



Using Hardware-in-the-Loop Simulation to Evaluate Signal Control Strategies for Transit Signal Priority

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Acknowledgments

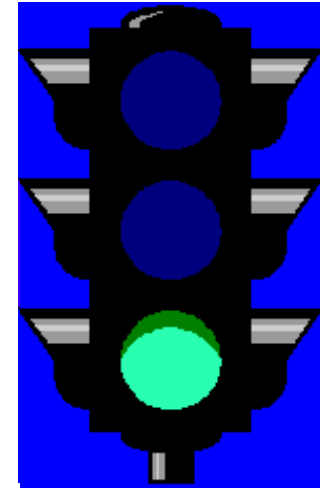
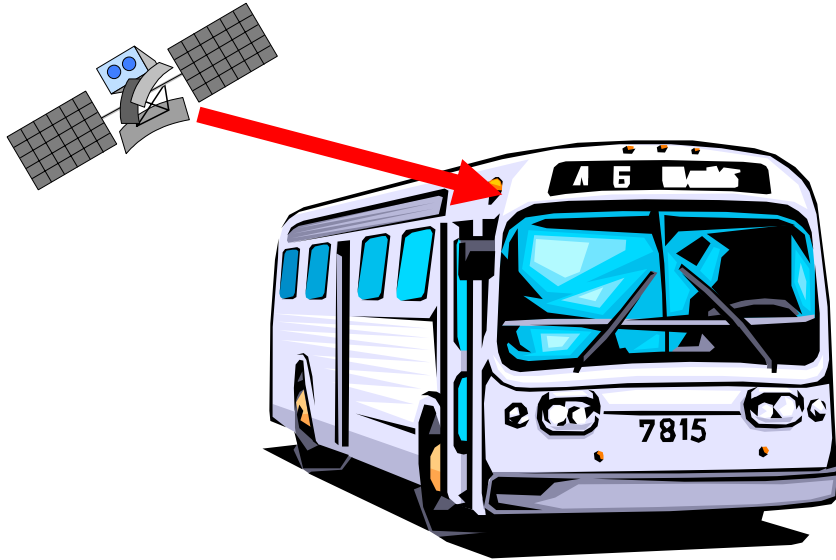
- Dave Crout of TriMet
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Outline

- Introduction
- Objective
- Study Design
- Test Scenarios
- Results
- Conclusions
- Future Research

Introduction

- Transit Signal Priority Concept



- Smart bus knows location and schedule status
- Bus communicates priority request to signal
- Local controller provides priority

Tri-Met Buses

- The "Smart Bus"

