
Near-Side, Far-Side, Uphill, Downhill: Impact of Bus Stop Location on Bus Delay

By: Joseph SanClemente
Peter Furth (Advisor)

Outline

- Background
- Incremental Delay Models
 1. Grade
 2. Signalized Intersections
- Conclusion

Background

- Part of a larger project concerned with optimizing bus stop locations (TCRP Transit-IDEA)
- Stop spacing models in literature take delay as a constant value
- Objective: Determine the incremental delay due to stopping on upgrades and near signalized intersections.

Objective

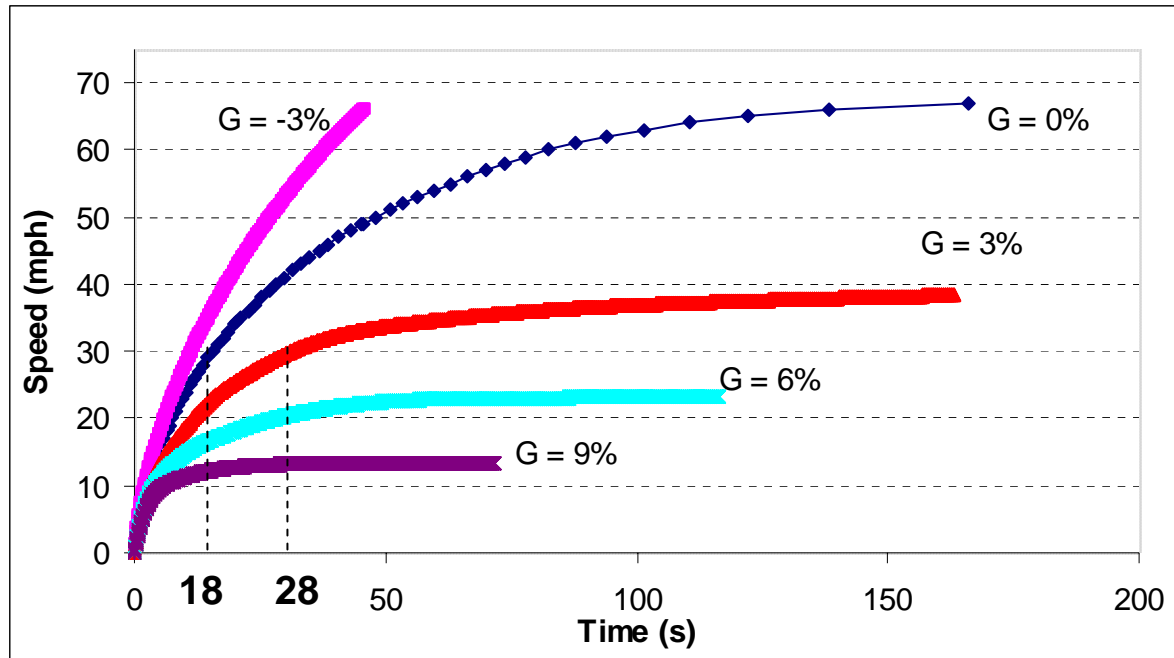
Why do we care?

- Factors may be used in a discrete location model
- To determine the impact of adding/removing/relocating a stop.
- For guidance on locating stops on hills, near-side, and far-side.

Model 1: Incremental Stopping Delay Due to Grade

- Industry practice is to specify rather weak engine performance.

