidence in aggregate rates pre-deployment is constrained by the available data collected during testing.
Not Included	 There are infinitely many operational scenarios that an ADS will be exposed to. Establishing a safety argument only on event-level instances precludes the holistic assessment of residual risk. Furthermore, aggregate-level criteria can provide validation for those trends observed from event-level indicators.	 No argumentation possible in the absence of acceptance criteria, since Absence of Unreasonable Risk is a necessary goal for ADS deployment

Favaro et al (2023)

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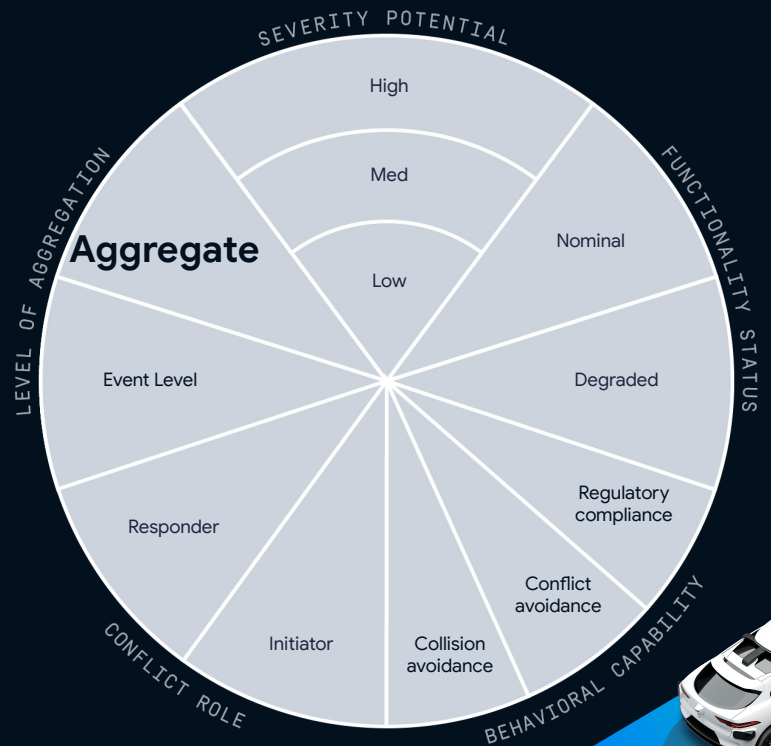
Aggregate-level



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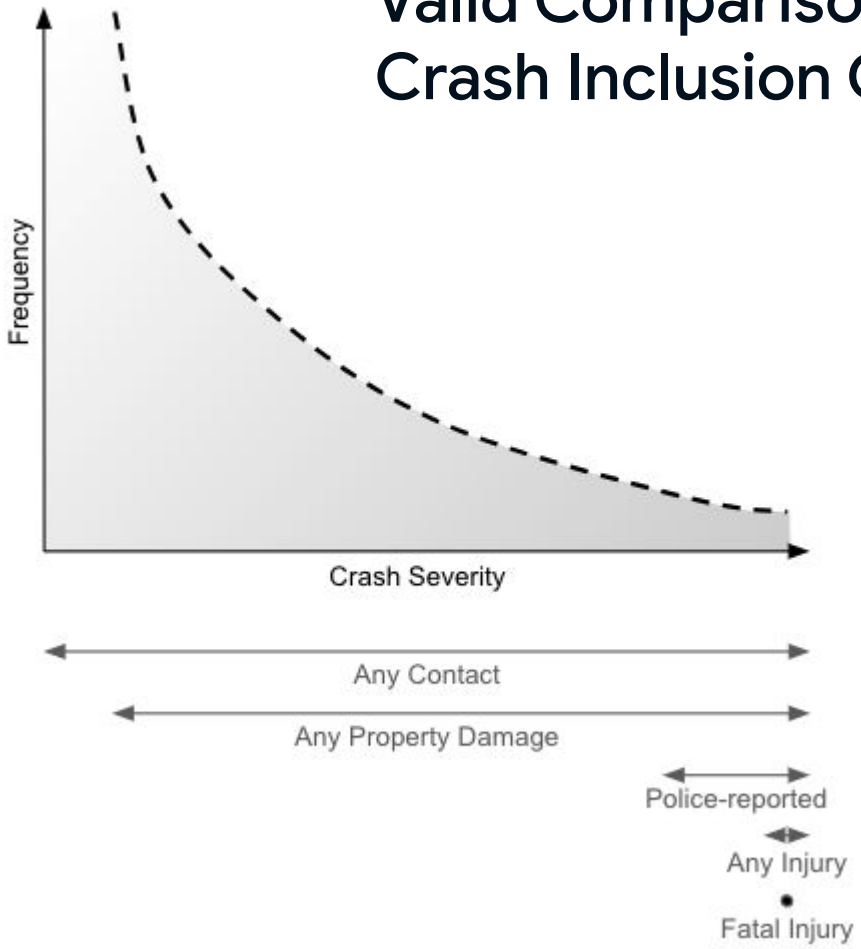
Valid Comparison: Crash Inclusion Criteria



