Evaluating Connected and Autonomous Vehicle (CAV) Impacts on Signalized Intersection Work Zone Capacity: A New Jersey Case Study

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Introduction

- Work zones contribute to 24% of nonrecurrent congestion, causing 482 million vehicle hours of delay annually (FHWA, 2006). Increasing travel demand and aging infrastructure can make work zone management challenging, as lane closures and lower speed limits reduce roadway capacity and lead to delays.
- The adoption of connected and automated vehicles (CAVs) offers a solution to enhance efficiency and reduce congestion through real-time traffic information, shorter gaps, smooth speed adjustments, and platooning.
- The Highway Capacity Manual (HCM) includes CAV impacts on roadway capacity for various facility types but falls short in providing guidance on signalized intersection work zones. Limited studies have explored the impact in work zones, necessitating evaluation to develop effective management strategies.
- With increasing CAV deployment, work zones will operate under mixed traffic conditions consisting of both HDVs and CAVs, making it important to understand their combined effects.

Study Goals

The objective of this study is to quantify the impact of CAV penetration rates and their driving behavior on the capacity of a signalized intersection approach with a right closure for:

- A shared through-and-right-turn movement
- A protected left-turn movement

Study Area and Data

A representative four-leg signalized intersection geometry was selected, with a major street and a minor street in Washington Township, NJ.

- Each approach consists of an exclusive left-turn lane, an exclusive through lane, and a shared through-and-right-turn lane.
- All lanes are 11 ft wide, and the posted speed limit on both the major and minor streets is 45 mph.
- Traffic count data were collected in the field on March 9, 2026, between 7:00 and 8:00 AM to capture peak-hour conditions. The observed traffic stream consisted of 96.5% passenger cars and 3.5% trucks.
- Left-turn storage length is 300 ft for each approach.
- A 100-s cycle length was selected, and the optimized timing plan was used for the analysis.

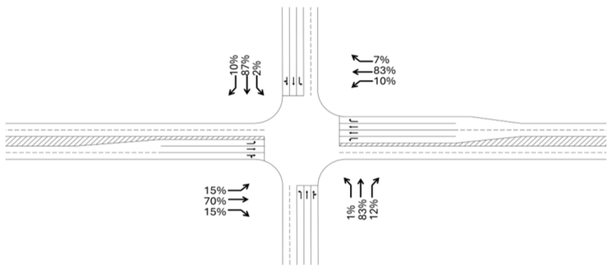


Figure 1: Study Intersection

Methodology

Modeling Approach

- Developed models in VISSIM microsimulation software for normal and work zone conditions.
- Calibrated using HCM saturation flow rates and verified the good fit of the model with Geoffrey E. Havers (GEH) (GEH < 5 is an acceptable fit).

Table 1: Comparison of HCM and simulated saturation flow rates for protected movements under normal condition

Movement	HCM SFR (pc/h/ln)	Simulated SFR (pc/h/ln)	GEH
Shared Right-and-Through	1800	1722	1.86
Through	1900	1916	0.37
Left Turn (Protected Phase)	1600	1585	0.38

Work Zone Setup

- Configured a right-lane closure at the signalized intersection approach.
- Calibrated for HDVs.

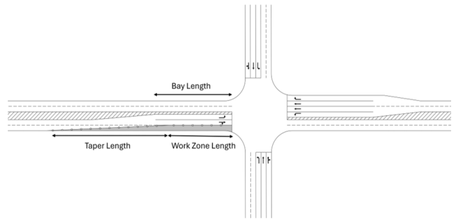


Figure 2: Schematic Diagram of Work Zone Configuration

Table 2: Work Zone Design Parameters

Attribute	Value
Work Zone Length, ft	250
Work Zone Speed Limit, mph	35
Taper Length, ft	495
Distance Between Warning Signs, ft	350

Table 3: Comparison of HCM and simulated saturation flow rates for work zone condition

Movement	HCM SFR (pc/h/ln)	Simulated SFR (pc/h/ln)	GEH	HCM Saturation Headway (s)	Simulated Saturation Headway (s)
Shared Right-and-Through	1575	1587	0.32	2.29	2.27
Left Turn (Protected Phase)	1400	1362	1.01	2.57	2.64

CAV Operation and Assumptions

- Level of Automation: 5
- Smoother and coordinated merging through V2V and V2I communication and cooperative lane-changing.
- Advanced merging.
- Minimize stop-and-go patterns & reduce speed variability
- Evaluated operations under mixed traffic conditions with CAV MPRs ranging from 0% to 100%.
- Applied Wiedemann 99 car-following parameters adopted for CAVs (CoEXist project) for three behavior categories: Cautious, Normal, and All-knowing.
- All-knowing CAVs feature more aggressive parameters, with a headway time of 0.6 s, compared to 0.7 sec for Normal CAVs and 1.1 s for Cautious CAVs.

