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Evaluating the safety and operational impacts of left-turn bay extension at signalized intersections using automated video analysis

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ABSTRACT

Left-turn lanes are commonly introduced to provide space to accommodate comfortable deceleration and adequate storage of turning vehicles. Operational shortcomings may arise due to inadequate length, including overflow and blockage of left-turn entrance by queues on an adjacent through lane. This study investigates the potential safety and operational benefits of treating left-turn lanes by extending the length further upstream a signalized intersection. Video data was collected at three treated left-turn lanes as well as three matched control lanes; all in both before and after treatment conditions. Safety parameters consisted of the counts and severities of traffic conflicts occurring on the left-turn lanes and inside the intersection. There was a marked reduction in traffic conflict counts in all treated sites. The overall treatment effect, which accounts for the simultaneous change in control sites, was 63.2% ($p < 0.05$). There was a marked reduction in frequency of traffic conflicts at different severity levels. The mobility benefit of the treatment was demonstrated in terms of the reduction in average travel time for left-turn as well as through vehicles. The count of traffic signal cycles with blocked left-turn entrance was considerably reduced after the treatment. The use of collision data gathered from more sites is suggested as potential future work to further evaluate this treatment.

1. Introduction

At-grade road intersectionsare vital components of the road network and are essential to its functionality in both urban and rural environments. Despite their functional value, intersections pose a concentrated risk to road users due to the relatively complex tasks they need to undertake in order to safely navigate them, *e.g.*, turning, following signal control, observe priority role, and maintaining awareness of all surrounding road users. One of the most complex tasks performed by drivers at intersections are left-turn movements. Left-turn vehicles are exposed to several hazards including: rear-end collisions by through vehicles, rear-end collisions with other turning movements, right-angle collisions with opposing traffic, and sideswipe as well as rear-end collisions when merging with cross-traffic. Conducting a successful turn maneuver requires multiple decisions in an environment which changes dynamically, *e.g.*, gap search in opposing traffic, following the leading turn vehicles, maintaining adequate speed and vehicle control, and responding promptly and correctly to signal indication and priority rules (Ma et al., 2017). When compared to right-turn movements, left-turn movements can give rise to distinct hazards due to merging onto the faster traffic lanes. This hazard can be elevated for minor-street traffic (Maze et al., 2010). Another distinct hazard is that opposing left-turn vehicles can block each other's visibility, a distinct challenge which is often addressed using positive offset of left-turn lanes (Persaud et al., 2009; Wang and Abdel-Aty, 2007; Osama et al., 2016). In order to achieve an efficient design, practitioners are armed with sophisticated array of traffic control devices as well as geometric design guiding procedures which assist in creating an orderly sharing of intersection resources among different traffic movements.

Traffic signalization is a potent countermeasure to reduce left-turn conflicts with other traffic streams. Traffic signal control in combination with separate left-turn lanes are typically used to improve safety and efficiency of left-turn movements. Traffic signals are used to guide drivers to perform left-turn movements with improved awareness of opposing traffic. Signalization solutions are mainly permissive, protected, protected-permissive, and variable mode (Persaud et al., 2009), with various configurations to signal indication to left-turn drivers (Schattler et al., 2015). Left-turn vehicles face a hazard along intersection approach segments due to their interactions with through traffic along faster lanes. To address this hazard, exclusive left-turn lanes are commonly used whenever possible to reduce conflicts with through traffic. Left-turn lanes serve two basic functions; accommodating

