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# Empirical Evaluation of Transit Signal Priority through Fusion of Heterogeneous Transit and Traffic Signal Data and Novel Performance Measures

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# Empirical Evaluation of Transit Signal Priority

*(Doug Beghtel/The Oregonian)*

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**Miguel Figliozzi,** Portland State University
**Robert Bertini,** Cal Poly State Univ., San Luis Obispo

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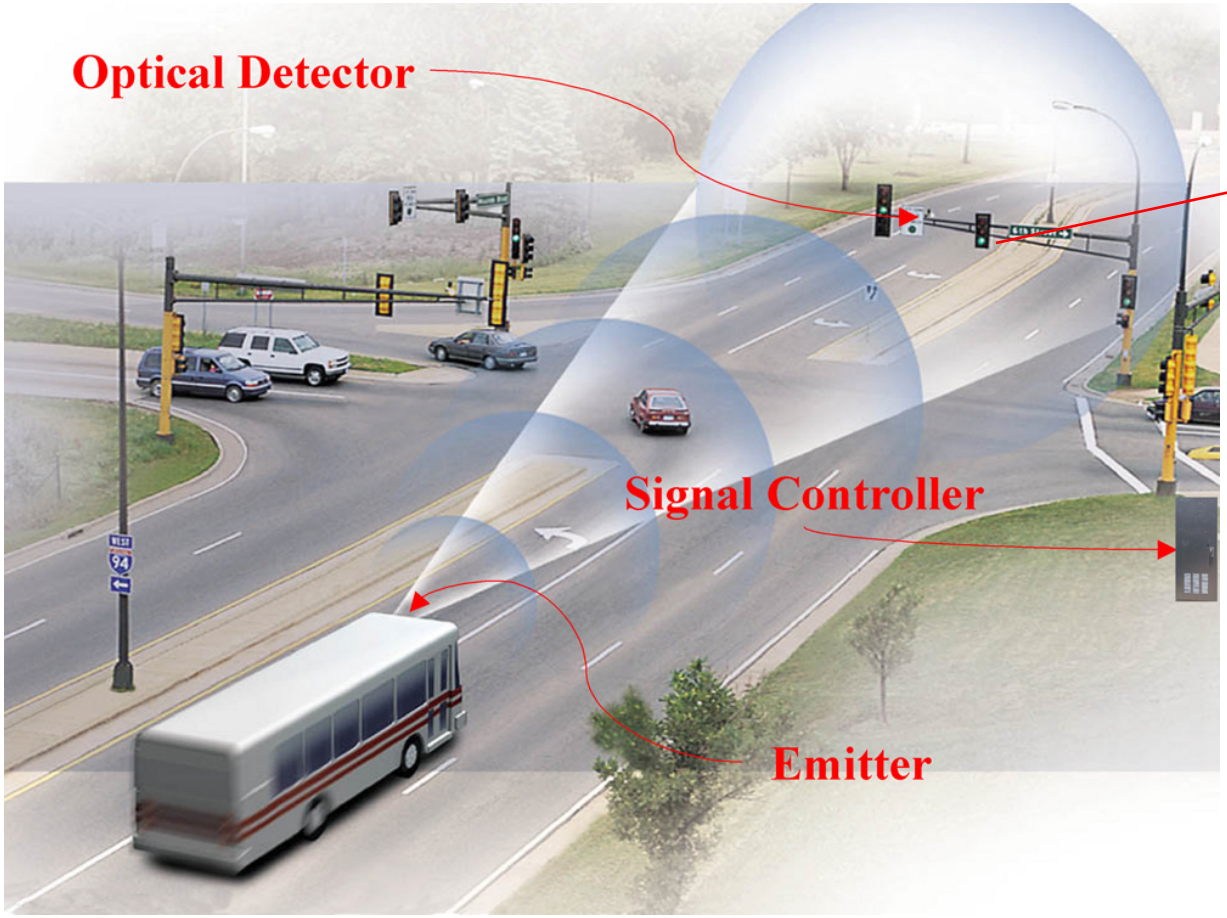
**Transportation Seminar March 6, 2015**

# Background—Transit Signal Priority




Green extension
Early Green

Passive
Active
Real-time optimal

*Kamila Widulinski and Matthew Lapointe (2013)*

# Background—Transit Signal Priority

**Evaluation methods**

- **Analytic:** Lin (2002); Abdy & Hellinga (2011)
- **Simulation:** Furth & Muller (2000); Dion et al. (2004)

} Pre-install

- **Empirical:** Kimpel et al. (2005); Albright & Figliozzi (2012)

↓

Before / after

**Performance measures**

- Bus travel time
- Schedule adherence
- Headway variability
- Delay for other vehicles
- **Lack of effectiveness and efficiency measures/evaluation**

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# Motivation

Unique set of complementary data sources

**TriMet**

**Bus AVL/APC data**

**AVL: A**utomatic **V**ehicle **L**ocation
**APC: A**utomatic **P**assenger **C**ount

**City of Portland**

**SCATS signal phase log data**

**Intersection vehicle count data**

**SCATS: S**ydney **C**oordinated **A**daptive **T**raffic **S**ystem

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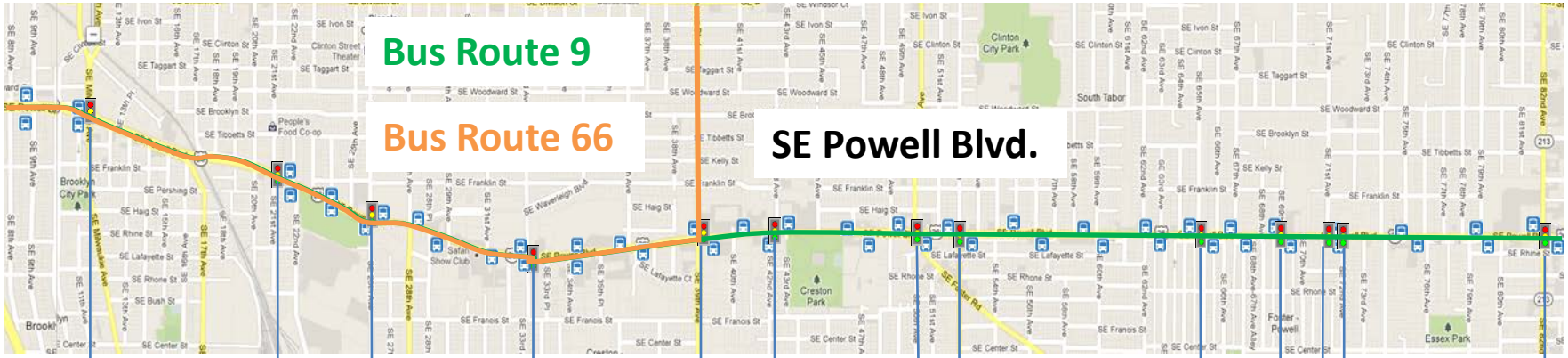
# Research Questions

Current TSP system in Portland:

- Effectiveness and efficiency?
- Time savings for buses vs. delay to cross street vehicles
- Green extension vs. early green phases?
- Near-side vs. far-side bus stops?
- Any problems and improvement opportunities?

# Study Corridor




**12 SCATS signals**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Near-side: | 26th EB<br>26th WB | 33rd EB | | 42nd EB<br>43rd WB | | | | | | 72nd EB |
| Far-side: | | 33rd WB | 39th EB<br>39th WB | 50th EB<br>50th WB | 52nd EB<br>52nd WB | 65th EB<br>65th WB | 69th EB | 71st EB | | 72nd WB |

**Stop-to-stop segment** **Near-side (6)**

**Far-side (12)**

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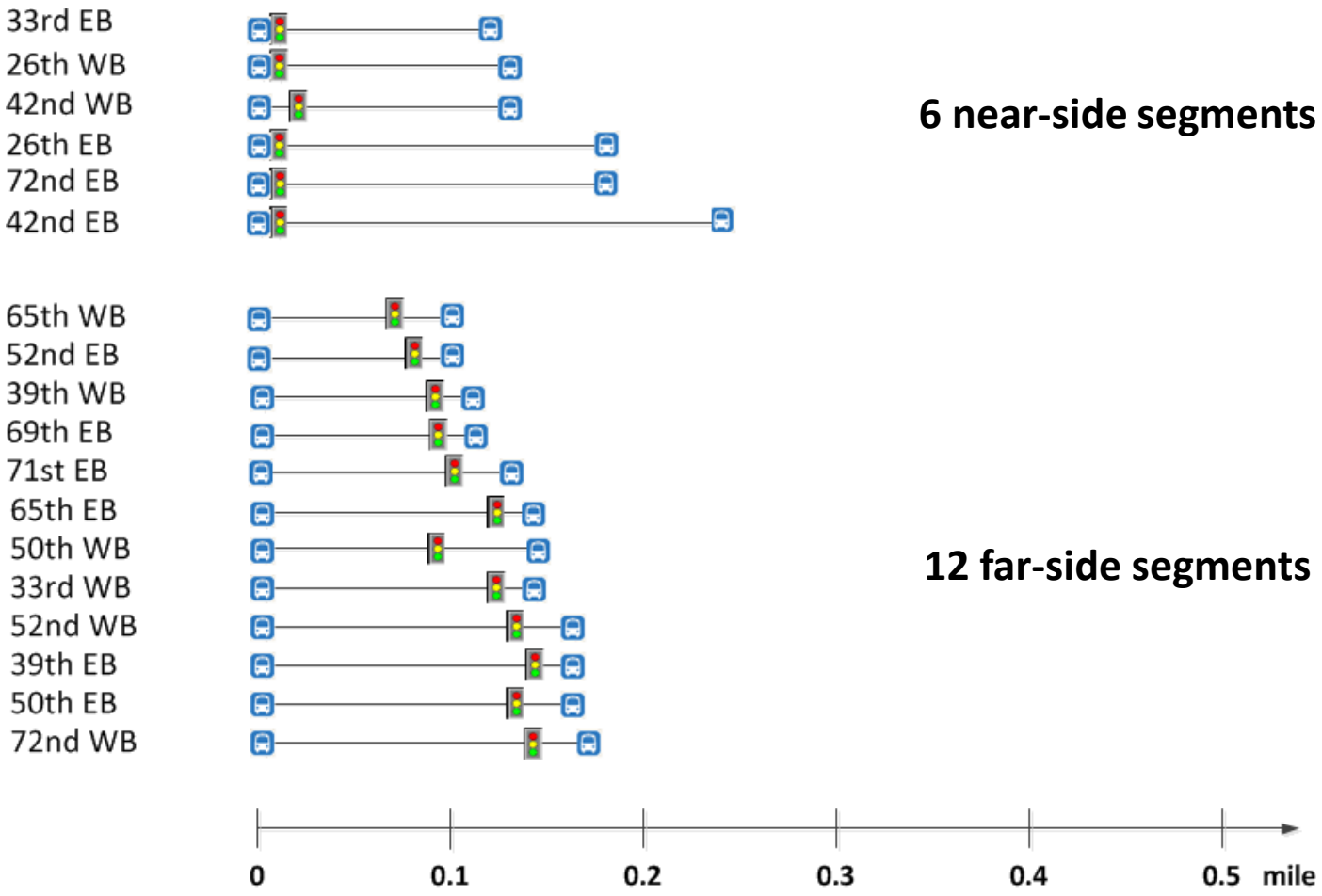
# Bus stop-to-stop segments




**6 near-side segments**

**12 far-side segments**

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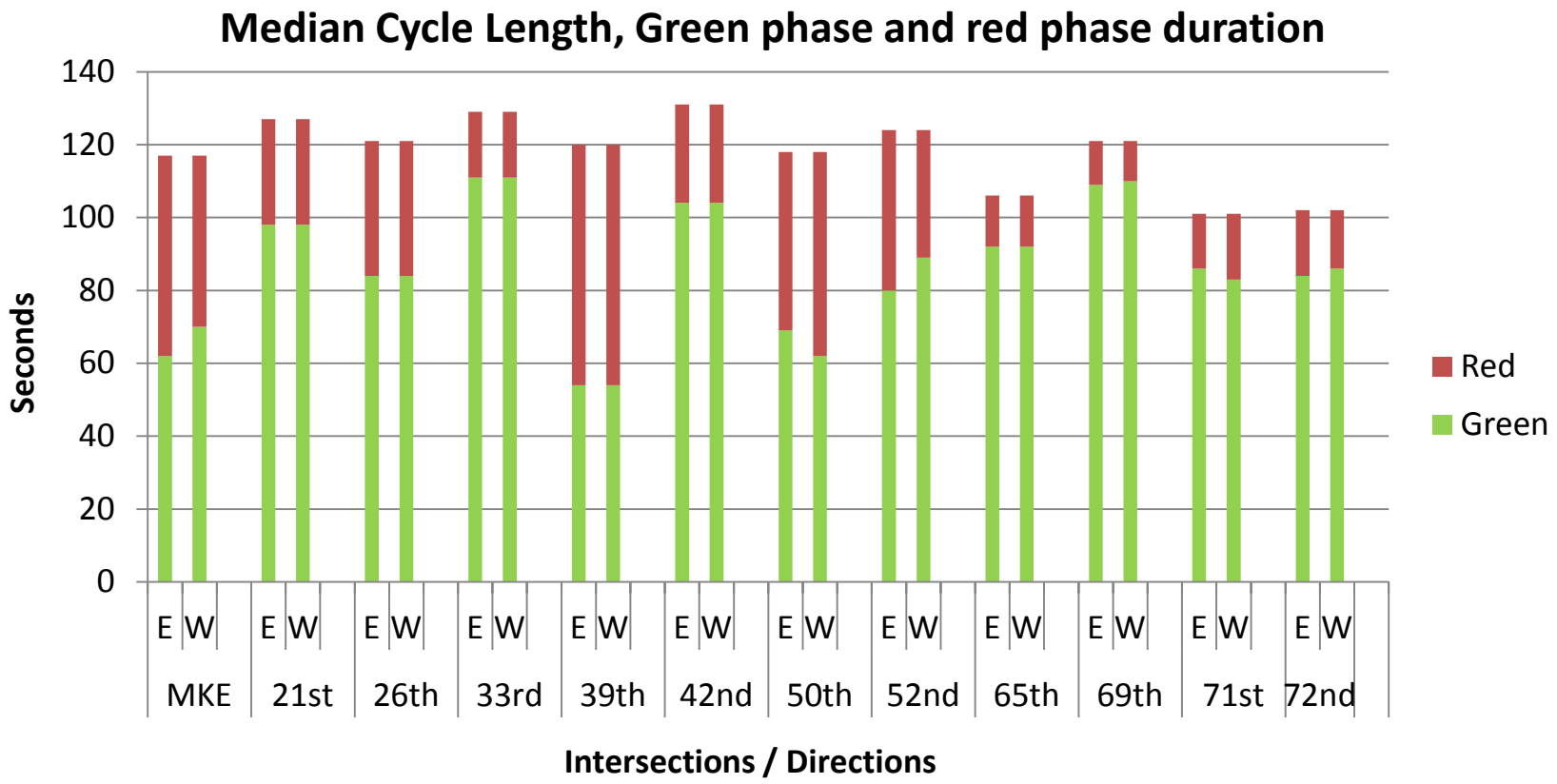
# SCATS Signals

