Improving Public Transport Service Regularity using Cooperative Driver Advisory Systems

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High stochasticity is inherent in the nature of public transport (PT) operations. One of the constituents of the variability in travel time, among congestion, roadworks or other disruptions, is the delay caused by signalized intersections. It contributes to a longer and less reliable travel time, which affects also the service regularity of the line. This is reflected into long waiting times, uneven passenger loads, bus bunching, and increase of tailpipe emissions and overall poor level of service.

Operators can react dynamically to any disruption and proceed to corrective actions via different control strategies, among others at bus stations. Station control strategies consist of two categories: holding and stop skipping. Holding is extensively used as a strategy, instructing vehicles to remain at the stop for additional time to maintain regularity or to minimize passenger cost. A literature review on real time control is provided by [1]. It is worth mentioning that holding has been combined with other strategies such as stop skipping [2], boarding limits [3], expressing [4] or combination of more such as in [5].

Today, emerging communication technologies allow not only to monitor the position of buses but also enable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity. This widens the range of control actions that can be applied in real time acting correctively or tackling potential disruptions. In general, typical control actions applied between intersections include speed adjustments and traffic signal priority (TSP). The former has been used by, e.g., [6] to reduce bunching. The latter is provided to public transport vehicles given pre-different criteria [9]. The main drawback of signal priority is the delay added to the rest of the traffic network. Access to signal phase and timing (SPaT) allows developing a new class of driver advisory systems (DASs) referred to green light optimal speed advisory (GLOSA) and green light optimal dwell time advisory (GLODTA). With GLOSA, buses adjust their speed in order to pass through a green phase at a downstream intersection [9]. With GLODTA, a vehicle is instructed to extend the dwell time in order to pass through the next green phase at the next intersection [10]. Integrating GLOSA and GLODTA in synergy with TSP has been proven to be very effective and beneficial for the whole traffic system [11].

We argue that the objectives of both SPaT-based DASs and holding strategies are moving on the same direction and may work in a complementary way. The aim of this study is to combine holding by introducing the aforementioned SPaT DAS and revisit their criteria for speed adjustment and departure from stops to account also for the regularity of a transit line.

The innovative features developed in this study are summarized in the following main points:

- The speed advice by GLOSA, which by default simply advices the driver to target a broad range of speeds with no specific service objective, takes into account the current headways of consecutive buses;

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- The extended dwell time at stops from GLODTA is applied in line with holding criteria for regularity, if holding needed; and
- By integrating the extended GLOSA and GLODTA with line regularity objectives, we consider also to reduce the need for TSP. In our approach, TSP is requested to a limited extend only if the TSP contribution is critical for the vehicle: to pass through a green phase or when provides significant benefits for line regularity.

In this work we derive analytically and present a novel control model in which, when a vehicle approaches a traffic light, the final decision for the speed is not limited to traverse the next intersection. Additionally, the decision involves the actual time headway between consecutive vehicles, in order to arrive evenly spaced as best as possible at stops, hence reducing the level of bunching.

At stops, where holding is applied (Time Control Points or TCPs), holding time for regularity is determined by a simple rule subject to the forward and backward headways [12], [13]. This holding strategy has proven its effectiveness, compared to other strategies [12], [14]. In order to ensure that vehicles, by the time of their departure, will also traverse the intersection without stopping, the additional time needed is estimated via GLODTA. The latter should be within a specific threshold (0.6 to 0.8 of the planned headway) in order to be acceptable. In case of a late arrival, only GLODTA time is checked and triggered only if it results in time saving for the line.

In the control strategy developed, calls for green time extension and green recall are also considered together with DAS, expecting to be in line with the findings of previous studies for need of weak TSP instead of strong TSP [11].

The proposed scheme is tested and evaluated by simulating an artificial high frequency line. Control is applied at specific stops of a bus line that high passenger demand and delays in terms of travel time are observed. We compare the new control criteria with independent application of holding and the DAS at the selected TCPs and a do-nothing case is used as a benchmark.

The main performance indicators used in this study are the adherence of headway of the line as well as total travel time and its variability. Moreover, we will also analyze the delay at the different intersections and the times the vehicles managed to pass through a green phase, in order to compare the results at both network level and at a local scale.

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