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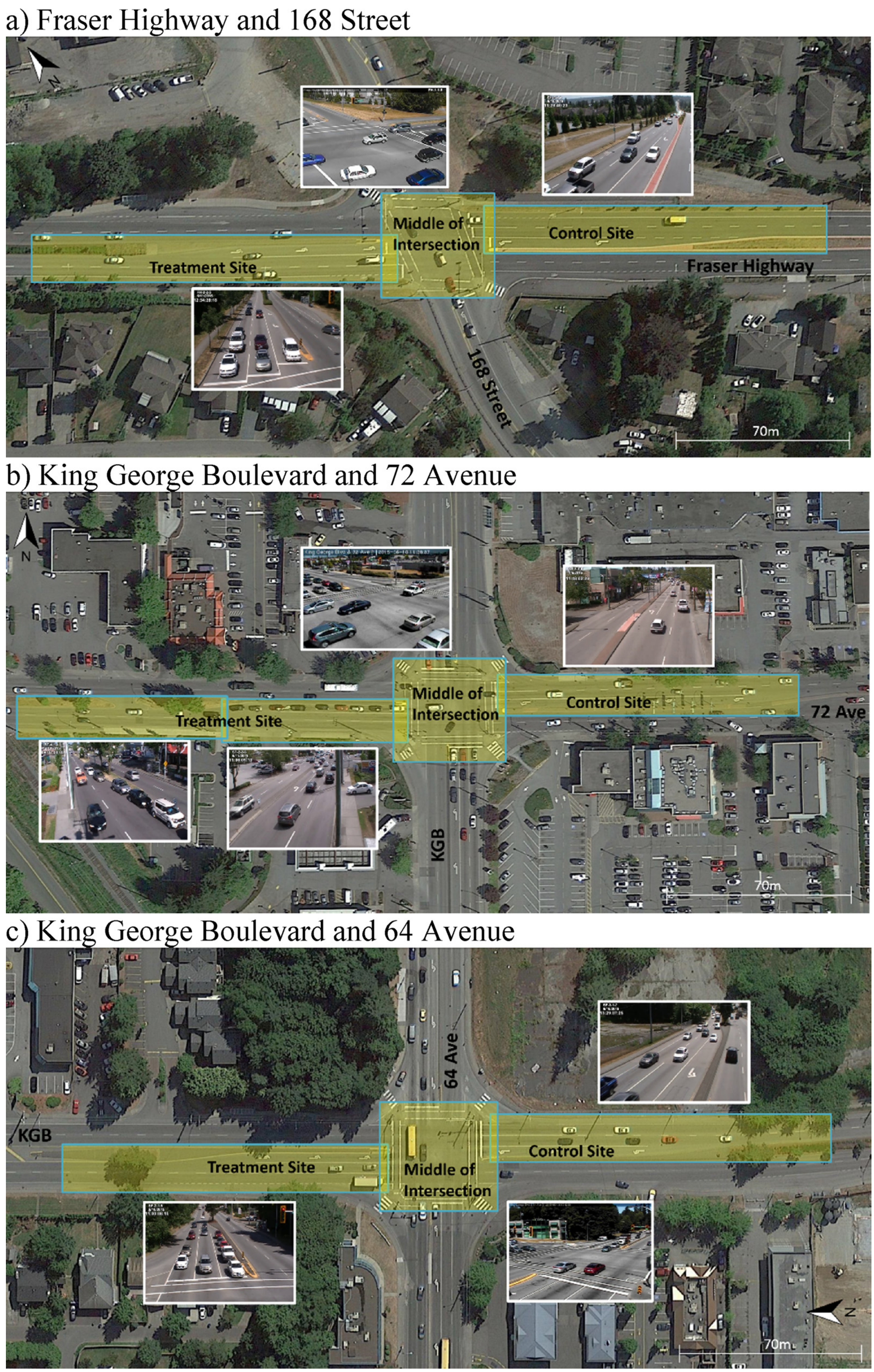

Fig. 1. Treatment intersections: (a) Fraser Highway and 168 Street, (b) King George Boulevard and 72 Avenue, and (c) King George Boulevard and 64 Avenue. Treated left-turn lanes are indicated. Untreated left-turn lanes on control approaches are also indicated. Each box represents a distinct field of view obtained from a unique camera. The number of cameras needed to collected the before and after data equals the number of distinct boxes in each figure.

deceleration and storage of turn vehicles. Left-turn lanes are typically composed of a tapered component and a straight segment. Tapers are introduced to aid in the lane-change and merging into the lane with the safety purpose of reducing rear-end collisions with though traffic and head-on collisions with opposing traffic (Chandler et al., 2013). The length of the full-width storage segment, or storage bay, depends