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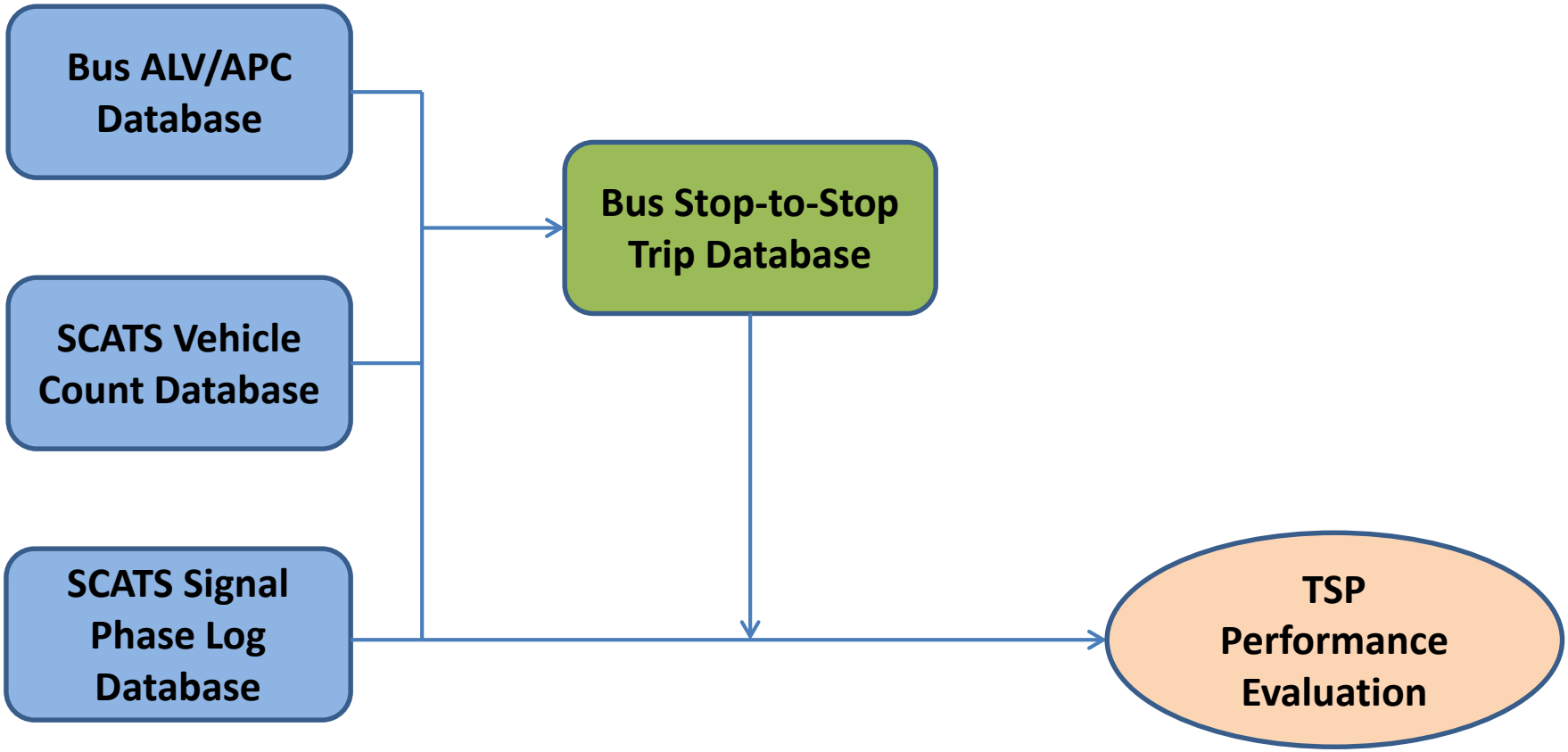
# Data Integration



# Bus Stop-to-Stop Trip Attributes

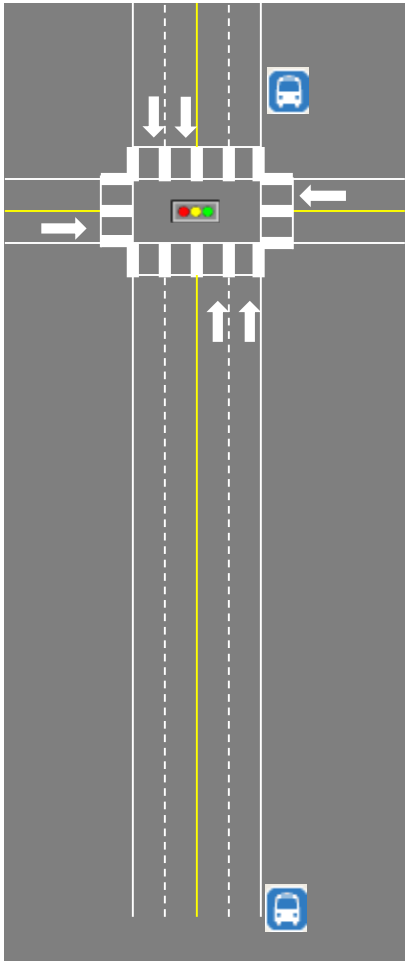
## Input data

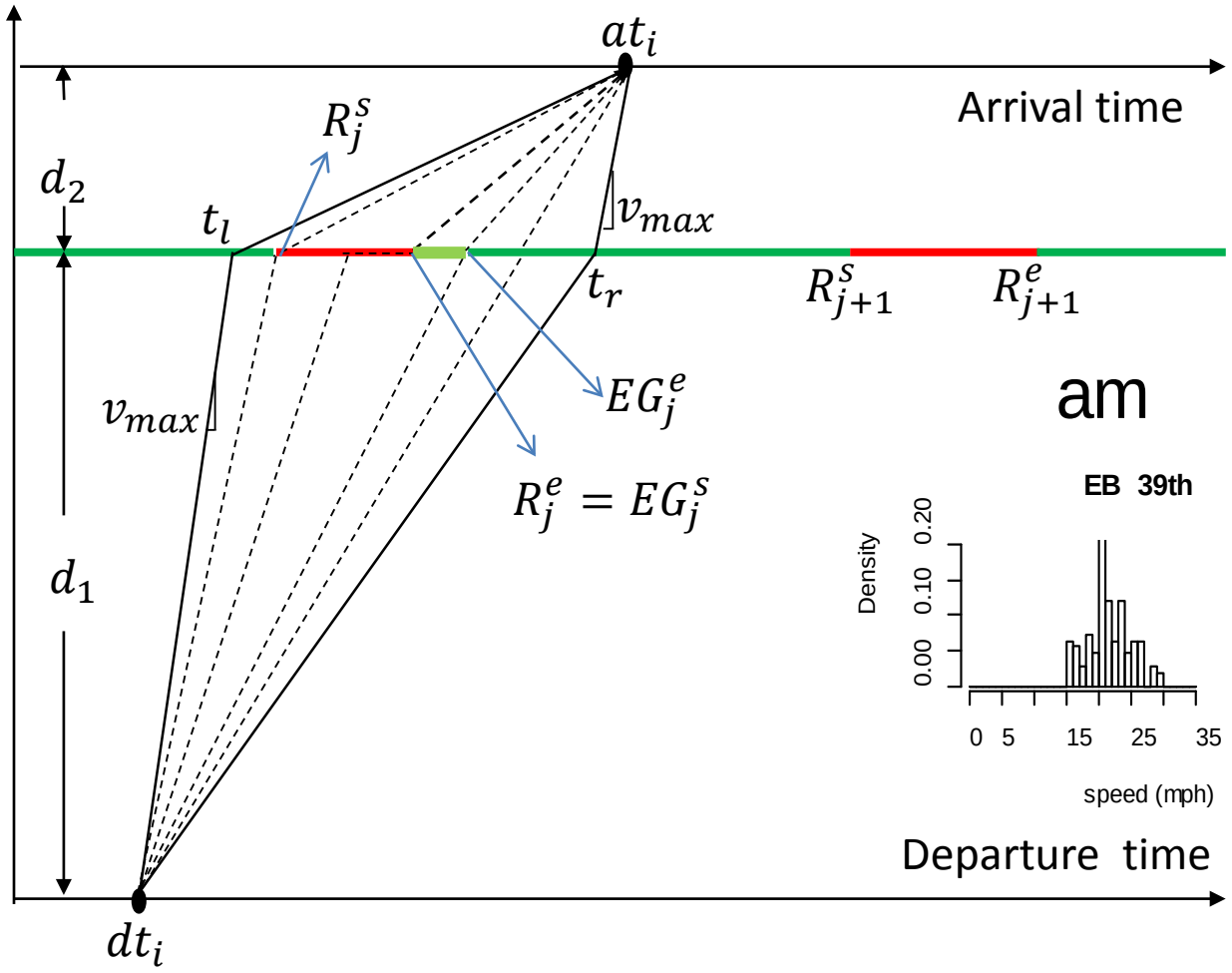
- Bus departure/arrival time
- Passenger activities
- Signal phase start/end time
- Priority request
- Upstream/downstream distance

## Output variables

- Probability of arriving at intersection in:
  - Green
  - Red
  - Green extension
  - Early green
- Signal delay
- Time savings

# Bus Time Saving (Early Green)



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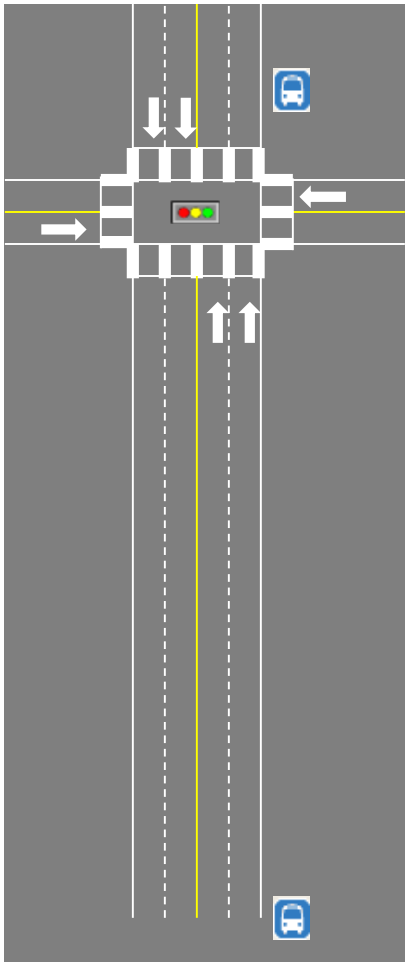
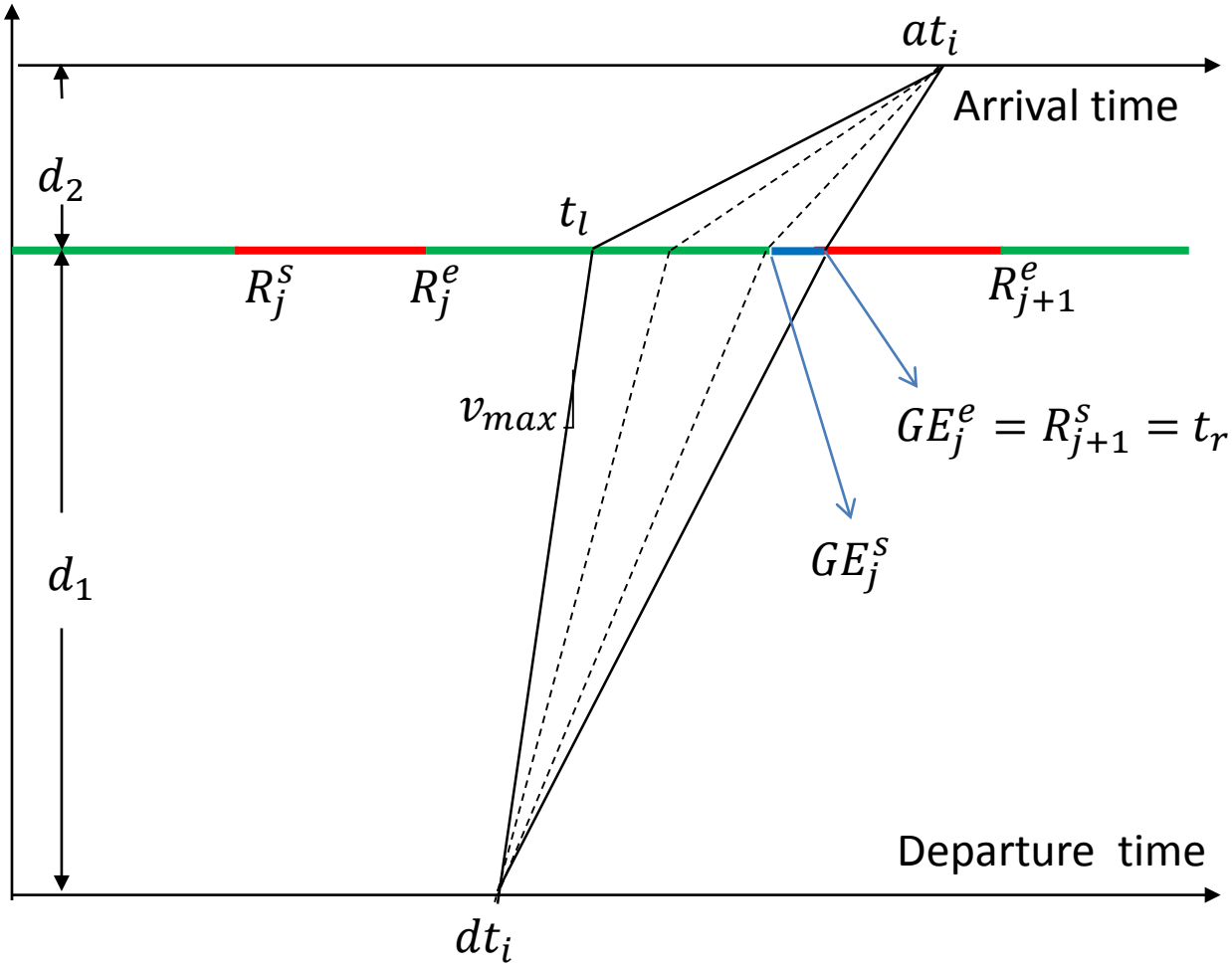
# Bus Time Saving (Green Extension)