Status quo crash data

Reduction

Waymo crash data

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The Waymo Driver considerably outperforms human benchmarks (all collisions)

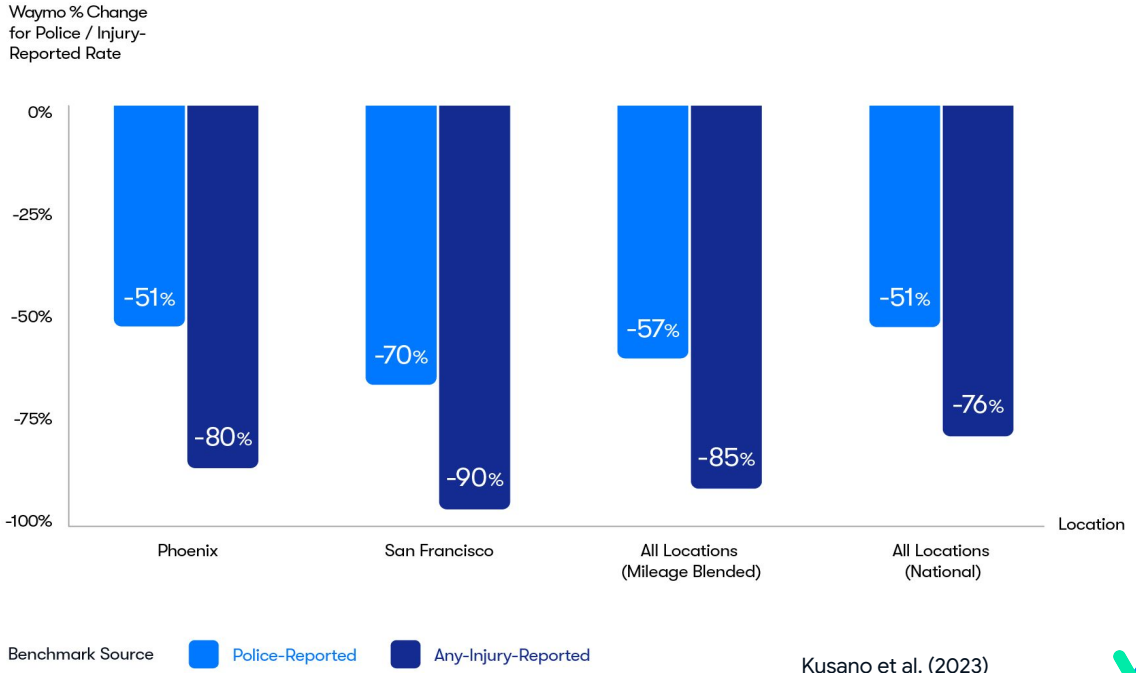
Considering all location together:

85%

reduction in injury-causing crash rates

57%

reduction in police-reported crash rates



Kusano et al. (2023)

