The Environmental Impact of Autonomous Vehicles' Driving Behavior

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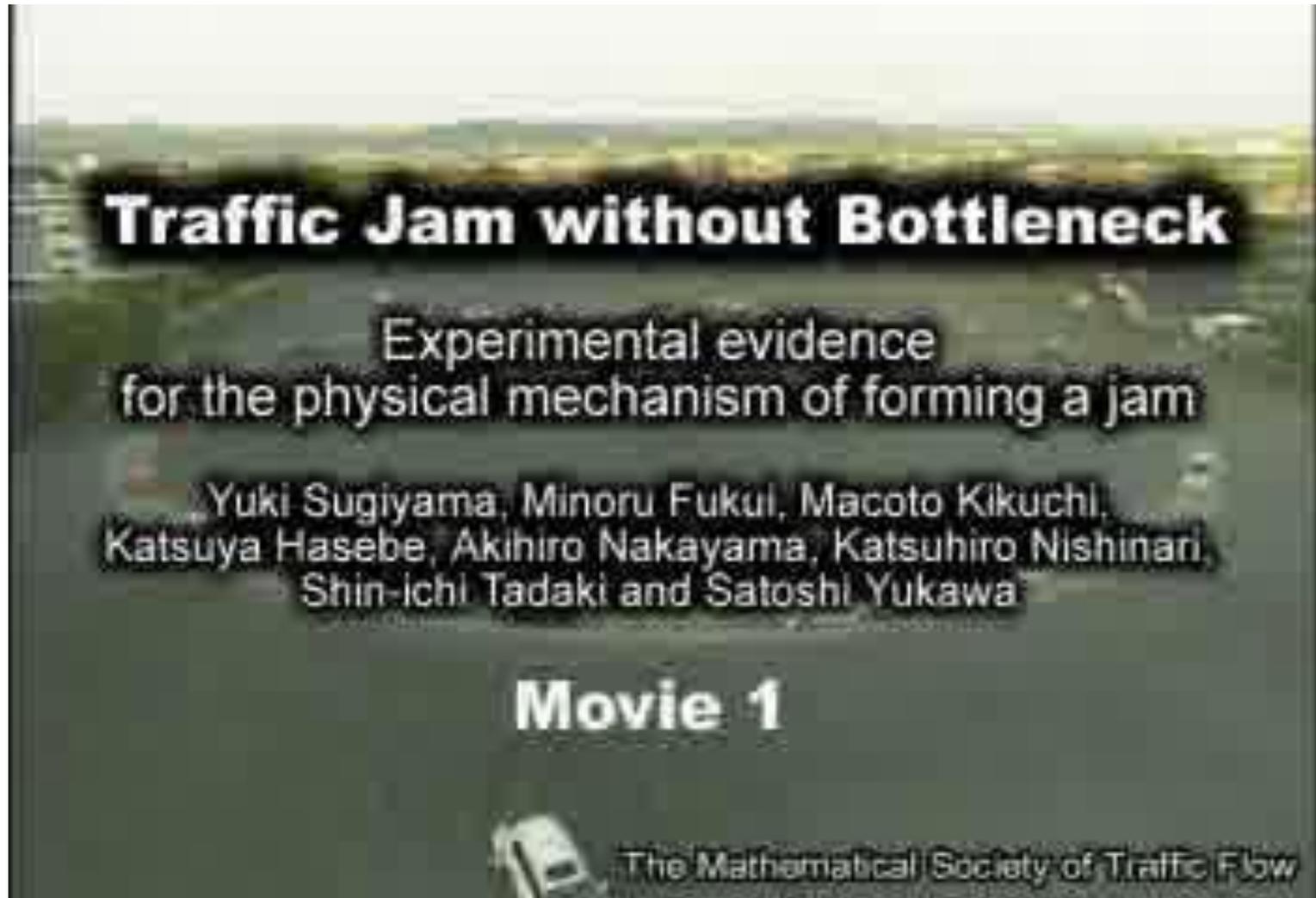University of New South Wales (UNSW)

Content

- What is wrong with human driving behaviour?

- How can autonomous vehicles (AVs) improve traffic flow?

- Regulations on AV driving behavior should not only focus on safety.

- Study of Waymo Dataset: Does Waymo's safety increase vehicle's emission?

