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Adaptive control algorithm to provide bus priority with a pre-signal

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ABSTRACT

In urban areas, where road space is limited, it is important to provide efficient public and private transportation systems to maximize person throughput, for example from a signalized intersection. To this end, this research looks at providing bus priority using a dedicated bus lane which is terminated upstream of the intersection, and placing an additional signal at this location, called a pre-signal. Although pre-signals are already implemented in some countries (e.g. UK, Denmark, and Switzerland), an adaptive control algorithm which responds to varying traffic demands has not yet been proposed and analyzed in the literature. This research aims to fill that gap by developing an adaptive control algorithm for pre-signals tailored to real-time private and public transportation demands. The necessary infrastructure to operate an adaptive pre-signal is established, and guidelines for implementation are provided. The relevant parameters regarding the boundary conditions for the adaptive algorithm are first determined, and then quantified for a typical case using a micro-simulation model. It is demonstrated with case studies that, under all considered scenarios, implementing a pre-signal with the proposed adaptive control algorithm will result in the least average person delay at the intersection. The algorithm is expected to function well with a wide range of car demands, bus frequencies, and bus passenger occupancies. Moreover, the algorithm is robust to errors in these input values, so exact information is not required.

1. Introduction

Providing priority to public transport (e.g. buses) in cities could reduce travel times of buses. Often, this kind of priority is provided with a dedicated bus lane. However, this might not always be feasible due to space restrictions or political issues. It might not be the most efficient solution either, especially if the bus flow is low, the private vehicle (e.g. car) demand is high, or bottlenecks such as traffic signals exist. Under such situations, alternative strategies could be proposed to provide bus priority while minimizing negative impacts on cars.

One such alternative strategy to provide bus priority at a signalized intersection where a dedicated bus lane exists, is to terminate the dedicated bus lane upstream of the main signal and place an additional signal at this location. This additional signal only controls cars and is hereafter referred to as a pre-signal (Wu and Hounsell, 1998; Guler and Menendez, 2013, 2014a,b). Its configuration is illustrated in Fig. 1a. The primary purpose of the pre-signal is to allow buses to jump the car

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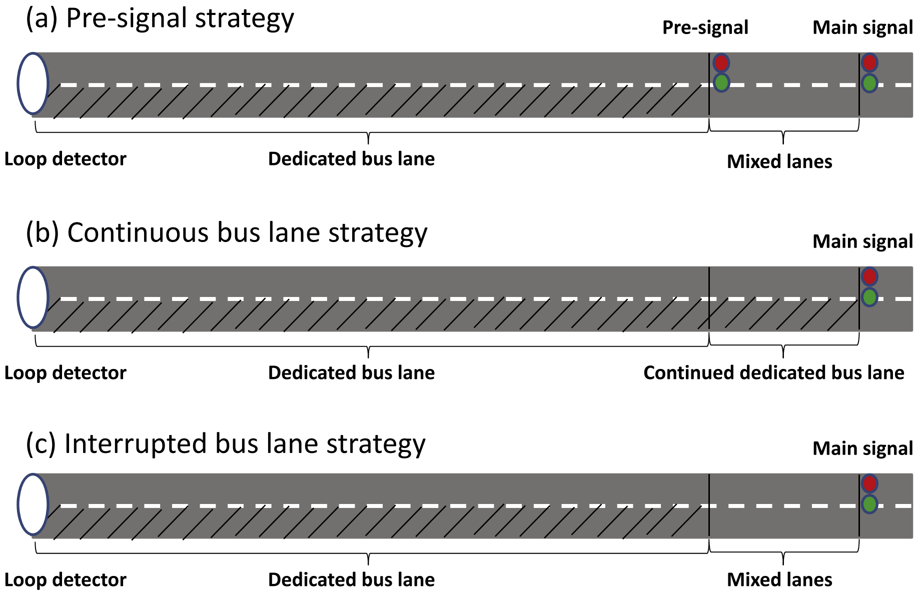

Fig. 1. Layout of the three strategies upstream of the intersection (not drawn to scale).

queues upstream of the intersection while cars can still use all the lanes at the main signal to fully utilize the capacity of the intersection. The distance between the pre-signal and the main signal is long enough to allow a queue of the required number of cars to saturate the green at the main signal for an over saturated scenario. In this way, bus delays are reduced, while the capacity loss at the intersection is minimized.

Some pre-signals are installed around the world (e.g. UK, Denmark, and Switzerland) with slightly different operating strategies. This paper assumes a previously proposed operating strategy (Guler and Menendez, 2014a). In this strategy, the pre-signal turns red for cars in advance of a red main signal by the free-flow travel time, and also when a bus arrives to the pre-signal irrespective of the status of the main signal.[1] The goal is to ensure that the space between the pre-signal and the main signal is kept free of cars for as long as possible, allowing any arriving bus to move in front of the car queue and discharge immediately when the main signal turns green. The pre-signal turns green for cars more than the free-flow travel time in advance of the main signal when no buses are present, such that cars do not experience additional delays, or after the bus has left the pre-signal when buses are present. Note that the pre-signal does not affect the operation of the main signal.

The commonly used strategy of extending the dedicated bus lane up to the main signal is another alternative (hereafter termed the continuous bus lane strategy, see Fig. 1b). This could further reduce the bus delay, and hence the average person delay if the bus occupancy or the bus frequency is high. Another feasible option is to still terminate the bus lane upstream of the main signal, however, do not apply any control to cars at this point and allow buses and cars to freely merge (hereafter termed the interrupted bus lane strategy, see Fig. 1c). This could further increase the traffic throughput and reduce the upstream queue length when traffic demand is high. Notice that the basic configuration of the road section upstream of the pre-signal location is the same across the three strategies.

The purpose of this research is to propose an adaptive control algorithm for pre-signals tailored to real time private and public transportation demands. To do so, this research establishes the analytical form of the boundary conditions (based on the car demand, bus occupancy, and bus frequency) for the implementation of the adaptive control algorithm. These boundary conditions determine when each of the three strategies considered would benefit the system the most. Using these boundary conditions, the control at the pre-signal is determined in real-time. There are two levels of control. The first level is the signal timing control algorithm for the operation of the pre-signal. However, continuously operating the pre-signal might not be optimal based on the boundary conditions. Hence, the two alternative strategies described above (the continuous bus lane strategy or the interrupted bus lane strategy) could be adopted by making the pre-signal continuously green, or using dynamic message signs. Switching between these strategies is possible because it only involves changes in lane allocation for a small portion of the road immediately upstream of the main signal. Hence, the second level control proposes an algorithm to switch between different strategies, based on real time traffic inputs. In this way, traffic operations at the intersection can be controlled dynamically in response to car and bus demand variations throughout the day.

[1] The pre-signal turning red for any bus arrival may not always save bus delays, while it will always impart additional car delays. However, this basic strategy is implemented since it reduces the required inputs to the algorithm, more specifically the knowledge of the existence of a queue at the main signal. Hence, this is a conservative assumption resulting in the car delays representing the worst-case scenario for the pre-signal strategy.