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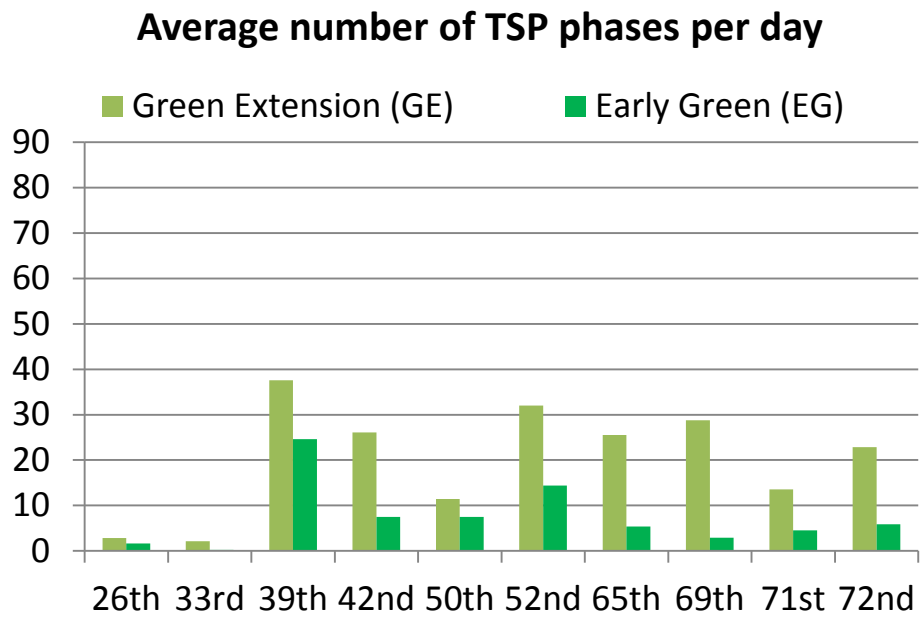
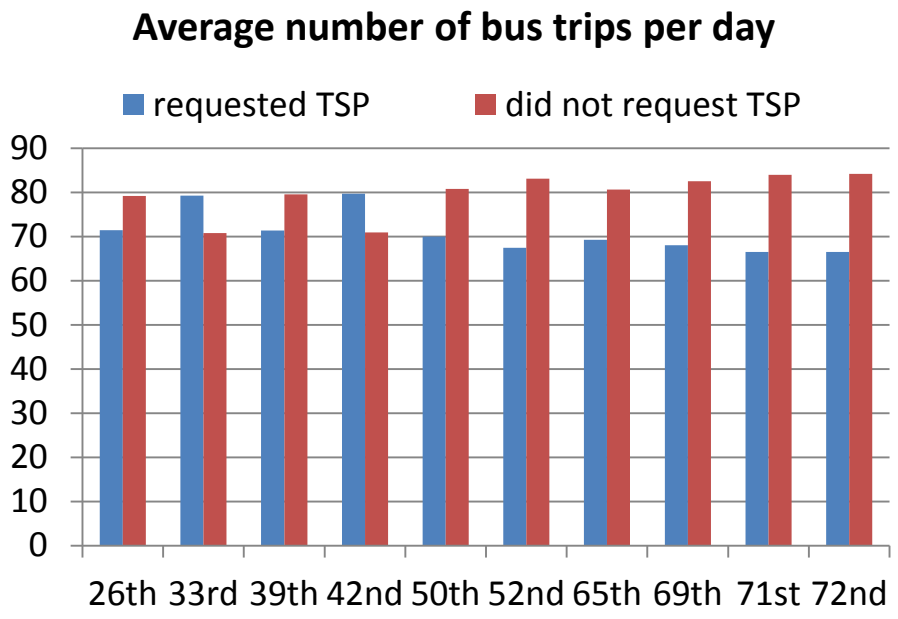
# Key Performance Measures

- TSP Frequency
- TSP Effectiveness (for each TSP request)
  - Probability of benefiting from a TSP phase
  - Expected time saving
- TSP Efficiency (for each TSP phase)
  - Probability of being beneficial to a TSP request
  - Expected time saving per second of TSP phase duration

# TSP Frequency

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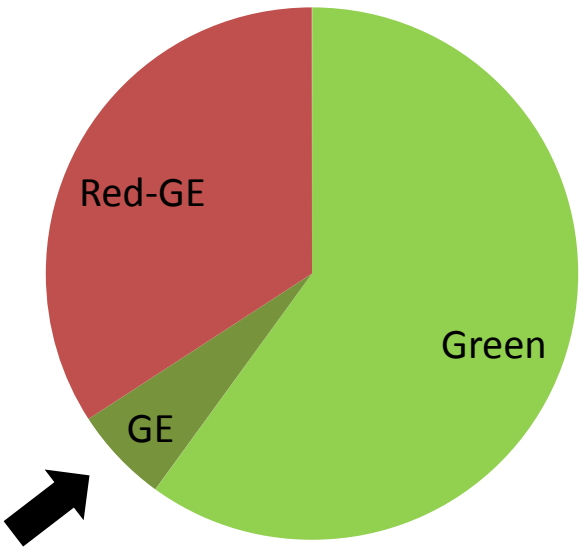
# When A TSP Request Will Benefit from GE/EG

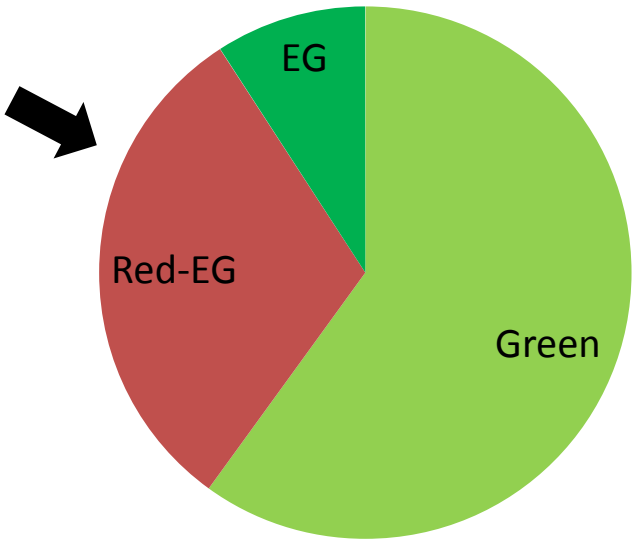
Benefit from
Green Extension

**Cycle**




Benefit from
Early Green

**Cycle**

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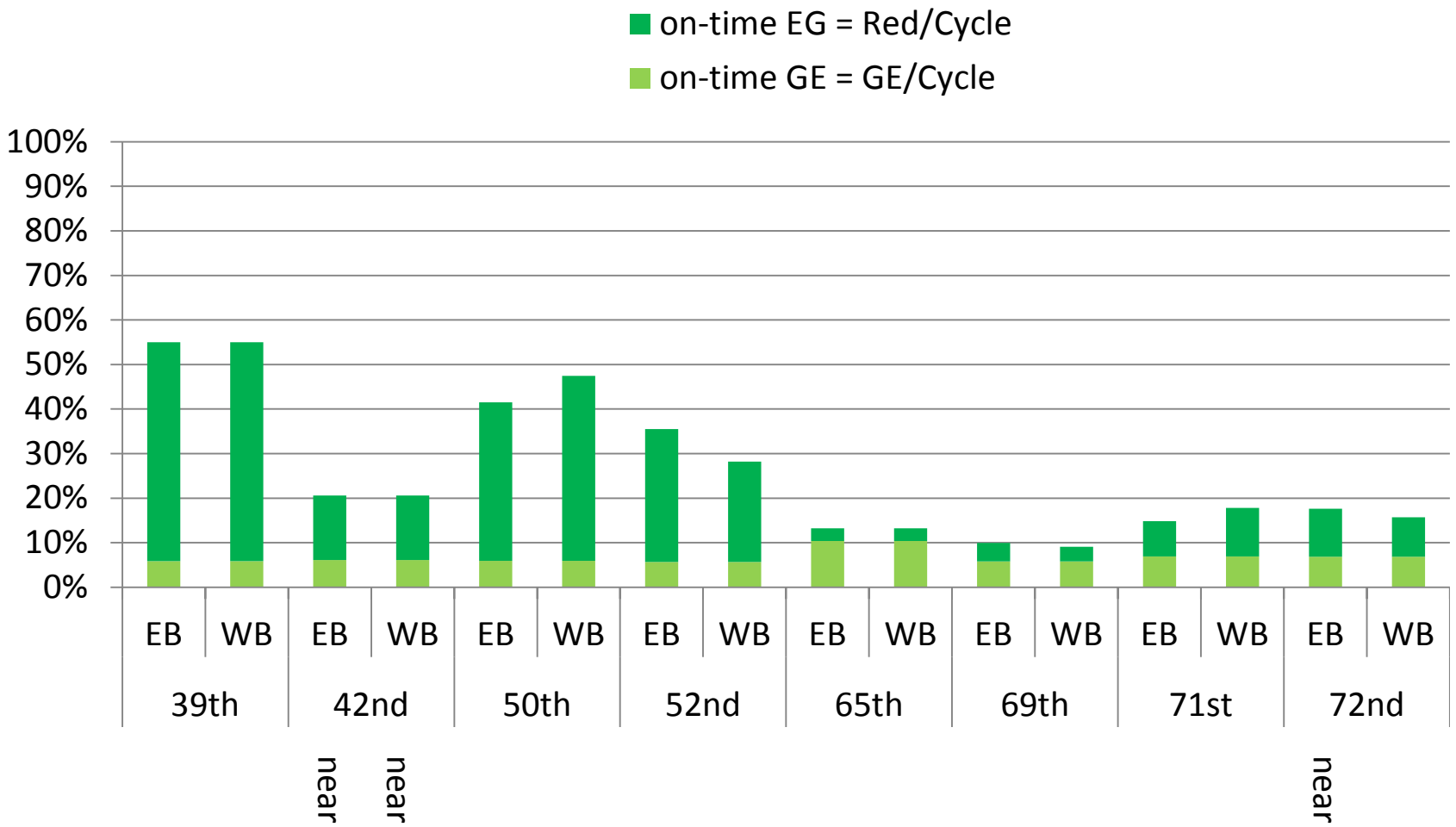
# Potential Results of A TSP Request

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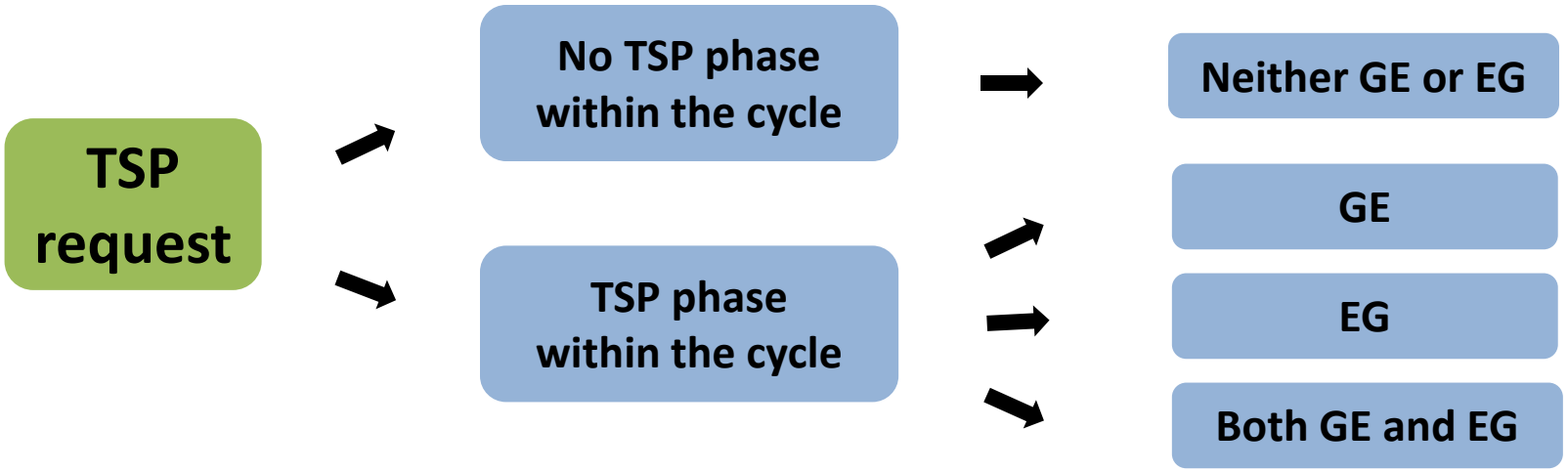
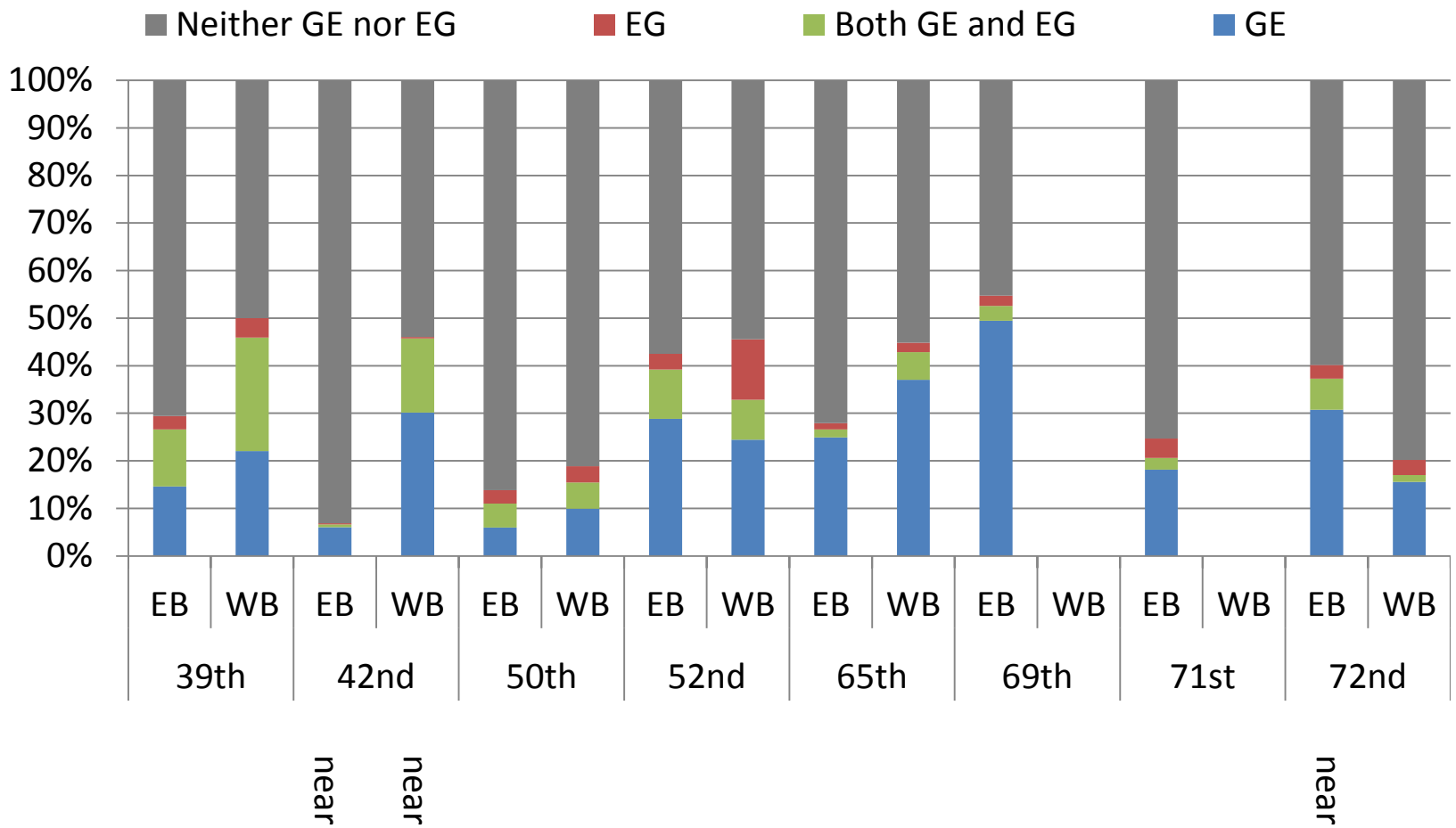
# Actual Outcomes of TSP Requests