What is wrong with human driving behaviour?
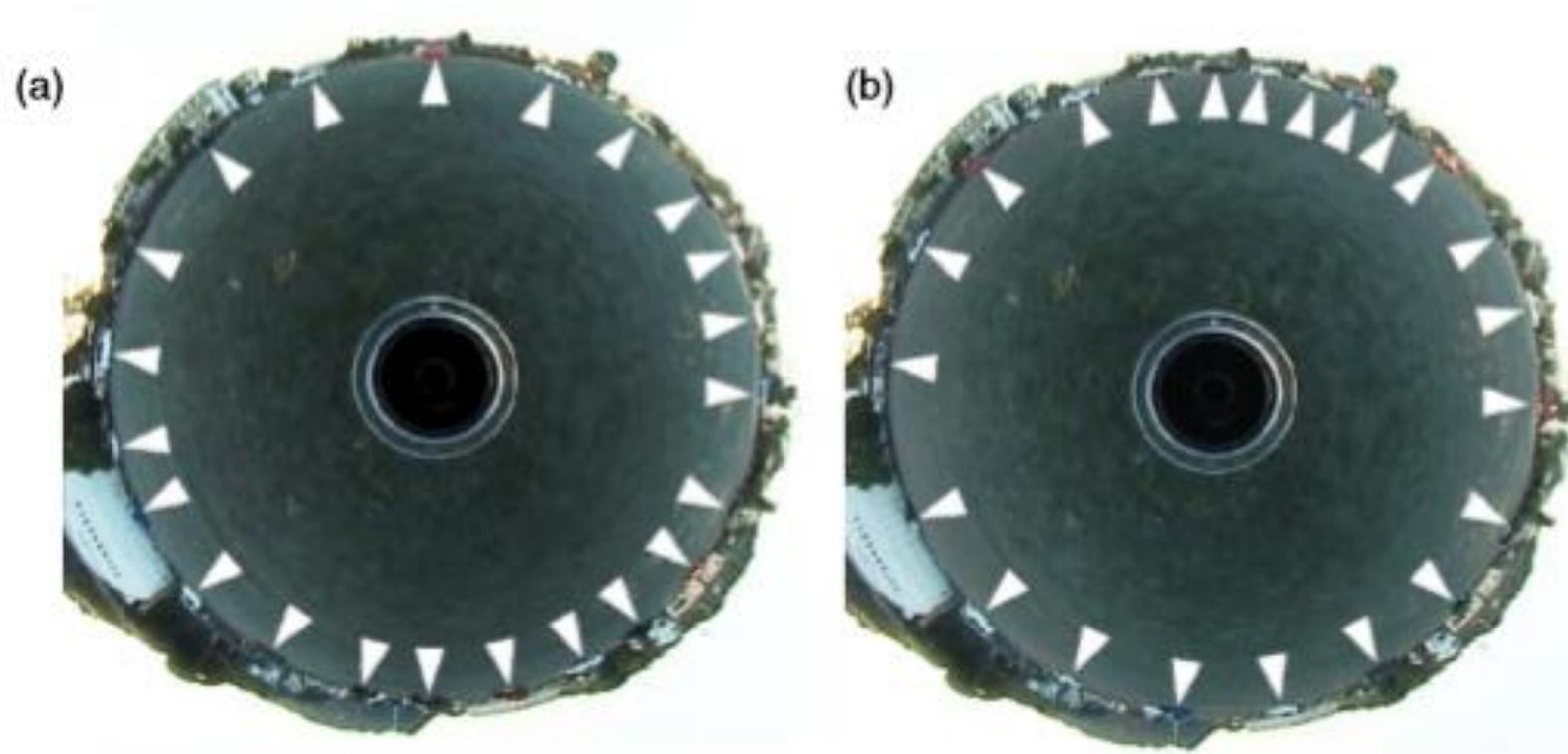
Gaps Before (a) and After (b) Jam Creation. (Sugiyama et al. 2008).

Sugiyama, Y., Fukui, M., Kikuchi, M., Hasebe, K., Nakayama, A., Nishinari, K., Tadaki, S. I., & Yukawa, S. (2008). Traffic jams without bottlenecks-experimental evidence for the physical mechanism of the formation of a jam. *New Journal of Physics*, *10*(March). https://doi.org/10.1088/1367-2630/10/3/033001
YouTube, video of the experiment : https://youtu.be/Suugn-p5C1M?si=SH28QsRAGleznh4h

What is wrong with human driving behaviour?

Traffic Jam without Bottleneck

Experimental evidence
for the physical mechanism of forming a jam

Yuki Sugiyama, Minoru Fukui, Macoto Kikuchi,
Katsuya Hasebe, Akihiro Nakayama, Katsuhiro Nishinari,
Shin-ichi Tadaki and Satoshi Yukawa

Movie 1

The Mathematical Society of Traffic Flow

Sugiyama, Y., Fukui, M., Kikuchi, M., Hasebe, K., Nakayama, A., Nishinari, K., Tadaki, S. I., & Yukawa, S. (2008). Traffic jams without bottlenecks-experimental evidence for the physical mechanism of the formation of a jam. *New Journal of Physics*, *10*(March). https://doi.org/10.1088/1367-2630/10/3/033001
YouTube, video of the experiment : https://youtu.be/Suugn-p5C1M?si=SH28QsRAGleznh4h

How can autonomous vehicles (AVs) improve traffic flow?

1 x Autonomous Vehicle

Stern, R. E., Cui, S., Delle Monache, M. L., Bhadani, R., Bunting, M., Churchill, M., … Work, D. B. (2018). Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies*, *89*(April 2017), 205–221. https://doi.org/10.1016/j.trc.2018.02.005

How can autonomous vehicles (AVs) improve traffic flow?

Dissipation of stop-and-go traffic waves via control of a single autonomous vehicle