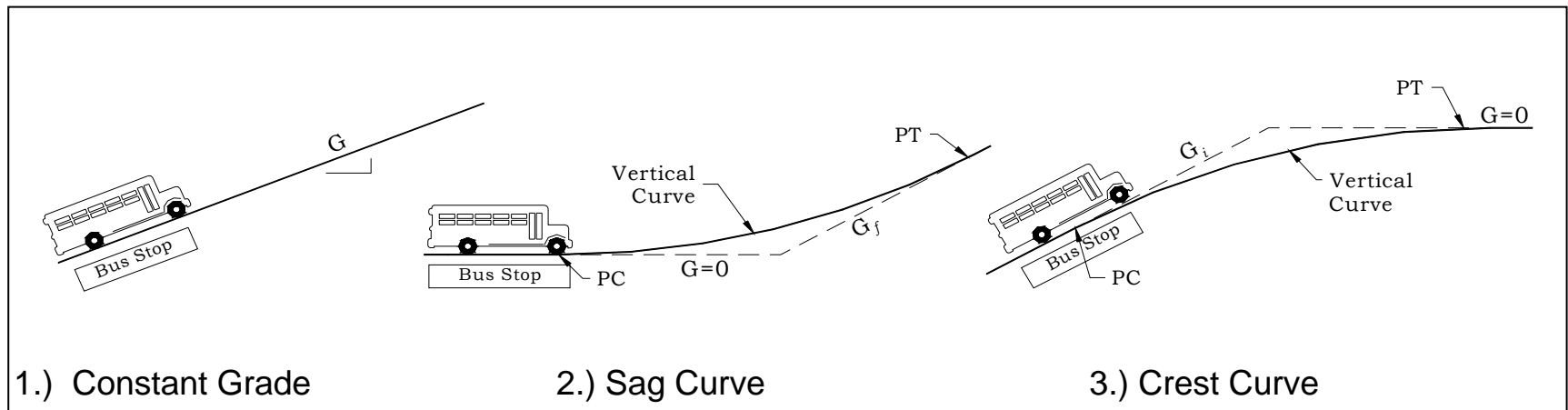
Acceleration Profile for Various Grades



- For large grades, electric buses are used
- Even small grades are a challenge for many buses, often resulting in large acceleration delays.

Incremental Stopping Delay Due to Grade

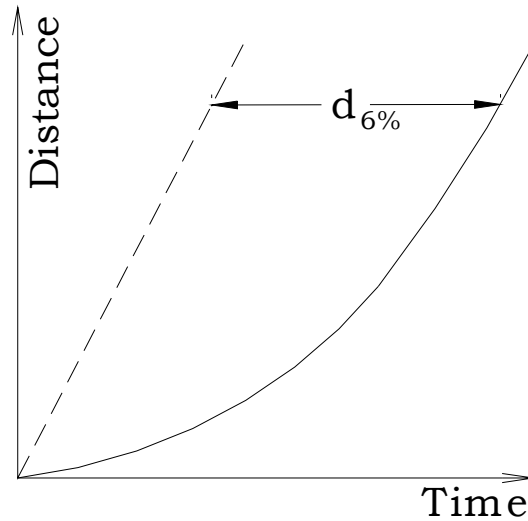
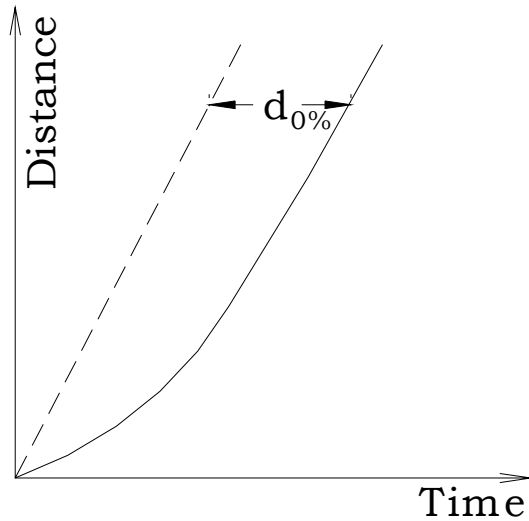
- For a stop spacing study, detailed roadway geometry is unlikely to be available.
- Therefore, 3 typical roadway profiles were examined.



- Acceleration was modeled as a function of grade and speed:

$$a(u, G) = a_o(u) - gG$$

Incremental Stopping Delay Due to Grade

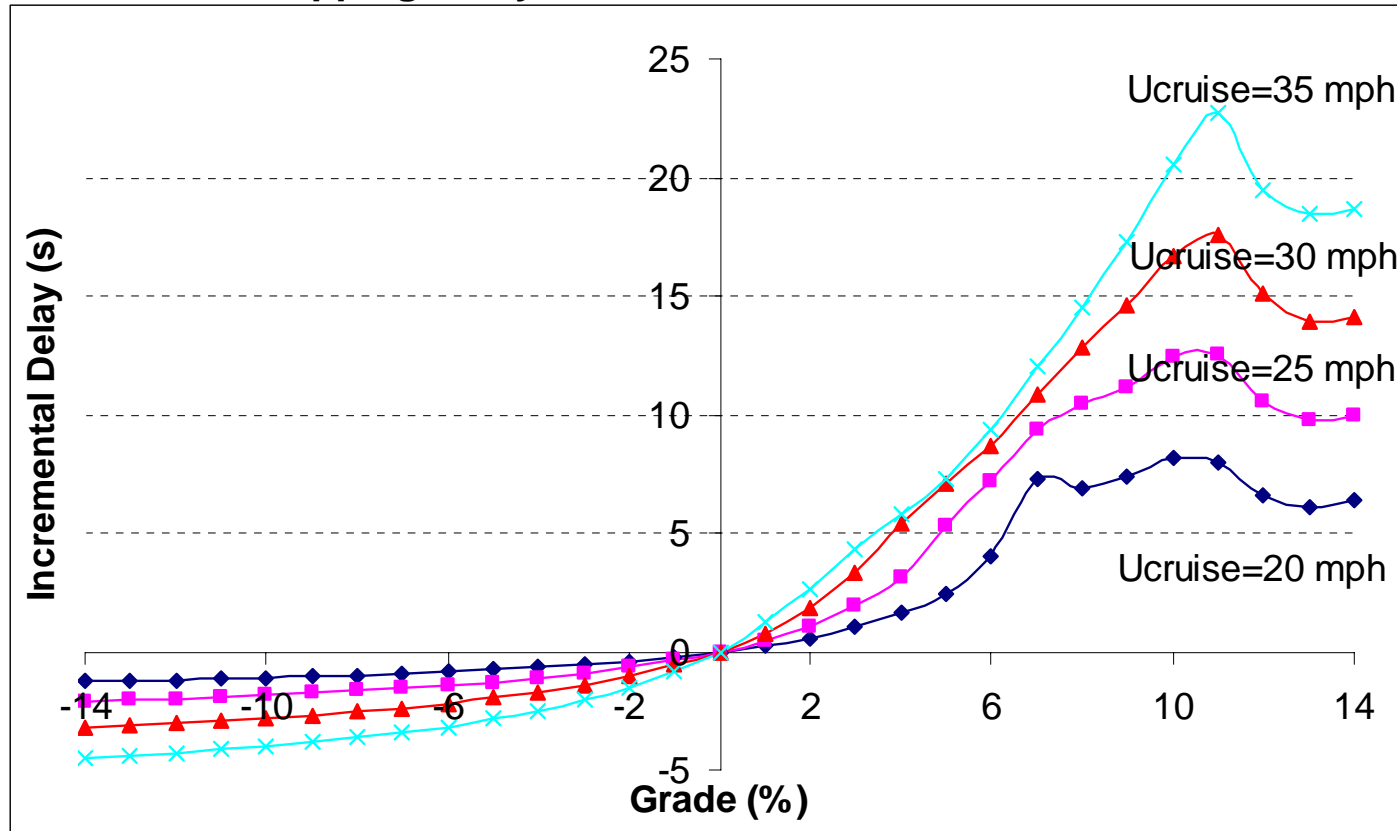


- Bus no-stop trajectory
- Acceleration from stop trajectory

$$\text{Incremental Delay} = d_{6\%} - d_{0\%}$$

Incremental Stopping Delay Due to Grade

Incremental Stopping Delay Due to Grade, Constant Grade Profile



Incremental Stopping Delay Due to Grade, for Various Grades

Grade (%)	Constant Grade/Crest Curves		Sag Curves		Overall Average
	20 - 25 (mph)	30 - 35 (mph)	20 - 25 (mph)	30 - 35 (mph)	All speeds
-10 to -14	-1	-3	-2	-4	-2
-7 to -9	-1	-3	-1	-4	-2
-4 to -6	-1	-2	-1	-3	-2
-1 to -3	0	-1	0	-2	-1
0	0	0	0	0	0
1 to 3	1	3	1	2	2
4 to 6	5	7	3	4	5
7 to 9	9	13	6	7	9
10 to 12	10	18	7	11	11
13 to 14	8	16	6	12	10

Example: relocating a stop from the middle of a hill with an 8% grade to a hill top can reduce running time by 10 seconds.