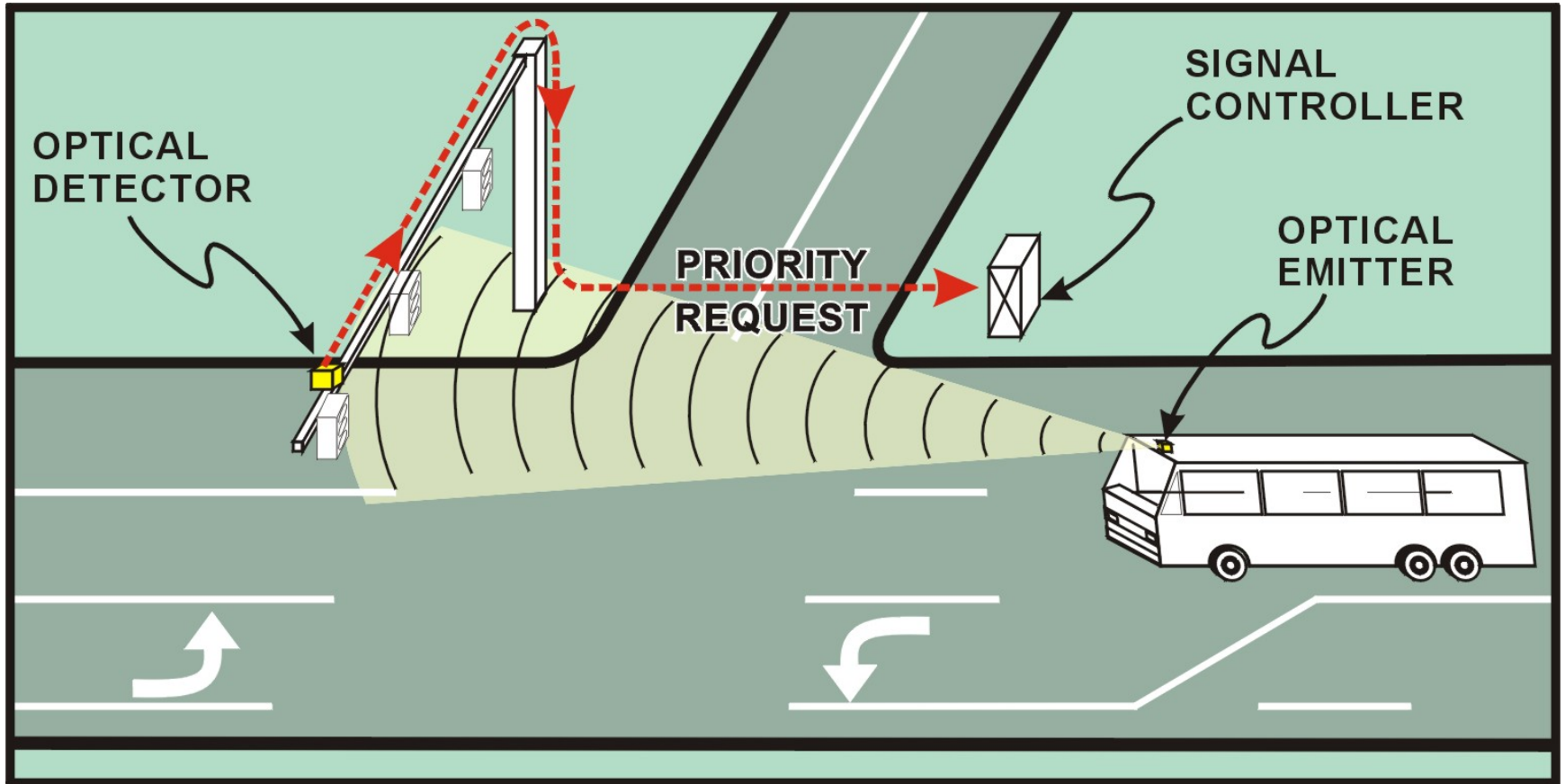
PCMI A Card



Control Head

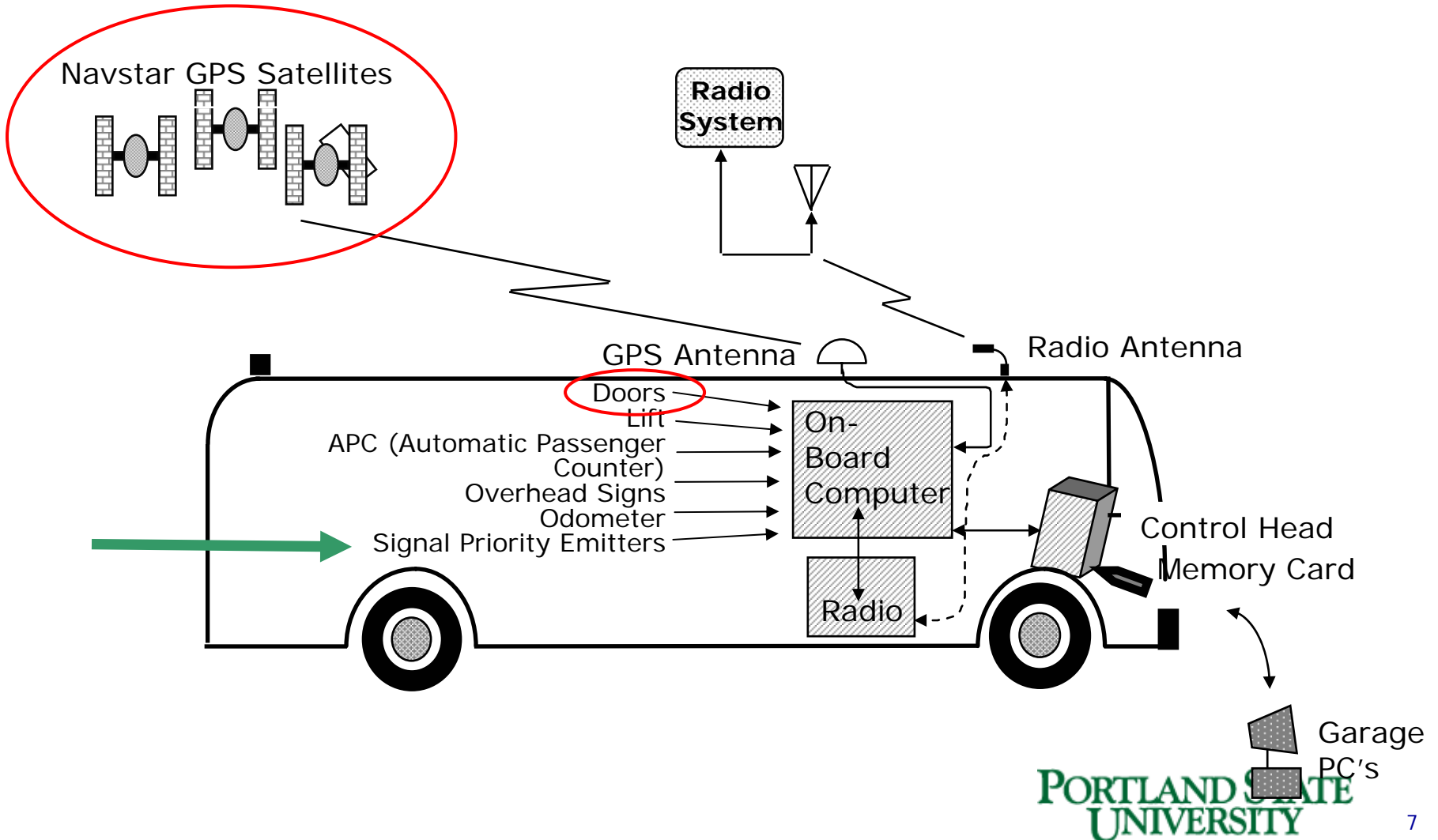


Call for TSP



TSP in Portland, OR

- Conditional Priority with TriMet's Bus Dispatch System



Priority Framework