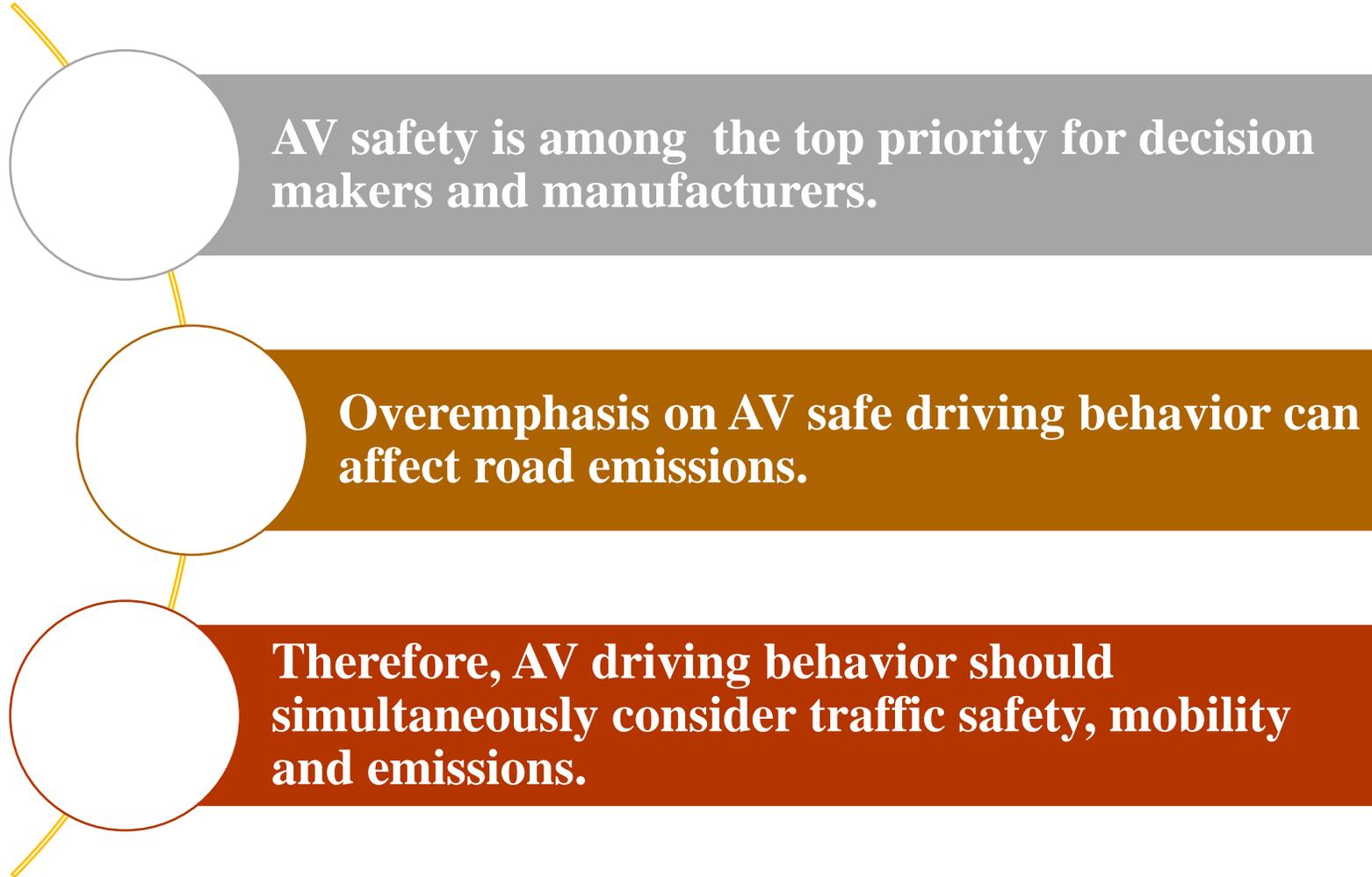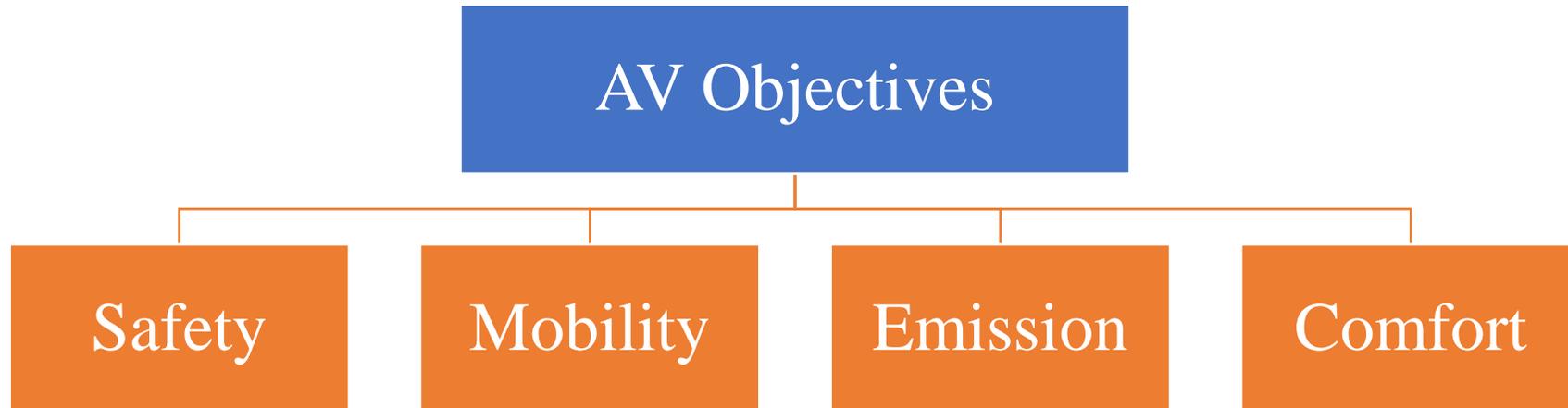ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

