Green-time usage metrics on signalized intersections with high-resolution data

S. Ilgin Guler, Assistant Professor, Penn State

Vikash V. Gayah, Associate Professor, Penn State

Renato Guadamuz, Penn State

Houjun Tang, Penn State

Zhengyao Yu, Penn State

TESC

December 12, 2019

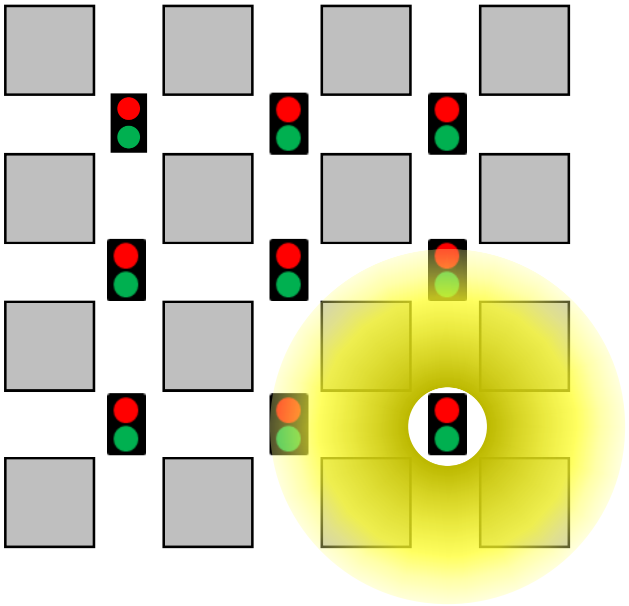
Signal timing impacts operational performance, as well as contribute to safety and environmental issues.

- Signal performance is sensitive to demands but signals are timed very infrequently.
- Automated methods are needed to alert analysts when and where signal retiming is needed.

Source: leungchopan / Shutterstock (n.d.)

Automated metrics to quantify the performance of signals can be used to:

- Identify WHEN and WHERE current signal phase and timing plans might need to be updated.



High resolution signal data from Salt Lake City, Utah in 2018

- Data consists of high resolution signal data (collected every 0.1 second) from two arterials
  - 7,039,547 observations corresponding to date and time of events.
- The data consists of events and corresponding time and date.
- Events include:
  - Signal plan: start and end time of green phase, yellow clearance and red clearance
  - Detector records: traffic counts of each movement

Methodology

Data

- Detector data
- Signal timing plan

Data processing and cleaning

- Convert detector data to traffic counts
- Determine signal timing plan corresponding to the period during which the detector data was collected

Compute Green Time Metrics

The detector data was converted to traffic counts using the following algorithm

Obtain high-resolution detector data

↓

Filter by:

- Lane type: Vehicle
- Detection type: Lane-by-lane Count
- Event code: Detector on