Model 2: Net Delay Due to Signalized Intersections

Near-Side vs. Far-Side: Conflicting Views

- Near-side is BETTER: bus can serve stop while waiting for red light – effectively killing two birds with one stone!
- Near-side is WORSE: can result in stopping for two red lights.

Methodology

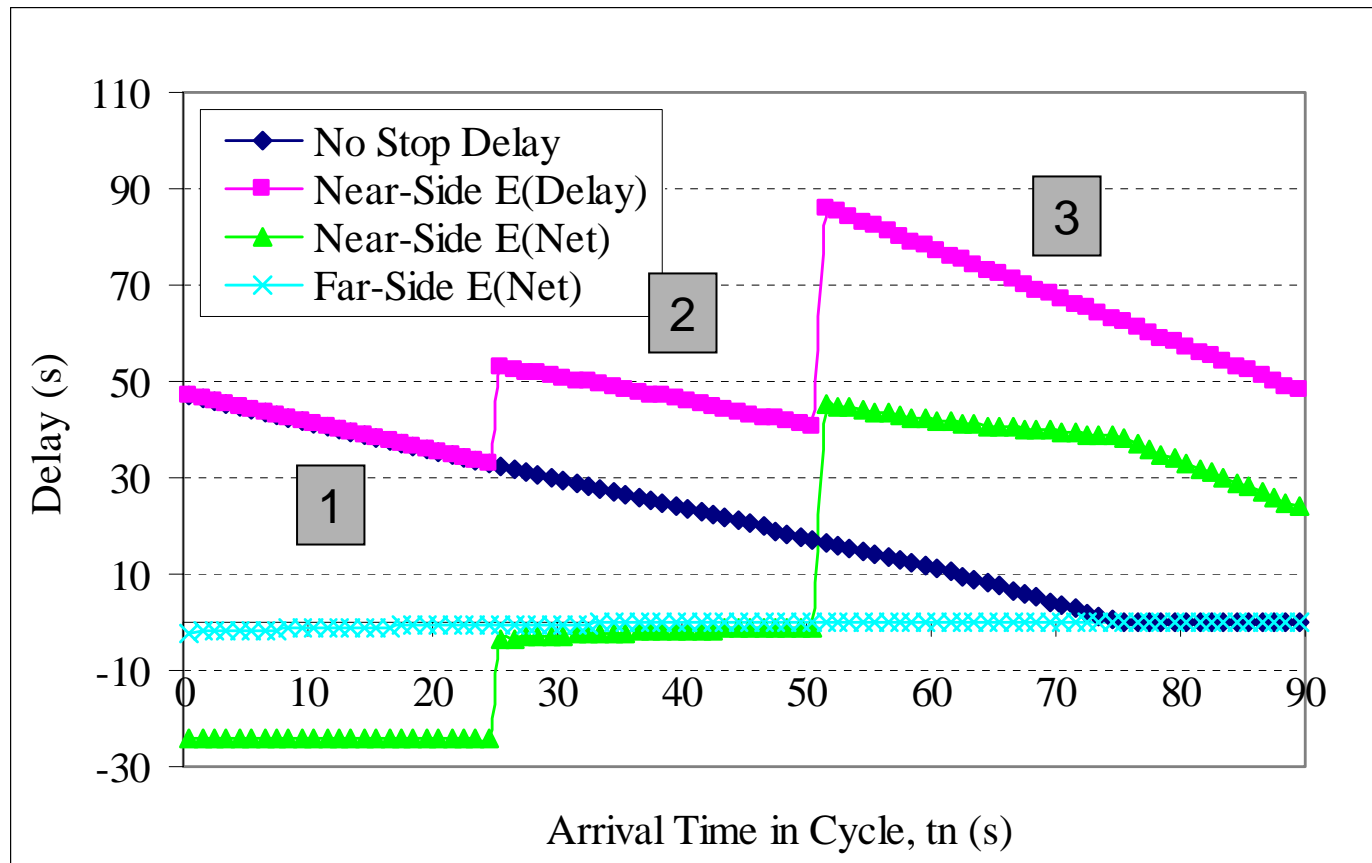
- Microscopic deterministic simulation
- Bus arrival time varied from 0 to C (C = cycle length)
- Inputs: C, r/C, v/c, u, dwell time, stop setback distance, etc.
- Bus delay is plotted as a function of the bus's projected arrival time in the cycle

Net Delay

- Net Delay = Total Delay – Control Delay – d_{normal}
- Where:
 - Control Delay = delay if bus did not stop and continued through the intersection.
 - d_{normal} = bus delay at a stop away from influence of a traffic signal.

