A bus-based progression system for arterials with heavy transit flows

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Abstract

Conventional Transit Signal Priority (TSP) controls often reach a limitation for arterials accommodating heavy bus flows since the priority function can significantly increase delay at minor streets.

To improve reliability of bus operations and increase the bus ridership, a bus-based progression model that considers the operational characteristics of transit vehicles is developed.

The VISSIM simulation with an arterial consisting of five intersections and three two-way bus stops demonstrates that the proposed model can significantly reduce bus passenger delay and the per person delays for the entire arterial.

Model Formulation

Control Objective

Max \( \sum_i q_i \bar{b}_i + \sum_i \bar{q}_i \bar{b}_i \)

Constraints

Interference constraints and progression constraints

\( w_i + 0.5\delta_b \leq g_i \), \( \forall i \)

\( \theta_i + 0.5 \delta_b \leq 0 \), \( \pi_0 + 0.5\delta_b \leq g_i \), \( \forall i \)

\( \delta_0 + \tau_i + \theta_i = \delta_{i-1} + \pi_0 + \pi_1 + \pi_C \), \( \forall i \in I' \)

\( \delta_0 + \tau_i + \theta_i = \delta_{i-1} + \pi_0 + \pi_1 + \pi_C \), \( \forall i \in I^T \)

\( \theta_i + 0.5 \delta_b \leq M \times \theta_i \), \( \forall i \in I' \)

\( \pi_0 + 0.5 \delta_b \geq M \times \pi_1 \), \( \forall i \in I' \)

\( \pi_0 + 0.5 \delta_b \geq M \times (1 - \pi_{10}) \), \( \forall i \in I' \)

This group of constraints is introduced to make sure that the bandwidths at the upstream intersections of bus stops will be less than a predetermined upper bound.

Problem Nature

Different from the design of progression for passenger cars, a transit vehicle may need to dwell at a bus stop for a short time when travelling between intersections. A green band designed for transit vehicles shall fully reflect the impact of bus dwell time.

Notably, bus dwell time is dependent on the varying level of passenger demand at bus stops. As shown in most field data, bus dwell time is not a constant, but is stochastic in nature. Hence, failing to fully account for such uncertainty, a transit vehicle may not stay within the preset green band after departing from bus stops.

For both operational and safety concerns, another critical issue to be addressed in design of bus progression system is the storage capacity at bus stops. When the number of arriving buses within a short time period exceeds the storage capacity of a bus stop, the queuing buses may spillback to the nearby intersection and thus block the traffic flows at that intersection. Hence, to prevent the occurrence of such queue spillback, one shall pre-determine an upper bound for bus bandwidth so as to limit the number of buses concurrently arriving at the same stops.

Case Study and Conclusions

Geometry information from Lufang Ave. North in Beijing

Green phase (s): 99,77,66,75,60

Dwell time distribution: N (30,9), N (27,7), N (24,6)

Maximal bandwidth: 50s
Models to be evaluated

Model-1: MAXBAND
Model-2: an extension of MAXBAND with avg. dwell time
Model-3: the proposed model

The proposed model (Model-3) can outperform Model-2 in terms of reducing the average bus delay (15.25%) and average person delay (14.00%).

Further sensitivity analysis indicates that the model is quite robust when two control parameters vary within a range.

Exploring a better method to analyze the stochastic nature of dwell time may be a future research direction.