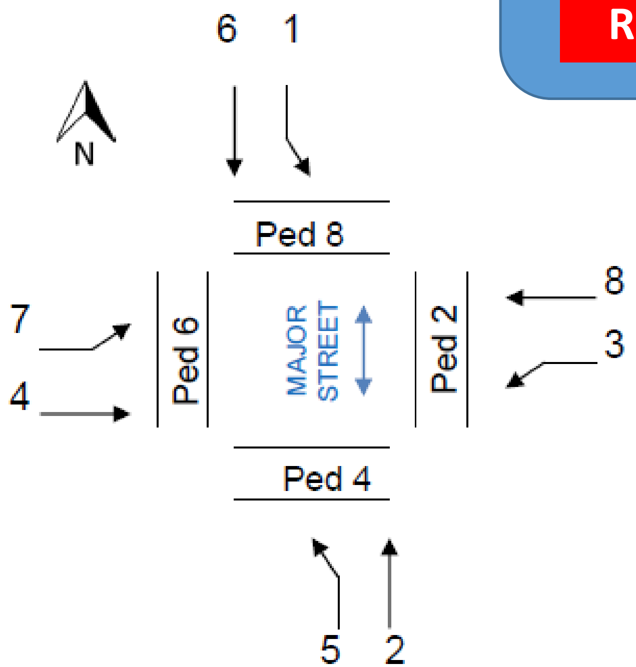
↓

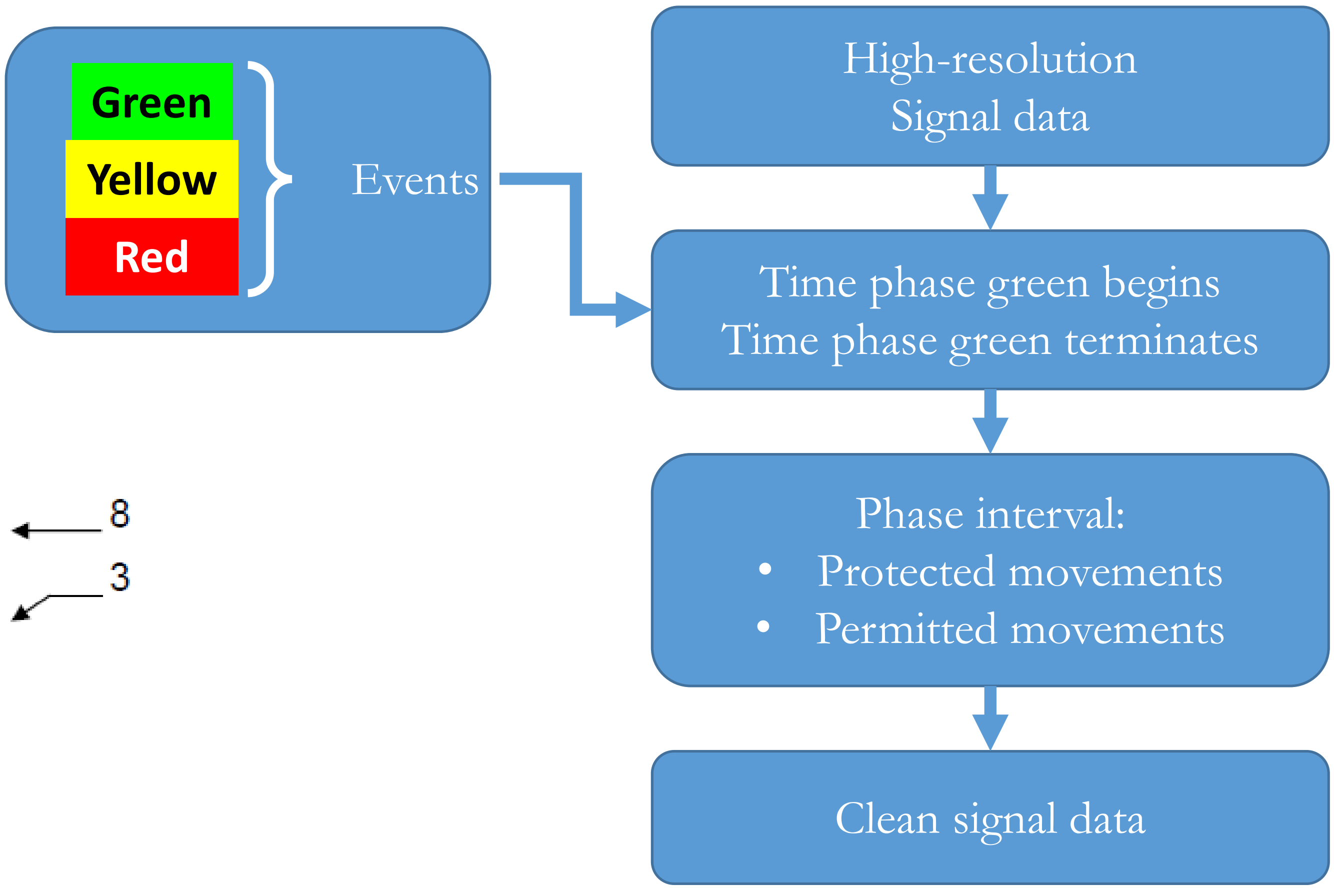
Merge by approach and movement

↓

Clean detector data

The signal timing plan was determined using the following algorithm



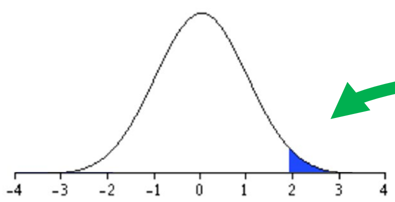


Source: UDOT (n.d.)

The detector and signal data are then merged:

- Sum all vehicle counts during identified green periods and label with the correct phase information
- Further, the data is cleaned:
  - Missing events, and
  - Flag long **green** intervals

Green begins
Green ends ???
Yellow begins
Yellow ends
Red begins
Red ends



$$\bar{y}_{green} + 2 * SD_{green}$$

Yellow (or **red**) time start occurs before **green** time ends.

Metrics to evaluate signal timing plans were developed

1) Normalized green flow
2) Standard deviation of normalized green flow
3) Range of green durations
4) The fraction of phases during which two or fewer vehicles discharge

Normalized green flow, $q_{i,t}$

- Normalized rate of vehicles that can discharge during a green period.

$$q_{i,t} = \frac{N_{i,t}}{L_i \times G_{i,t}} \text{ [veh/green-min/lane]}$$

$N_{i,t}$: number of vehicles that discharge during green period i for a given time period t.