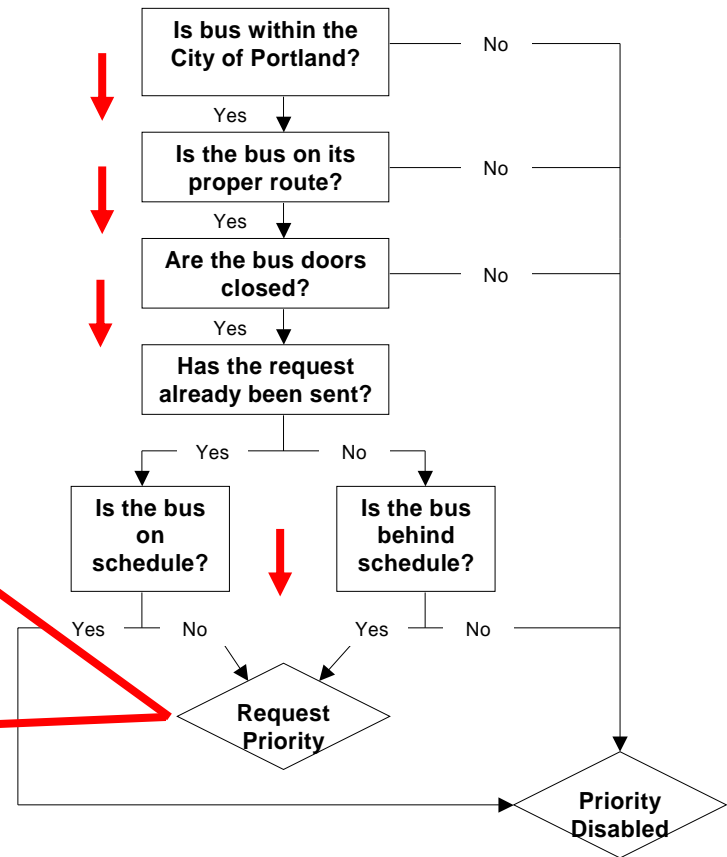
Green Extension



Conditional
Priority

Red Truncation

Framework



Objective

- Examine relationship between Transit Signal Priority and bus stop location
- Explore concept of hardware-in-the-loop simulation