RUTGERS

TEMPLE UNIVERSITY

THE UNIVERSITY OF ARIZONA

Jonathan Sprinkle (May 6, 2017). Self-driving cars experiment demonstrates dramatic improvements in traffic flow. YouTube. https://www.youtube.com/watch?v=2mBjYZTeaTc&ab_channel=JonathanSprinkle
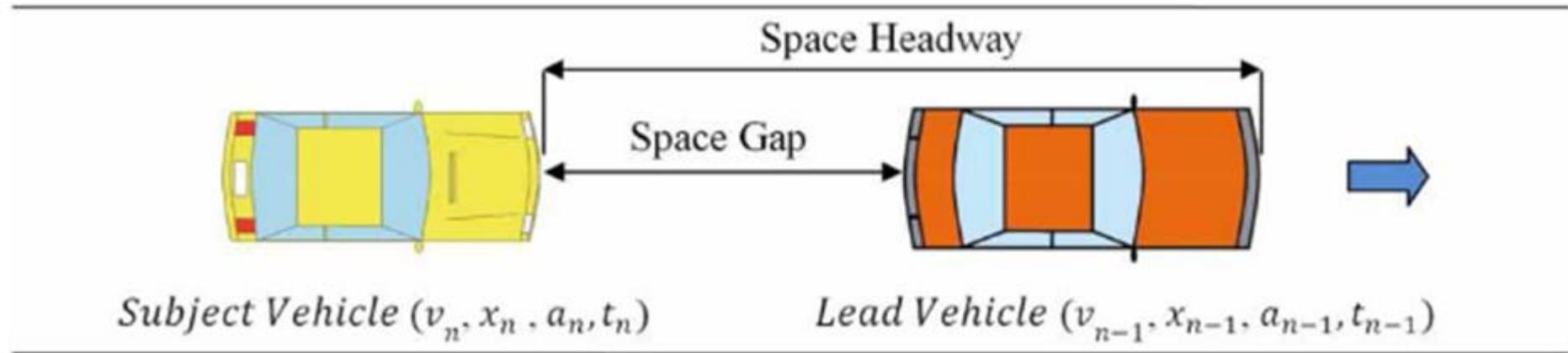
Stern, R. E., Cui, S., Delle Monache, M. L., Bhadani, R., Bunting, M., Churchill, M., … Work, D. B. (2018). Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies*, 89(April 2017), 205–221. https://doi.org/10.1016/j.trc.2018.02.005

AV Activation Improves Mobility & Emissions (g/mile)
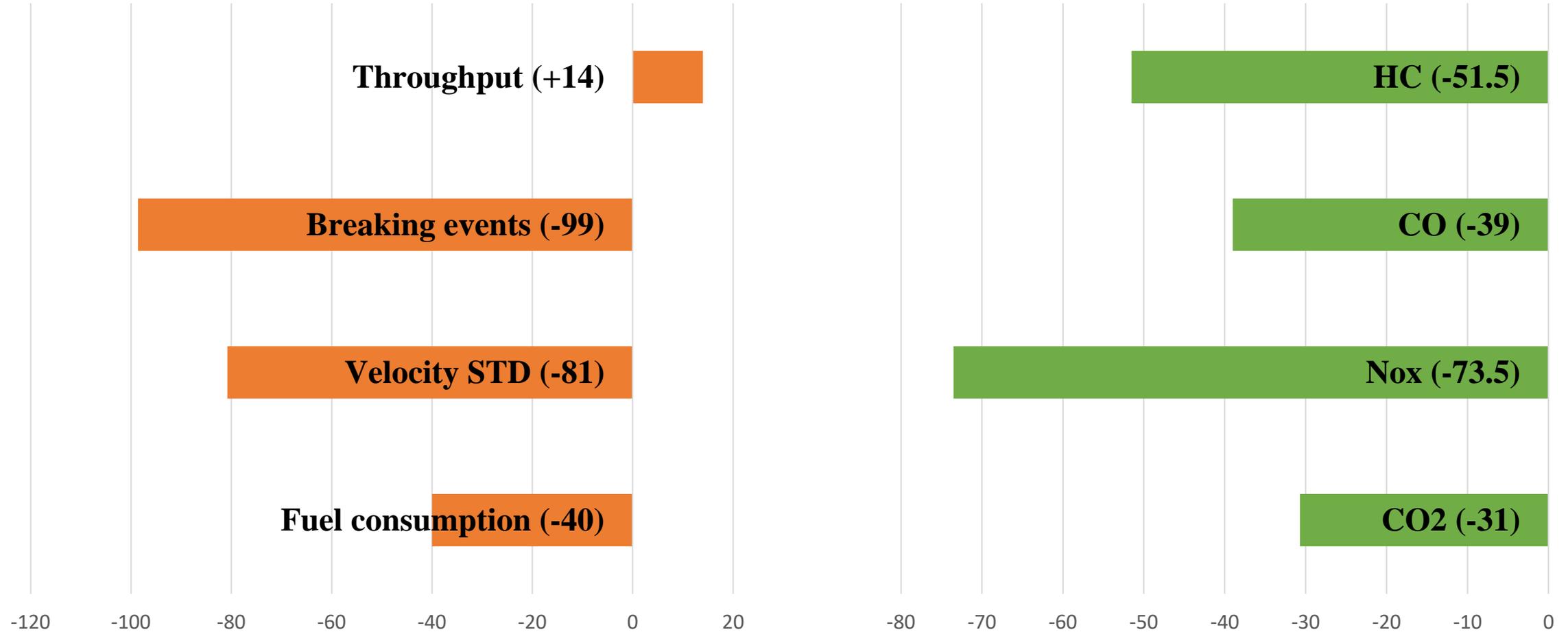
Throughput (+14)
HC (-51.5)
Breaking events (-99)
CO (-39)
Velocity STD (-81)
Nox (-73.5)
Fuel consumption (-40)
CO2 (-31)

-120 -100 -80 -60 -40 -20 0 20   -80 -70 -60 -50 -40 -30 -20 -10 0

Stern, R. E., Cui, S., Delle Monache, M. L., Bhadani, R., Bunting, M., Churchill, M., … Work, D. B. (2018). Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies*, 89(April 2017), 205–221. https://doi.org/10.1016/j.trc.2018.02.005

Stern, R. E., Chen, Y., Churchill, M., Wu, F., Delle Monache, M. L., Piccoli, B., Seibold, B., Sprinkle, J., & Work, D. B. (2019). Quantifying air quality benefits resulting from few autonomous vehicles stabilizing traffic. Transportation Research Part D: Transport and Environment, 67(December 2018), 351–365. https://doi.org/10.1016/j.trd.2018.12.008

Regulations on AV driving behavior

AV safety is among the top priority for decision makers and manufacturers.