$G_{i,c}$: green duration of the phase and movement (minutes).

L_i : number of lanes.

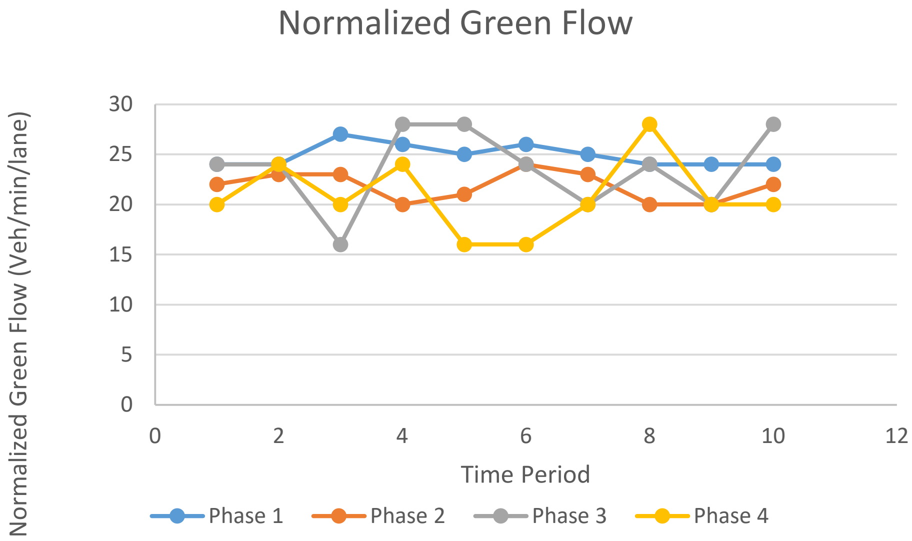
Normalized green flow provides an indication of how well-used the green time is during any given time period:

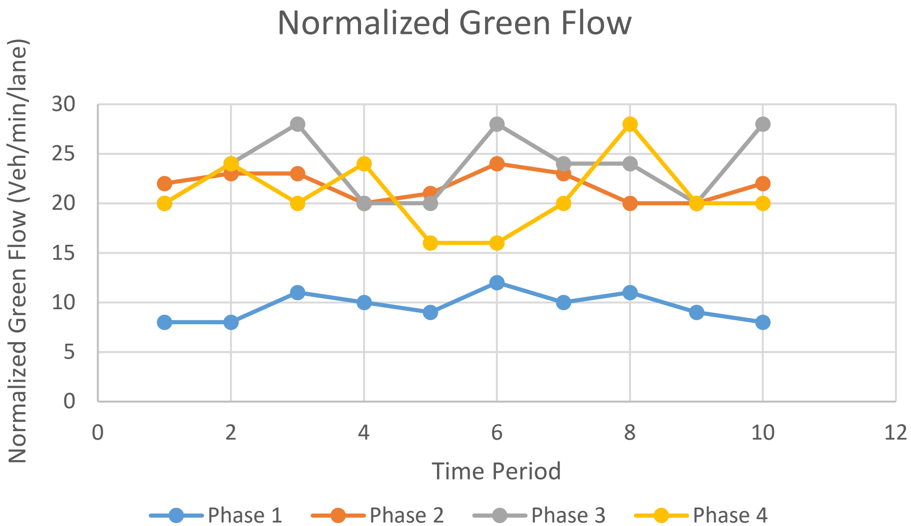
- Should be approximately equal to saturation flow when intersection is operating near saturation
- Will be lower if under-saturated

- Normalized green flow alone does not indicate if signal is well-timed
  - Compare normalized flow across different movements at an intersection
  - Imbalance among normalized flows suggests that some movements green time are being wasted and could be better used by others

Normalized green flow, $q_{i,t}$

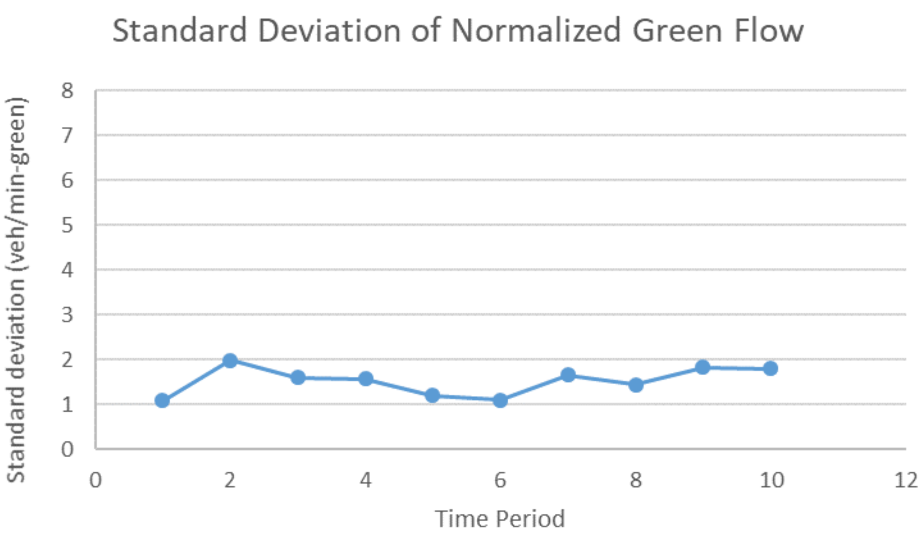
- Indicator of the level of utilization of each phase.