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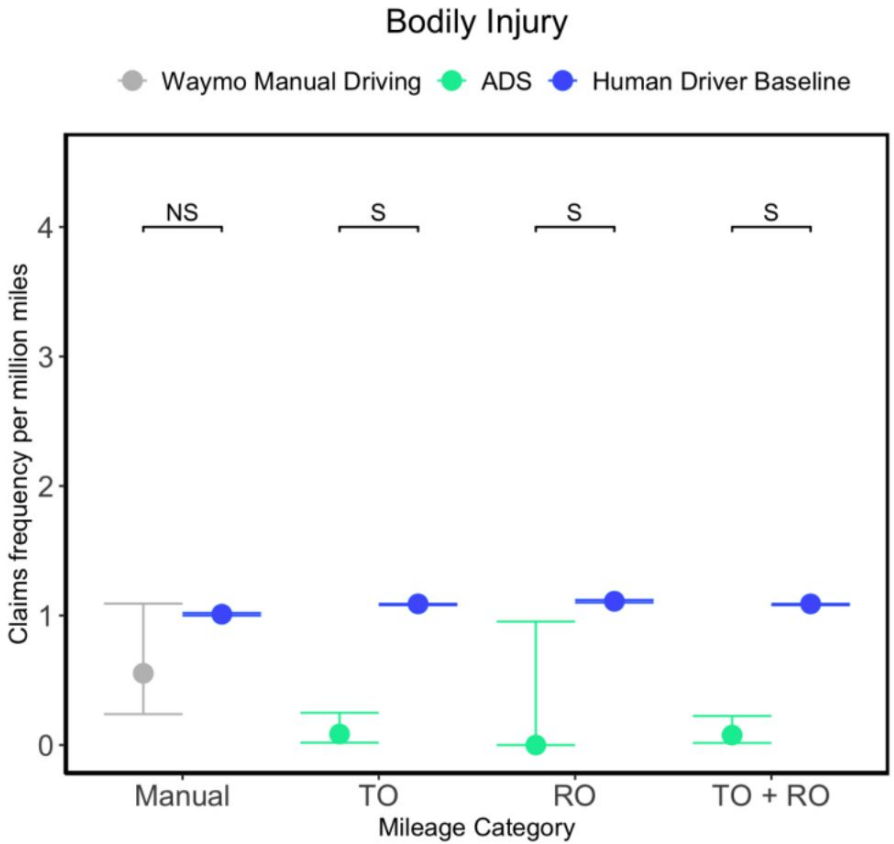
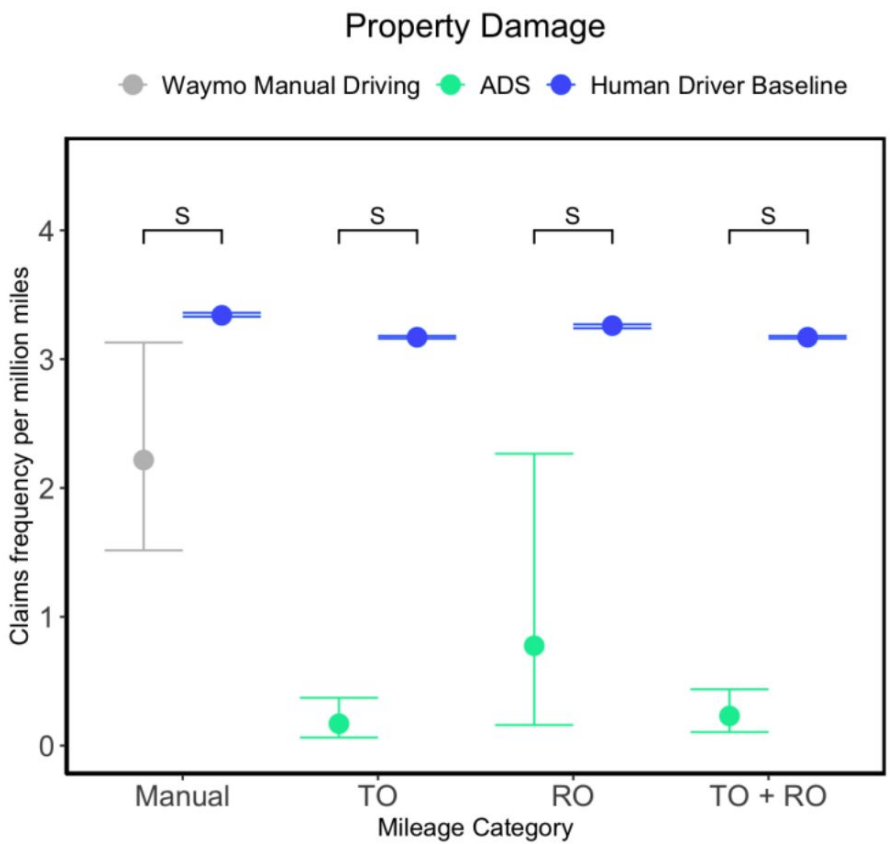
Insurance Data (Waymo contribution to crashes)





Di Lillo, L., Gode, T., Zhou, X., Atzei, M., Chen, R., Victor, T. (2023). Comparative Safety Performance of Autonomous- and Human Drivers: A Real-World Case Study of the Waymo One Service. ArXiV