Overemphasis on AV safe driving behavior can affect road emissions.

Therefore, AV driving behavior should simultaneously consider traffic safety, mobility and emissions.

AV's objectives can be conflicting !

Subject Vehicle (v_n, x_n, a_n, t_n) Lead Vehicle $(v_{n-1}, x_{n-1}, a_{n-1}, t_{n-1})$

AV Objectives

Safety   Mobility   Emission   Comfort

Waymo Open Dataset

First Fully Autonomous Ride hailing service.

Operating in many U.S. cities including Austin, Phoenix, San Francisco, and Los Angeles

Wen et al., (2022) found that Waymo AVs can improve traffic safety, behavioral certainty and driving dynamics given their ability to drive with less velocity fluctuation compared to HVs.

Waymo's AV is safer than human-driven vehicles (Swiss Re).

Supplemental Sensors

Vision System

LiDAR System

Radar System
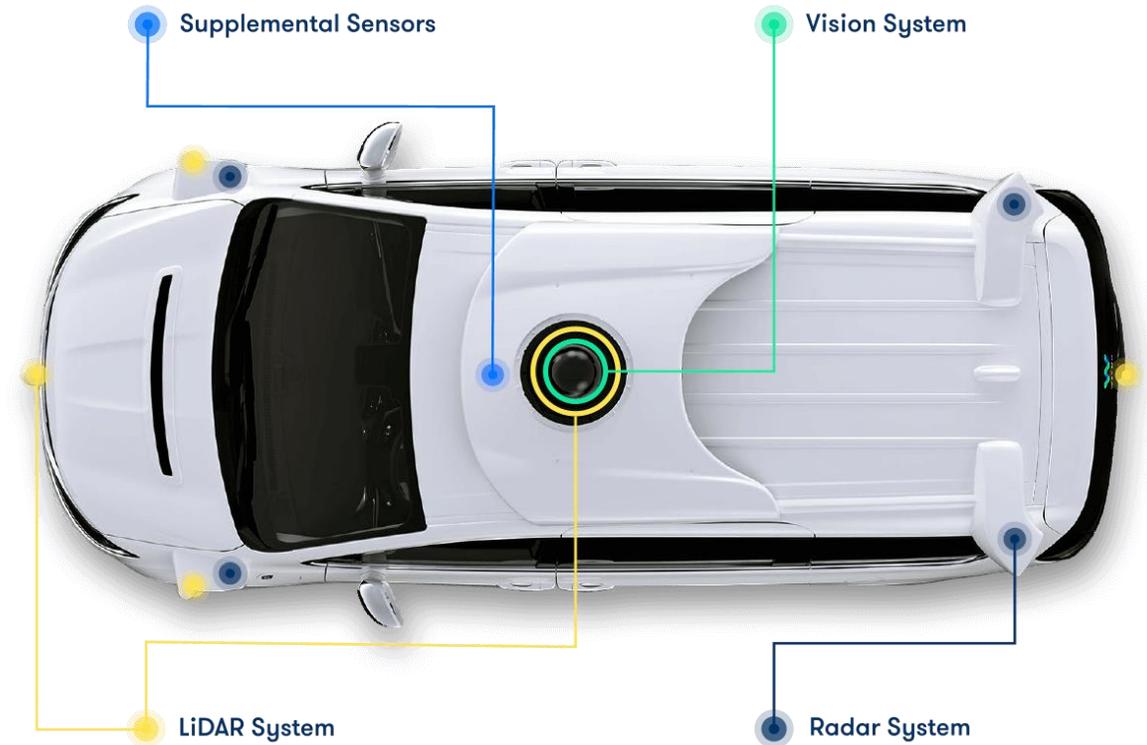
How Autonomous Vehicles Work : https://ltad.com/about/how-autonomous-vehicles-work.html
Waymo's safety : https://waymo.com/blog/2023/09/waymos-autonomous-vehicles-are.htmll
Photo source: https://waymo.com/blog/2022/03/taking-our-next-step-in-city-by-bay.htm
Wen, X., Cui, Z., & Jian, S. (2022). Characterizing car-following behaviors of human drivers when following automated vehicles using the real-world dataset. *Accident Analysis and Prevention*, *172*(January), 106689. https://doi.org/10.1016/j.aap.2022.106689
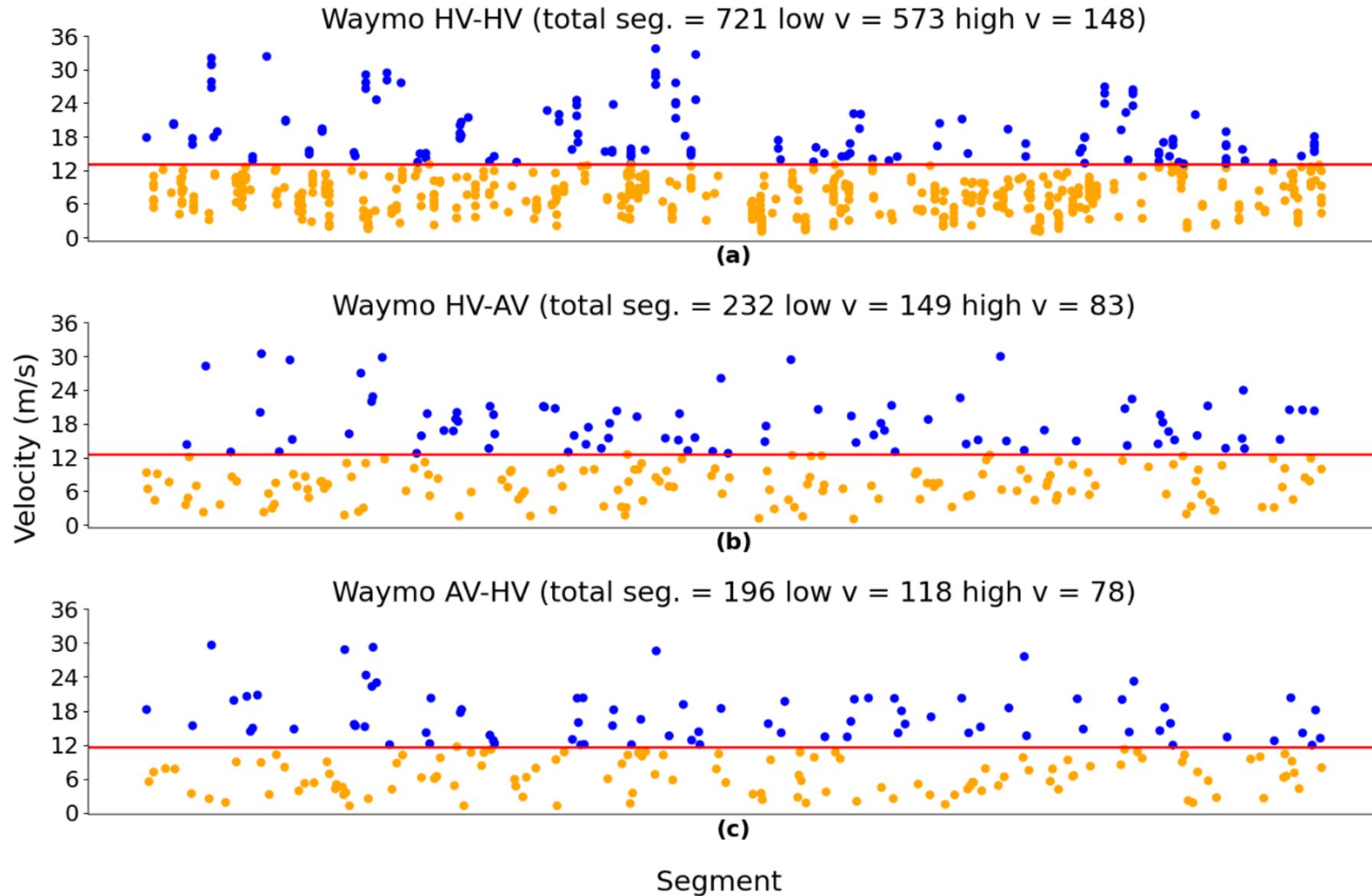
Does Waymo's safety increase vehicle's emission?