**GE:** **G**reen **E**xtension
**EG:** **E**arly **G**reen

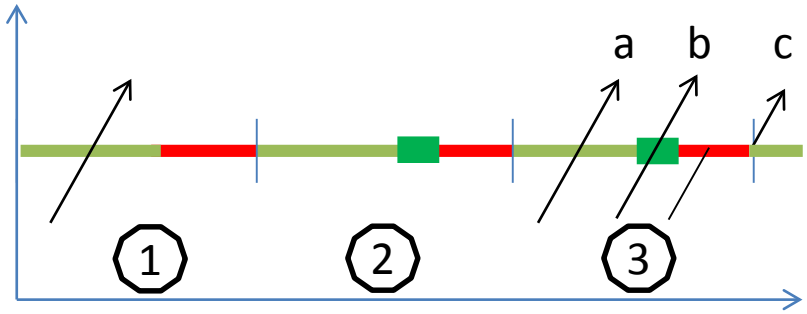
# Actual Outcomes of TSP Requests



# TSP Effectiveness

Bus trips that request TSP

Green extension




**Effectiveness** **Benefit**

**TSP request**

1 → **No TSP phase within the cycle**

3 → **TSP phase within the cycle**

GE or/and EG

c → **Early**

b → **On-time**

a → **Late**

→ **Time saving**

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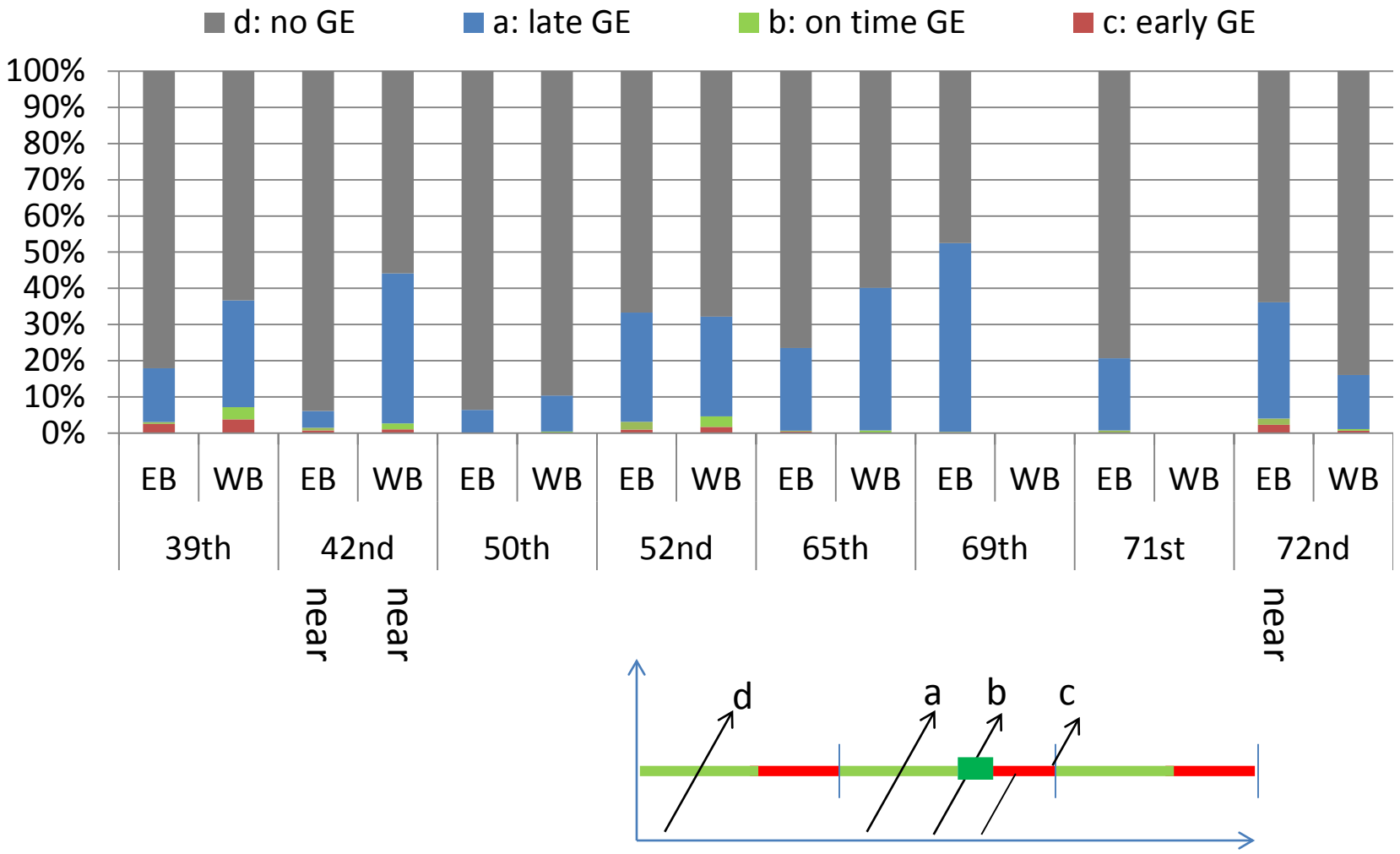
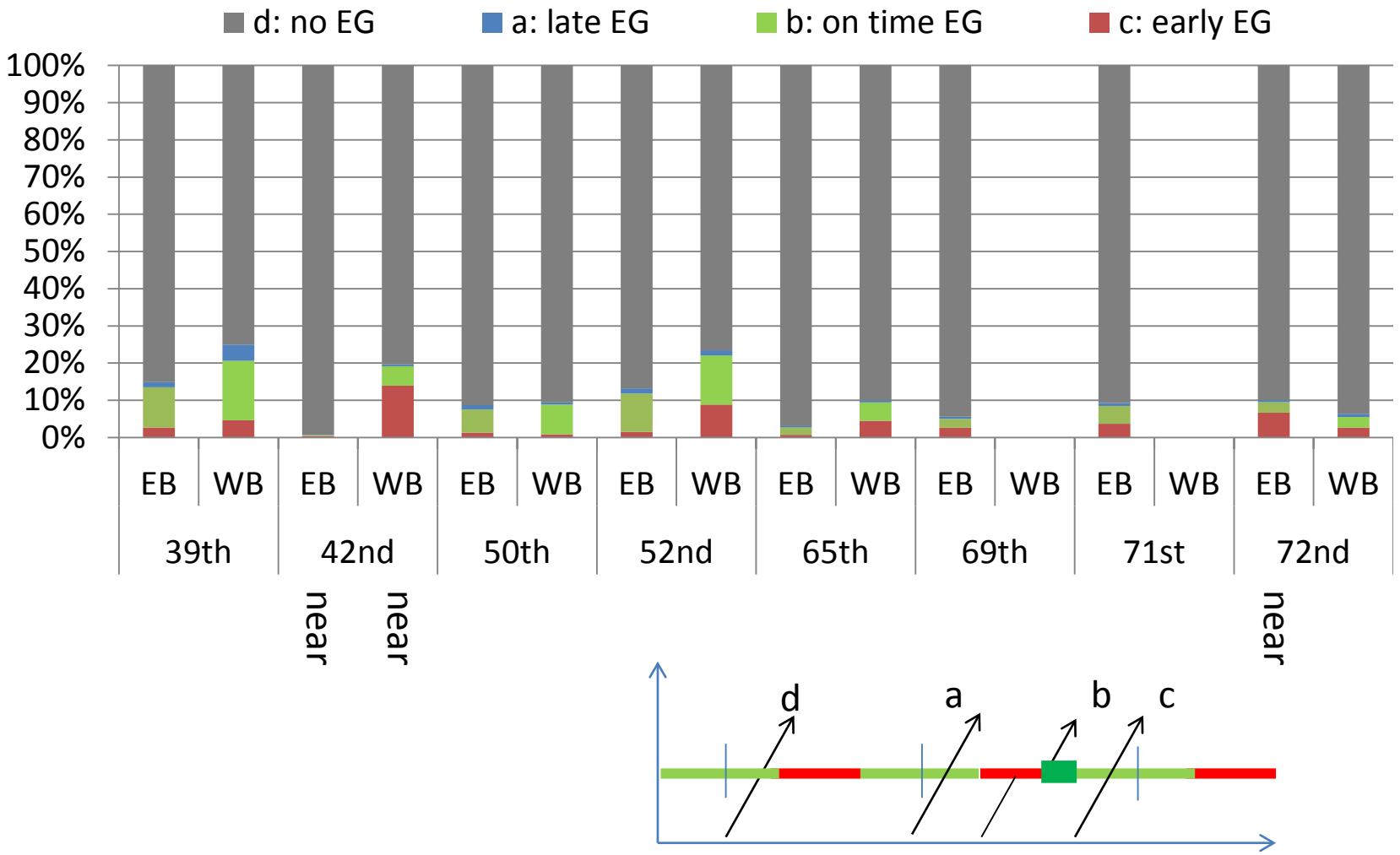
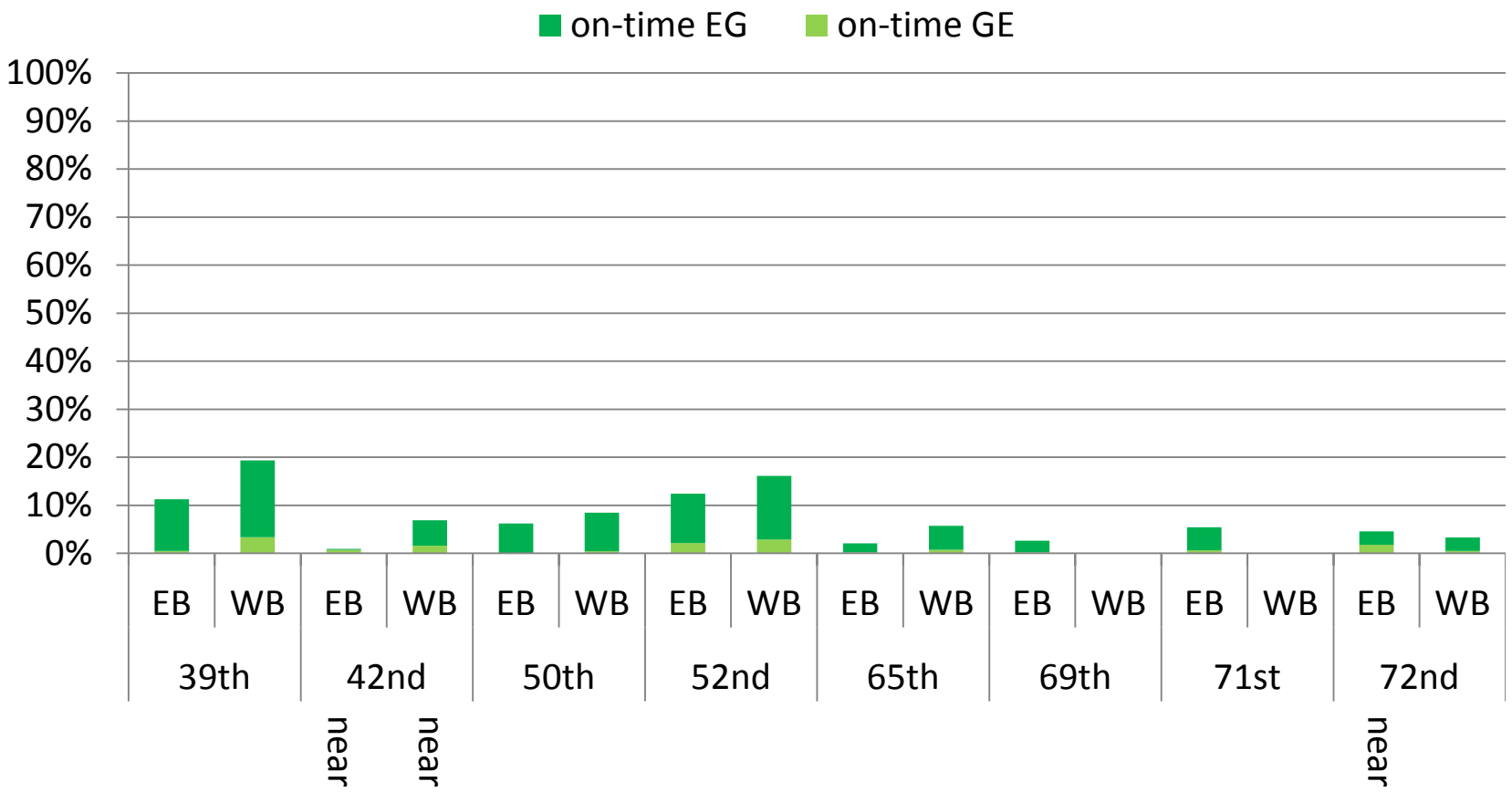
# TSP Request Outcomes for GE



