Comparison of Automated Vehicle Struck-from-Behind Crash Rates with National Rates Using Naturalistic Data

Poster number: 21-02511

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BACKGROUND

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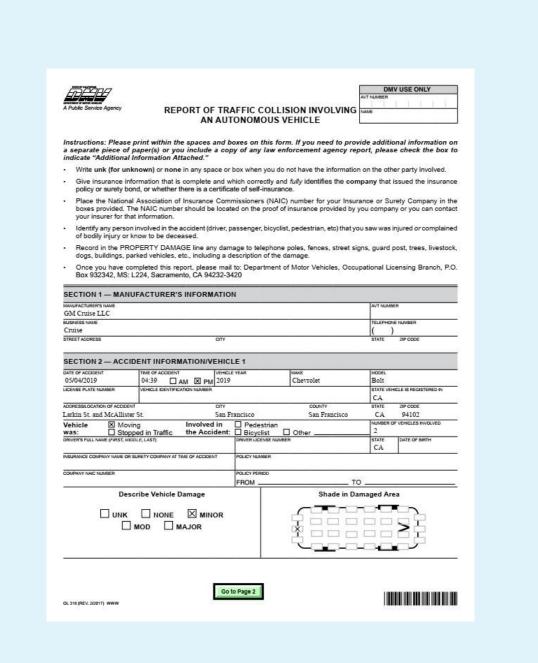- **73% of automated vehicle (AV) crashes involve the AV being struck from behind.**

- **Rear-end collisions represent 33% of all U.S. crashes and $3.9 B in annual economic costs.**

- **Are AVs struck from behind at greater rates than the general public?**

LITERATURE REVIEW

Comparable Metrics?	AV Metric	AV Crashes per Million Miles	Baseline Metric	Baseline Crashes per Million Miles	Source
	All crashes	9.1 (4.5,16.3)	Police-reportable crash estimates	4.1 (3.5, 4.7)	(Schoettle and Sivak, 2015)
	All crashes	23.8	Reported crashes	2.0	(Favarò et al., 2017)
	All crashes	21.2	Reported by CHP, limited coverage	0.5	(Dixit et al., 2016)
	Waymo police-reportable in California	2.19 (0.44, 6.39)	Police-reported in Mountain View	6.06 (5.93, 6.18)	(Teoh and Kidd, 2017)
	Google police-reportable	4.57 (2.09, 8.68)	Police-reported	3.59 (2.31, 4.87)	(Teoh and Kidd, 2017)
	All Waymo crashes	9.7 (5.8, 15.1)	SHRP 2 all crashes	27.6 (25.8, 29.5)	(Teoh and Kidd, 2017)
	All Waymo rear-end struck	7.1 (3.9, 11.9)	SHRP 2 rear-end struck	2.7 (2.1, 3.3)	(Teoh and Kidd, 2017)
	All Waymo Crashes	8.8 (2.6, 22.8)	All SHRP 2	26.8 (23.9, 30.1)	(Blanco et al., 2016)
✓	**All Waymo Crashes**	**8.8 (2.6, 22.8)**	**All SHRP 2, age-adjusted**	**20.2 (17.7, 23.0)**	**(Blanco et al., 2016)**
	Waymo Police-Reportable	3.2 (0.4, 11.4)	SHRP 2 police reported	1.4 (0.9, 2)	(Blanco et al., 2016)
	Waymo Police-Reportable	3.2 (0.4, 11.4)	SHRP 2 police reported, age-adjusted	0.9 (0.5, 1.5)	(Blanco et al., 2016)
	Waymo Police-Reportable	3.2 (0.4, 11.4)	SHRP 2 police reportable	8.2 (6.9, 9.7)	(Blanco et al., 2016)
✓	**Waymo Police-Reportable**	**3.2 (0.4, 11.4)**	**SHRP 2 police reportable, age-adjusted**	**5.8 (4.7, 7.0)**	**(Blanco et al., 2016)**
✓	**Waymo Police-Reportable**	**3.2 (0.4, 11.4)**	**NHTSA police reportable**	**4.2 (2.8, 9.9)**	**(Blanco et al., 2016)**

Automated Vehicle Crash Comparisons in the Literature

Sample California DMV AV Crash Reporting Form OL316 and Disengagement/ Mileage Report

REFERENCES

1. Saeed, U., J. Hämäläinen, M. Garcia-Lozano, and G. David González. On the Feasibility of Remote Driving Application over Dense 5G Roadside Networks. Presented at the 2019 16th International Symposium on Wireless Communication Systems (ISWCS), 2019.

