Empirical evaluation of Transit Signal Priority Effectiveness and Efficiency

Wei Feng
Ph.D. Candidate
wfeng@pdx.edu

Miguel Figliozzi
Associate Professor
figliozzi@pdx.edu
Department of Civil and Environmental Engineering
Portland State University

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Outline

- Introduction
- Objectives
- Corridor description
- TSP effectiveness analysis
- TSP efficiency evaluation
- Summary
- Next steps

Introduction

- Transit signal priority (TSP) strategies
  - Green extension
  - Early green (red truncation)
- TSP grant conditions
  - Unconditional
  - Conditional
  - Real-time optimization

Introduction

Data archive systems in SE Powell Blvd, Portland, Oregon

- **Bus stop event data**
  - Bus arrival/departure time and passenger activities at each bus stop
- **SCATS data**
  - Signal phase logs (start/end time for each phase including TSP phase) at each intersection
  - Traffic counts (15 minutes aggregation level) for each lane at each intersection

Objectives

At the intersection level, evaluate

1. TSP effectiveness:

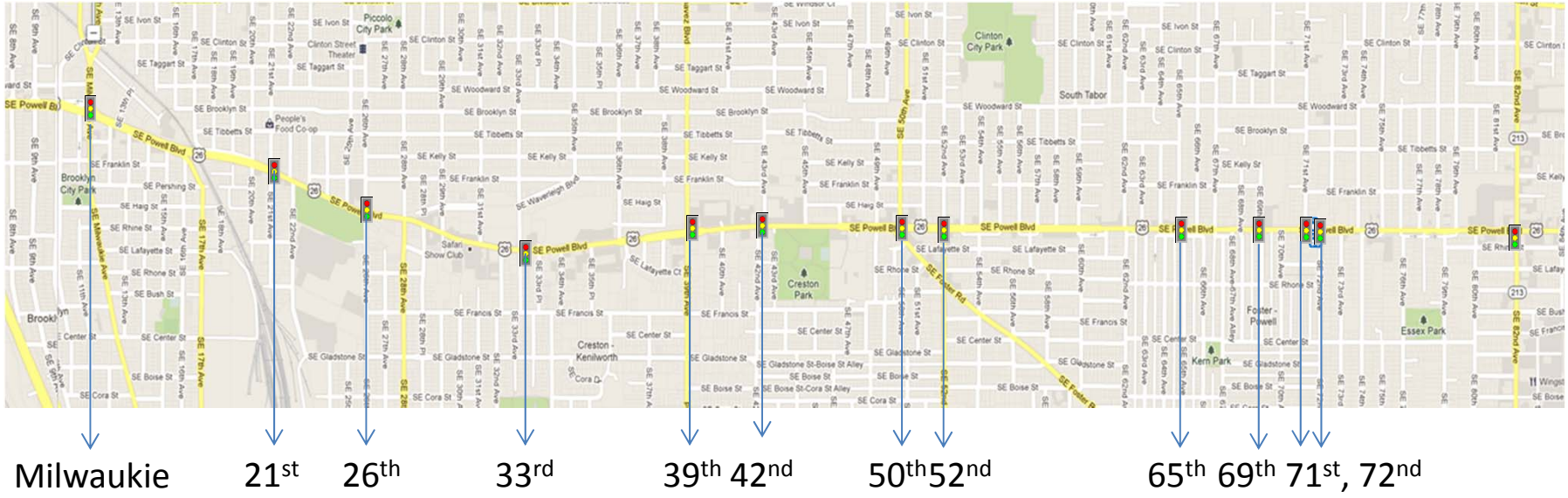
   whether TSP helped reduce bus travel time crossing intersection (and by how much), controlling for traffic conditions and signal delay

2. TSP efficiency

   How many granted TSP phases were effective and how many were wasted

Corridor description

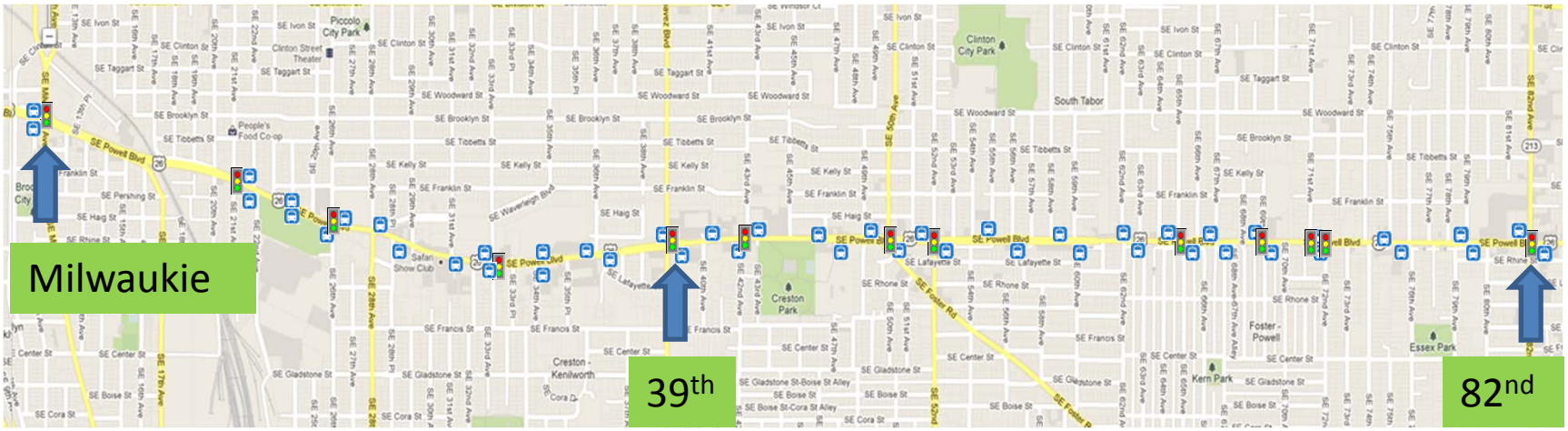
Traffic signals



- 12 SCATS signals implemented in November, 2011
- TSP was turned off in April, 2013