Capacity Estimation

- Saturation flow rates (SRFs) and mean saturation headways were extracted from the simulation across varying CAV levels to estimate capacity.

$$s = \frac{3600}{h}$$

$$capacity = s \times \frac{g}{C}$$

Where,
s = Saturation Flow Rate
h = Saturation Headway
g = Effective Green Time
C = Cycle Length

Results and Applications

Shared Through-and-Right-Turn Lane

- SFR increases nonlinearly with CAV penetration.
- Mean saturation headway decreases as CAV MPR increases from 0% to 100%.
- At 100% CAV penetration, SFR increases by approximately 84% for All-Knowing, 81% for Normal, and 70% for Cautious CAVs.

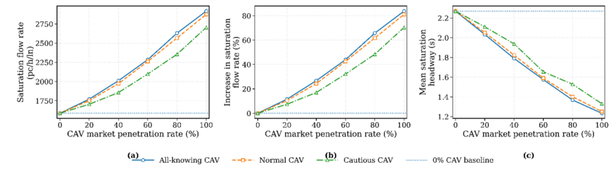


Figure 3: Impact of CAV penetration rate and driving behavior on saturation flow rate and saturation headway for the shared through-and-right-turn lane (work zone condition): (a) SFR, (b) percent SFR increase, and (c) mean saturation headway

Protected Left-Turn Lane

- SFR increases consistently with higher CAV MPRs.
- Experienced greater relative improvements due to a lower baseline SFR, allowing greater reductions in discharge headway.
- At 100% CAV penetration, capacity increases by approximately 88% for All-Knowing, 83% for Normal, and 78% for Cautious CAVs.
- Even the Cautious scenario provided substantial capacity improvements.

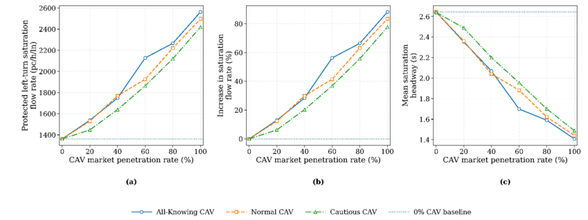


Figure 4: Impact of CAV penetration rate and driving behavior on saturation flow rate and headway for the protected left-turn lane (work zone condition): (a) SFR, (b) percent SFR increase, and (c) mean saturation headway

Practical Applications

- Developed HCM-compatible Capacity Adjustment Factors (CAFs) to support work zone planning and design.
- Look-up tables provide specific CAFs for Shared Through-and-Right-Turn and Protected Left-Turn movements based on targeted CAV penetration levels and driving behavior.

Table 4: Capacity Adjustment Factors

CAV MPR	Shared Through-and-Right-Turn			Protected Left Turn		
	All-knowing	Normal	Cautious	All-knowing	Normal	Cautious
0	1.00	1.00	1.00	1.00	1.00	1.00
20	1.12	1.10	1.07	1.13	1.12	1.06
40	1.27	1.24	1.17	1.28	1.30	1.20
60	1.44	1.43	1.32	1.56	1.41	1.37
80	1.66	1.62	1.48	1.66	1.63	1.56
100	1.84	1.81	1.70	1.88	1.83	1.78

Conclusion & Future Work

- CAVs significantly improve work zone capacity, even without full connectivity.
- Protected left-turn movements experience the greatest capacity improvements.
- The proposed CAFs should be applied within the context of this study.
- Behavioral parameters will be recalibrated as real-world CAV and HDV mixed traffic data become available.
- The work will be expanded to other intersection layouts, right-turn proportions, and lane-closure configurations.