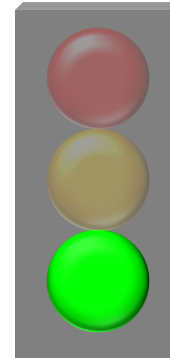


Intelligent Traffic Signal Management using Probe Data

Information Network R & D Center
Sumitomo Electric Industries, Ltd.
Date: September, 2022



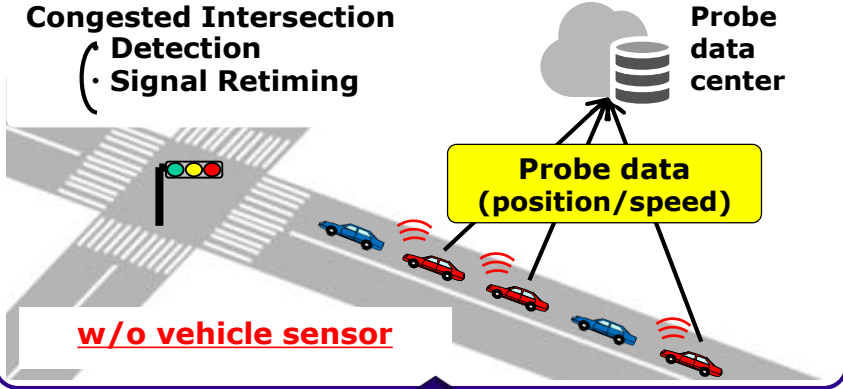
Intelligent Traffic Management using Probe Data



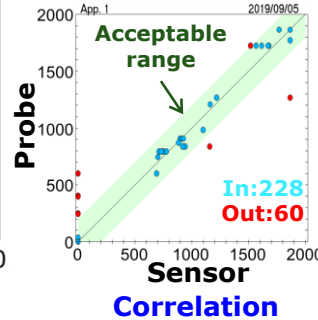
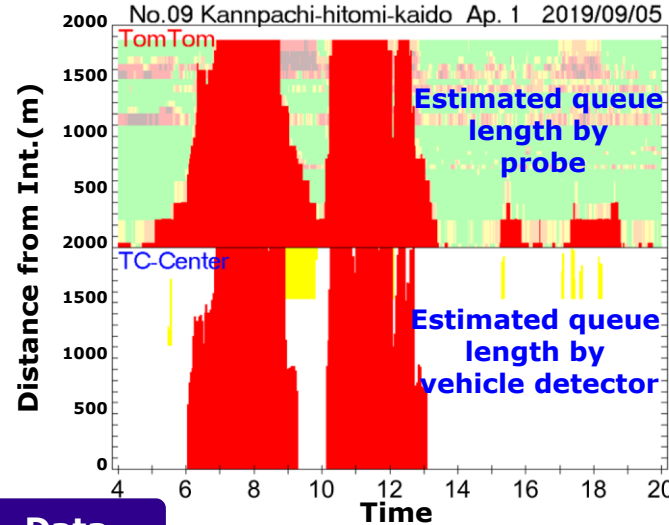
We are expecting that probe based data will become key resource for traffic signal control. And it will relieve from the detector equipment and maintenance.

Overview

Congested Intersection Detection
 • Signal Retiming



Comparison



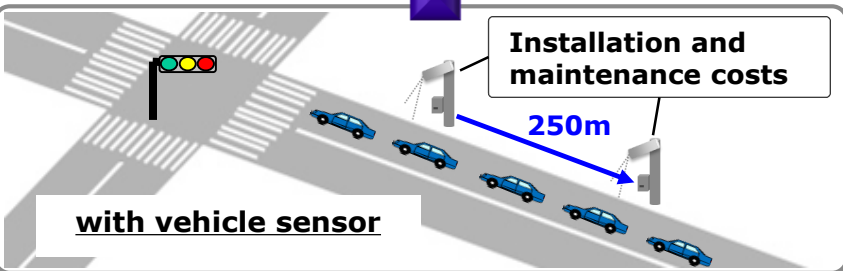
Data

- **TOMTOM** probe-based analysis data
- TomTom and SEI have been in partnership since 2019.
- TomTom's data is provided worldwide, include the entire U.S.