Event-level

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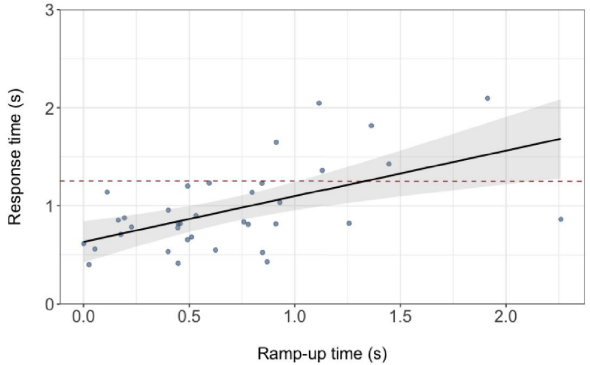
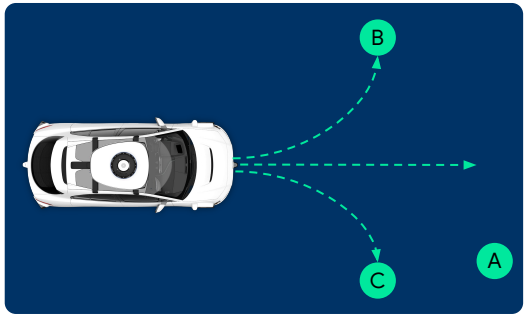
The Non-impaired Eyes ON Model (NIEON) Driver

1 Attentive with eyes always on the conflict



2 Model fit response response time using eyes-on-road, non-impaired naturalistic driving data*



3 Three chances given (best outcome selected):

A. Brake only
B. Brake + steer left
C. Brake + steer right

Engström, J., Liu S-Y, Dinparastdjadid, A. and Simoiu, C. 2022. Modeling Road User Response Timing in Naturalistic Traffic Conflicts: A surprise-based framework. arxiv.org/abs/2208.08651

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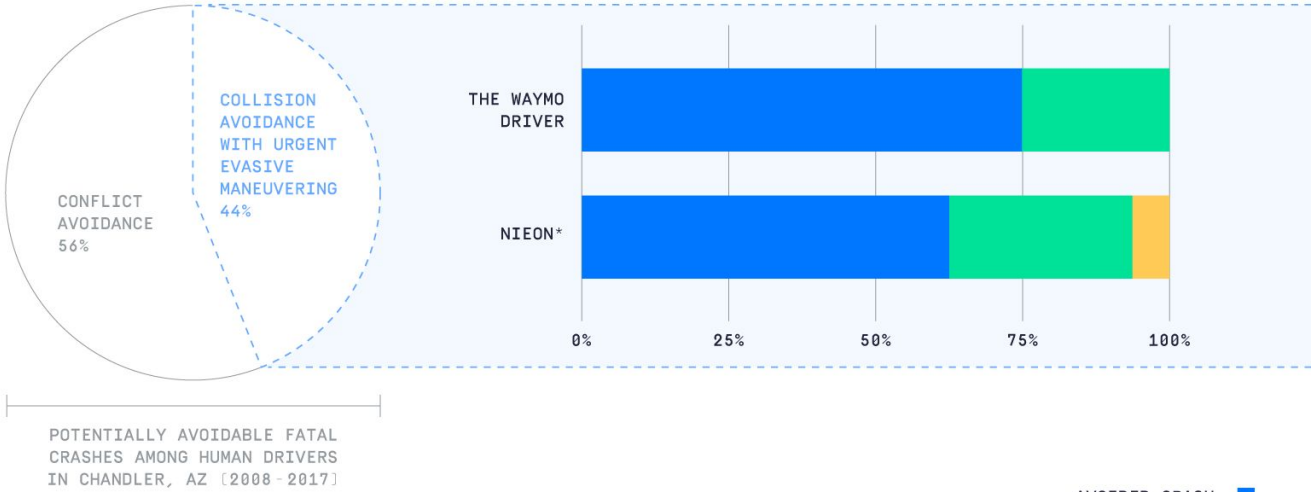
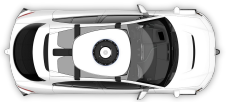
Event-level comparison with Safety Reference Models

The Waymo Driver's collision avoidance performance in simulated tests



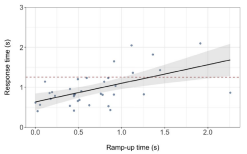
*NON-IMPAIRED, WITH EYES ALWAYS ON THE CONFLICT HUMAN DRIVER THAT DOESN'T EXIST IN THE HUMAN POPULATION