Corridor description

Bus route 9 and 66



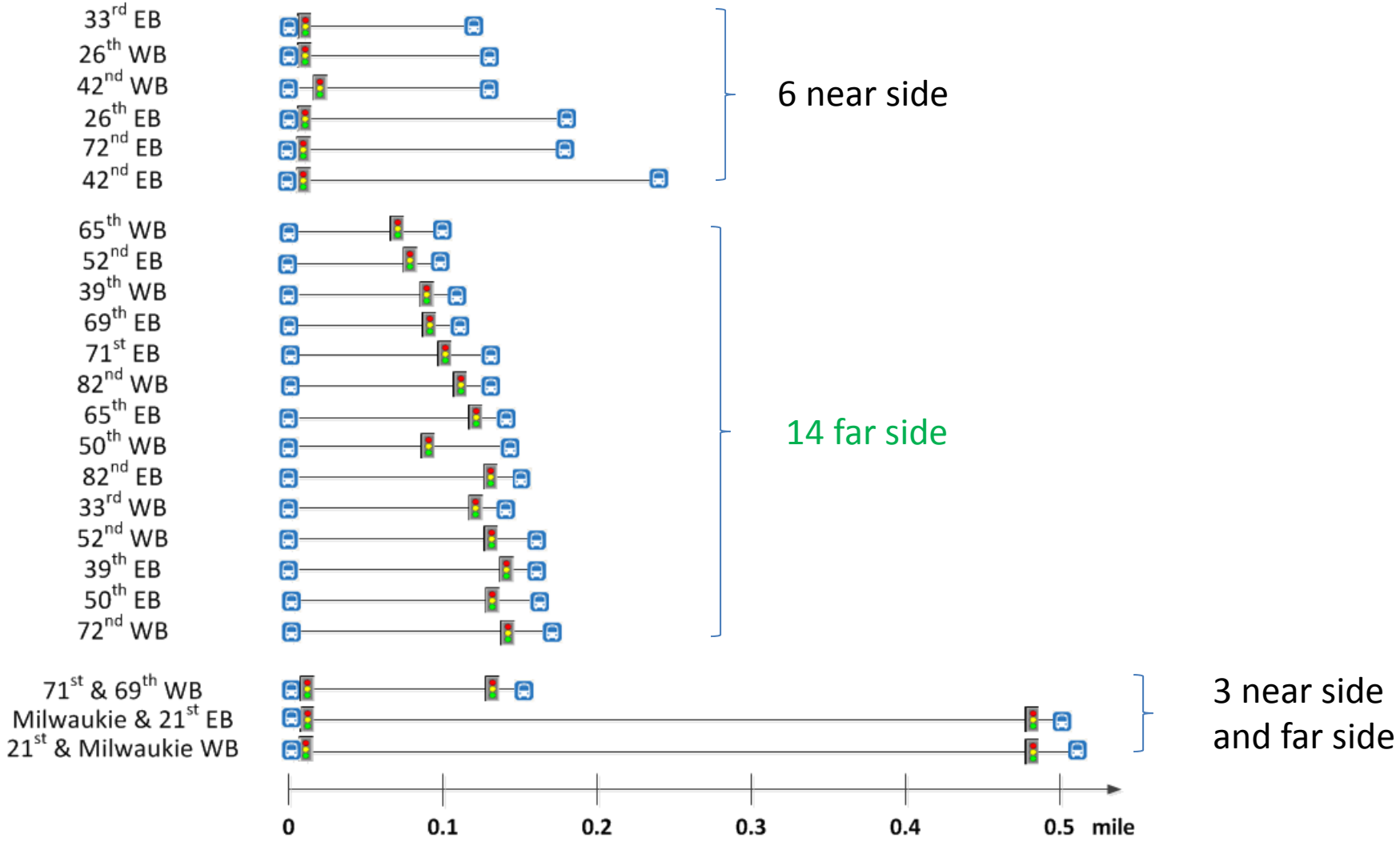
EB: 24 bus stops, **WB:** 25 bus stops

Time points:

Milwaukie Ave.
39th Ave.
82nd Ave.