Installation and maintenance costs

250m

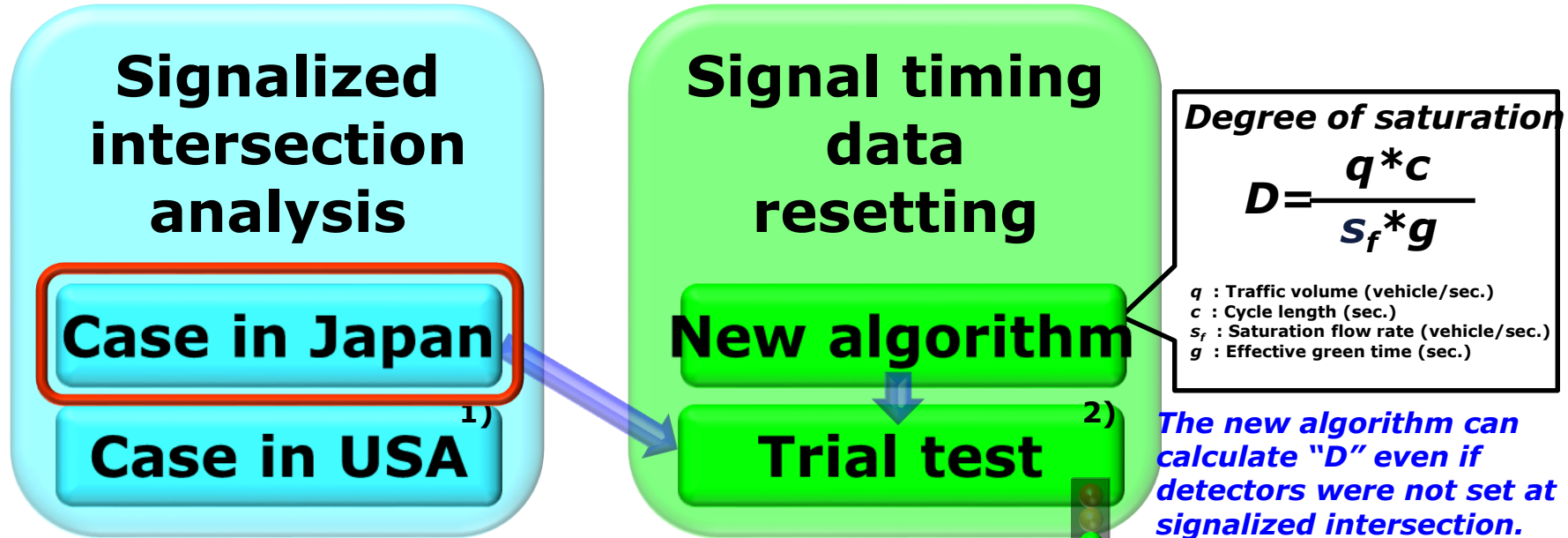
with vehicle sensor



Intelligent Traffic Management using Probe Data

What can we do using probe based data?

The acquisition information : Congestion length, Travel time → Delay time



1) TS16 : Managing Congestion ,

2) TS34 : How Technology Impacts Transportation I, Sep.21st 08:00-09:30 AM, Room 402A

Sep.20th 03:00-04:30 PM, Room 402B



Signalized intersection analysis (Case in Japan)

Sorting out unbalanced congestion intersections

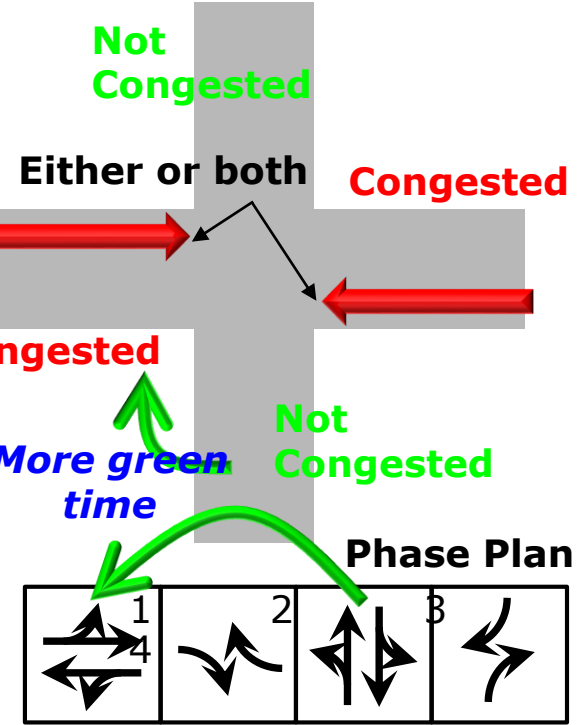
Tokyo

Kan8 Hitomi-Kaido Int.