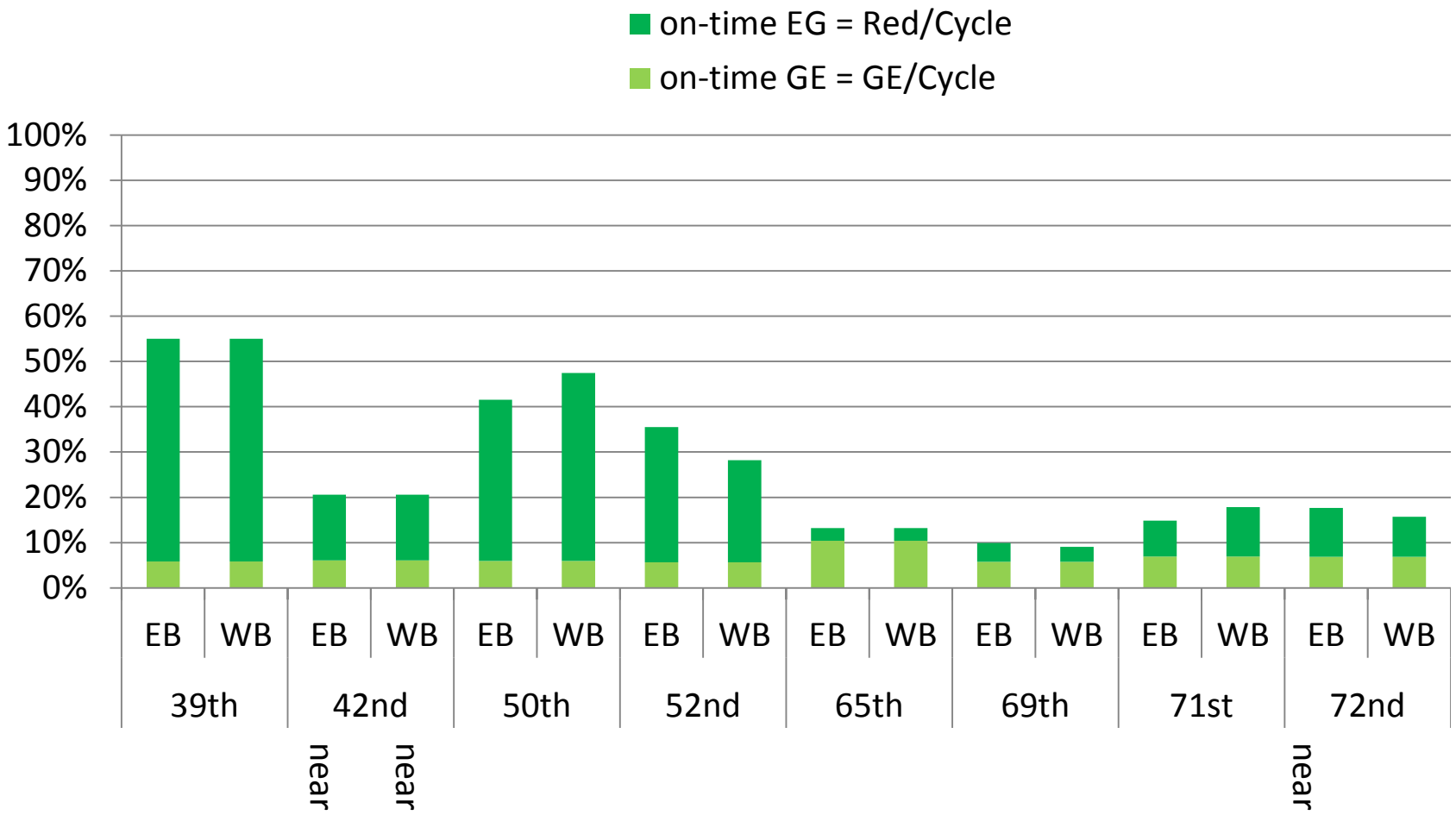
# TSP Request Outcomes for EG



# Actual TSP Effectiveness



# Ideal TSP Effectiveness

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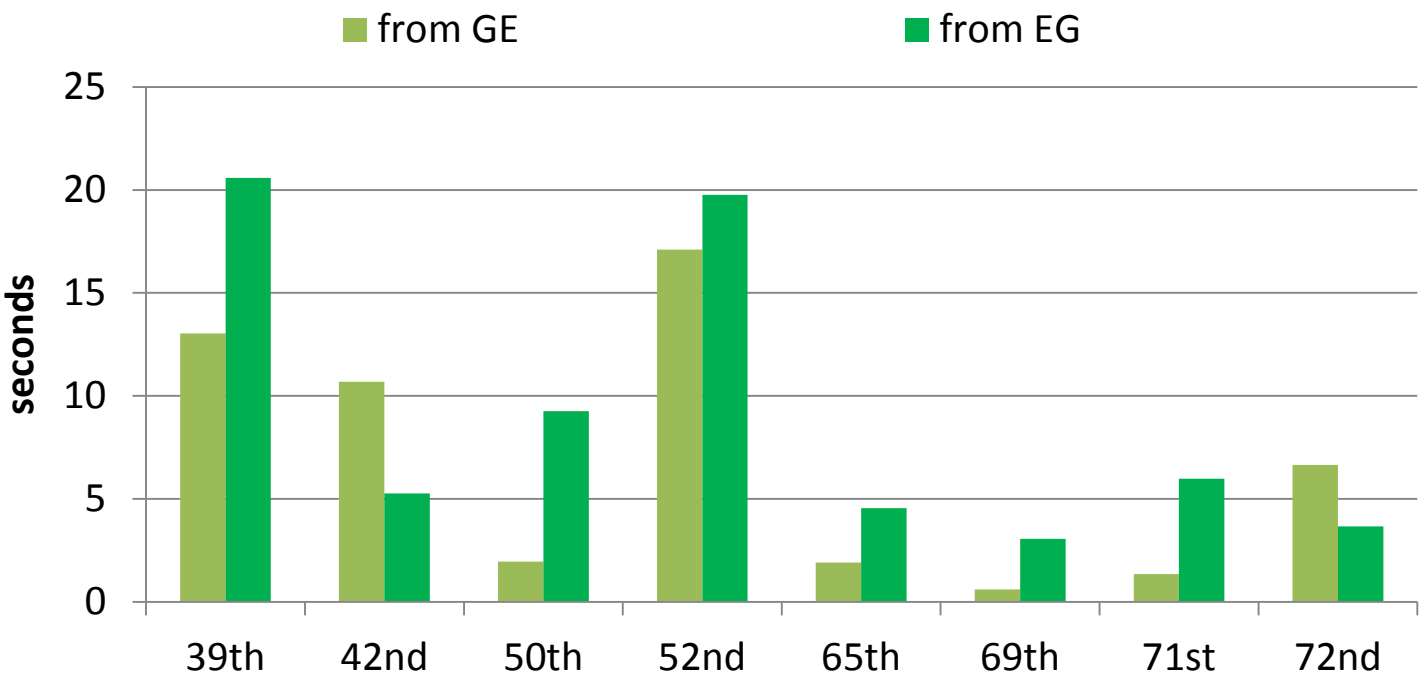
# Passenger Time Saving per TSP Request




$$\frac{\sum_i Time\ saving\ from\ GE_i}{\sum_i TSP\ request_i}$$

$$\frac{\sum_i Time\ saving\ from\ EG_i}{\sum_i TSP\ request_i}$$

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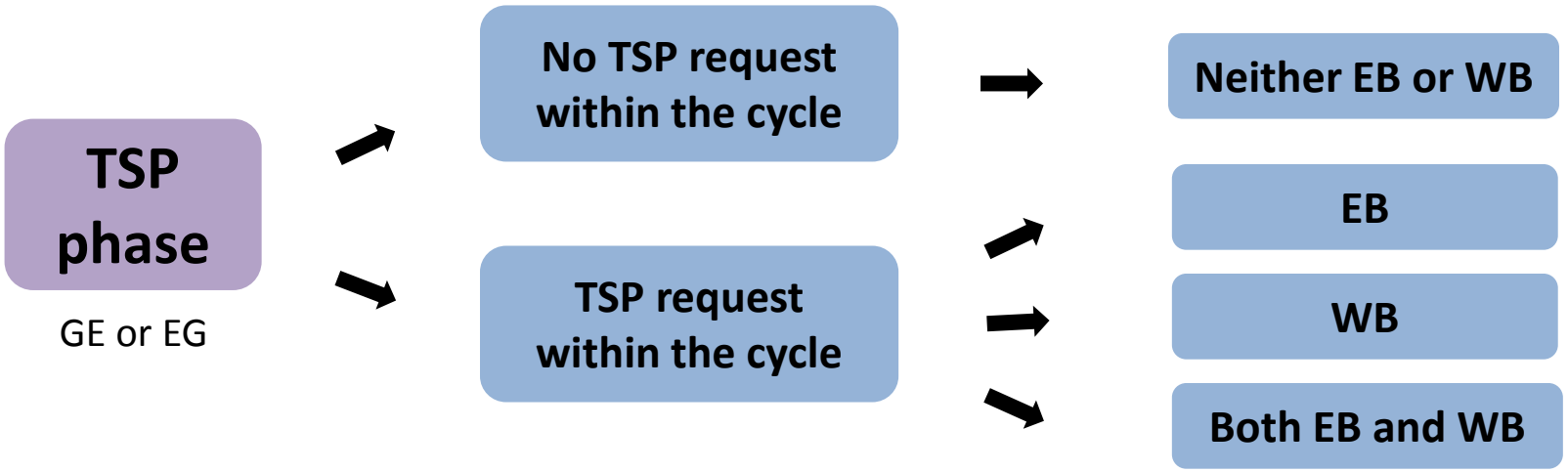
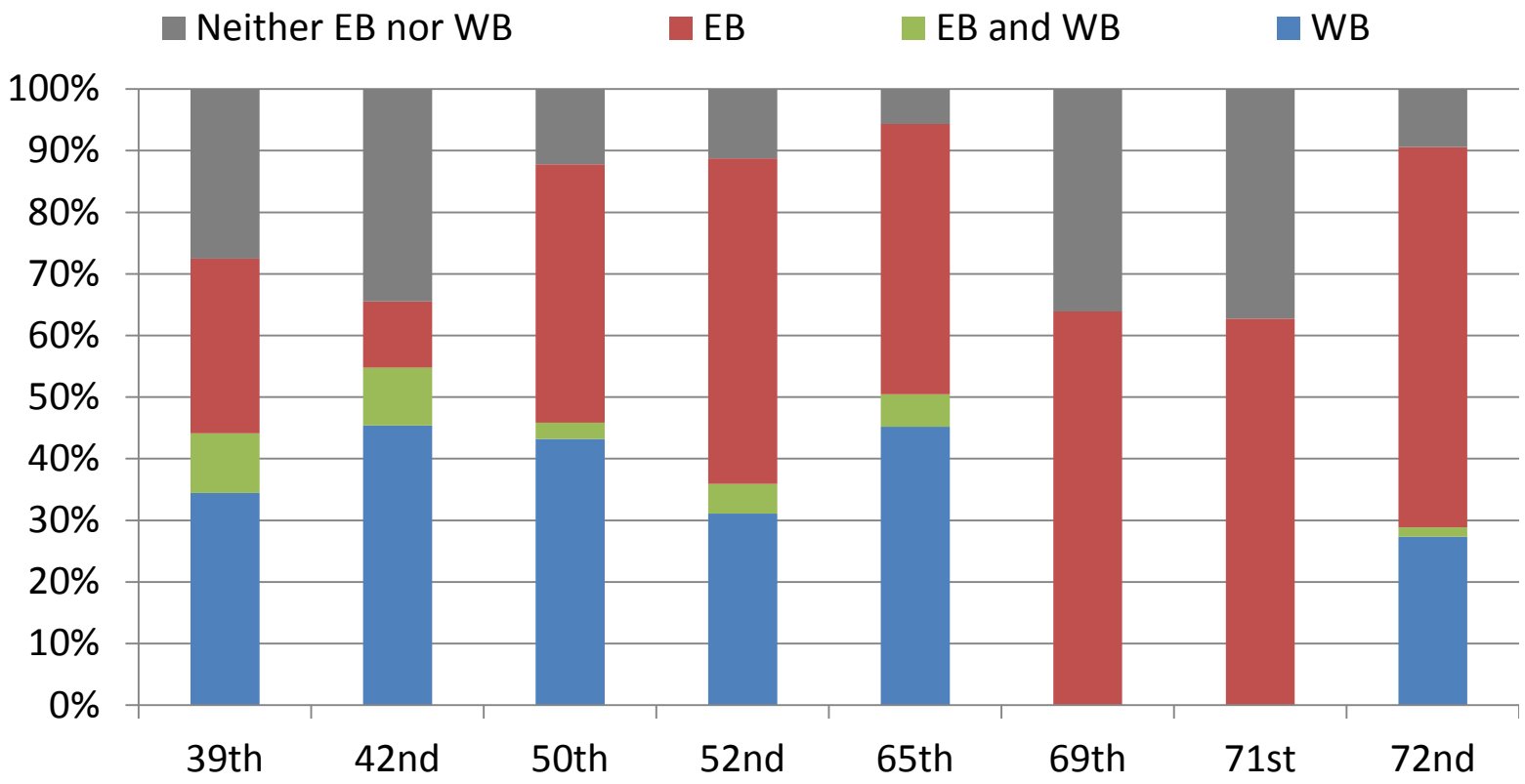
# TSP Phase Triggered by TSP Requests