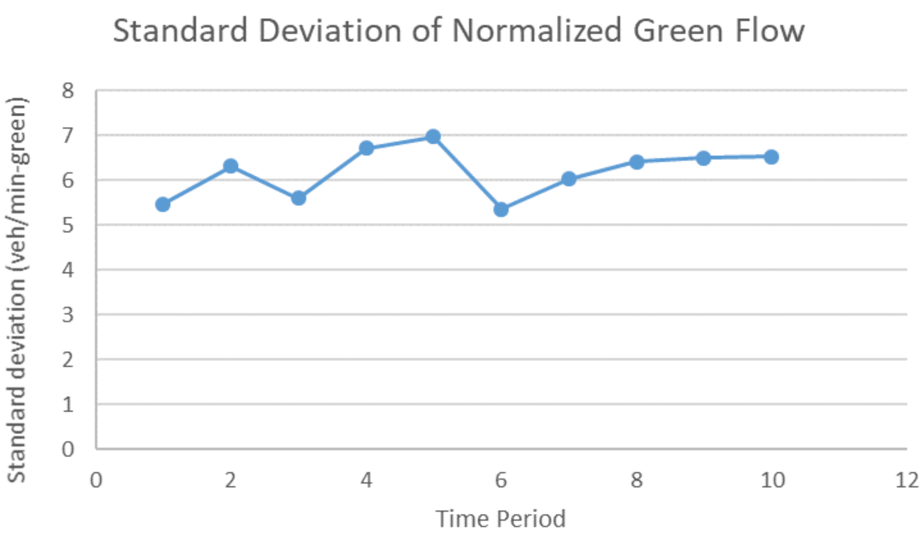




Standard deviation of normalized green flow

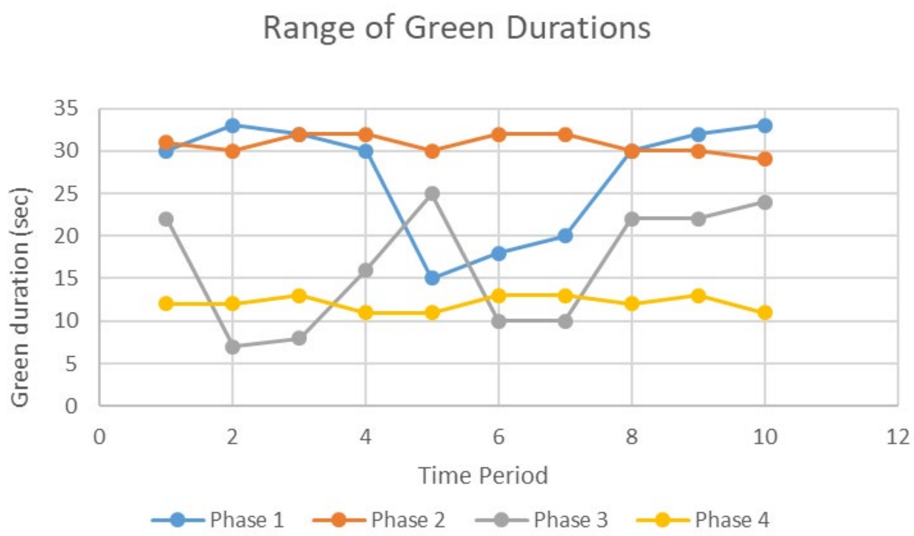
- Variability of normalized green flow per lane aggregated during a time period across all phases