Shin-Hukurobashi Int.

- Target area
- Unbalanced Intersection
 - congested in more than 50% of all time
 - congested in 25-50% of all time
 - congested in less than 25% of all time

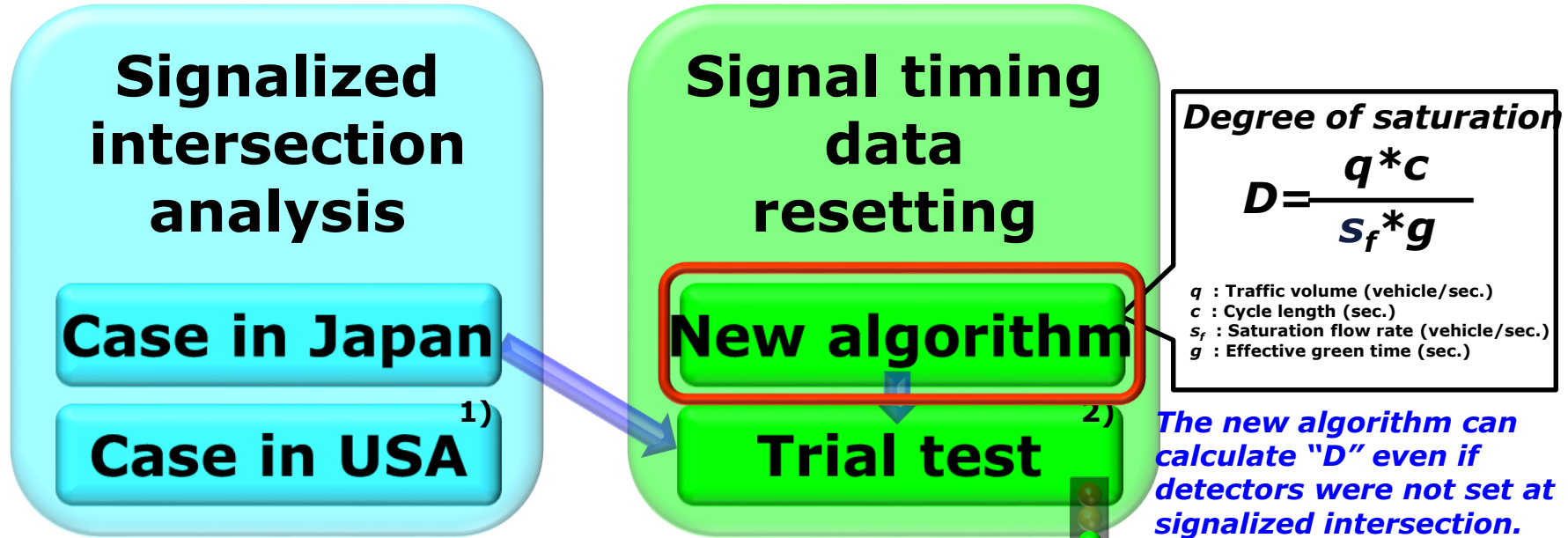
© OpenStreetMap contributors



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New Method Development

Indexes such as "Degree of saturation", "TOSI" can be obtained from probe data even if vehicle detectors are not installed at intersection.

Newell mentioned average delay time per vehicle (w) can be obtained the formula as follows;

$$w = 0.5(1-g/c)^2 * c / (1-q/s_f)$$

Newell, Gordon F : Theory of highway traffic signals, ITS Reports 1989(07), Jan.1989

This formula can be modified to $q =$.

$$q = \{1-(c-g)^2 / (2wc)\} s_f \quad \{\text{Under-saturation}\}$$

Extension of the theory for over saturation

$$q = \{1-(c-g)/c\} s_f \quad v_q = [\{w-(c-g)/2\} / (c-g)] * \{1-(c-g)/c\} s_f \quad \{\text{Over-saturation}\}$$

$$\begin{aligned} w &= 0.5(1-g/c)^2 * c / (1-q/s_f) \\ &= 0.5(c-g)^2 / ((1-q/s_f)c) \\ &= 0.5(c-g)^2 s_f / ((s_f-q)c) \\ 2w(s_f-q)c &= (c-g)^2 s_f \\ 2ws_f c - 2wqc &= (c-g)^2 s_f \\ 2wqc &= 2ws_f c - (c-g)^2 s_f \\ q &= \{1-(c-g)^2 / (2wc)\} s_f \end{aligned}$$

q : Traffic volume (vehicle/sec.)
 c : Cycle length (sec.)
 g : Effective green time (sec.)
 s_f : Saturation flow rate (vehicle/sec.)
 v_q : Vehicles in queue

s_f can not be taken from probe data, however!!