Wen et al., (2022) found that Waymo AVs can improve traffic safety, behavioral certainty and driving dynamics given their ability to drive with less velocity fluctuation compared to HVs.

*Waymo's AV is safer than human-driven vehicles (Swiss Re).*

HV following HV   HV following AV   AV following HV

Traveling direction

Alhariqi, **A.,** Gu, Z., & Saberi, M. (2023). Environmental impact of automated vehicles' driving behavior in mixed autonomy traffic considering vehicle arrangements: an empirical study of Waymo open dataset (working paper).
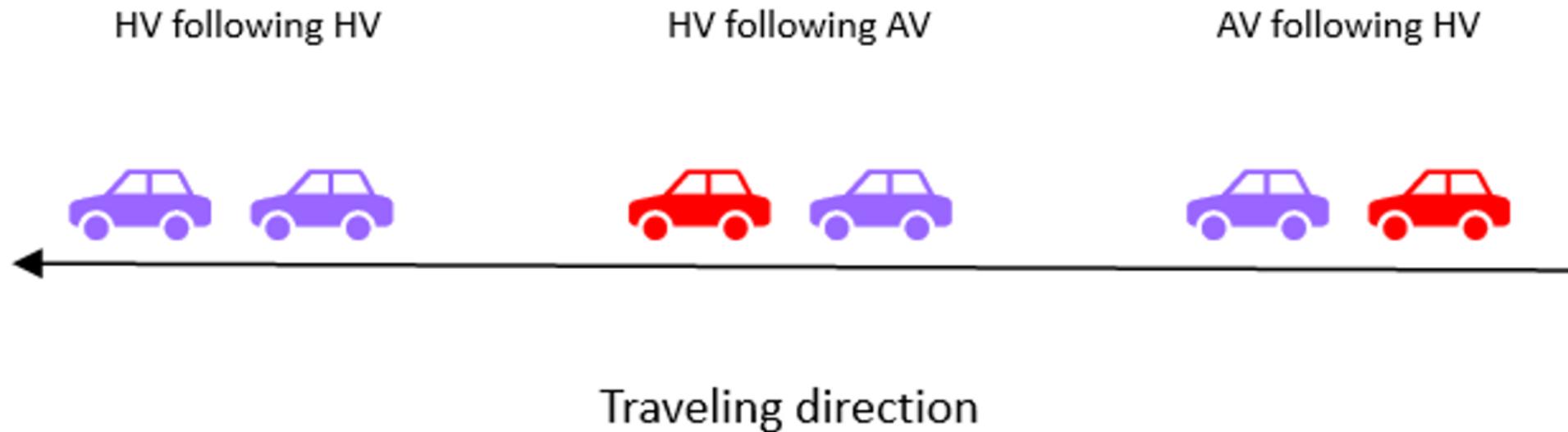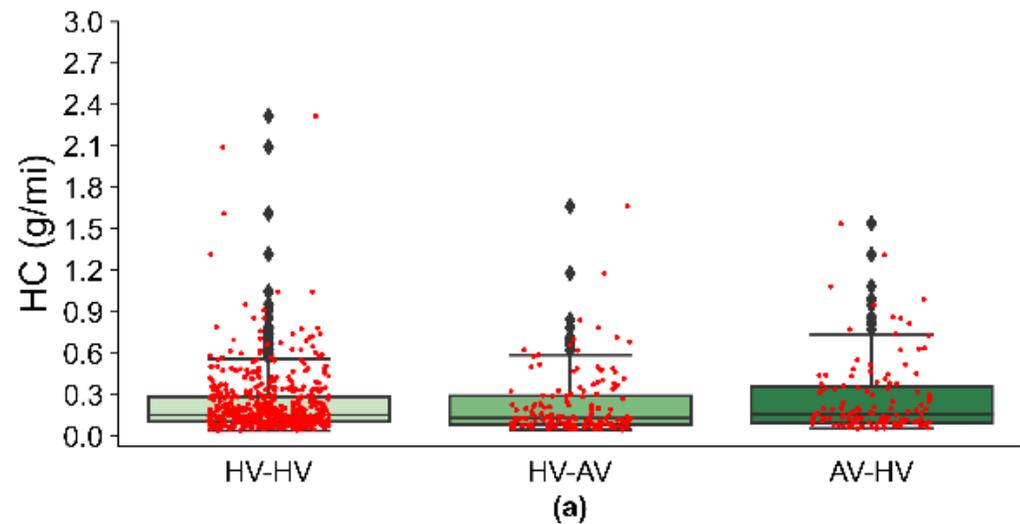
Waymo Dataset: segments clustering based on velocity for (a) HV-HV (b) HV-AV and (c) AV-HV