# % of GEs Associated to TSP Requests From

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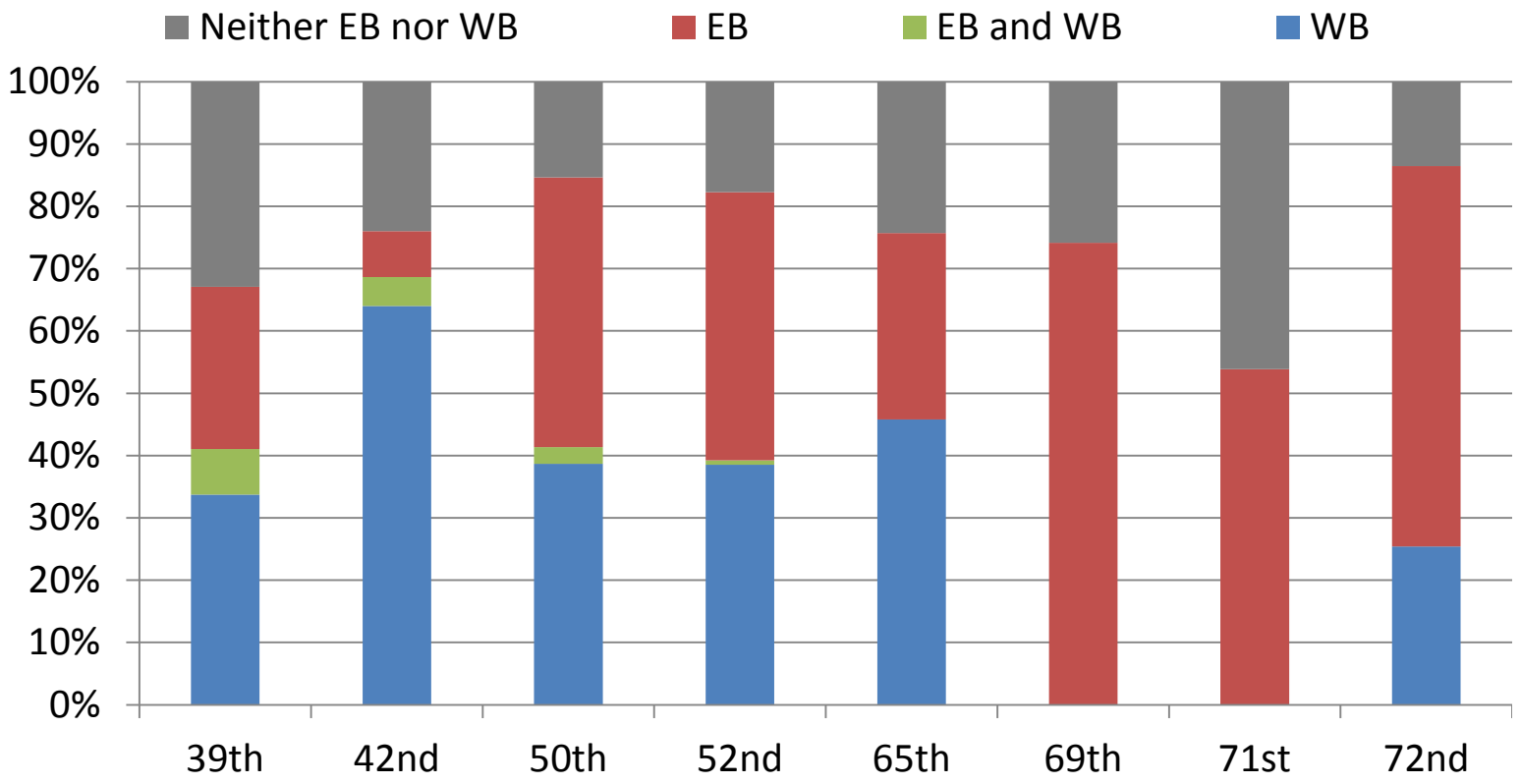
# % of EGs Associated to TSP Requests From

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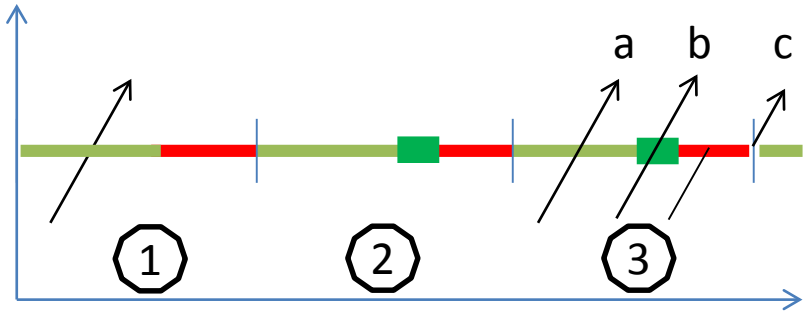
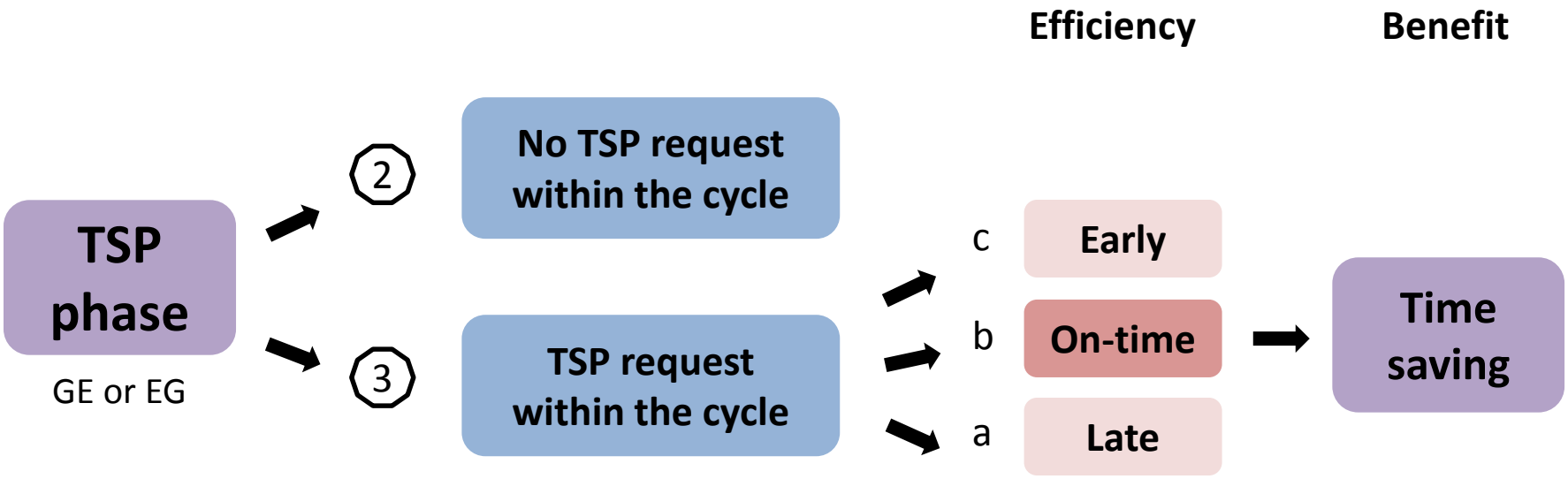
# TSP Efficiency