2. Kang, L., W. Zhao, B. Qi, and S. Banerjee. Augmenting Self-Driving with Remote Control: Challenges and Directions. Presented at the 19th International Workshop on Mobile Computing Systems & Applications, New York, NY, USA, 2018.
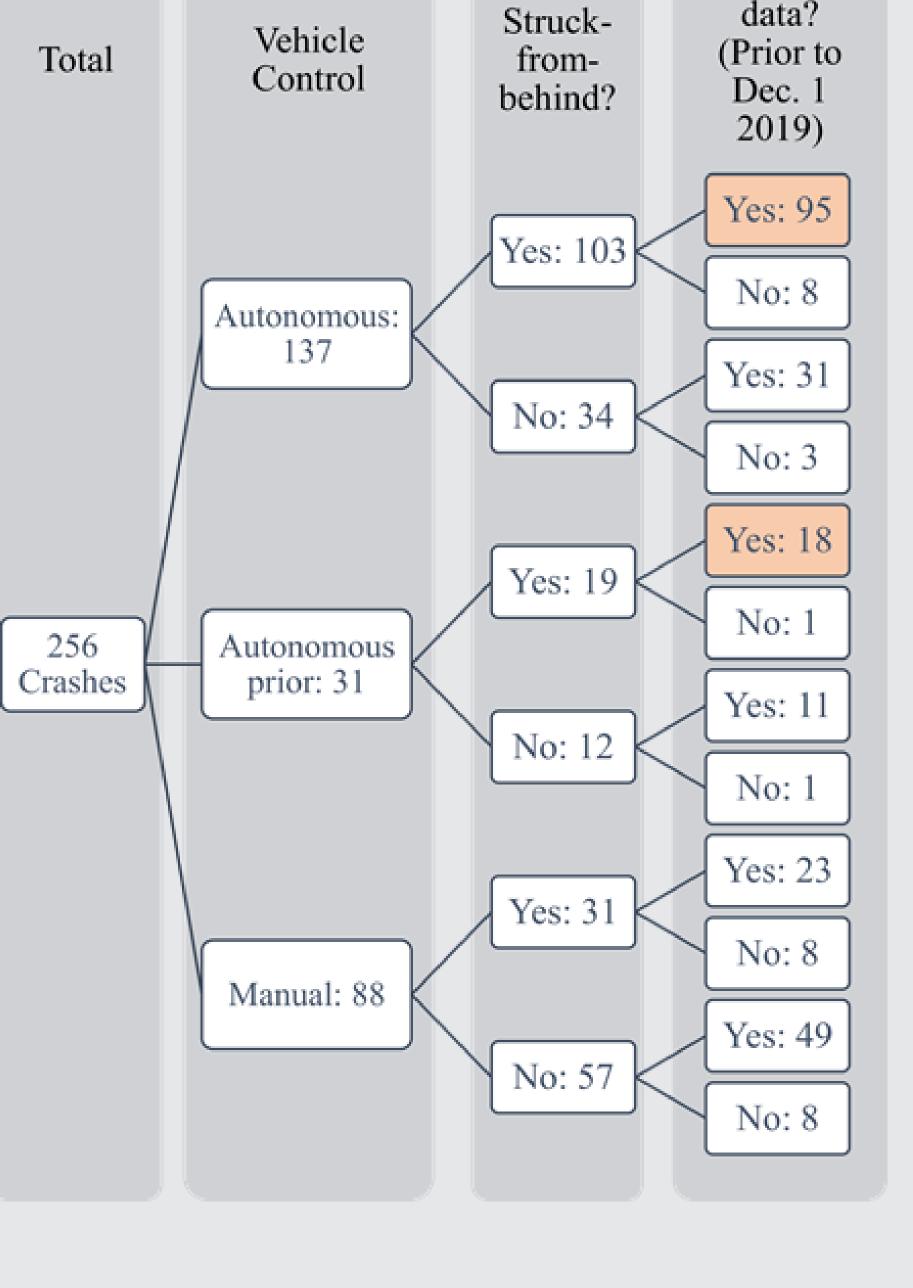
METHODS

MATERIALS AND METHODS

- **Automated Vehicle Data**
  ⇒ Crashes: California mandatory reporting Form OL316
  ⇒ Mileage: California disengagement reporting incudes mileage

- **General Public Data**
  ⇒ SHRP2 Naturalistic Driving Study, 33.6M miles and 3,500 drivers passively recorded from 2012–2014
  ⇒ Mileages and crashes age-weighted to represent US population