Corridor description

Bus stop-to-stop segments with at least one signal



TSP effectiveness analysis

- Bus stop-to-stop travel time

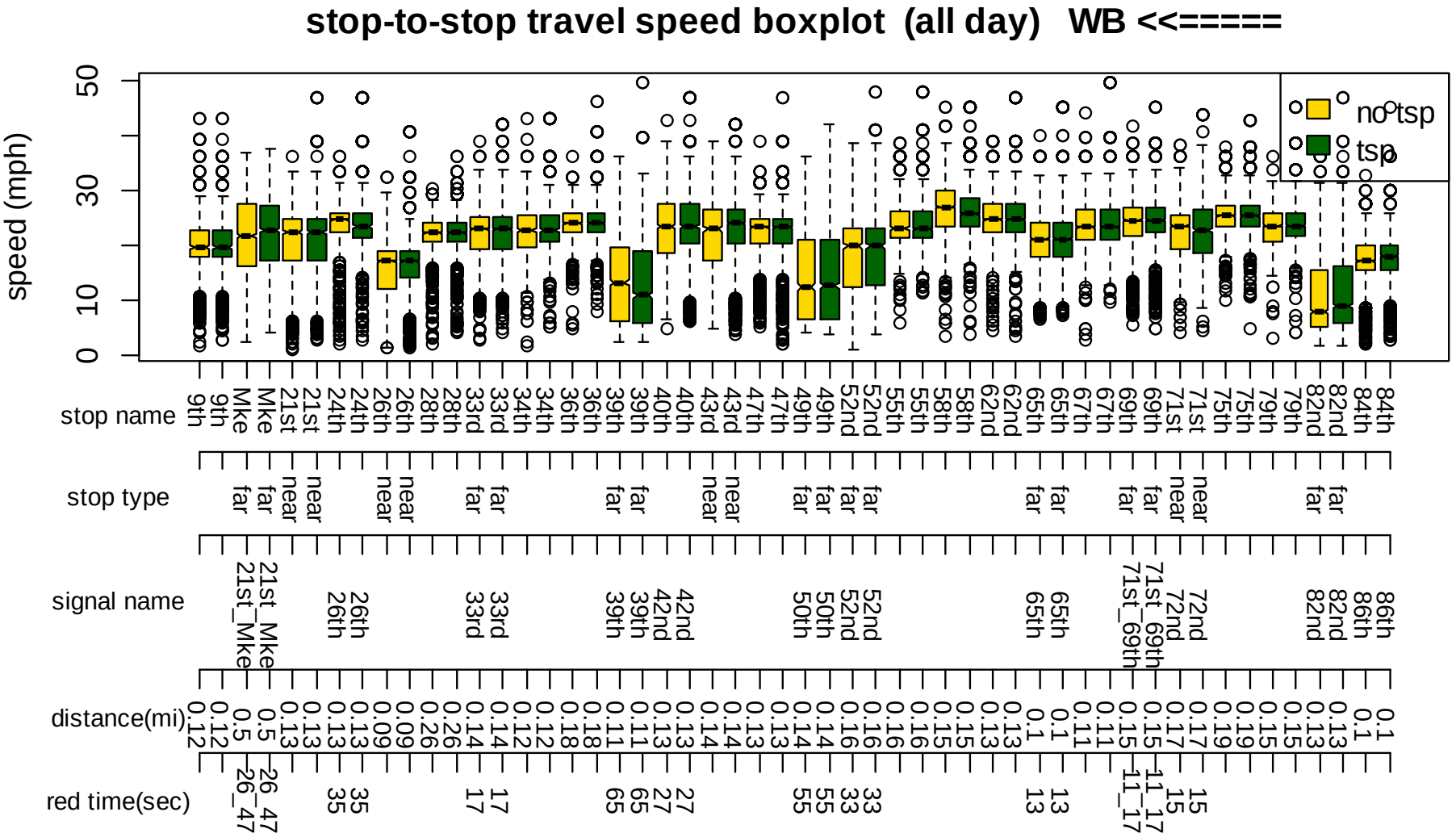
  = arrive time (i) – leave time (i-1)

- 2900 observations at each stop-to-stop segment

  (March and May 2013, weekdays only)

  – In March 2013, TSP was working at all intersections
  – In May 2013, TSP was turned off

TSP effectiveness analysis



TSP effectiveness analysis

- Method:
  - Regression model for each stop-to-stop segment crossing intersection
- Dependent variable:
  - bus stop-to-stop travel time crossing intersection
- Control variables:
  - bus pass by
  - Time of day effects
  - Traffic volume
  - Red light delay
  - TSP is working or not (a bus trip was made in March or May)
  - Bus trips that requested TSP or not

TSP effectiveness analysis

Eastbound	39th	50th	52nd	65th	69th	71st
TSP (seconds)	-3.5 ***	-6.5 ***	-3.4 ***	-0.7 *	-1.1 ***	
Westbound	**33rd**	**39th**	**50th**	**52nd**	**65th**	**72nd**
TSP (seconds)	-1.4 ***		-6.1 ***	-3.3 ***	-0.8 ***	-1.3 ***

***: significant at the 0.001 level

*: significant at the 0.05 level

- 5-15% travel time reduction
- TSP effectiveness was not significantly different between buses that requested TSP and buses that did not request TSP