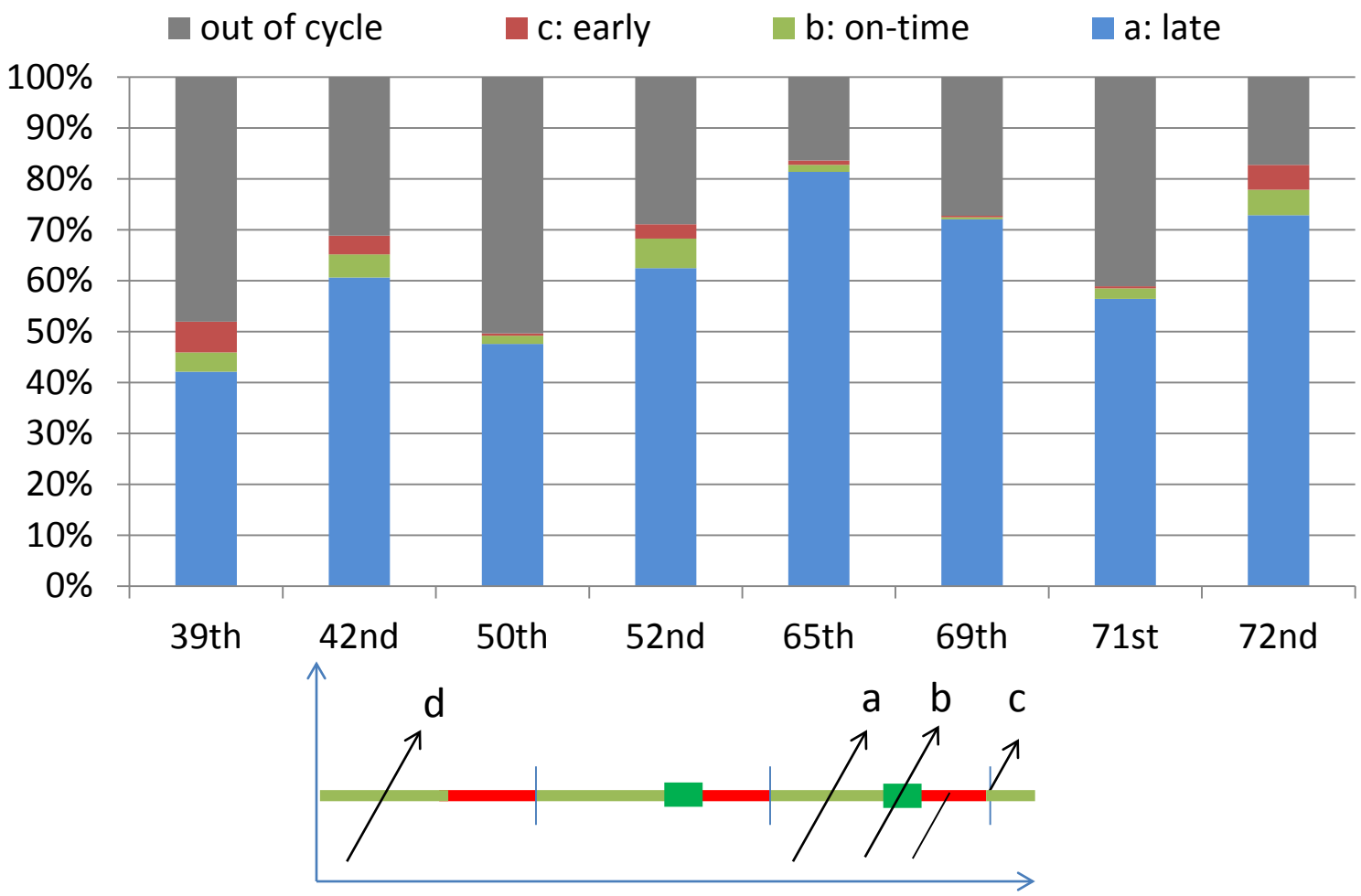
Bus trips that request TSP

Green extension

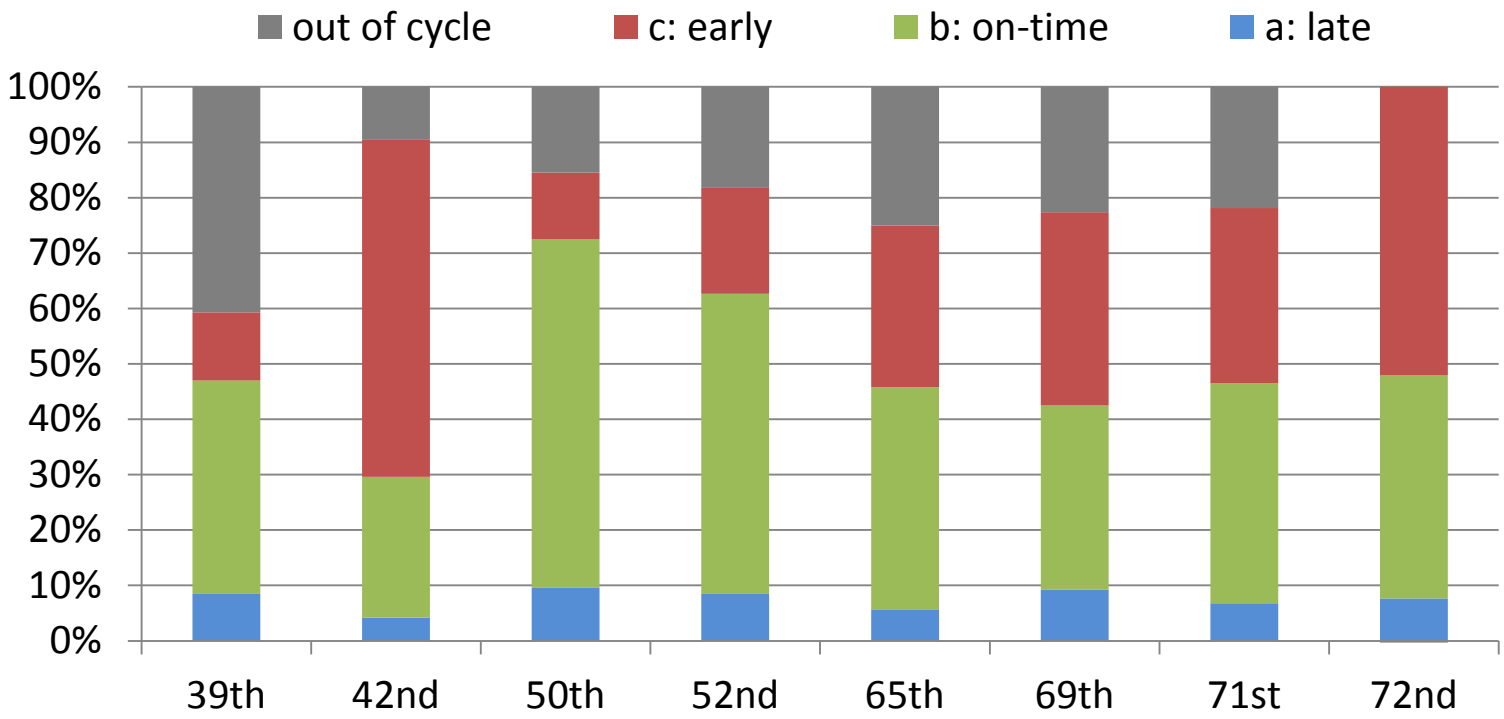


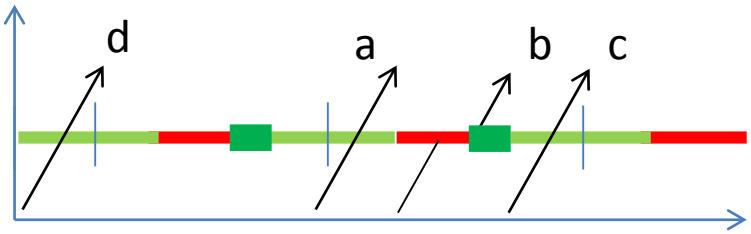



# Actual Green Extension Efficiency



# Actual Early Green Efficiency

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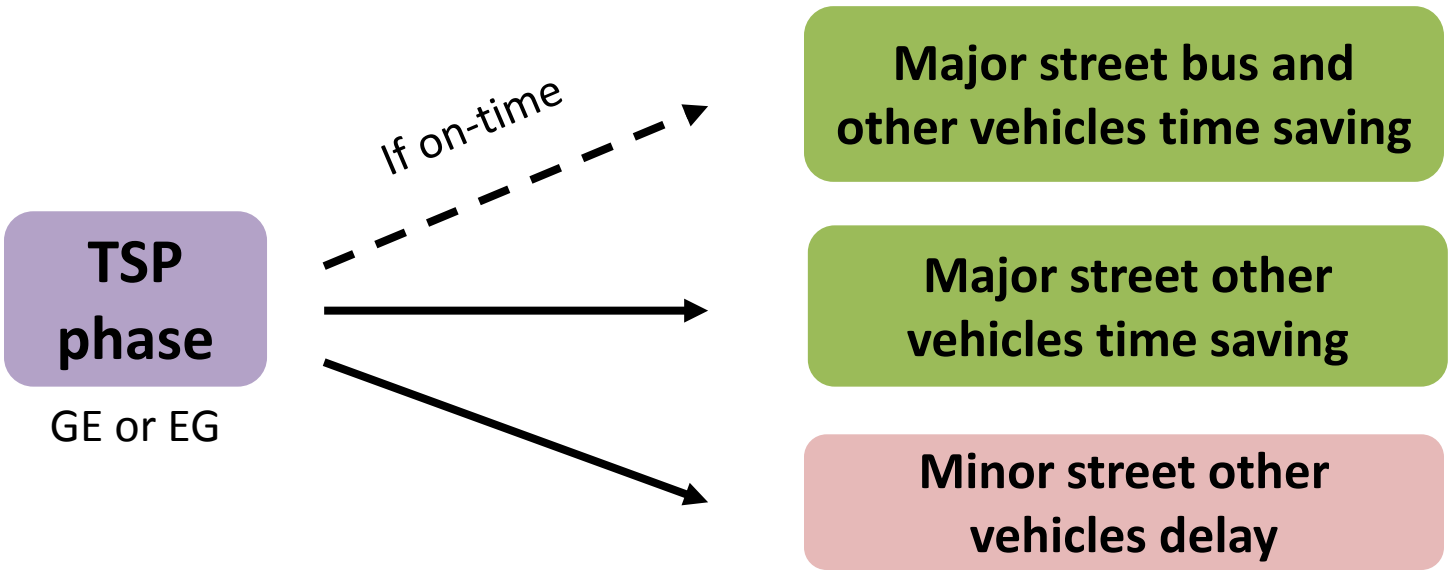
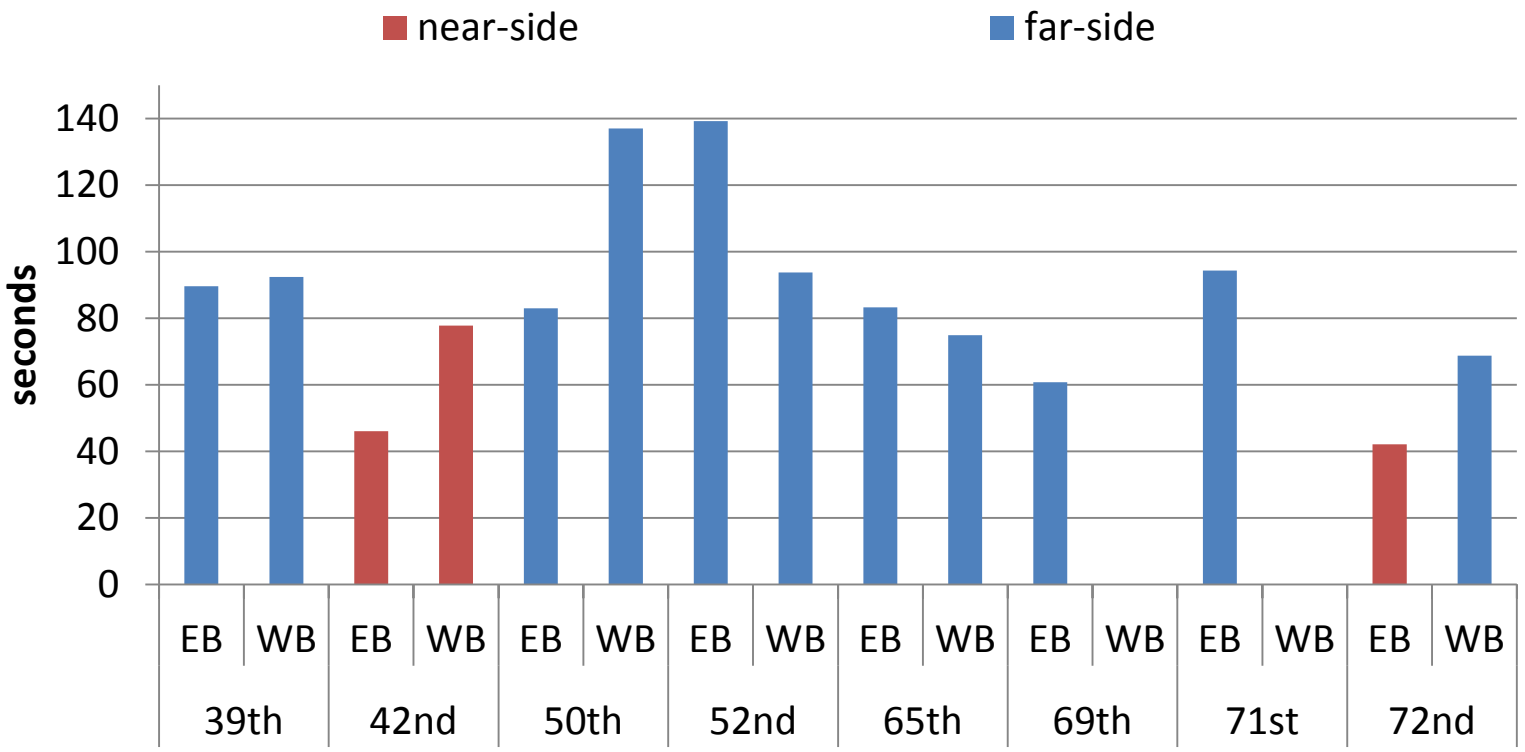
# TSP Efficiency (Time Saving vs. Delay)



# Bus Passenger Time Saving per EG




$$\frac{\sum_j Time\ saving\ of\ EG_j}{\sum_j EG_j}$$

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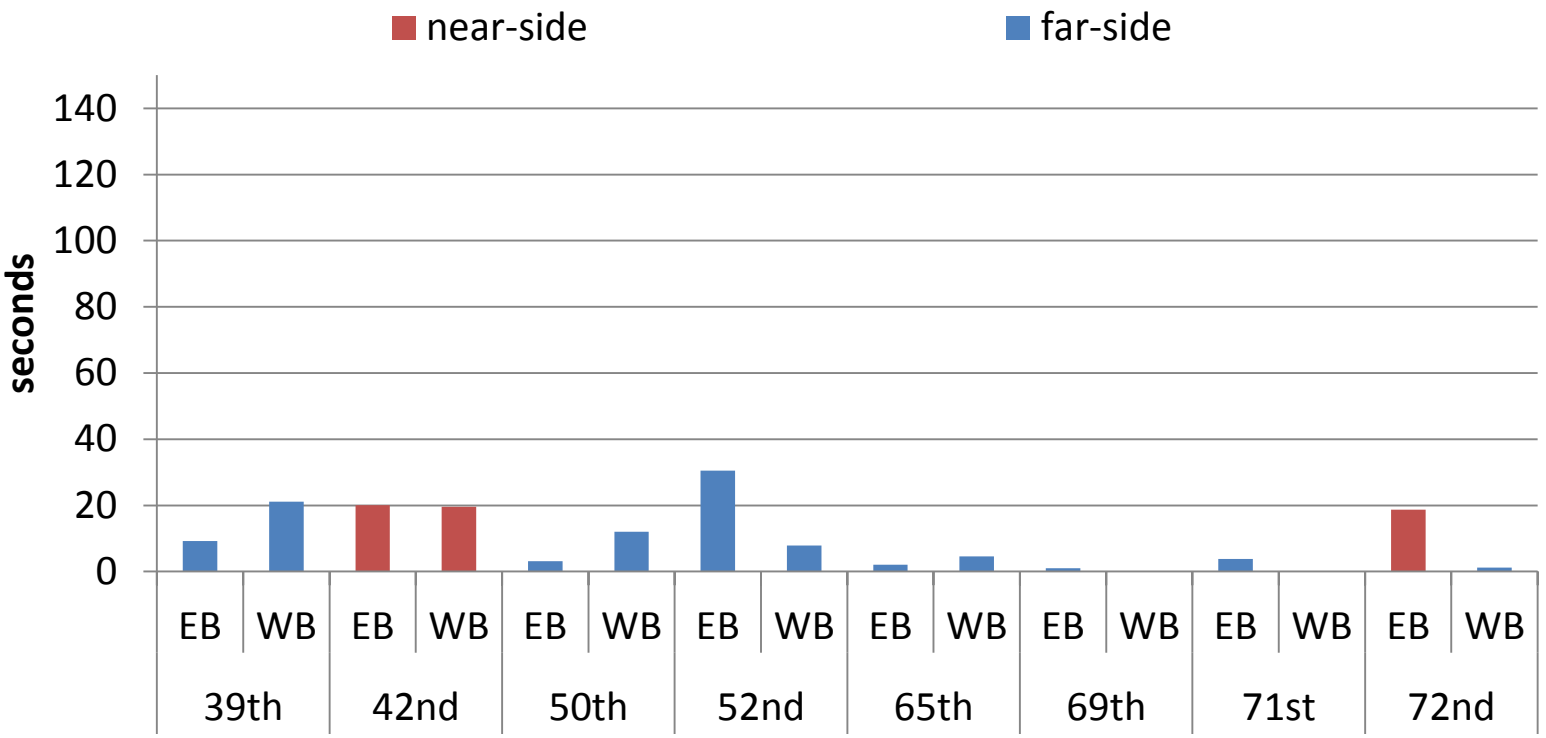
# Bus Passenger Time Saving per GE




$$\frac{\sum_j Time\ saving\ of\ GE_j}{\sum_j GE_j}$$

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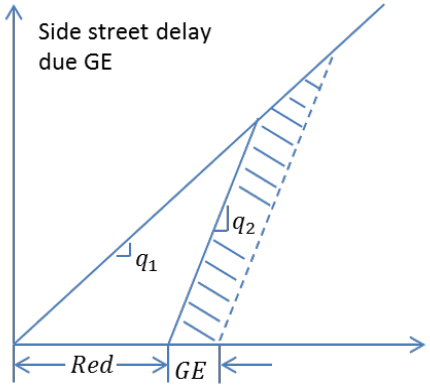
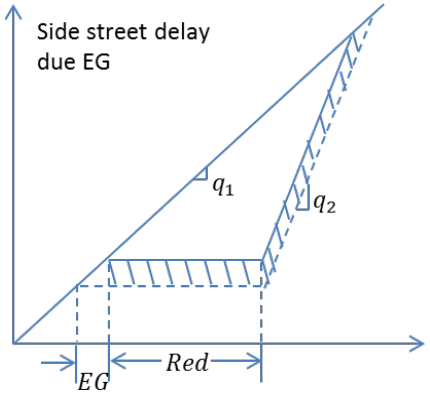
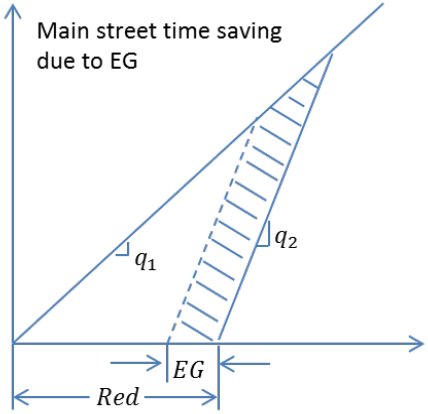
# Vehicle Time Savings and Delay



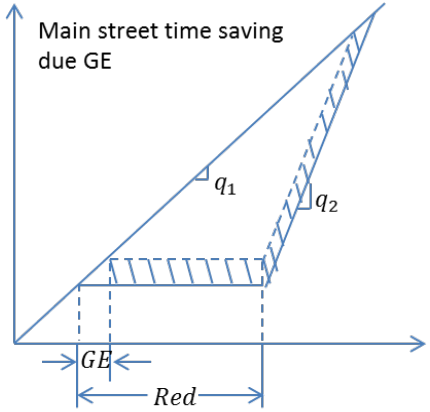

$$TD = \frac{q_1 \cdot q_2}{2(q_2 - q_1)}\left(2 \cdot Red \cdot GE + GE^2\right)$$




$$TD = \frac{q_1 \cdot q_2}{2(q_2 - q_1)}\left(2 \cdot Red \cdot EG + EG^2\right)$$




$$TTS = \frac{q_1 \cdot q_2}{2(q_2 - q_1)}\left(2 \cdot Red \cdot EG - EG^2\right)$$




$$TTS = \frac{q_1 \cdot q_2}{2(q_2 - q_1)}\left(2 \cdot Red \cdot GE - GE^2\right)$$

