A REAL-TIME SIGNAL CONTROL STRATEGY FOR MITIGATING THE IMPACT OF BUS STOPS ON URBAN ARTERIALS

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Motivation

• Buses stopping near a signalized intersection may adversely affect the capacity of that intersection.

• The effect might be different depending on the location of the bus stop and the time the bus spends dwelling.
Background

• Several studies have investigated the impact of bus stops on capacity of signalized intersections.

• Few have suggested real-time control strategies to mitigate their impacts:
  • Bus holding strategies have been recommended
Research Objective

• Use kinematic wave theory to quantify the impact of:
  • bus stop location
  • dwell time
  • start and end time of a bus stop event

on the capacity of signalized intersections

• Develop and test a real-time signal control strategy that:
  • mitigates the impacts of bus stop operations on traffic by increasing green time over the next cycle,
  • while ensuring that oversaturation in the cross streets does not last more than one cycle.
Research Approach

• Undersaturated signalized intersections

• Focus is on the impact on the downstream to the bus stop intersection

• Real-time information is available on:
  • Bus arrival and departure time
  • Arrival demand
  • Signal timings

• Arrival demand at the bus stop approach can be higher or lower than the bus stop induced restricted capacity.

• Dwell times do not exceed one cycle length

• Control strategy is implemented in the cycle after the bus leaves the bus stop.
Research Approach

\[
D_R = \max \left\{ \min \left\{ G - \frac{N_o - N_i + N}{q_C}, 0 \right\}, D_{R_{\text{max}}} \right\}
\]

- \(D_R\): red truncation for cross street (\(\leq 0\)) [sec]
- \(G\): green for bus stop approach [sec]
- \(N_o\): number of vehicles that arrived during the cycle(s) the bus is present [veh]
- \(N_i\): number of vehicles served during the cycle(s) the bus is present [veh]
- \(N\): number of vehicles arriving during the cycle following the bus stop event [veh]
- \(q_C\): road capacity of bus stop approach [vph]
- \(D_{R_{\text{max}}}\): maximum red truncation allowed [sec]
Accounting for Impact on Cross-street

\[ D_{R_{max}} \geq \frac{2q_{Ax}C}{q_{Cx}} - 2G_x \]

- \( G_x \): green time for cross-street approach \( x \) [sec]
- \( q_{Ax} \): arrival rate at the cross street [vph]
- \( q_{Cx} \): road capacity of cross street approach [vph]
- \( C \): cycle length [sec]
Research Approach

\[ D_R = \max \left\{ \min \left\{ G - 3600 \frac{N_o - N_i + N}{q_C}, 0 \right\}, D_{R_{max}} \right\} \]

\( D_R \): red truncation for cross street [sec] \((\leq 0)\)
\( G \): green for bus stop approach [sec]
\( N_o \): number of vehicles that arrived during the cycle(s) the bus is present [veh]
\( N_i \): number of vehicles served during the cycle(s) the bus is present [veh]
\( N \): number of vehicles arriving during the next cycle [veh]
\( q_C \): road capacity of bus stop approach [vph]
\( D_{R_{max}} \): maximum red truncation allowed [sec]

\[ N_i = \frac{\tau_C q_C + \tau_I q_I + \tau_A q_A}{3600} \]

\( q_I \): road capacity of signalized approach when a bus is blocking a traffic lane [vph]
\( q_A \): arrival flow at signalized approach [vph]
\( \tau_C, \tau_I, \tau_A \): total time that the flow rate is \( q_C, q_I, q_A \) [sec]
Research Approach
Research Approach

![Graph showing distance and time with labeled points and intervals]
Bus stop event cases

Three parameters define the different cases:

- bus stop location, $X$
- start of bus stop event, $T_o$
- end of bus stop event, $T_e$

in combination with signal timing design and demand

www.sfgate.com

http://en.wikipedia.org/wiki/San_Antonio
Case Identification

Case 1 \( q_A > q_I \) and \( q_A \leq q_I \)

Case 2 \( q_A > q_I \)

Possible \( T_o \) locations

Possible \( T_e \) locations
Example I: control needed
Example II: control not needed
Application

- University and San Pablo Avenues, Berkeley, CA
- Only geometry, phasing scheme, and bus demand was used
- Demands were adjusted so that conditions represent major and minor street operations
- Degrees of saturation:
  - San Pablo Avenue: 0.28 (low), 0.44 (high)
  - University Avenue: 0.57 (low), 0.96 (high)
Application

• Bus stop locations tested:
  • 30, 50, 100, and 500 ft

• Average dwell time = 40 sec
  (with 30 sec standard deviation)

• A bus at a stop was assumed to be blocking a whole traffic lane

• Simulations were performed with AIMSUN
Results: Average Vehicle Delay

Bus stop approach

Cross-street approaches
Results: Average Queue Length

Bus stop approach

Cross-street approaches
Summary

Conclusions:

• For cases that $q_A \leq q_I$ there is rarely a need for control

• When $q_A > q_I$:
  • average delay of bus stop approach can be reduced by 17% (~6 seconds)
  • average delay of cross-street approach increases by 3-5 seconds
  • overall intersection delay decreases

• Highest benefits when:
  • bus stops located close to the stopline
  • bus stop approach has a much higher demand than the cross street
Summary

Advantages:

- It can be implemented for any demand level, bus stop location, and bus dwell time.
  - Therefore, it is applicable to any type of incident on urban signalized arterials.
- No bus arrival prediction is necessary
- Input data are available from widely used sensing technologies.

http://ilovebikingsf.com/category/bicycle-infrastructure/
Next Steps

- Test different geometries, demand patterns, number of phases
- More than one bus stop events within one cycle or consecutive cycles
- Dwell times longer than a cycle length
- Investigate the impact of farside bus stops on capacity of the intersection just upstream of them
Questions?

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