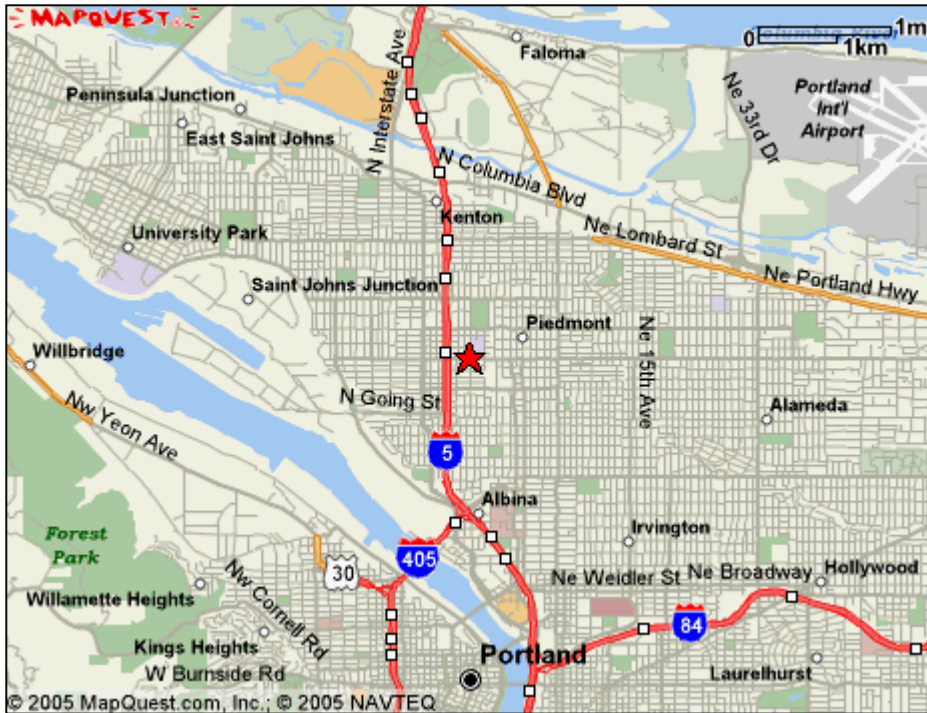
Measures of Effectiveness:

- Bus Travel Times
- Bus Intersection Delays
- Side Street Delays

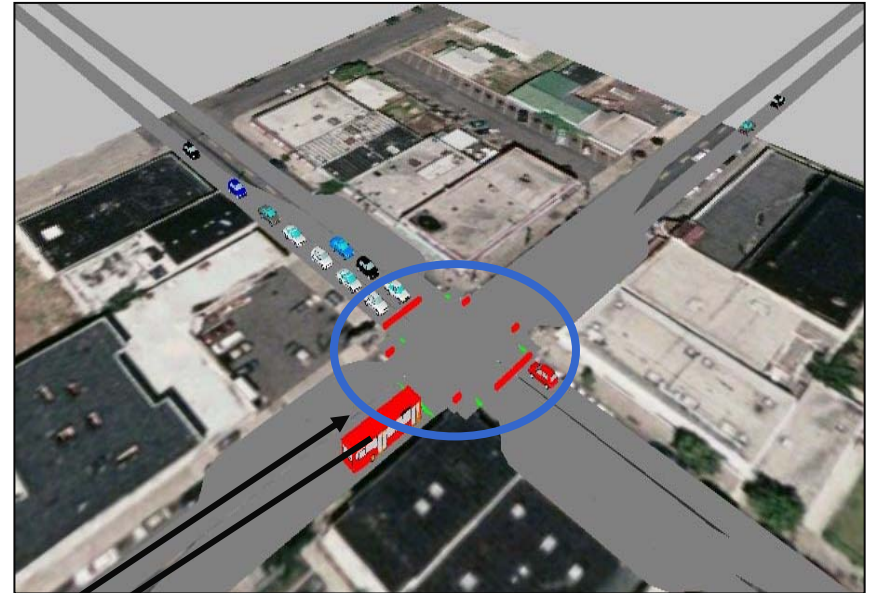
Study Design

Model a single intersection

N. Killingsworth at N. Albina

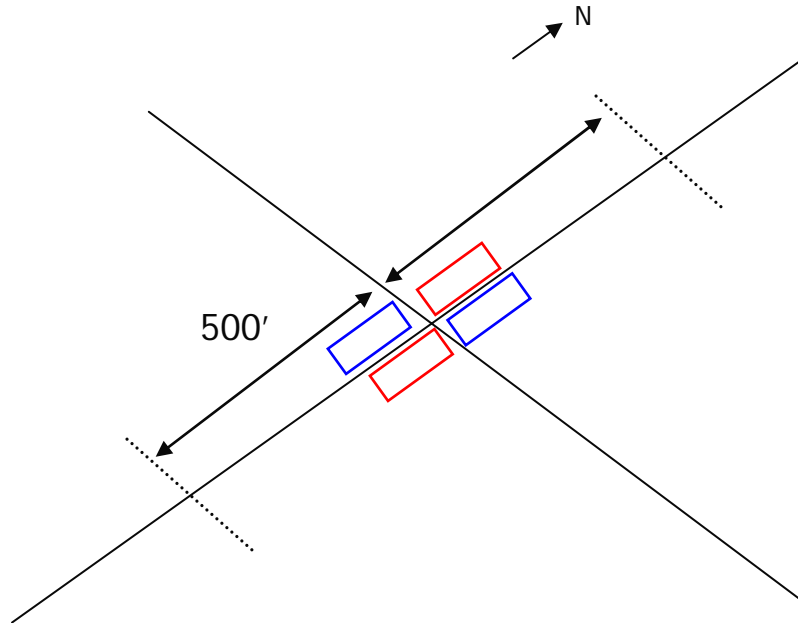


Study Design



- VISSIM 3.70
- Model 170E Signal Controller
- NIATT Controller Interface Device
- **“Hardware-in-the-loop” simulation**

Study Design



- TSP Detection Range = 500'
- 12 minute one-way headways
- Dwell times of 20-40 seconds
- 70 second cycle time
 - 31 green, 3 amber, 1 AR

Phase	Traffic Volumes			
	Volume (veh/hr)	Thru	Right	Left
2 NB	500	70%	15%	15%
4 EB	500	85%	5%	10%
6 SB	500	50%	20%	30%
8 WB	500	80%	15%	5%

- Green Extension: + 12 seconds
- Red Truncation: - 12 seconds

Test Scenarios



Far Side Transit Stops



Near Side Transit Stops

	TSP	No TSP
Near Side Stop	X	X
Far Side Stop	X	X

Study Design

- 25-hour real-time simulation runs for each scenario, 2 runs per scenario
- Aggregate data every hour (50 samples)
 - Vehicle/Person delay
 - Travel Times
 - Queue Lengths
 - Much More...