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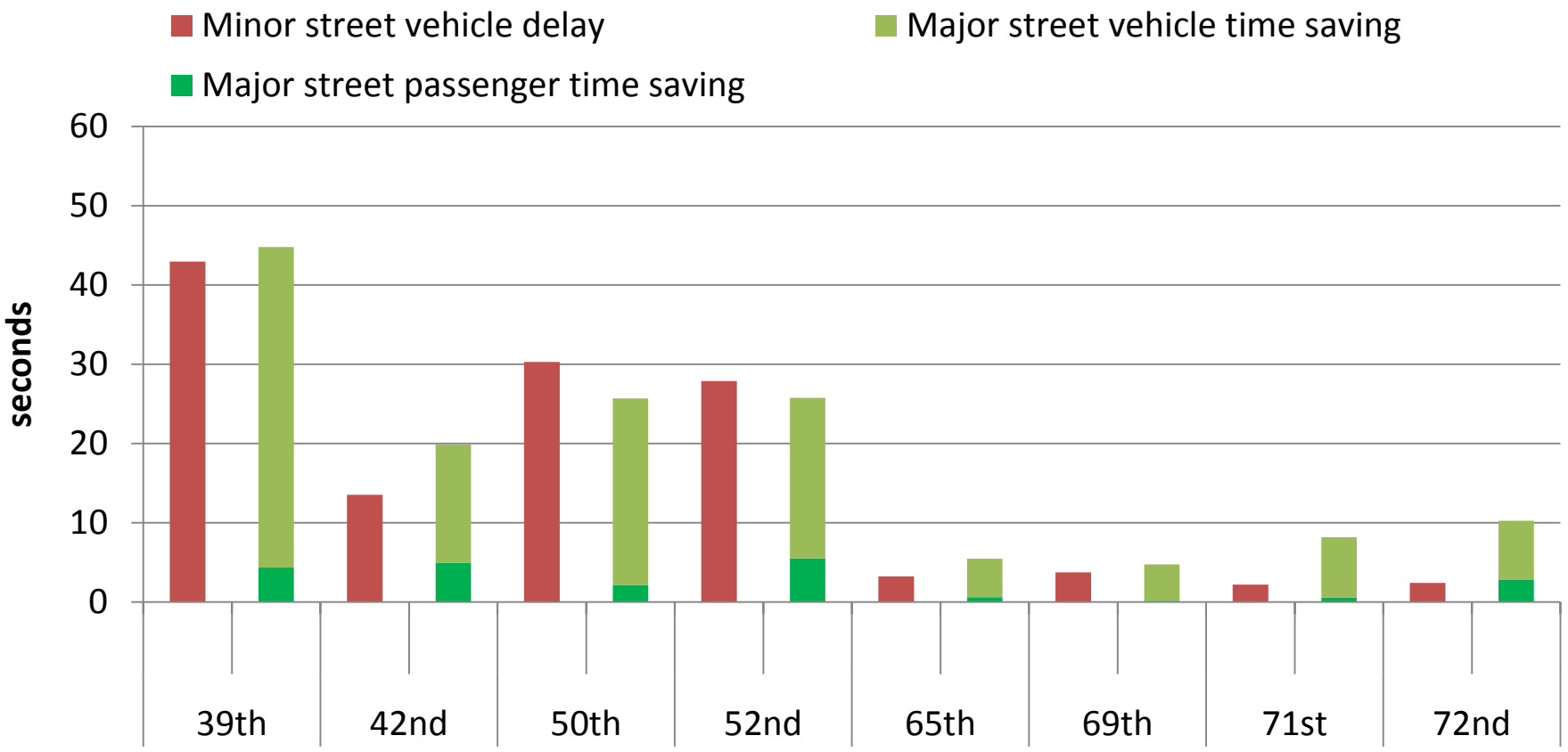
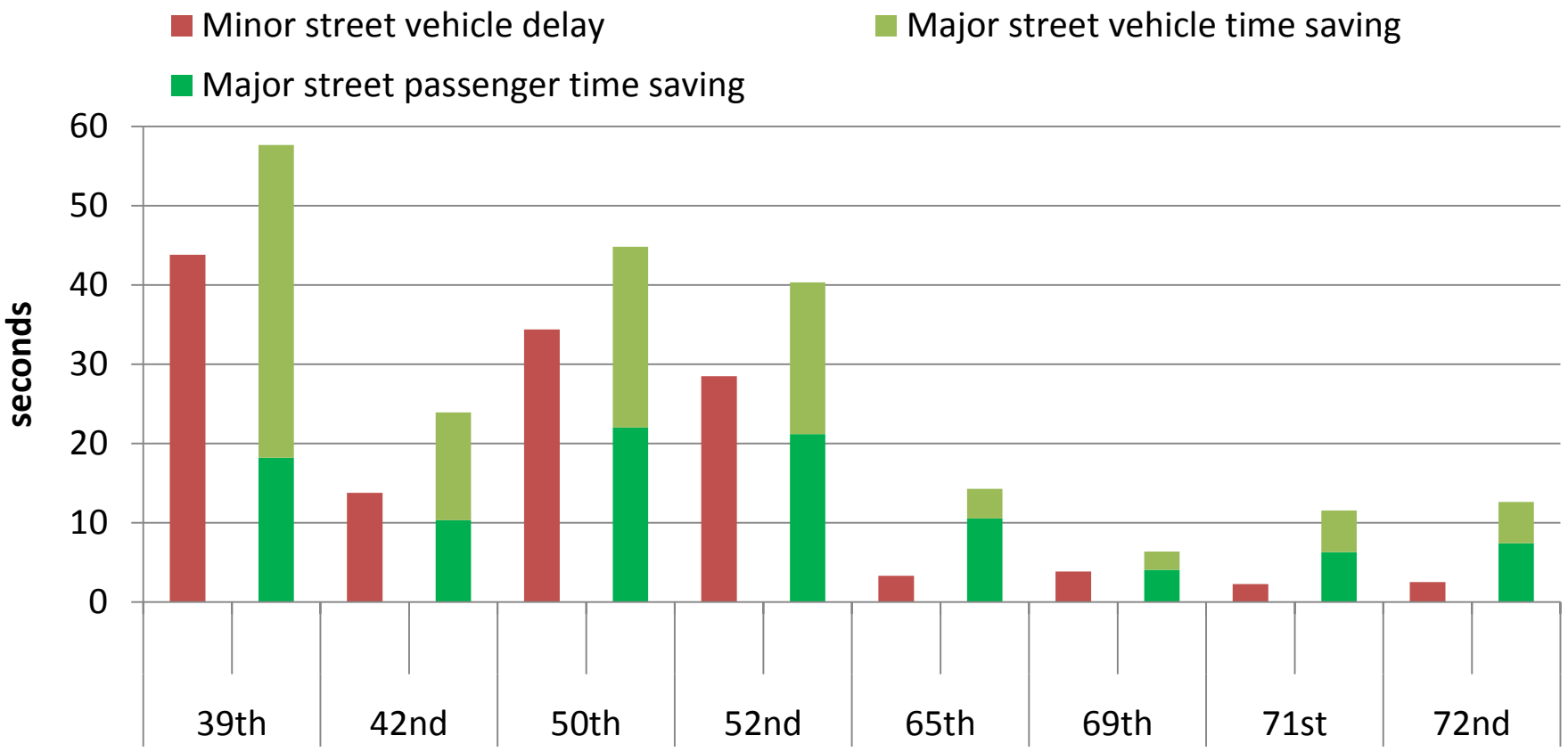
# Green Extension Efficiency




Assume single occupancy vehicles

# Early Green Efficiency




Assume single occupancy vehicles

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# Summary of Findings

**TSP performance**

- Vary significantly across intersections
- Big gap between actual and ideal performance

**Green extension**

- Too many late green extension phases
- Time savings $\approx$ Delay

**Early green**

- Time savings > Delay

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# Conclusions

- Proposed TSP performance measures can help identify problems/improvement opportunities and support planning decisions
- Findings from this study may be site-specific, but the methodologies are transferable to other corridors/cities
- TSP effectiveness and efficiency can be greatly affected by control logic, parameter calibration and signal detection/communication reliability

# Future Work

- Consider vehicle queuing effect when estimating bus arrival time probabilities at intersections

- Utilize new and higher resolution data such as:
  - 5-second bus AVL data (finer bus trajectory between bus stops)
  - TSP Optical detector log data (priority log in/out records)

# Acknowledgements

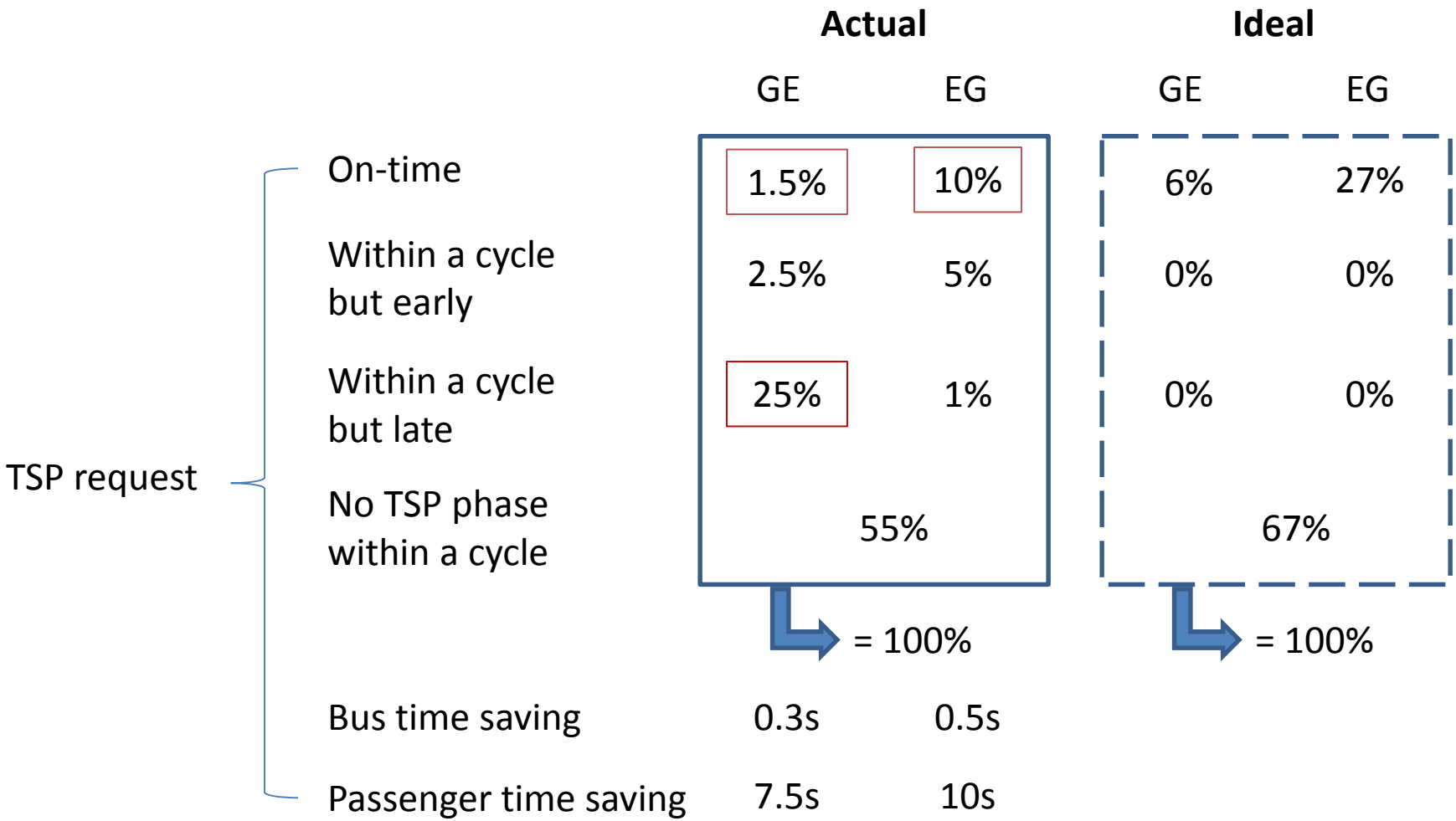
Steve Callas
David Crout

Peter Koonce
Willie Rotich

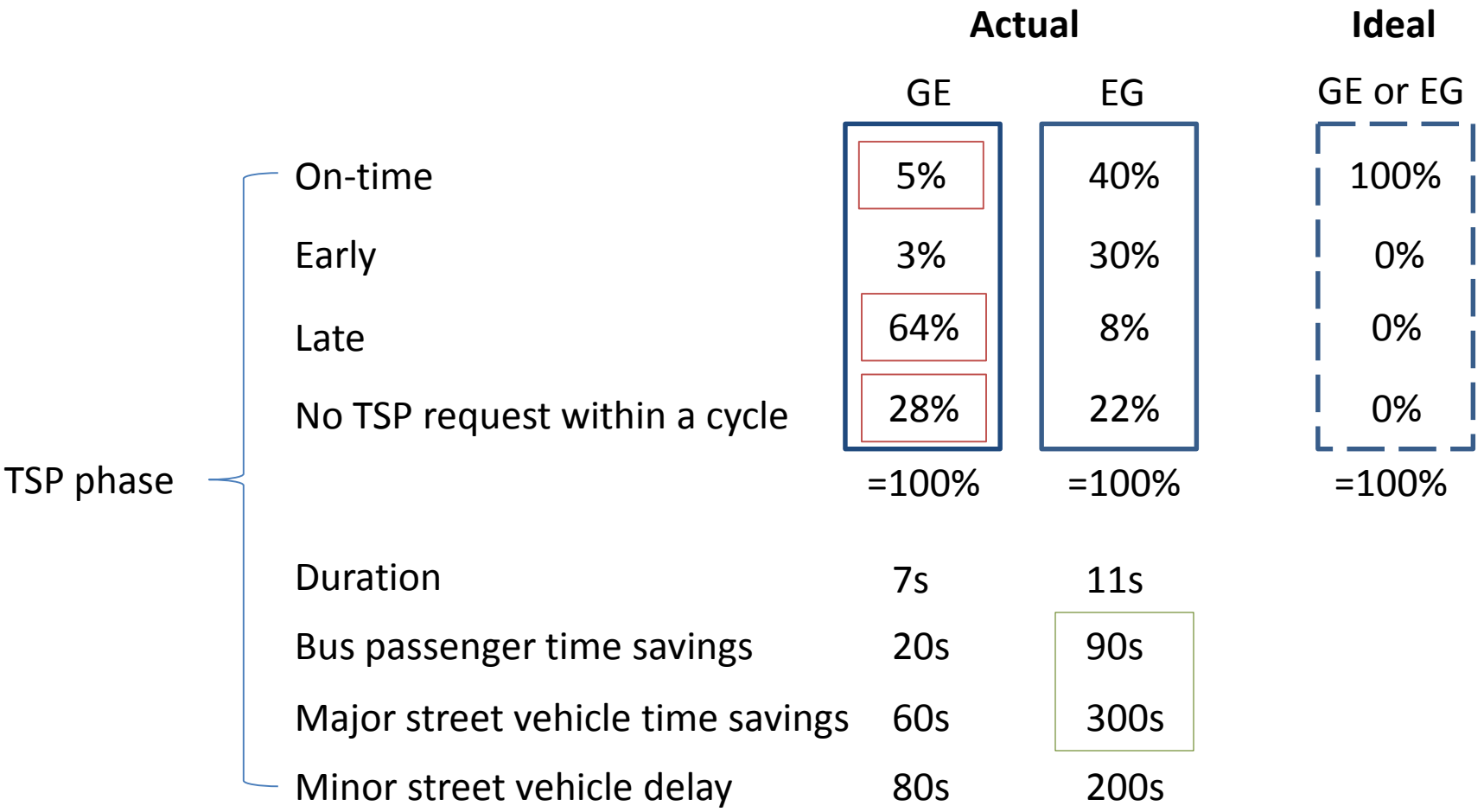



# Questions?

# On Average


Actual
Ideal
GE
EG
GE
EG
TSP request
On-time
1.5%
10%
6%
27%
Within a cycle but early
2.5%
5%
0%
0%
Within a cycle but late
25%
1%
0%
0%
No TSP phase within a cycle
55%
67%
= 100%
= 100%
Bus time saving
0.3s
0.5s
Passenger time saving
7.5s
10s

# On Average


Actual
Ideal
GE
EG
GE or EG
TSP phase
On-time
5%
40%
100%
Early
3%
30%
0%
Late
64%
8%
0%
No TSP request within a cycle
28%
22%
0%
=100%
=100%
=100%
Duration
7s
11s
Bus passenger time savings
20s
90s
Major street vehicle time savings
60s
300s
Minor street vehicle delay
80s
200s