- **Additional Methods**
  ⇒ Data sorted by locality based on primary AV testing by developer and SHRP2 NDS locality based on data reductionist's judgement from vehicle's forward-facing video
  ⇒ Poisson distribution confidence intervals

Age	Weight	Percentage in SHRP 2 NDS	Percentage of US Licensed Drivers	Million miles driven	Weighted million miles driven
16-24	0.32	37	12	12.9	4.1
25-39	1.53	17	26	6.4	9.8
40-54	2.33	12	28	4.6	10.7
55-74	1.35	20	27	6.3	8.5
75+	0.5	14	7	3.4	1.7
Totals	-	100	100	33.6	34.8

Road vehicle remote operation demonstrations

MOVING VS. STOPPED

Over half of all AV struck-from-behind crashes occur while stopped, compared to 20% for conventional vehicles. When considering possible causes of struck-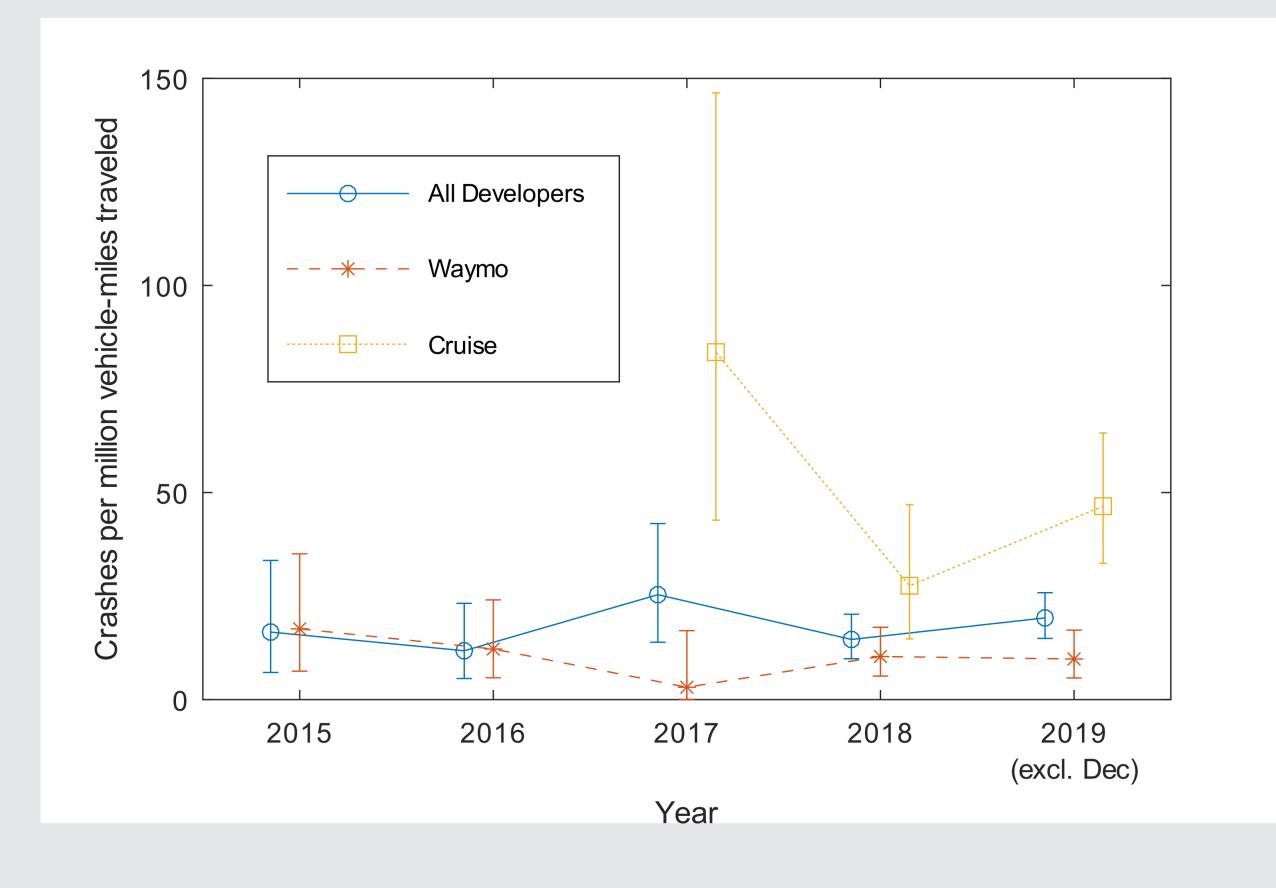from-behind crashes, this suggests that AVs might be stopping at unexpected times or locations. It also suggests that AV deceleration behavior may not be influencing struck-from-behind crashes.