Net Delay Due to Signalized Intersections

Bus Delay vs. Arrival Time in Cycle: Base Case



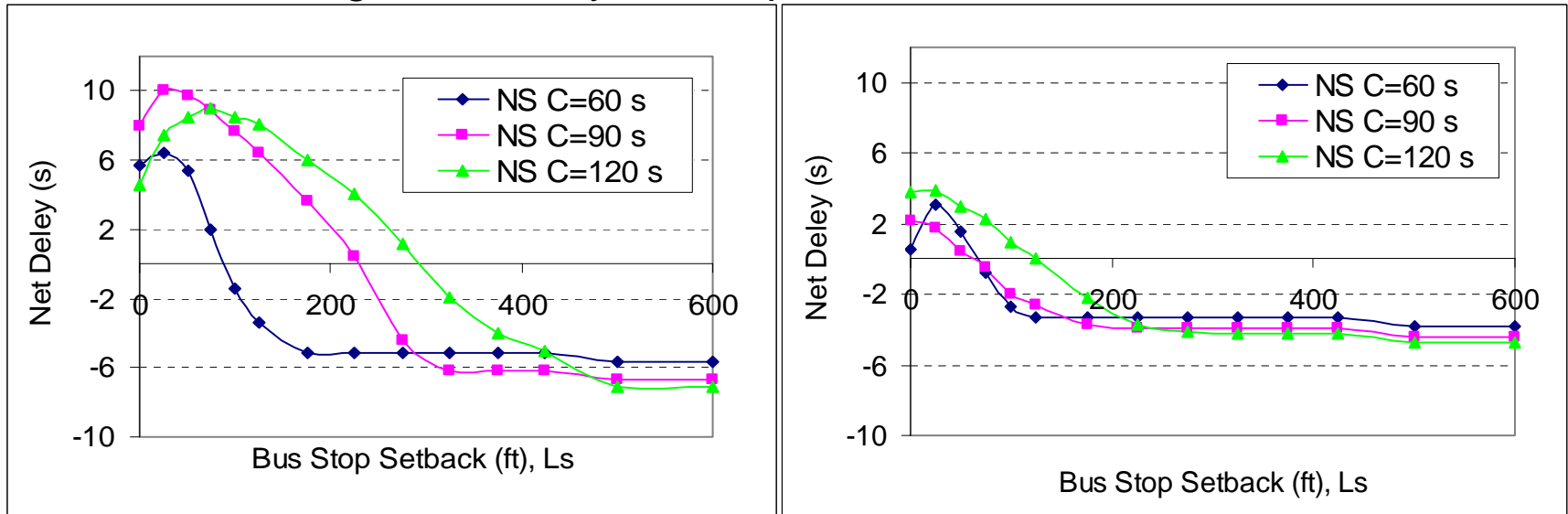
Net Delay Due to Signalized Intersections

Results for other Parameters

- Evaluated wide range of parameter values – averaging over bus arrival times.
- Far-Side: net delay always remains near zero,
- Near-Side: Delay varies greatly – most important parameters are those that determine:
 - (1) how much of the cycle the queue blocks the stop, and
 - (2) how costly it is to have to wait for the next green.