*This technique is protected by U.S.patent 11,263,900.

Degree of saturation

$$D = \frac{q * c}{s_f * g} = \frac{\{1-(c-g)^2 / (2wc)\} * c}{s_f * g}$$

The temporal oversaturation severity index (TOSI)

$$TOSI = \frac{L/J \times H}{g} = \frac{L/J}{s_f \times g} = \frac{[\{w-(c-g)/2\} / (c-g)] * \{1-(c-g)/c\} s_f}{s_f \times g}$$

L : Minimum residual queue length (feet)

J : Headway under congested traffic conditions (feet) } L/J : Vehicles in queue

H : Saturation discharge headway (sec.)

$$H = 1/s_f$$

Intelligent Traffic Management using Probe Data

What can we do using probe based data?

The acquisition information : Congestion length, Travel time → Delay time

Signalized
intersection
analysis

Case in Japan

Case in USA¹⁾

Signal timing
data
resetting

New algorithm

Trial test²⁾

Degree of saturation

$$D = \frac{q * c}{s_f * g}$$

q : Traffic volume (vehicle/sec.)
c : Cycle length (sec.)
s_f : Saturation flow rate (vehicle/sec.)
g : Effective green time (sec.)

The new algorithm can calculate "D" even if detectors were not set at signalized intersection.

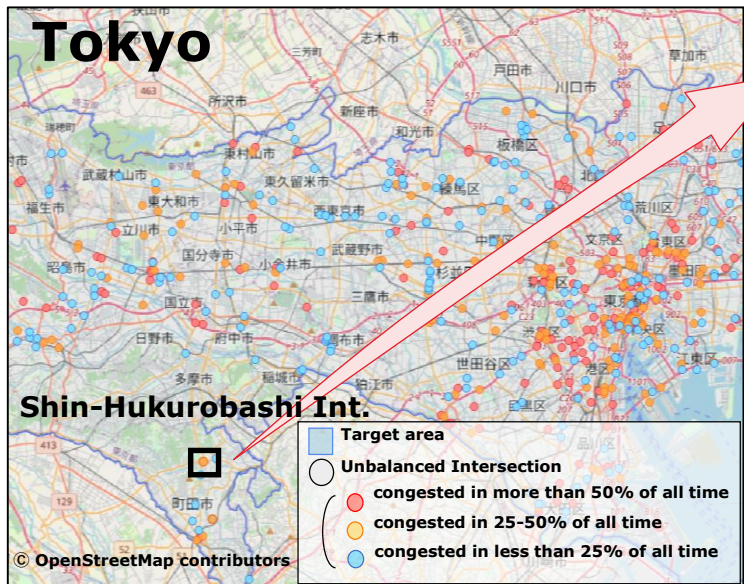
1) TS16 : Managing Congestion ,

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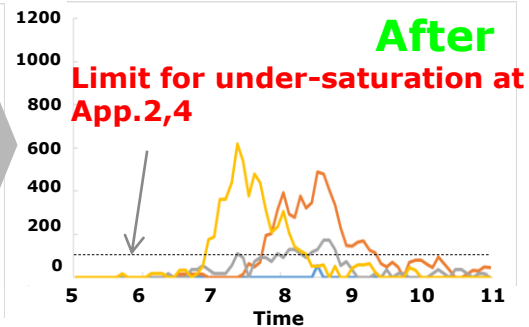
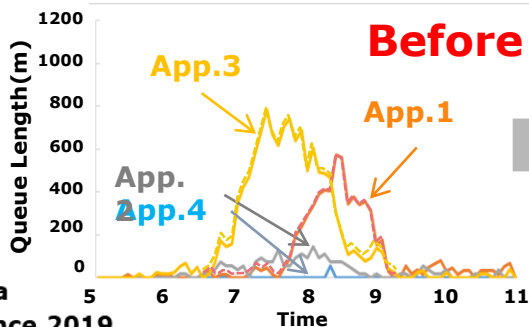
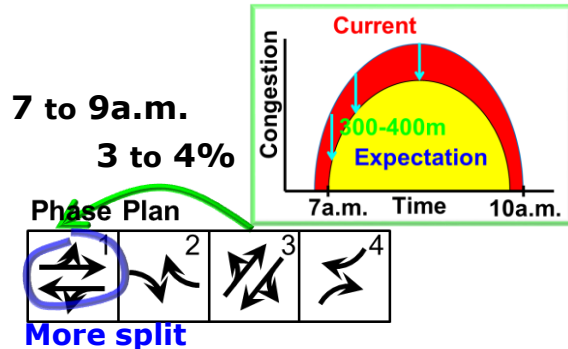
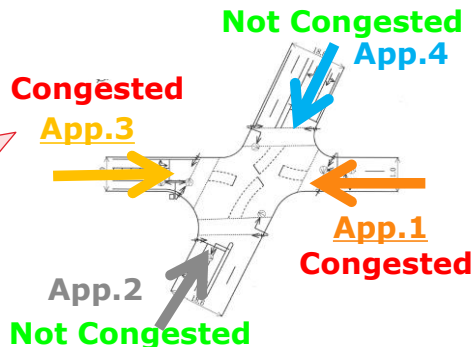
Use Case in Tokyo, Japan