The Waymo Driver

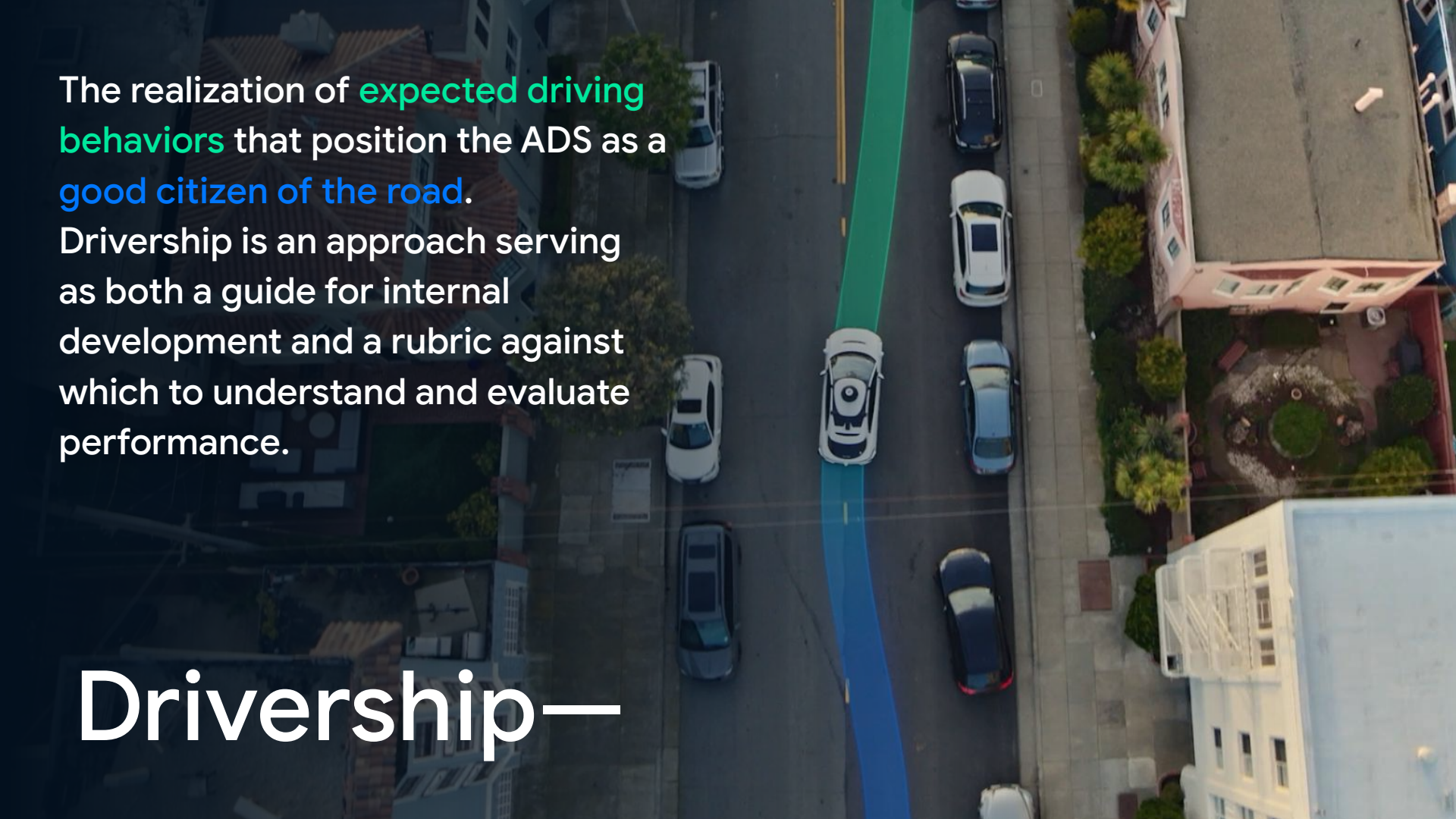


Outperforms

NIEON
Reference model



Scanlon, J.M., Kusano, K.D., Engström, J., Victor, T. 2022. Collision Avoidance Effectiveness of an Automated Driving System Using a Human Driver Behavior Reference Model in Reconstructed Fatal Collisions. Available at https://waymo.com/safety/



The realization of expected driving behaviors that position the ADS as a good citizen of the road.
Drivership is an approach serving as both a guide for internal development and a rubric against which to understand and evaluate performance.

Drivership—

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Closing Remarks