TSP efficiency evaluation

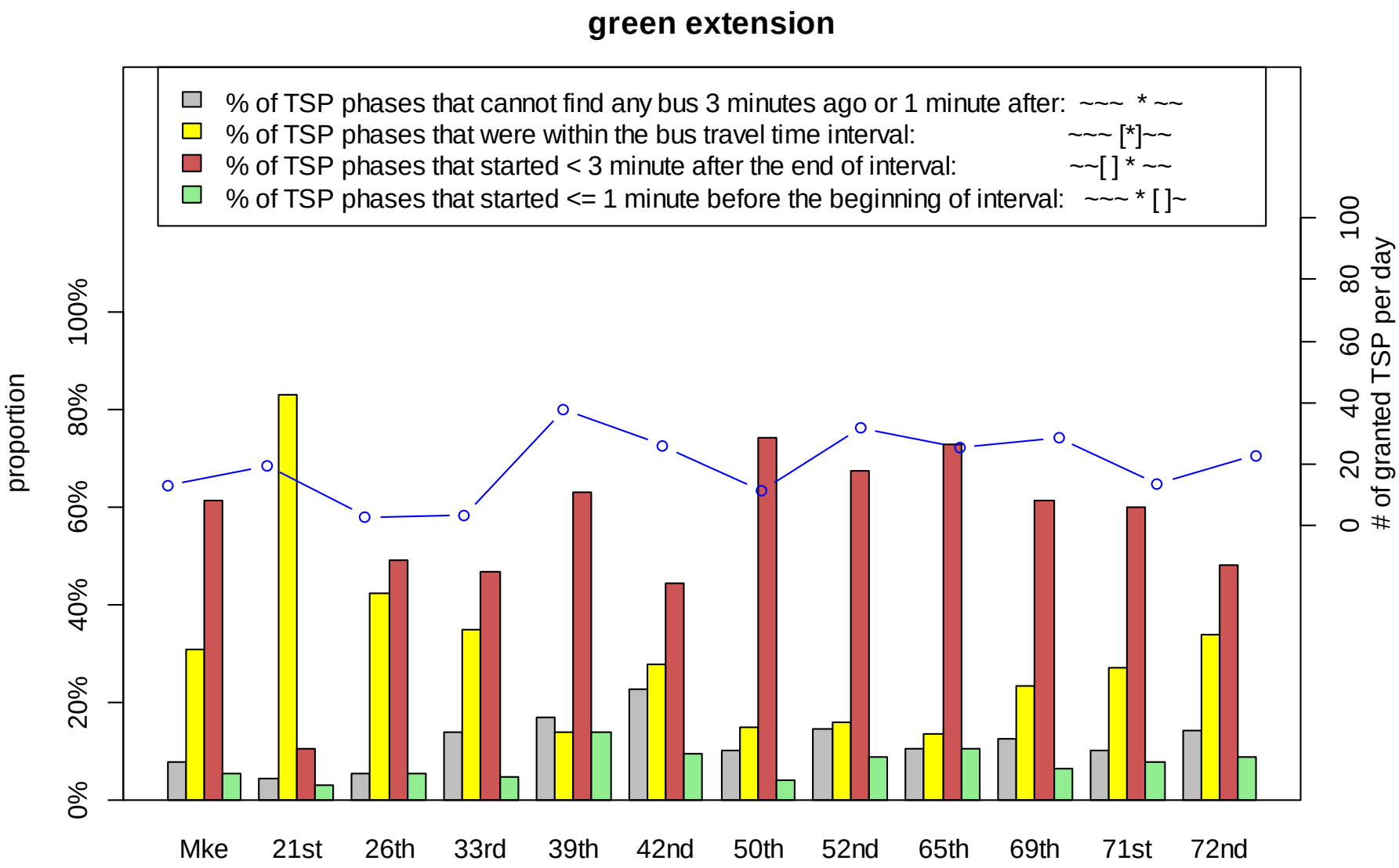
[: leave time from stop i-1;

] : arrive time at stop I;