Stopped	Crashes per MVMT	95% CI	n
Automated Vehicles	8.9	(6.7, 11.4)	58
SHRP 2 NDS Age Weighted	0.6	(0.4, 0.9)	23.3
SHRP 2 Urban	0.0	(0.0, 5.4)	0.0
SHRP 2 Business/Industrial	1.8	(1.1, 2.7)	19.9
SHRP 2 All Other Roads	0.1	(0.0, 0.4)	3.4
Moving			
Automated Vehicles	8.4	(6.3, 10.9)	55
SHRP 2 NDS Age Weighted	3.0	(2.5, 3.6)	104.8
SHRP 2 Urban	6.9	(2.9, 18.3)	4.7
SHRP 2 Business/Industrial	6.5	(6.2, 9.6)	73.4
SHRP 2 All Other Roads	1.2	(0.8, 1.7)	26.7

AV Struck-from-behind Crash Rates when Moving vs. Stopped

CRASH RATE OVER TIME

Although AV developers continue to improve their algorithms, the struck-from-behind crash rate for AVs does not appear to have changed since the start of crash reporting in 2015.
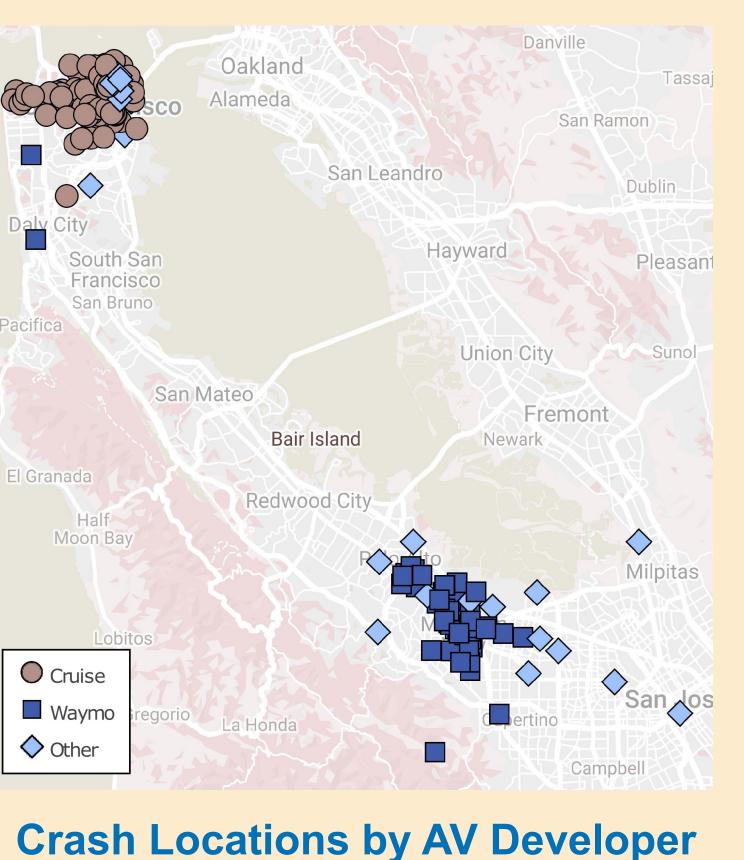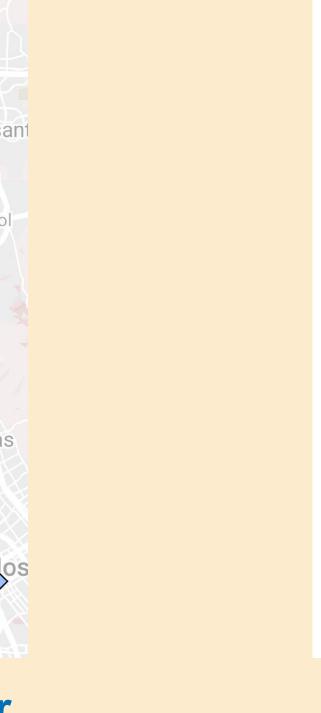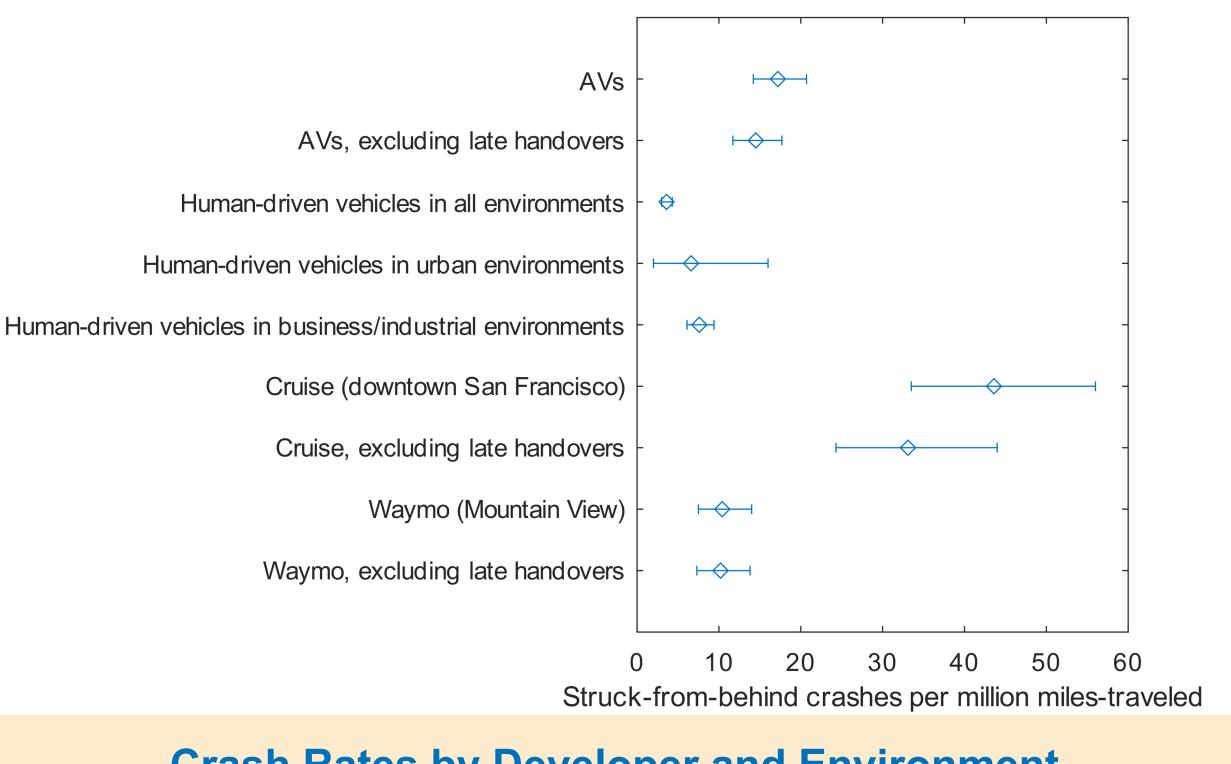