Waymo Dataset: Emissions for Low Velocity Segments
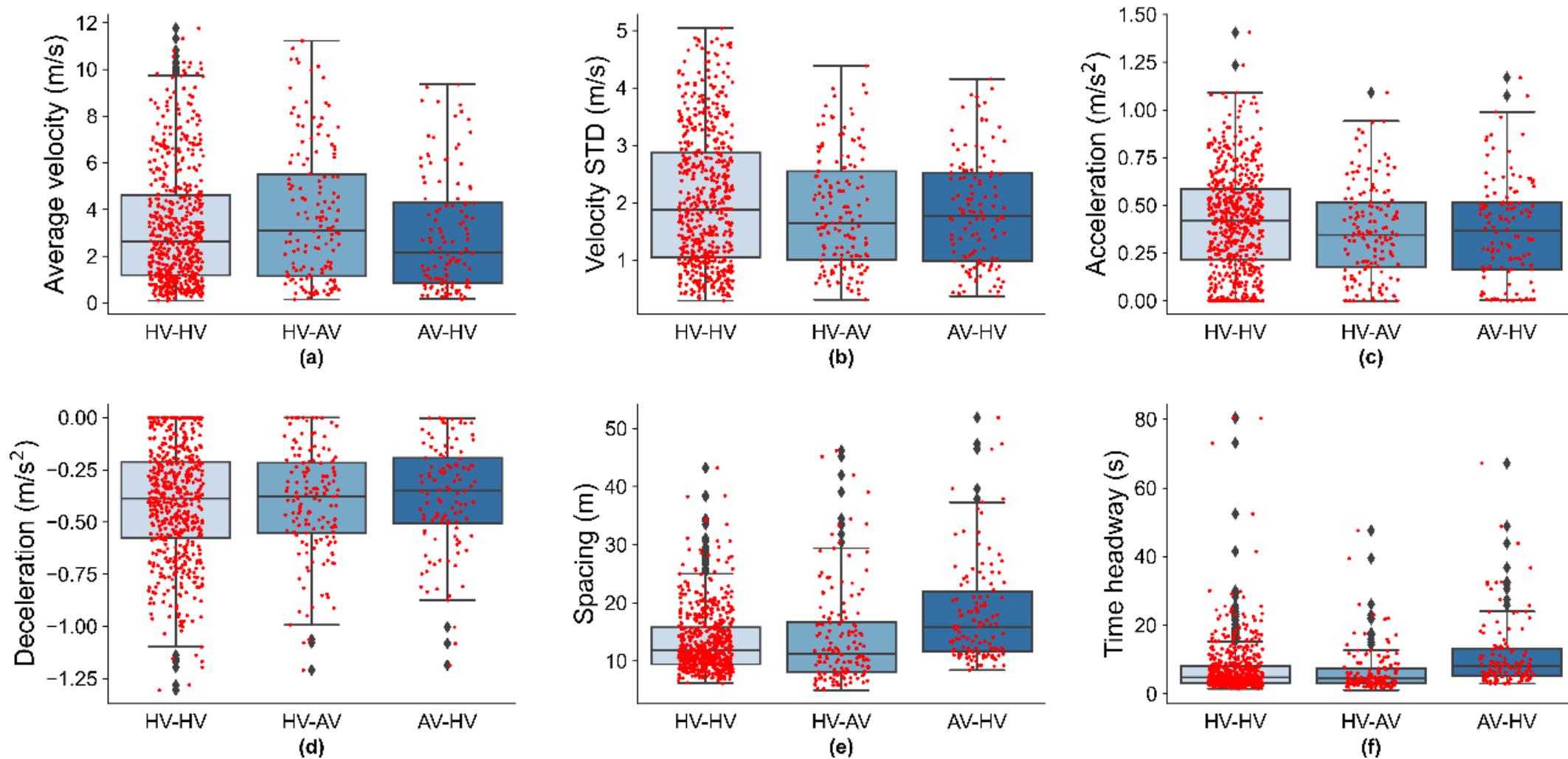
Waymo Dataset: Emissions for Low Velocity Segments
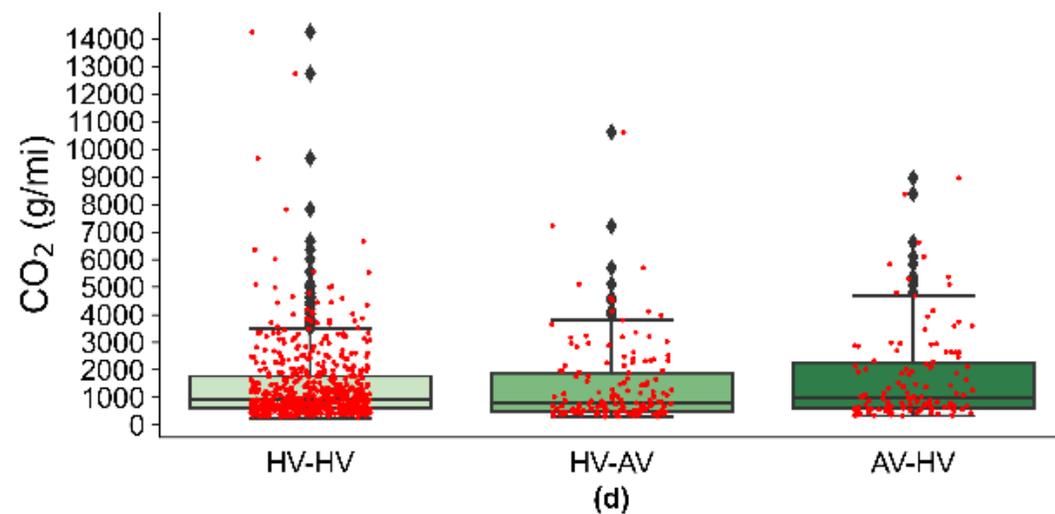