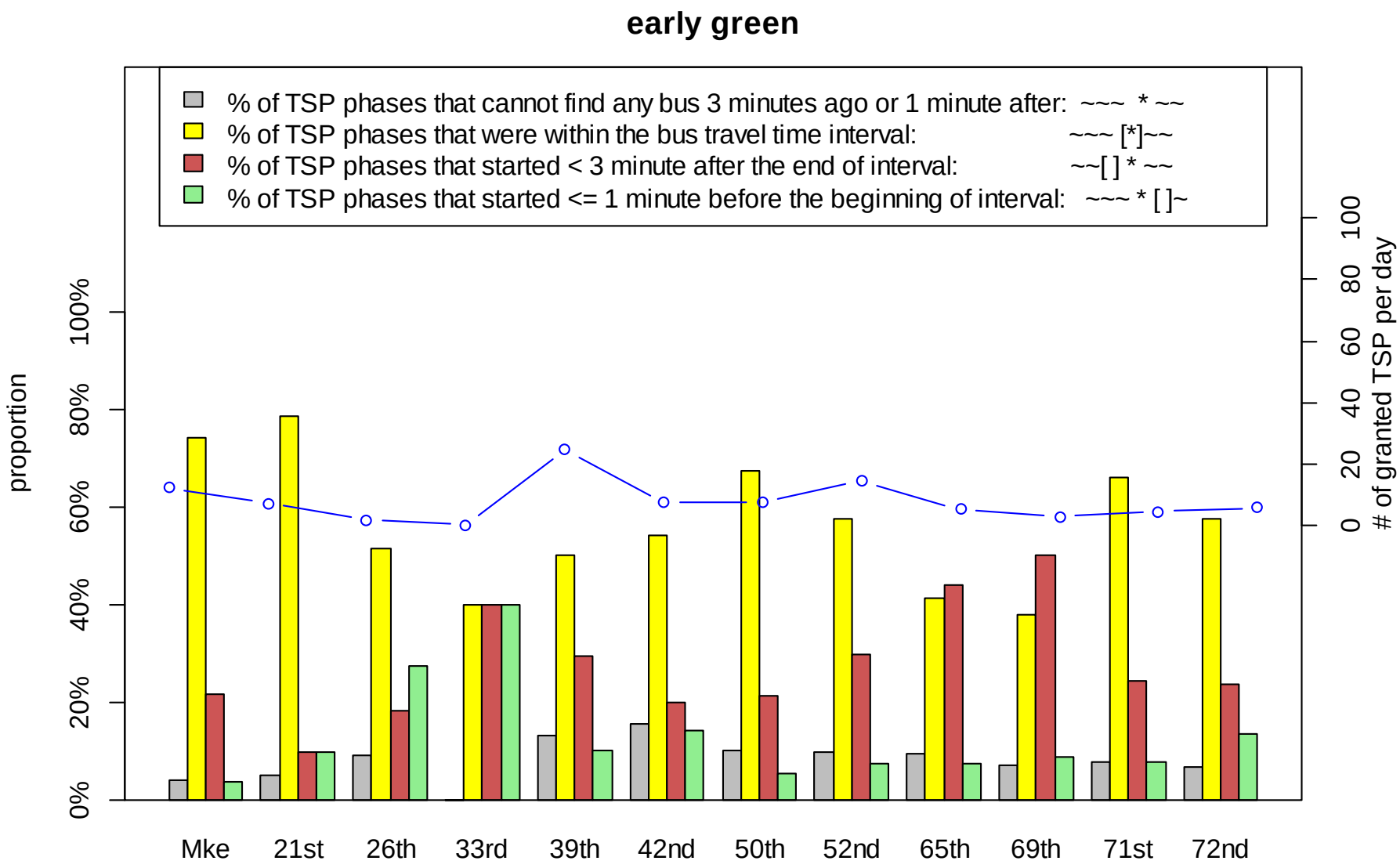
* : TSP phase start time at signal j

- [*] : a TSP phase was granted efficiently;
- [ ] * : a TSP phase was granted too late (<3 minutes late);
- * [ ] : a TSP phase was granted too early (<1 minute early);
- * : a TSP phase was granted incorrectly.

TSP efficiency evaluation



TSP efficiency evaluation



Summary

- On average, TSP significantly reduced bus stop-to-stop travel time crossing intersections (for far-side stop segments)
- The benefits of the conditional TSP implementation are not significantly different between buses that requested TSP and buses that did not request
- A large proportion of granted TSP phases were wasted (green extension worse than early green)

Next steps

- Study bus stop location effects (near-side / far-side)
- Study TSP effects on:
  - bus travel time variability
  - headway variability
  - on-time performance

  controlling for traffic conditions variability and passenger activities variability.

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Questions?

Wei Feng
Ph.D. Candidate
wfeng@pdx.edu
Department of Civil and Environmental Engineering
Portland State University

Miguel Figliozzi
Associate Professor
figliozzi@pdx.edu
Department of Civil and Environmental Engineering
Portland State University

Additional slides

Introduction

- TSP performance measures
  - Intersection level: passenger delay

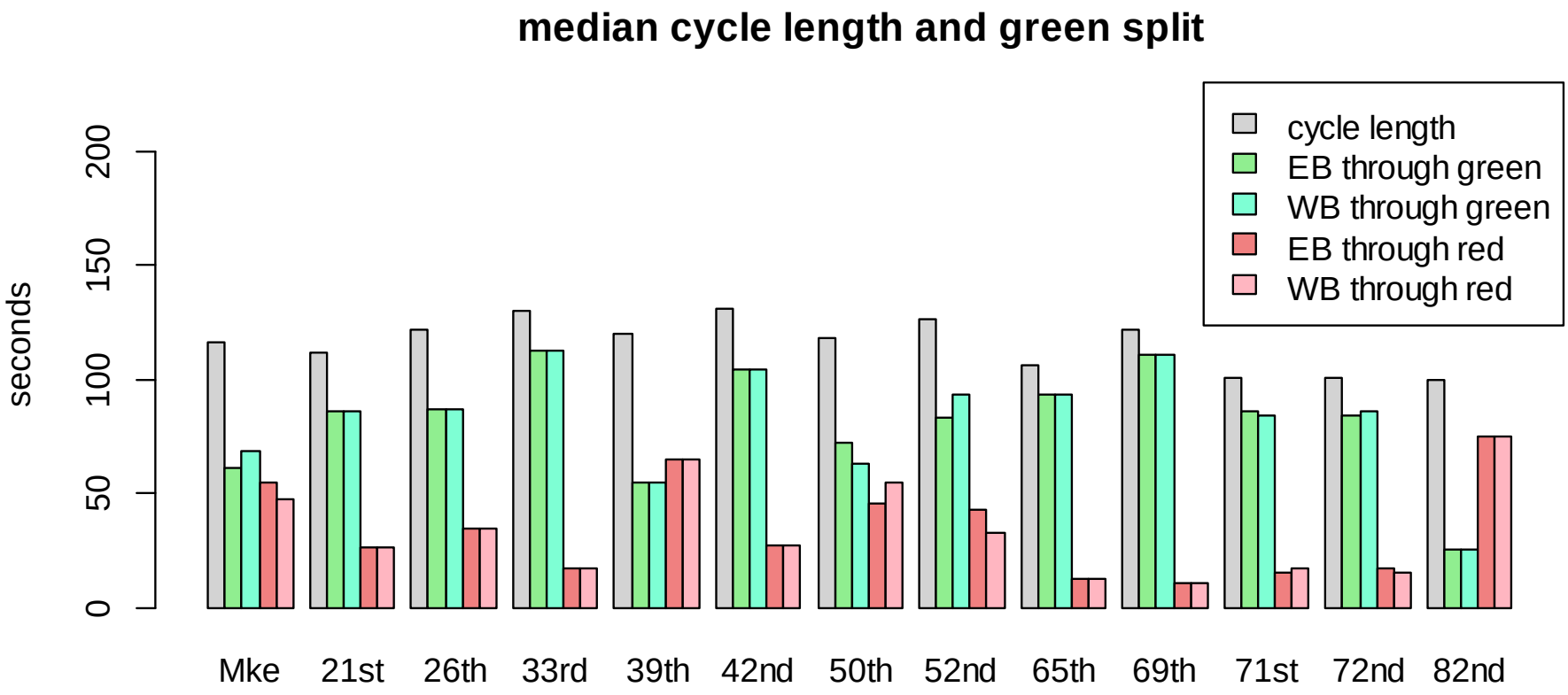
    (analytical or simulation approach)

