Evaluation of Autonomous Vehicle Speed Consistency Compared to Human-driven Vehicles in Work Zones

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Poster No. 12422

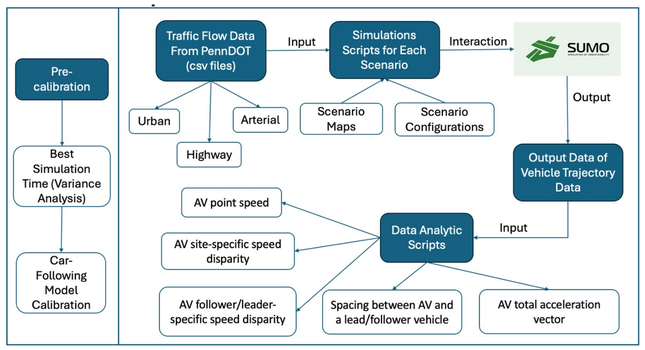
Research Question

How do autonomous vehicles (AV) perform in work zones compared to human-driven vehicles (HV)?

- Work zones create special challenges to the feasibility and performance of AVs on public roads including complex AV interactions with construction workers and surrounding human-vehicle (HV) traffic
- It is important to predict, measure, and compare AV and HV behaviors to understand their travel consistency and motions in work zones
- Rather than use actual collisions or safety violations, it is preferred to use safety metrics: object-avoidance, collision avoidance, sensing errors in traffic simulations.
- **This research includes simulation-based and field-based experiments of AVs in work zones – particularly the analysis of both AV performance and the AV impacts on HV traffic and work zone occupants.** Evaluations include:
  3 typical traffic flow regimes (highway, arterial, and urban),
  tested across 20 work zone configurations, for peak and off-peak flows.
  The most demanding situation – highway flow – is shown in this poster.

Simulation Methodology

Simulation Pipeline



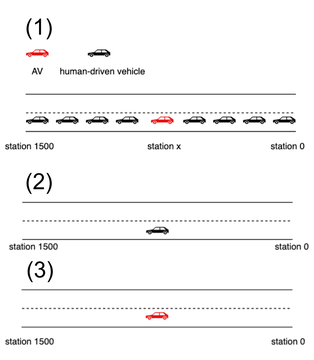
Data Analytics Pipeline

Trajectory dada (timestep, station, speed, etc.) → Build reference line for test track → Project trajectory data to reference line → Station interpolation, range from 0 to 1500, (1 station increment) → Metric aggregated on each station; statistics calculate with 95% confidence

Three Types of Simulations

- With traffic interaction:
  (1) One AV traveling within HVs flow
- Without traffic interaction:
  (2) One AV traveling in a free-flow state
  (3) One HV traveling in the free-flow state.

Each type of simulation is run for N times



Car-following Models

- AVs behavior represented by a calibrated Wiedemann car-following model.
- HVs behavior represented by a Krauss car-following model calibrated to field-measured HV data.

Simulation Methodology

Use Surrogate Safety Metrics

Each metric calculated at each station from repeated simulations with randomness

- **Site speed**: speed of AV or HV
- **Site speed disparity:** speed disparity between AV and HV
- **Speed disparity to follower/leading vehicle:** AV/HV speed disparity to follower/leading vehicle
- **Leading/ Follower spacing:** spacing between AV and leading/follower HV
- **Acceleration/Deceleration rates:** acceleration/deceleration of AV or HV

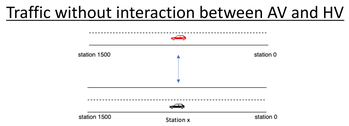
Note each metric is calculated for traffic with interaction and traffic without interaction, respectively, in each modality of peak or off-peak period

Statistics

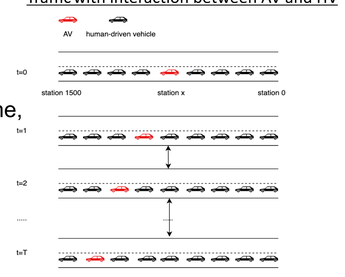
- **Average:** $\bar{y}_x = \sum_{t=0}^{T} y_{x,t} / T$
- **Standard deviation:** $S = \sqrt{\sum_{t=0}^{T} (y_{x,t} - \bar{y}_x)^2 / T}$

where x is the station index, T is simulation time, y is evaluation metric

Traffic without interaction between AV and HV



Traffic with interaction between AV and HV



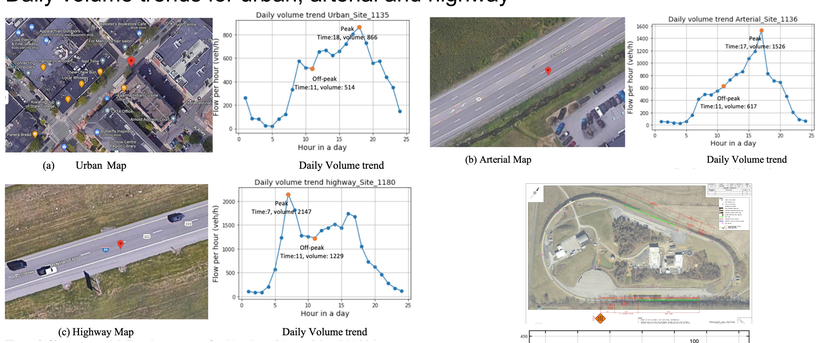
Experiments and Results

Traffic Demand and Sites

Flow calibration is via PennDOT field data: https://gis.penndot.gov/tire.