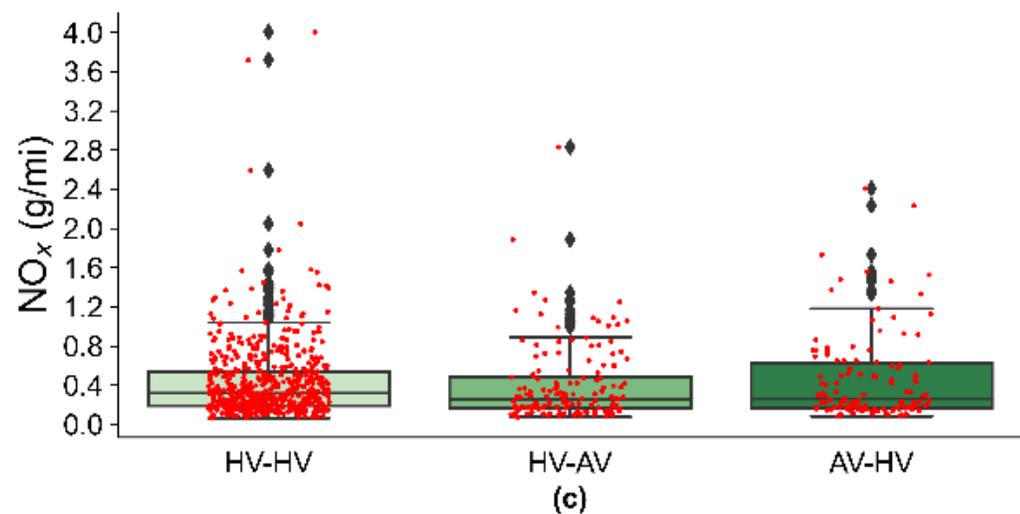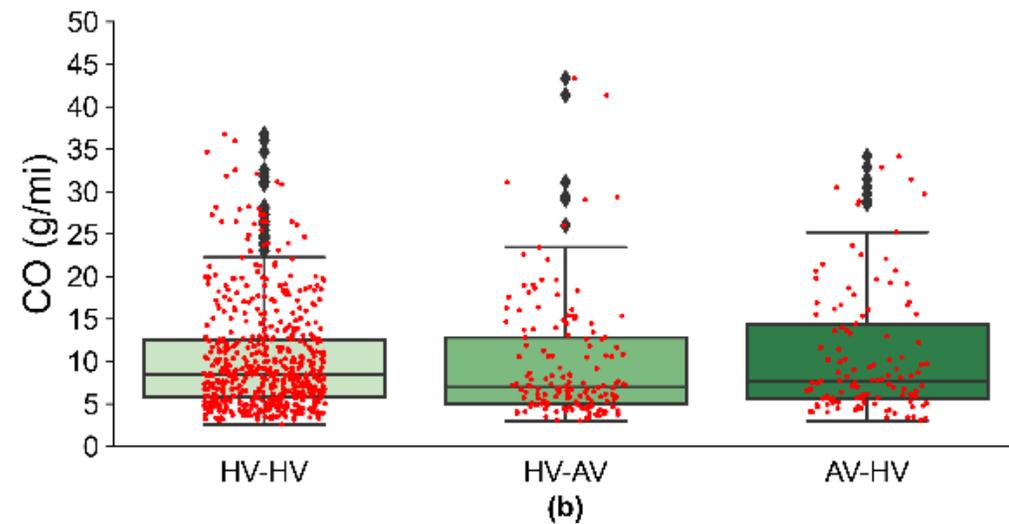
Conclusion

AV driving behavior should address all traffic challenges including safety, mobility and emissions.