  - Corridor level: bus running time, service reliability

    (simulation or empirical analysis)

Corridor description

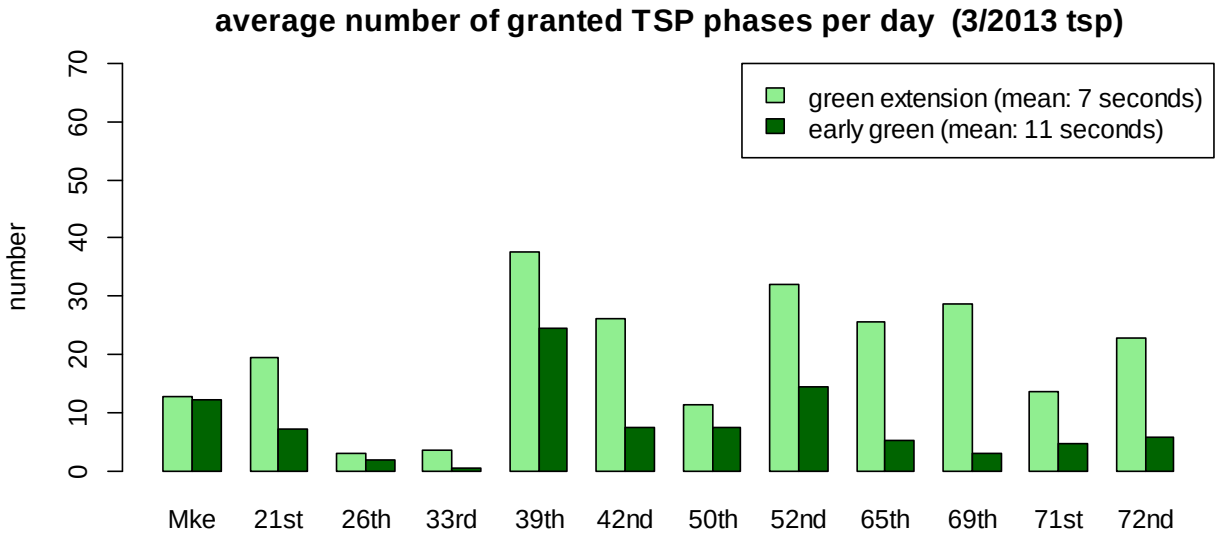
Traffic signals



TSP effectiveness analysis

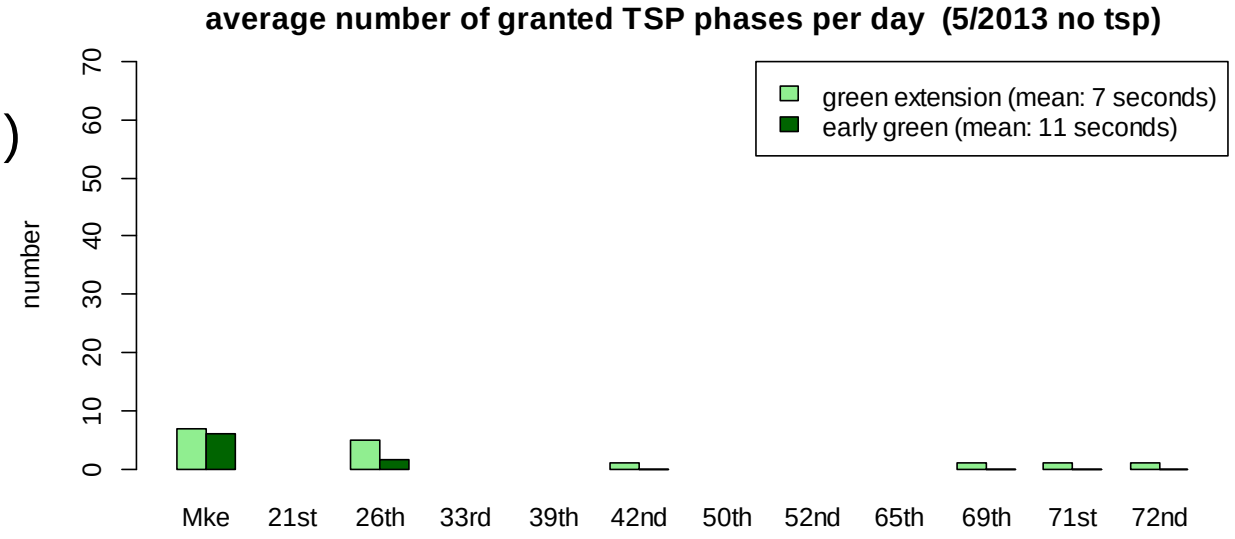
March 2013:

(TSP was working)