Modalities (flow)	Location Description	Site Number	Year	Peak Time (h)	Peak Volume (vehicles/h)	Off-peak Time (h)	Off-peak Volume (vehicles/h)	Speed limit	Number of lanes in N direction
Urban	Beaver Ave - 225 Feet North of Allen St. (NB Direction Only)	1135	2015	18	866	11	514	25(mph) 11.18(m/s)	2
Arterial	College Ave - 0.65 MILE NORTHEAST OF SR-3022 (UNIVERSITY DR)	1136	2016	17	1526	11	617	45(mph) 20.12(m/s)	2
Highway	I-99 - 1.35 Mile North of Exit 71	1180	2017	7	2147	11	1229	65(mph) 29.05(m/s)	2

Daily volume trends for urban, arterial and highway



Simulation Maps

High-definition (HD) simulation maps are created using field mapping data of physical work zone layouts at test track facility wherein AVs were also physically tested without traffic.

Experiments and Results

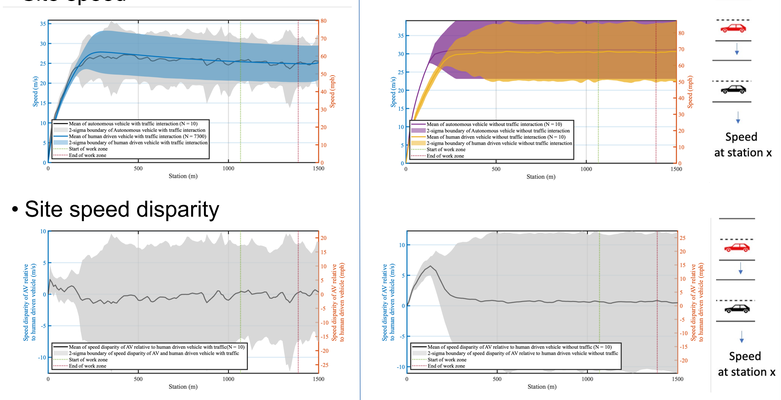
AV human-driven vehicle

Simulation Results of Each Safety Metric

Traffic with interaction between AV and HV

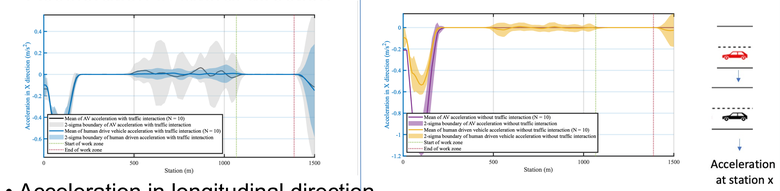
Traffic without interaction between AV and HV

- Site speed

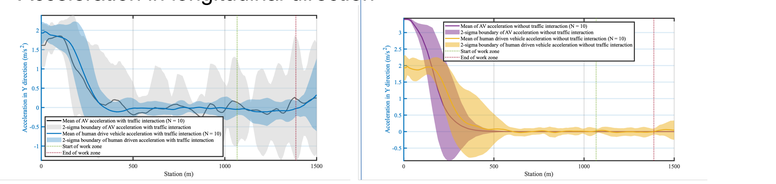


- Site speed disparity

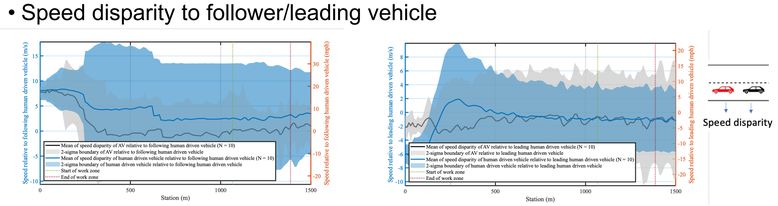
- Acceleration in lateral direction



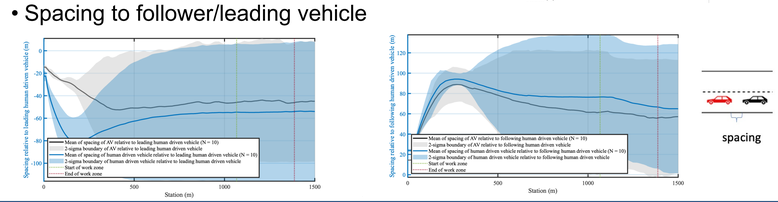
- Acceleration in longitudinal direction



- Speed disparity to follower/leading vehicle



- Spacing to follower/leading vehicle



Conclusions

This poster summarizes key results comparing HV and AV traffic flows and safety results. The results show that the AVs behavior versus the HVs behavior has, in nearly all metrics from each scenario, no statistically significant differences with 95% confidence bounds.