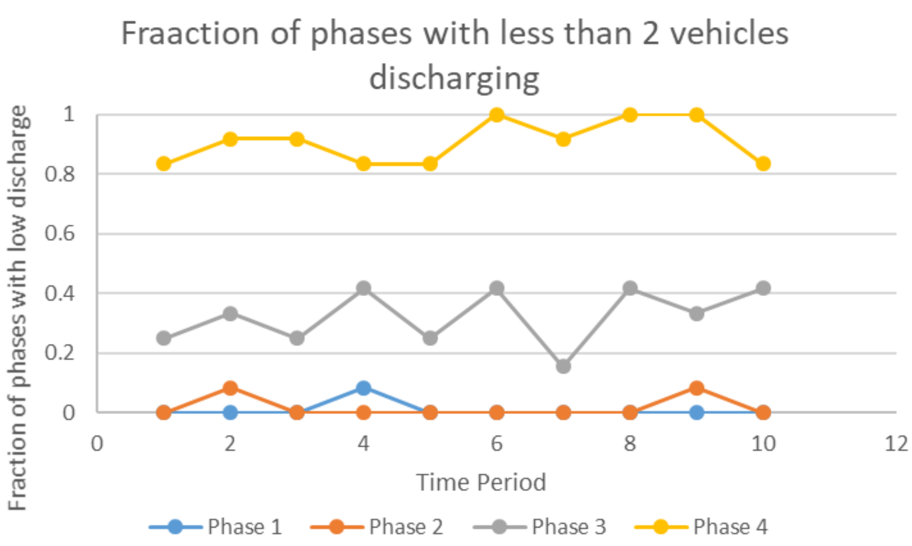
Range of green durations

- High values are indicative of movements that have highly variable demands
- Low values are indicative of movements that have constant demands

