Connected - Automated Vehicles' Impact on Operations at Signalized Intersections: An Investigation of Lane Restriction Policy

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Objective

This study seeks to identify the changes expected at signalized intersections based on gradual penetration of connected-automated vehicles (CAVs) in the traffic stream. Performance indicated used are Control delay, Queue length and Saturation flow rate.

Methods

Using VISSIIM traffic microsimulation software, a typical signalized intersection with four (4) approaches was analyzed.
Different market penetration rates (MPR) of CAVs ranging from 10% to 90% were tested.
CAVs were modelled in VISSIM by adjusting the Wiedemann '94 driver behavior parameters to match the ones obtained from review of past literatures.

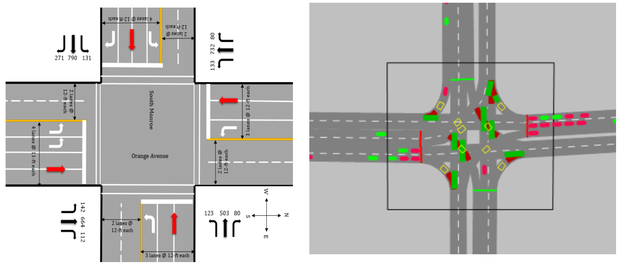


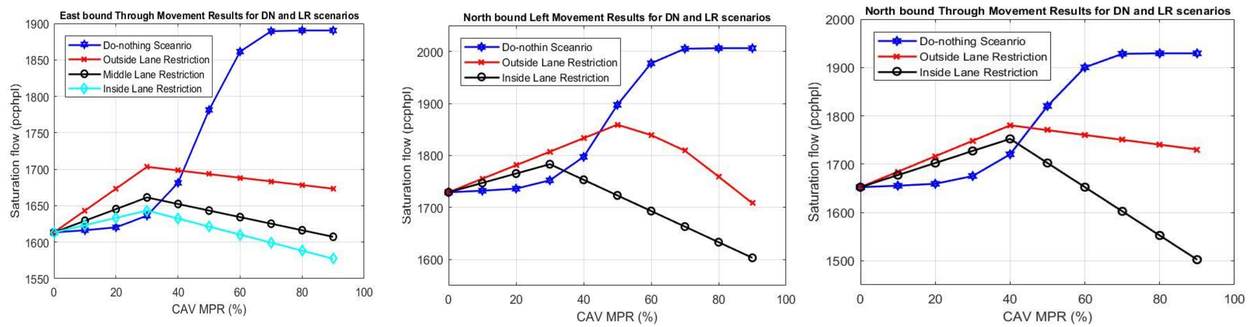
Fig. 1(a) Site Geometric and Traffic Characteristics, (b) Simulation Screen Capture

Scenarios Created

Scenarios: do-nothing (DN) and the lane restriction (LR) scenarios.
In DN, no traffic or geometric characteristics were adjusted and the vehicles were allowed to mix with regular traffic.
In the LR scenario the movement of CAVs was restricted to specific lanes. Restriction was done for both inside lanes and outside lanes.

Results

Saturation flow rate

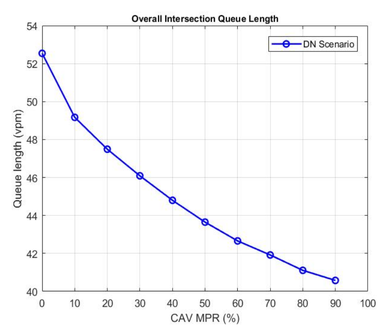


(a) (b) (c)

Fig. 2 Saturation flow for East bound thru, North bound left and North bound thru respectively

Lane restriction policy (with outside lane restriction) shown in figures 2 for all the movements has better performance for all movements at low (<40%) MPR. The DN policy performs better at higher (>40%) MPR

Average Queue Length



Left figure shows gradual decrease in queue length with increasing MPR for DN scenario. Right figure shows that the outside lane restriction policy is better at lower MPR (<30%).

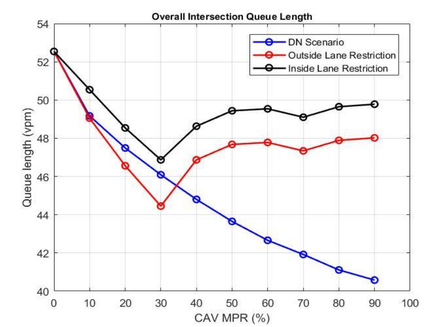


Fig. 3 (a) Average queue length for DN scenario, (b) Average queue length in DN and LR scenarios

Control Delay

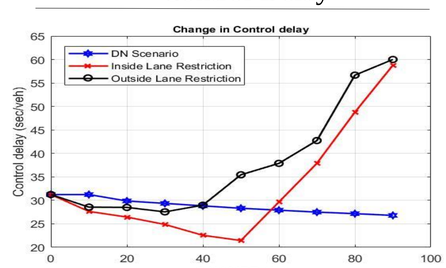


Fig. 4 Change in Control delay for each scenario

Table 1. Level of Service (LOS)

	Outside lane		Inside lane	
CAV MPR (%)	Control delay (sec/veh.)	LOS	Control delay (sec/veh.)	LOS
0	31.24	C	31.24	C
10	27.65	C	28.56	C
20	26.44	C	28.50	C
30	24.87	B	27.55	C
40	22.56	B	28.98	C
50	21.45	B	35.45	D
60	29.65	C	37.88	D
70	37.89	D	42.74	D
80	48.78	D	56.67	E
90	58.78	E	60.01	E

From Figure 4, restricting the CAVs to the outside lane is more efficient at low (<40%)MPR), but the DN policy is better at CAV MPR more than 40%. Control delay in form of LOS is shown in Table 1.

Summary of Findings

- For the DN scenario, improvement in saturation flow was only obtained between MPR 30% and 70%, then constant values were observed.
- The LR scenario gave a better performance than the DN scenario at low MPR, it then falls to a worse performance at high MPR.
- Control delay reduced faster when the CAVs were restricted to the outside lane. But at higher MPR it reaches LOS E.
- In both lane restriction cases (outside/inside lane), the outside lane restriction was seen to give better performance at low MPR.

Conclusion

This study investigates the effects of CAV operations at signalized intersections. We used VISSIM microsimulation software to analyze performance measures by varying the percentage of CAVs in the traffic stream. Also, lane restriction policy was investigated and was observed to perform better at lower penetration of CAV.

Future Work

- Effect of CAV on urban street segments and lane restriction policy will be tested.
- Changes in human factors will be investigated to determine the prevailing driver behaviors based on CAV MPR.
- Red light recognition algorithm will be proposed for CAVs.

References

[1] J. Zmud, I. N. Sener, and J. Wagner, "Self-Driving Vehicles: Determinants of Adoption and Conditions of Usage," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2565, pp. 57–64, Jan. 2016.
[2] L. Fu and B. Hellinga, "Delay variability at signalized intersections," *Transp. Res. Rec. J. Transp. Res. Board*, no. 1710, pp. 215–221, 2000.