



Developing Highway Capacity Manual Capacity Adjustment Factors for Connected and Automated Traffic at Two-Way Stop-Controlled Intersections

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Abstract: Connected and automated vehicles (CAVs) hold great promise in enhancing transportation operations and roadway capacity. However, there is still limited guidance in the field of highway capacity analysis to help agencies account for the potential benefits. This paper investigates the impact of CAVs on the capacity of two-way-stop-controlled (TWSC) intersections and quantifies capacity adjustments under different CAV scenarios. An isolated TWSC intersection is considered in this research to analyze the CAV impacts on various intersection movement capacities under different CAV market penetration rates (MPRs) and conflict flow rates (CFRs). To model CAVs, cooperative adaptive cruise control (CACC) is considered because it directly impacts the vehicle's longitudinal car-following behavior and therefore the capacity. Additionally, enhanced gap-acceptance behavior based on vehicle-to-vehicle (V2V) communication is included because it can benefit minor road movements via advanced notifications. This paper collects data from customized, well-calibrated TWSC simulation models constructed in commercially available software. The results show that with the increase in MPRs, CAVs can substantially enhance the capacity of the stop or yield controlled movements, and the improvement is more significant under low CFR scenarios. CAVs can also reduce the follow-up headway and thus improve the potential capacity based on the existing HCM TWSC capacity estimation method. Finally, based on the data collected from the simulation, a capacity adjustment factor (CAF) table is proposed for HCM implementation. DOI: 10.1061/JTEPBS.7EENG-7082. © 2022 American Society of Civil Engineers.

Author keywords: Connected and automated vehicles (CAVs); Highway Capacity Manual (HCM); Capacity adjustment factor (CAF); Microscopic simulation; Two-way-stop-controlled (TWSC) intersection.

Introduction

The ongoing technological advancements in wireless communication, artificial intelligence, and sensory systems provide opportunities for vehicle automation and connectivity applications. This has led to the development of connected and automated vehicles (CAVs), with safety and mobility applications being incorporated into vehicles' driving decisions to improve traffic performance (Ilu and Som 2019). A tremendous amount of research on CAVs has been presented in the last years from the public and private sectors (Zhan 2019). However, the development of CAVs is still at an early stage, and a high market penetration rate (MPR) of CAVs does not yet exist. This limitation restricts the possibility of obtaining field data to understand the capacity effects of CAV under real-world situations. Due to various implementation uncertainties, most studies currently use simulation with realistic assumptions of CAV operating

parameters to estimate their potential benefits (Stephens et al. 2016). With the foreseeable growth in CAV MPRs, it is worthy of understanding these potential benefits under various MPRs and facility types, especially for transportation planning-level purposes.

Previous studies have provided insights into the various impacts of CAVs. Hartmann et al. (2017) found that CAVs can provide a 45% increase in capacity on basic freeway segments. Wang et al. (2017) pointed out the increment in capacity with the growth of CAV MPR. Although these studies stated that CAV capacity benefits are not significant at low MPR, Adebisi et al. (2020) showed that low CAV MPR could also provide benefits on roadway segments where the prevailing capacity is originally low.

The impact of CAVs has also been quantified by using other performance measures such as fuel savings, efficiency, and safety. For example, Ma et al. (2019) pointed out that CAVs with an eco-drive system can potentially reduce fuel consumption and emissions. Gao et al. (2019) proved the efficiency of 32% fuel consumption savings at signalized intersections when using CAV technologies. Ghiasi et al. (2019) revealed the risk reduction capability of CAVs by using speed harmonization. Le Vine et al. (2015) figured out CAV's impact on the improvement of vehicle delay. By bundling three CAV applications: cooperative adaptive cruise control (CACC), speed harmonization, and cooperative merge, Guo and Ma (2020) found that at 100% CAV MPR, existing freeway segments can be improved to accommodate 120% of their present traffic demand, thereby improving the capacity.

Two-way-stop-controlled (TWSC) intersections are unsignalized intersections at which drivers from the major road approach have absolute priority over drivers from the minor road approach. A vehicle on the minor road must stop before entering the intersection and wait for a critical gap that can accommodate itself

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