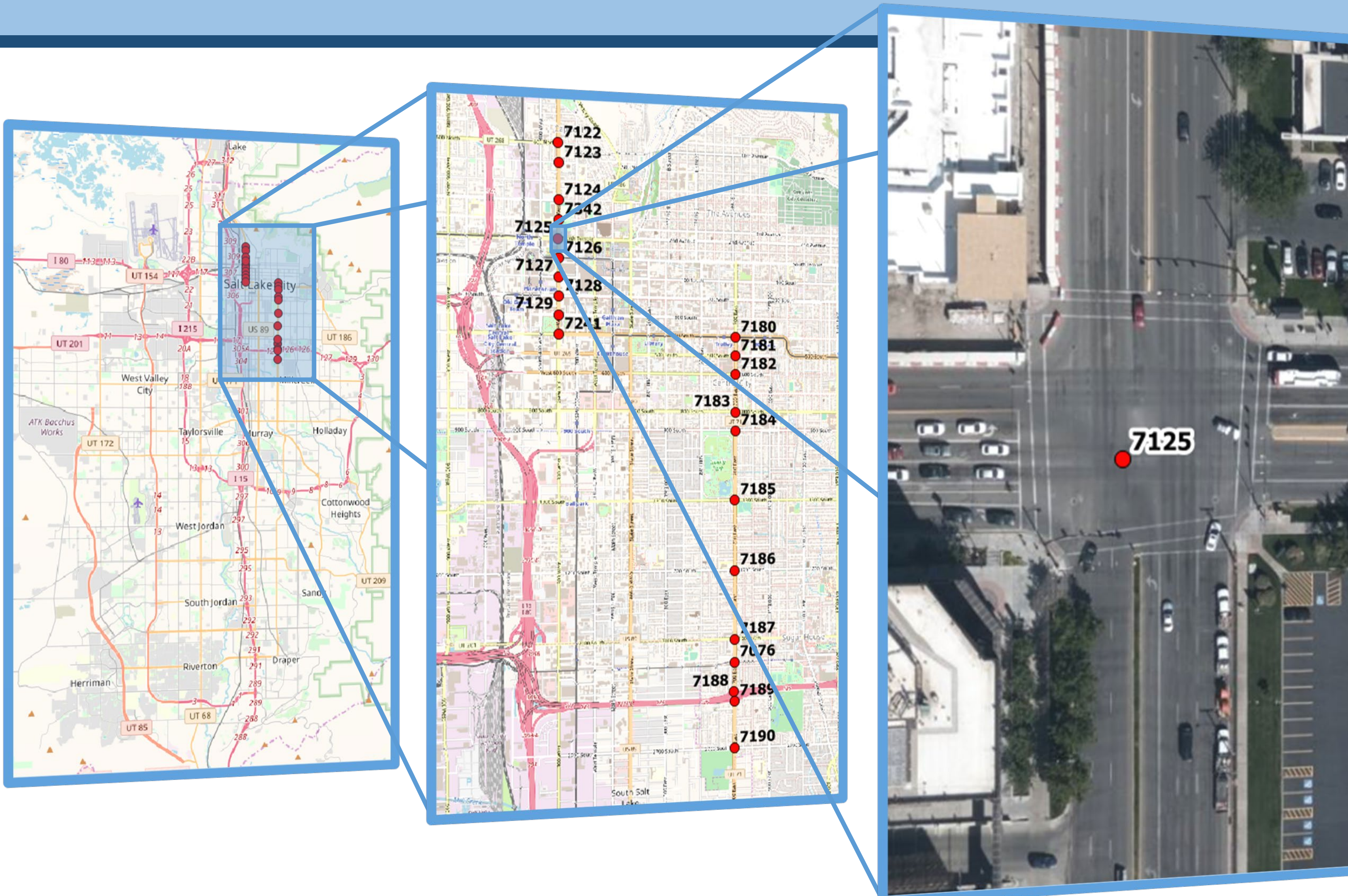


The fraction of phases during which two or fewer vehicles discharge

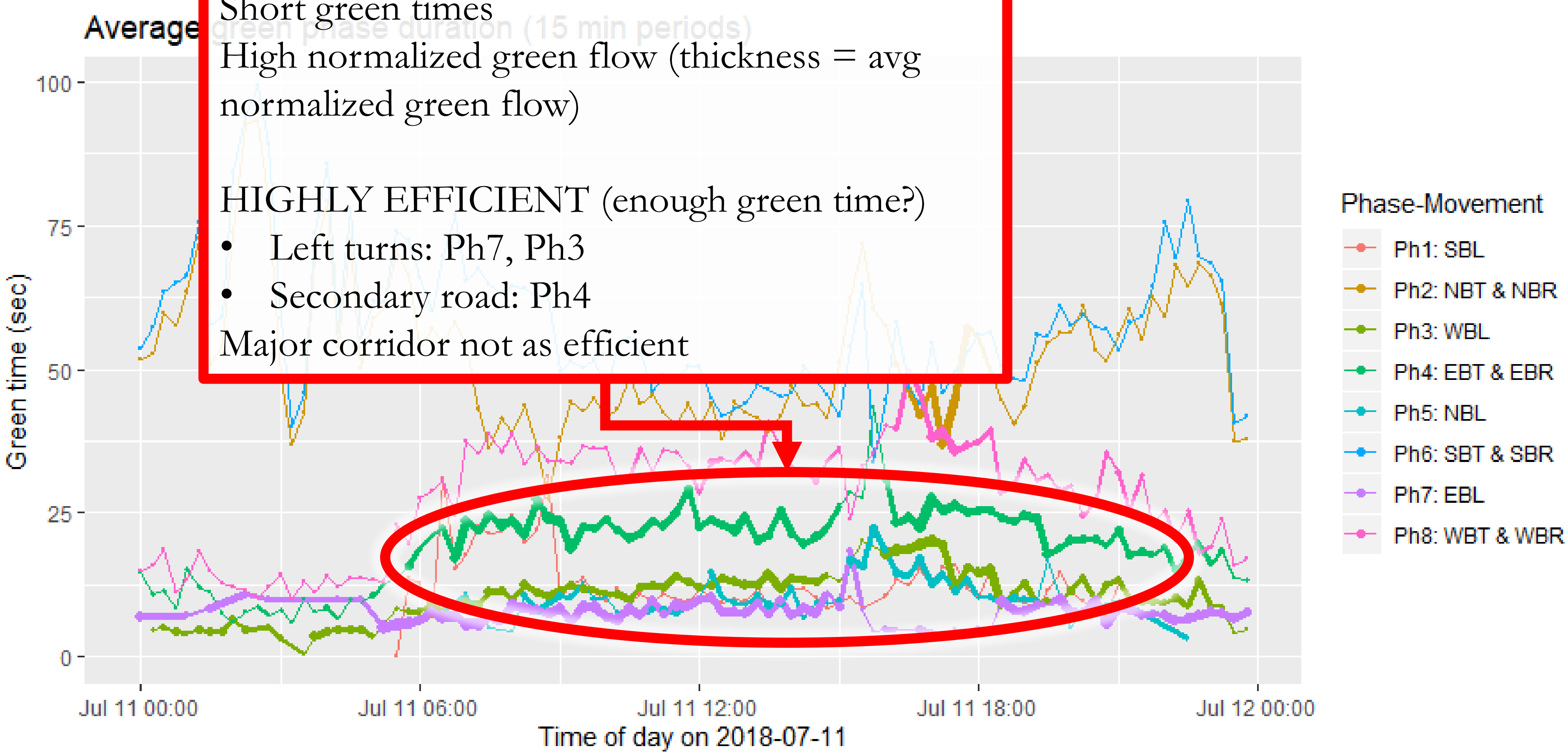
- Represents how many phases are being called but barely being used
- Discrepancies for this metric among movements may be indicative of a SPaT plan that does not match the demand



Data was collected for July 1st at the following intersection:



Results: Range of green time

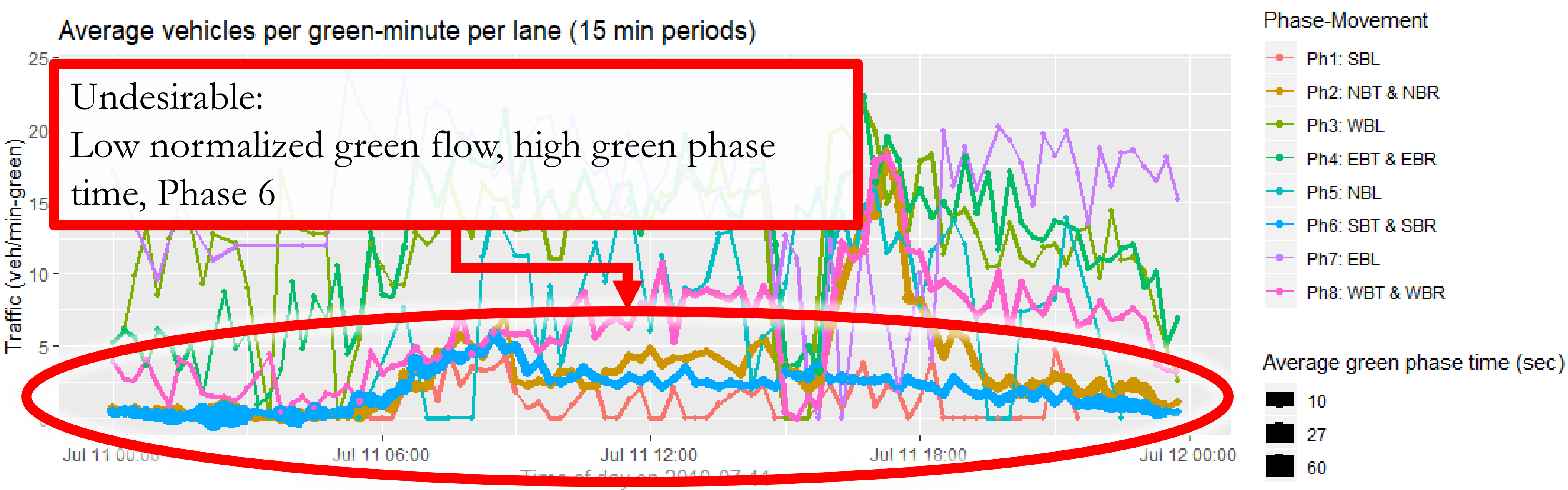


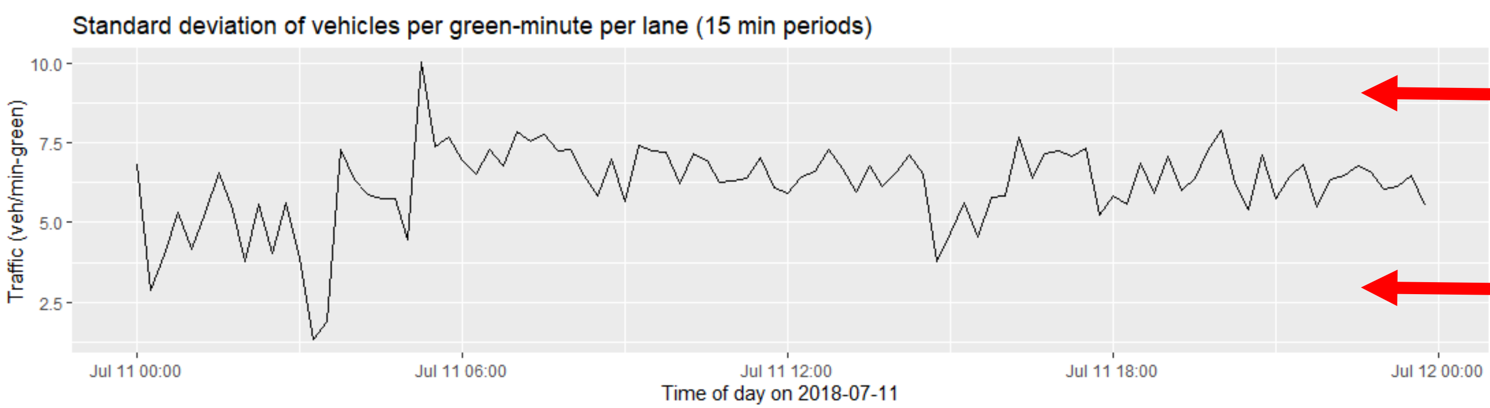
Short green times
High normalized green flow (thickness = avg normalized green flow)

