Estimation of Arterial Traffic Operations Using Field Detector and Signal Phasing Data

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Issue

Simulation models are increasingly used to evaluate design and control strategies in highway facilities. Simulation models require as input the initial state of traffic conditions in the network. The state-of-the-practice method of generating a set of "reasonable" initial states in traffic simulation is to use a "warm-up" period with given inputs. However, this method becomes time-consuming and unreliable as the network size increases, e.g., the size of the I-210 corridor pilot [1].

Furthermore, the assessment of intersection performance at signalized intersections requires metrics of delay and Level of Service (LOS), which are typically computed based on the HCM methodology [2]. However, the HCM method is very complicated and sometimes produces unreliable estimates [3], particularly when queue spillback and lane blockage occur. Alternative methods on arterial traffic estimation require data inputs in fine-scale, e.g., at 30 seconds [4] or even event-based [5]. However, field data are retrieved and stored at transportation management centers (TMCs) either at each signal cycle, or at 5-minute intervals, which makes them unsuitable for the aforementioned studies.

Therefore, it is crucial to develop a method that can utilize conventional loop detector and signal phasing data from the field and provide direct and reliable traffic estimates (particularly queues) at individual intersection approaches.

Key Research Findings

Traffic states at advance and stopbar detectors can be clearly identified

At signalized intersections, advance and stopbar detectors are installed at different locations to detect vehicle movements and to facilitate signal control. According to their intrinsic traffic characteristics, we develop two occupancy thresholds to divide their flow-occupancy plots into different regimes. Such occupancy thresholds are explicitly calculated based on road geometry, detector placement, signal settings, and default vehicle headways. Each regime corresponds to a different traffic state. Figure 1 illustrates the proposed occupancy thresholds can clearly divide the observed flows and occupancies into different regimes.

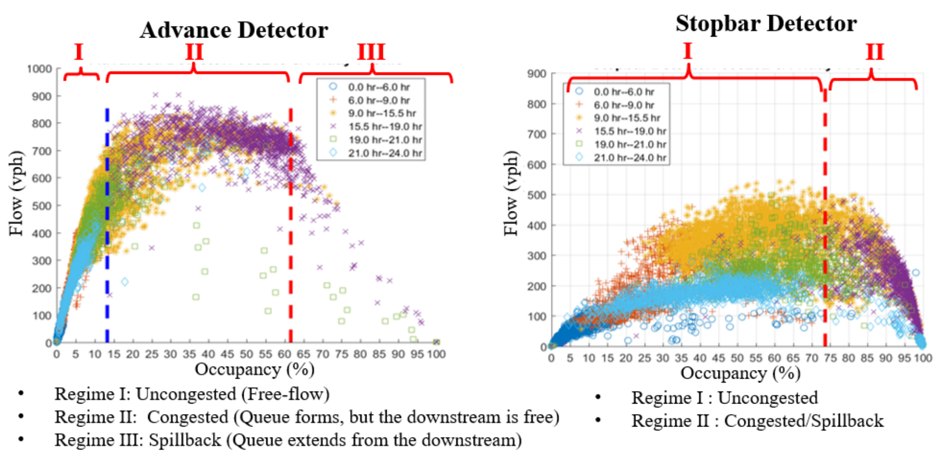

Figure 1. Categorization of traffic states at advance and stopbar detectors.

A linear relationship between Total Queues and Travel Times under traffic congestion

We developed an algorithm to estimate the "average" queues for each traffic movement (i.e., left-turn, straight through, and right-turn) at each intersection approach based on both loop detector and signal phasing data. To assess the performance of the proposed algorithm, we validate the estimated queues with Bluetooth travel times from the field. We selected five intersections along Huntington Drive in the city of Arcadia, CA: @Santa Clara St, @Santa Anita Ave, @First Ave, @Second Ave, and @GateWay Dr, where we have good coverage of detectors and Bluetooth stations. Theoretically, we prove that under traffic congestion, the Total Queues along an arterial have a linear relationship with the corresponding Travel Times. Figure 2 further validates such a linear relationship using the estimated Total Queues and the observed Travel Times at the aforementioned intersections.

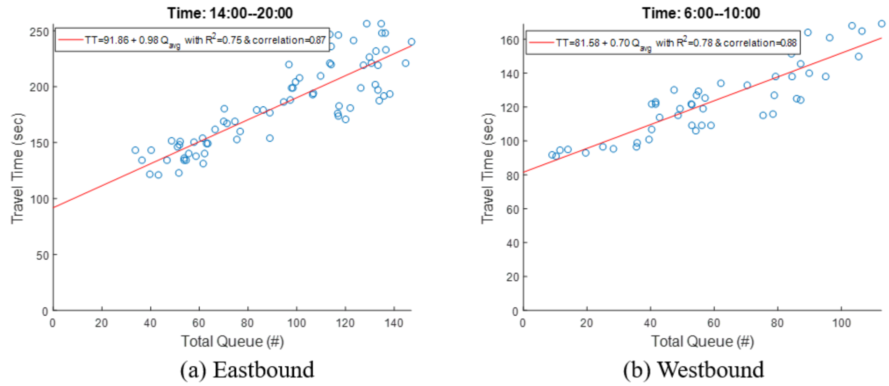

Figure 2. Validation of the linear relationship between Total Queues and Travel Times under traffic congestion at the five intersections along Huntington Dr in Arcadia, CA.

Generation of initial traffic states from the queue estimates: An application to the I-210 Pilot

We demonstrated the application of traffic state initialization using the I-210 corridor network (Figure 3) developed in the Aimsun simulation model [6]. Using Aimsun APIs, we are able to generate "simulated" vehicles from the queue estimates and place them to the right positions at each intersection approach. We are also able to overwrite the active phase at each signalized intersection according to the signal settings in the field.

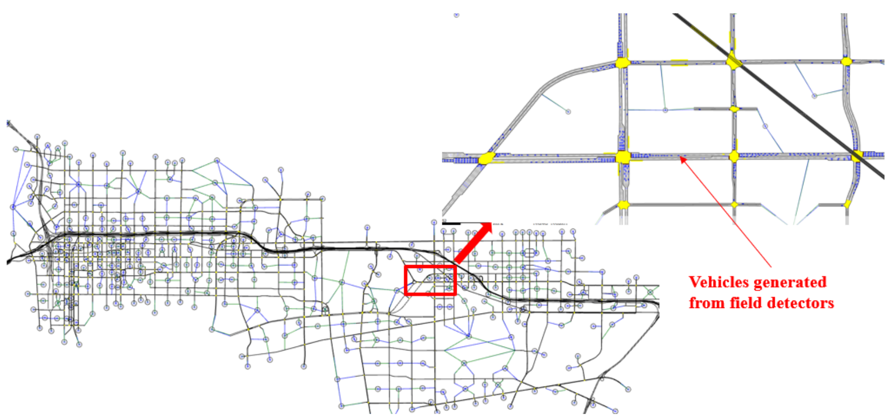

Figure 3. Example of traffic state initialization: the I-210 Aimsun network.

Conclusion

We developed an algorithm that utilizes conventional detector and signal phasing data from the field and provides reliable queue estimates for different traffic movements at an intersection approach. Unlike the traditional method of simulation "warm-up", this method is direct and data-driven, which means better sensing coverage and data quality can further improve estimation accuracy. Also, the proposed method treats each intersection approach independently and can be paralleled to speed up the estimation process. Thus, it is suitable for real-time traffic estimation in large-scale networks.

References

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