Net Delay Due to Signalized Intersections

Near-Side Average Net Delay vs. Stop Setback



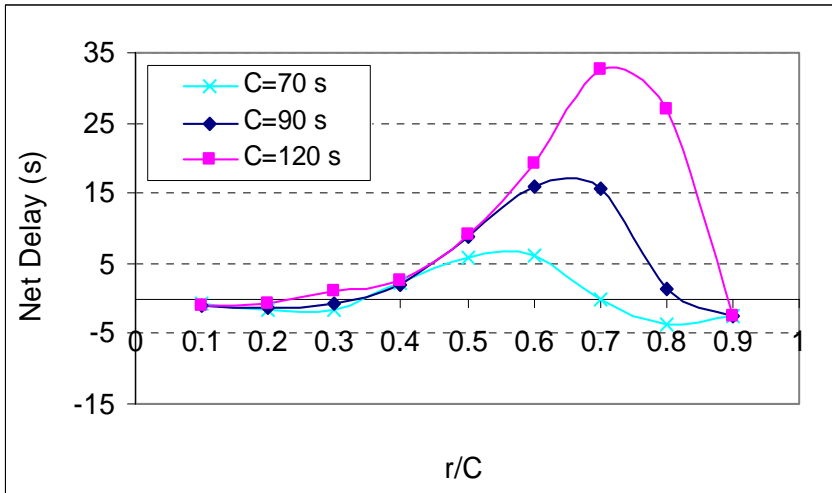
a.) $v/c = 0.8$

b.) $v/c = 0.6$

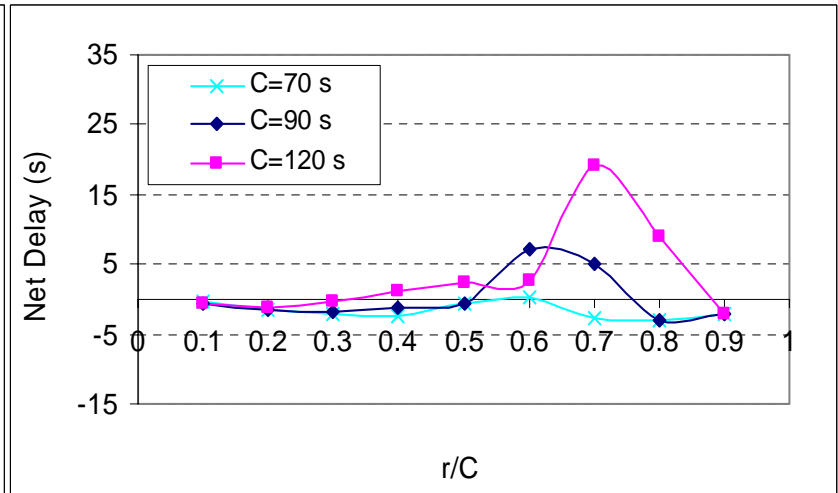
- Stop setback: when setback extends beyond the range of the queue, the signal has no effect on delay.
- Cycle Length: For short cycles, queues are shorter and the penalty of missing the first green is smaller.
- Low v/c or Bus Lane: Optimal stop placement on the stop line, resulting in negative incremental delay.

Net Delay Due to Signalized Intersections

Near-Side Average Net Delay vs. Fraction Red (no overtaking)



a.) $v/c = 0.8$



b.) $v/c = 0.6$

- Short red ratios: (e.g., major st. intersecting a minor st.) delay is minimal since queues never become long and buses rarely miss the first green.
- Overtaking Permitted: If cars can overtake stopped bus, bus delay can be a few seconds larger.
- Key parameter is the ratio L_s/LQ_{Ave} , where L_s = stop setback and $LQ_{Ave} = 0.5vt_q^2 L_{veh} / C$ = average reach of queue.

Net Delay Due to Signalized Intersections

Expected Incremental Net Delay for Near-Side Stops

r/C	Bus Stop Setback Ratio	v/c = 0.6			v/c = 0.8		
(ft/s)	Ls:LQAve	C = 60s	C = 90s	C = 120s	C = 60s	C = 90s	C = 120s
0.9	0.00		3	28		15	43
	0.25			18		10	32
	0.50			8			17
	1.00	-3			-3		
	1.50	-3					
	2.00						
	3.00						
0.5	0.00		3	4	9	7	5
	0.25	3	3	5	8	11	10
	0.50	4		4	8	11	10
	1.00	3		3		8	8
	1.50					4	3
	2.00						
	3.00						
0.3	0.00 - 3.00						

Note: Blank cells = (-2 to 2 seconds)

Conclusion

- Results may be used in the context of a study of alternative stop locations.
- Where possible:
 - Stop placement should avoid steep upgrades.
 - Far-side stop placement is always a safe bet.
 - Near-side delay can be reduced by reducing queue interaction.
 - For exclusive bus lanes, placing the stop at the stop line yields the least delay.
 - It is possible to suggest an ideal location for a bus stop on an approach with frequent cycle overflows

Thank you.