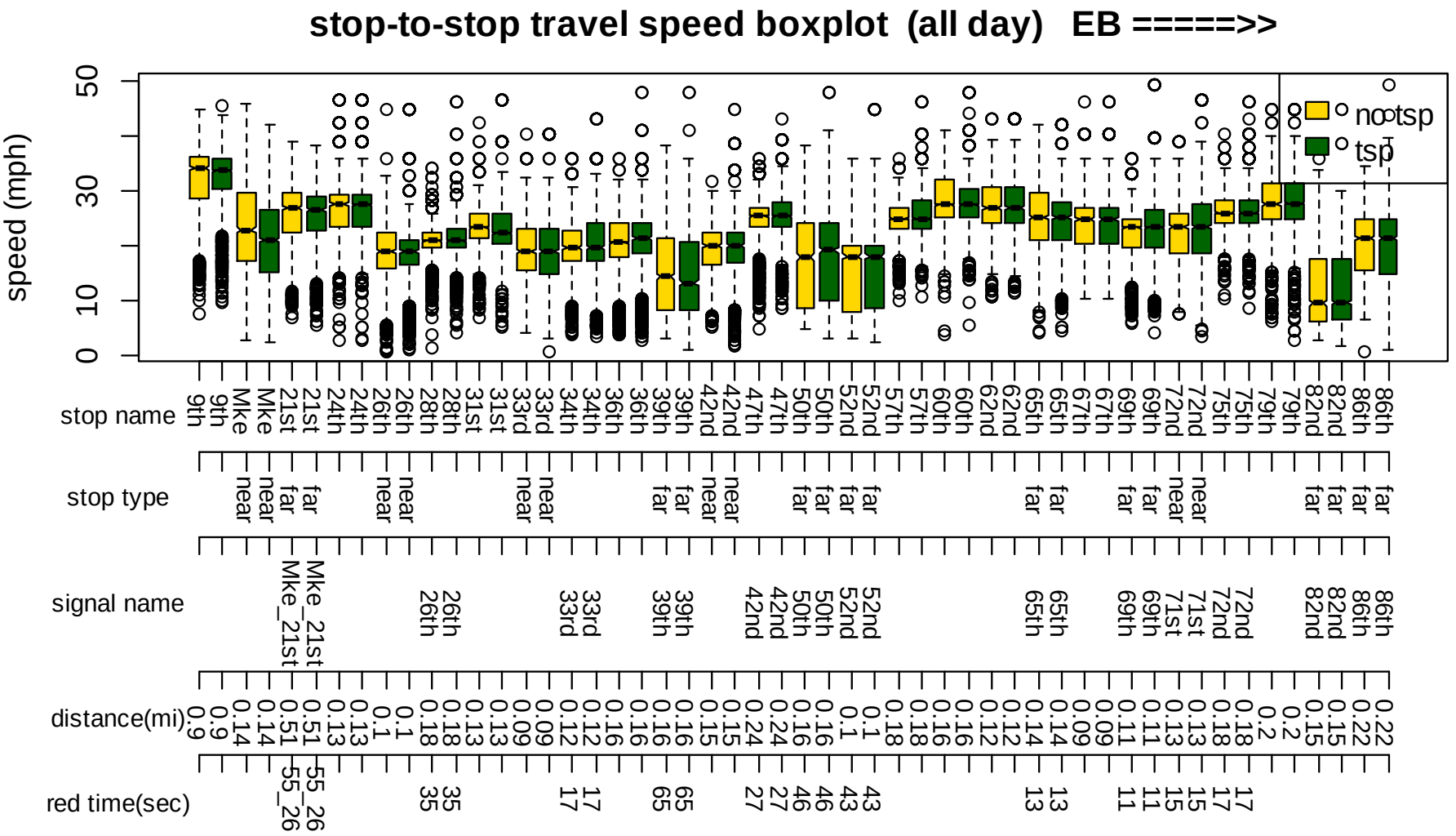


May 2013:

(TSP was not working)



TSP effectiveness analysis



TSP effectiveness analysis

- Control variables:

Variable name	Type	Description
Pass by	Dummy	=1, If a bus skipped departure stop
Am	Dummy	=1, if a bus trip was made in 6-8 am
Pm	Dummy	=1, if a bus trip was made in 3-5:30 pm
Mid	Dummy	=1, if a bus trip was made in 8 am – 3 pm
Red	Dummy	=1, if there was a red phase within the bus trip
Volume (vph)	Continuous	Vehicles per hour in the bus traveling direction
TSP	Dummy	=1, if a bus trip was made in March 2013 (when TSP was working)
Request	Dummy	=1, if a bus was more than 30 seconds late from departure stop (met the TSP request condition)