AV Struck-from-behind Crash Rates by Year

RESULTS

EFFECT OF URBAN DRIVING ENVIRONMENTS

- Automated vehicle testing locations may not correspond to locations in the SHRP2 Naturalistic Driving Study
  ⇒ Waymo: testing primarily in business/industrial Mountain View
  ⇒ Cruise: testing primarily in urban San Francisco
- Results
  ⇒ Waymo crash rates not statistically significant compared to SHRP2 NDS business/industrial crash rates
  ⇒ Cruise crash rates were higher than SHRP2 NDS urban crash rates. NDS locations were estimated from a visual inspection of the video feed during baseline events. A brief scan indicates that urban environments in the SHRP2 NDS are less dense than San Francisco, suggesting crash rates are not comparable.

Crash Locations by AV Developer

Crash Rates by Developer and Environment

CONCLUSIONS

- Automated vehicles are struck from behind at 4.8 times greater rates than conventional vehicles.

- This difference is greatly reduced when accounting for business/industrial environments where most AVs test. AVs in business/industrial environments (e.g. Waymo's) are struck from behind at 1.4 times the rate of conventional vehicles, and the difference is not statistically significant. AVs in urban environments (Cruise) are struck at higher rates, but crashes classified as "urban" in the SHRP2 dataset do not appear to be as dense as downtown San Francisco.

- AV struck-from-behind crash rates do not appear to be decreasing over time.

- Differences between AV and conventional vehicle struck-from-behind crash rates are not statistically significant when the subject vehicle is moving, only when the subject vehicle is stopped. This suggests that the timing and location of AV stops may contribute to the crash rate, and not the deceleration behavior of AVs.