HIGHLY EFFICIENT (enough green time?)
- Left turns: Ph7, Ph3
- Secondary road: Ph4

Major corridor not as efficient

Results: Normalized green flow

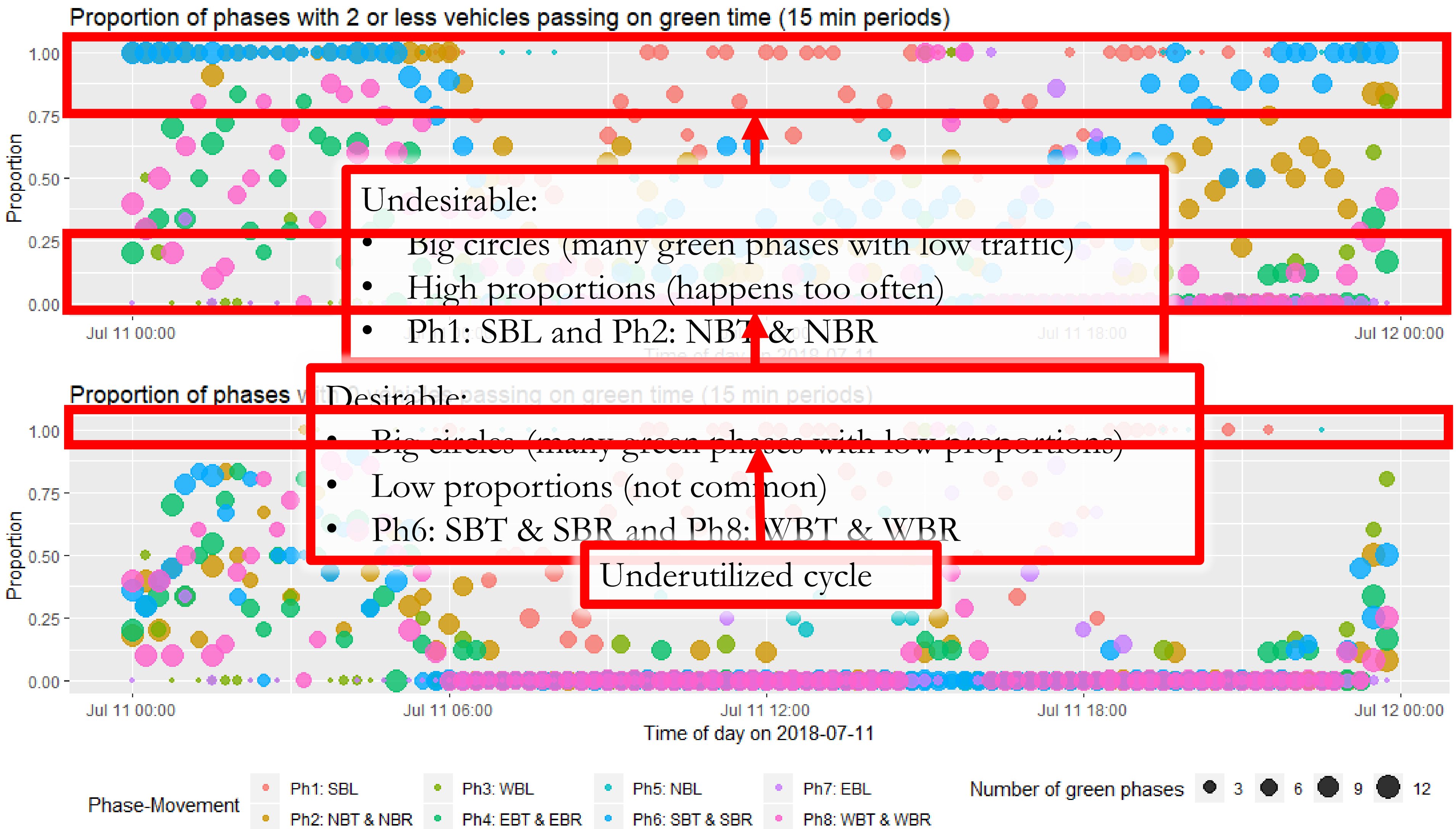




High variability among phases

Low variability among phases

Results: Proportion of phases with low discharge



Conclusions

- New metrics for analyzing green-time usage in ~real time is developed
- High-resolution traffic data can be used to calculate these metrics
  - Determine when re-timing of signals might be required
- Process can be automated to create a useful tool for traffic engineers

Thank you!

S. Ilgin Guler
Assistant Professor
Department of Civil and Environmental Engineering
The Pennsylvania State University
221B Sackett Building
University Park PA 16802
iguler@engr.psu.edu
phone: 814-867-6210
sites.psu.edu/iguler