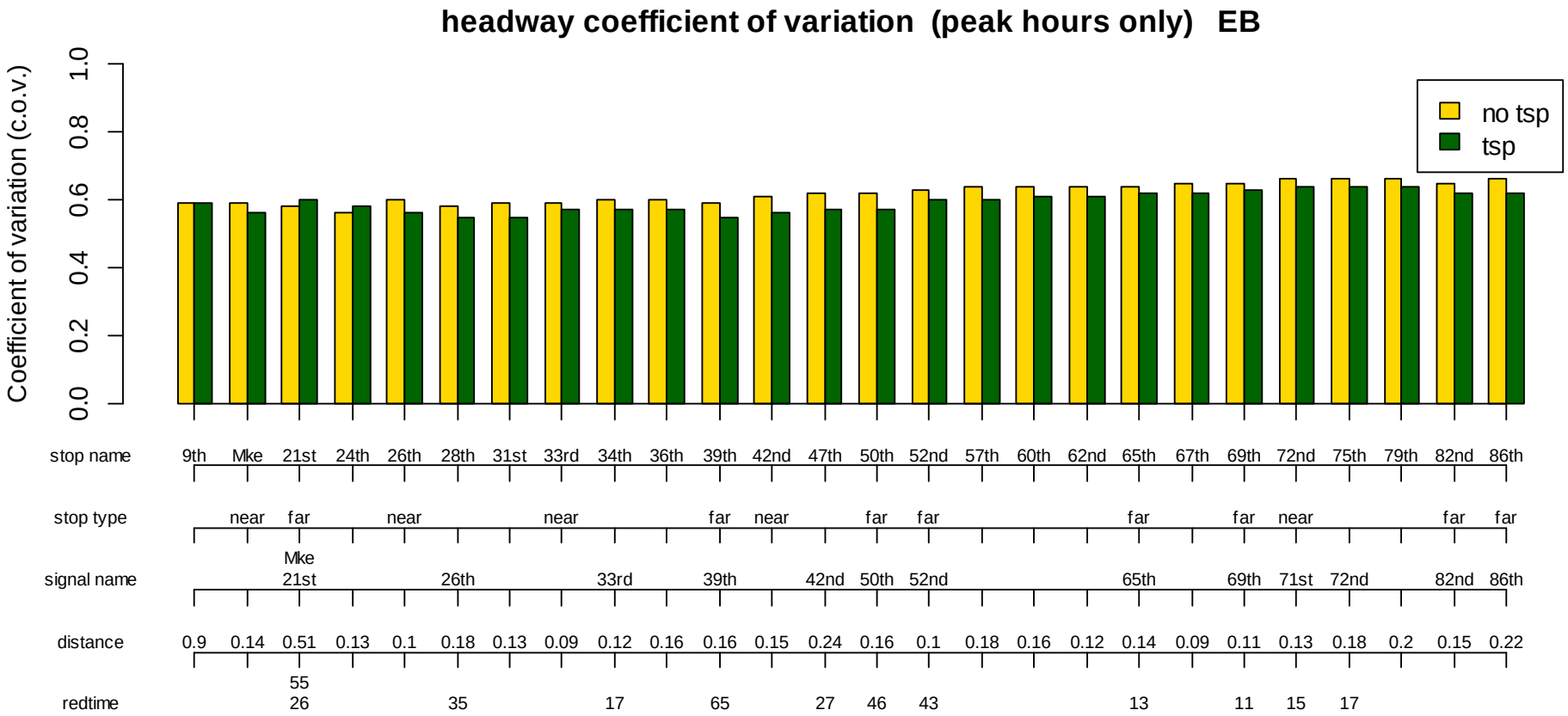
Bus travel time regression analysis

	39th EB		50th EB		52nd EB		65th EB		69th EB		71st EB	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Travel time (seconds)	51.4		41.1		32.7		22.4		18.6		23.3	
(Intercept)	35.4	***	30.5	***	20.9	***	20.5	***	18.3	***	21.1	***
Pass by			-4.7	***	-10.9	***	-2.8	***	-2.5	***	-3.3	***
no Red (ref.)												
Red	53.7	***	41.7	***	44.2	***	15.1	***	17.3	***	19.6	***
volume (vph*1000)	19.2	***	42.6	***	22.2	***	4.9	***	2	***	4.6	***
volume (vph*1000)^2			-21.3	***								
no TSP, no request (ref.)												
no TSP, request	-4.1	**					-0.8	0.07	-0.4	0.12		
TSP, no request	-6.2	***	-6.7	***	-2.6	*	-1	*			-0.8	*
TSP, request	-5.8	***	-6.4	***	-3.8	***	-1.3	**	-1	***	-1.5	***
R-Square	0.34		0.32		0.34		0.3		0.3		0.33	
Adj. R-Square	0.34		0.32		0.34		0.3		0.29		0.32	
N	1556		1554		1545		1538		1551		1550	
Distance (miles)	0.16		0.16		0.10		0.14		0.11		0.13	
Red time duration (sec.)	66		48		45		14		12		15	

Bus travel time regression analysis

	33rd WB		39th WB		50th WB		52nd WB		65th WB		72nd WB	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Travel time (seconds)	25.2		44.5		50.4		37.4		18.9		29.5	
(Intercept)	26	***	42.3	***	35.6	***	28.6	***	15.6	***	29.6	***
Pass by	-2	***	-6.7	***	-7.5	***	-4.8	***	-2.1	***	-2.6	***
no Red (ref.)												
Red	18.7	***	45.3	***	44.6	***	30.3	***	13.3	***	17.3	***
volume (vph*1000)			14.7	**	24.3	***	19.1	***	7.5	***		
volume (vph*1000)^2			-8.4	**			-6.6	**	-2.1	0.05	2.2	***
no TSP, no request (ref.)												
no TSP, request					-2.4	0.11					-1.5	**
TSP, no request	-1.1	*			-6.8	***	-2.8	**	-0.8	**	-1.4	***
TSP, request	-1.7	***	-4.2	***	-7.6	***	-4.6	***	-1	**	-3	***
R-Square	0.11		0.11		0.19		0.14		0.16		0.26	
Adj. R-Square	0.11		0.11		0.19		0.14		0.15		0.26	
N	2756		2760		2762		2761		2760		2761	
Distance (miles)	0.14		0.11		0.14		0.16		0.10		0.17	
Red time duration (sec.)	18		66		56		35		14		16	

Impacts of TSP on bus headway



Impacts of TSP on bus headway