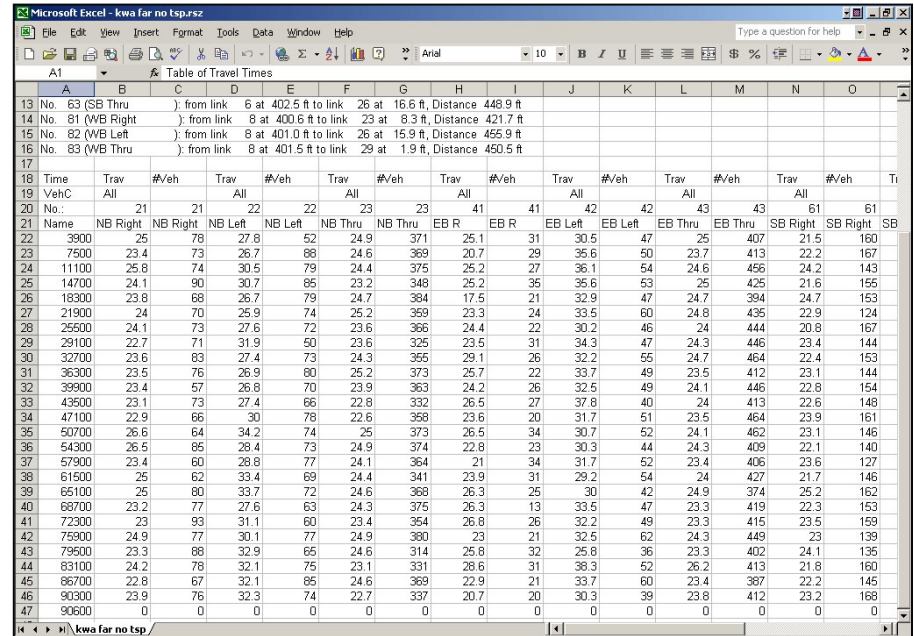


Table of Travel Times															
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
13	No. 63 (SB Thru)	)	from link	6 at 402.5 ft to link	26 at 16.6 ft, Distance	448.9 ft									
14	No. 81 (WB Right)	)	from link	8 at 400.6 ft to link	23 at 8.3 ft, Distance	421.7 ft									
15	No. 82 (WB Left)	)	from link	8 at 401.0 ft to link	26 at 15.9 ft, Distance	455.9 ft									
16	No. 83 (WB Thru)	)	from link	8 at 401.5 ft to link	29 at 1.9 ft, Distance	450.5 ft									
17															
18	Time	Trav	#/veh	Trav	#/veh	Trav	#/veh	Trav	#/veh	Trav	#/veh	Trav	#/veh	Trav	#/veh
19	VehC	All	All	All	All	All	All	All	All	All	All	All	All	All	All
20	No.	21	21	22	22	23	23	41	41	42	42	43	43	61	61
21	Name	NB Right	NB Right	NB Left	NB Left	NB Thru	NB Thru	EB R	EB R	EB Left	EB Left	EB Thru	EB Thru	SB Right	SB Right
22		3900	25	78	27.8	52	24.9	371	25.1	31	30.5	47	25	407	21.5
23		7500	23.4	73	26.7	88	24.6	369	20.7	29	35.6	60	23.7	413	22.2
24		11100	25.8	74	30.5	79	24.4	375	25.2	27	36.1	54	24.6	456	24.2
25		14700	24.1	90	30.7	85	23.2	348	25.2	35	35.6	53	25	425	21.6
26		18300	23.8	68	26.7	79	24.7	384	17.5	21	32.9	47	24.7	394	24.7
27		21900	24	70	25.9	74	25.2	359	23.3	24	33.5	60	24.8	435	22.9
28		25500	24.1	73	27.6	72	23.6	366	24.4	22	30.2	46	24	444	20.8
29		29100	22.7	71	31.9	50	23.6	325	23.5	31	34.3	47	24.3	446	23.4
30		32700	23.6	83	27.4	73	24.3	355	29.1	26	32.2	55	24.7	464	22.4
31		36300	23.5	76	26.9	80	25.2	373	25.7	22	33.7	49	23.5	412	23.1
32		39900	23.4	57	26.8	70	23.9	363	24.2	26	32.5	49	24.1	446	22.8
33		43500	23.1	73	27.4	66	22.8	332	26.5	27	37.8	40	24	413	22.6
34		47100	22.9	66	30	78	22.6	358	23.6	20	31.7	51	23.5	464	23.9
35		50700	26.6	64	34.2	74	25	373	26.5	34	30.7	52	24.1	462	23.1
36		54300	26.5	85	28.4	73	24.9	374	22.8	23	30.3	44	24.3	409	22.1
37		57900	23.4	60	28.8	77	24.1	364	21	34	31.7	52	23.4	406	23.6
38		61500	25	62	33.4	69	24.4	341	23.9	31	29.2	54	24	427	21.7
39		65100	25	80	33.7	72	24.6	368	26.3	25	30	42	24.9	374	25.2
40		68700	23.2	77	27.6	63	24.3	375	26.3	13	33.5	47	23.3	419	22.3
41		72300	23	93	31.1	60	23.4	354	26.8	26	32.2	49	23.3	415	23.5
42		75900	24.9	77	30.1	77	24.9	380	23	21	32.5	62	24.3	449	23
43		79500	23.3	88	32.9	65	24.6	314	25.8	32	25.8	36	23.3	402	24.1
44		83100	24.2	78	32.1	75	23.1	331	28.6	31	38.3	52	26.2	413	21.8
45		86700	22.8	67	32.1	85	24.6	369	22.9	21	33.7	60	23.4	387	22.2
46		90300	23.9	76	32.3	74	22.7	337	20.7	20	30.3	39	23.8	412	23.2
47		90600	0	0	0	0	0	0	0	0	0	0	0	0	0

Example: Without TSP



Example: With TSP



Results

Travel Times

	NearSide without TSP	FarSide without TSP	NearSide with TSP	FarSide with TSP
Average Bus Travel Time (Sec.)	79.1	76.8	84.1	68.3

- Far Side Bus Stops: 11% travel time reduction
- Near Side Bus Stops: 6% travel time *increase*

Results

Intersection Delay

Bus	NearSide		Overall Delay Savings (s)	FarSide		Overall Delay Savings (s)
	W/o TSP Delay (s)	w/ TSP Delay (s)		w/o TSP Delay (s)	w/ TSP Delay (s)	
Average (NB/SB)	27.6	32.5	+4.9	25.2	16.7	-8.5
Standard Deviation	5.34	5.56		5.18	2.05	

- Far Side Bus Stops: 33% delay savings
- Near Side Bus Stops: 18% delay *increase*

Results

Side Street Delays

Side Street	NearSide Delay (s)		Overall Delay Change (s)	FarSide Delay (s)		Overall Delay Change (s)
	w/o TSP	w/ TSP		w/o TSP	w/ TSP	
EB	17.8	21.1	+3.3	17.1	19.6	+2.5
WB	16.2	18.4	+2.2	16.6	18.6	+2.0
Average	17.0	19.7	+2.7	16.8	19.1	+2.3

- Minimal delays on side street (non-transit street)

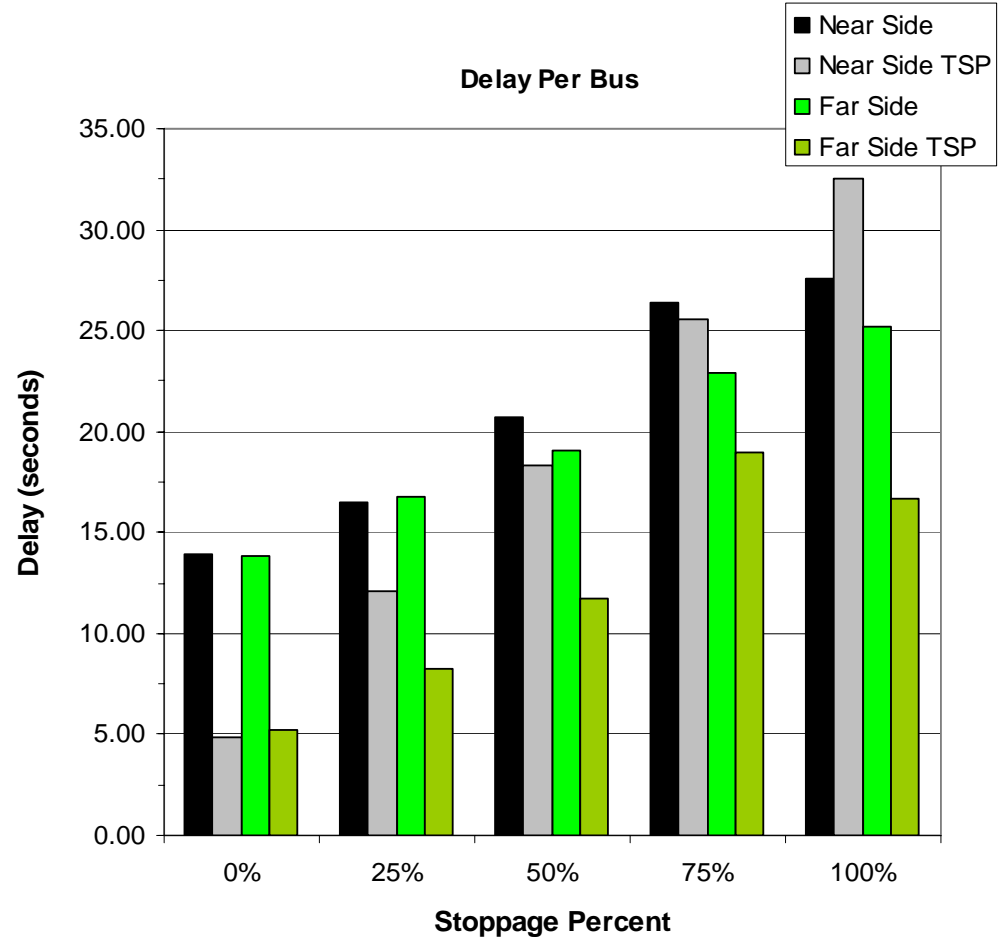
Results

Stop Utilization

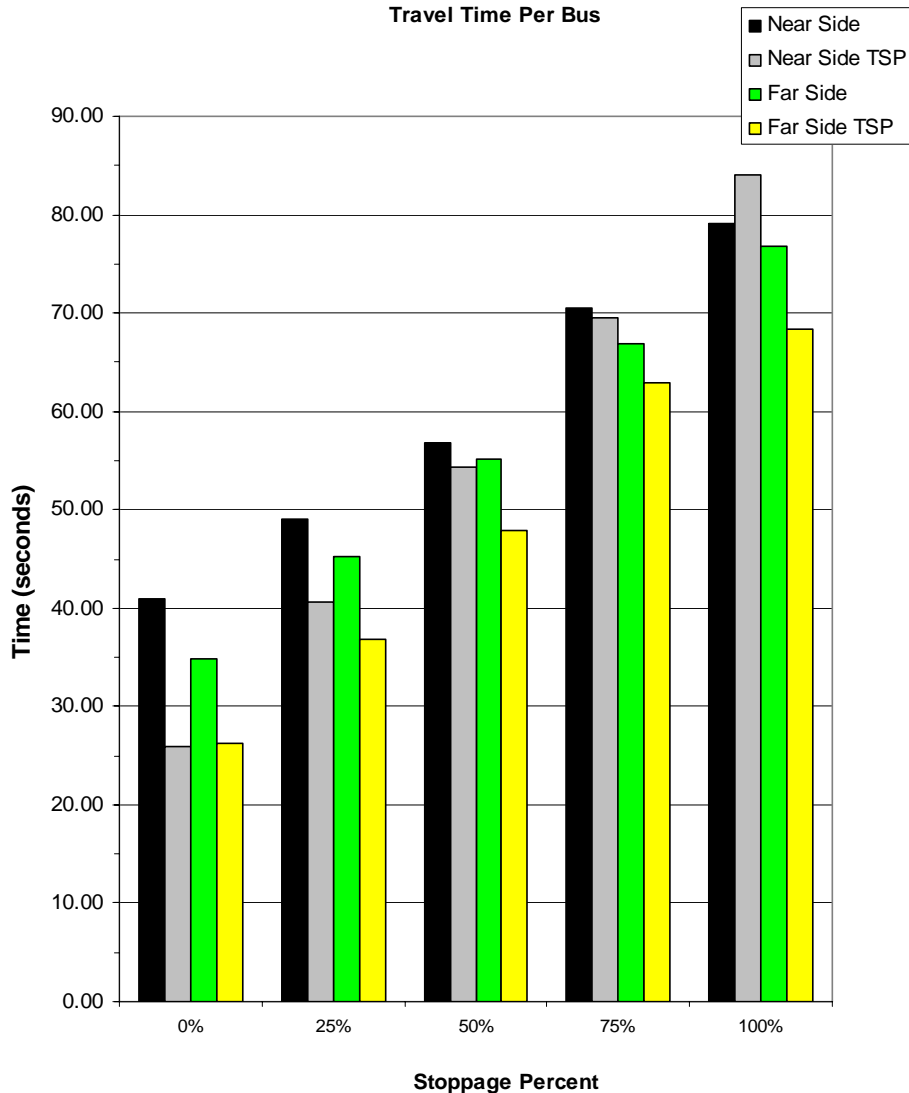
0%, 25%, 50%, 75%, 100%

Delay

- Near Side and Far Side results are similar with 0% stoppage
 - Near Side reacts as if it was a Far Side stop
- Near Side delay reductions decrease with higher utilization
- Far side receives benefits regardless of stoppage



Travel Time



- Near Side travel time reduction occurs in every scenario EXCEPT 100% stoppage
- Far side receives travel time reduction for all scenarios.
- Far Side results have better consistency with TSP
- Unpredictability of dwell time for Near Side can make call for TSP ineffective.

Conclusions

- With no Transit Signal Priority, bus stop location has a negligible effect on delays and travel times.
- With Transit Signal Priority AND a very high stop utilization, far side stops are clearly beneficial.
- Minimal increase in side street delay with short cycle length (70 seconds) and modest volume to capacity ratios.

Future

- Effect of detection length
- Different Transit Signal Priority plans (i.e. no green extensions)
- Traffic volumes

For More Information

<http://www.its.pdx.edu/tsp.html>