The new methods were implemented at the intersections in Tokyo. And the results proved the effectiveness of the methods.

- Probe-based detection of "Unbalanced Intersections"



- Probe-based signal parameter retiming

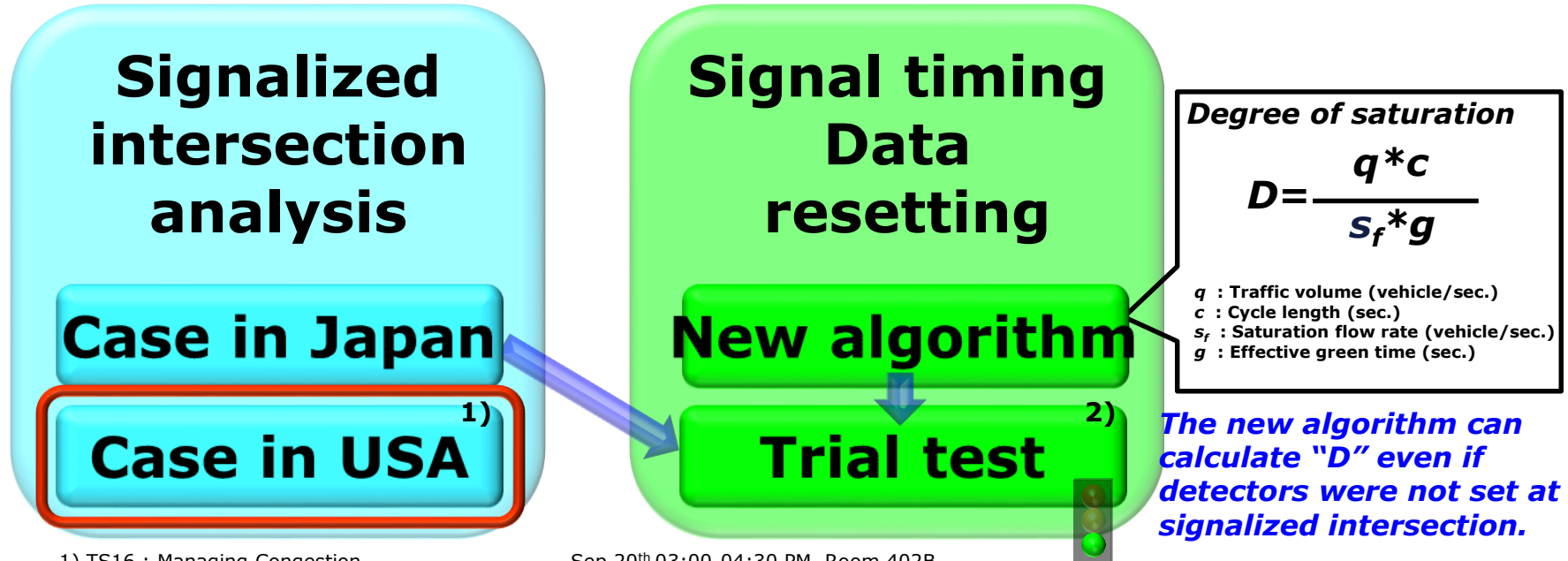


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1) TS16 : Managing Congestion ,

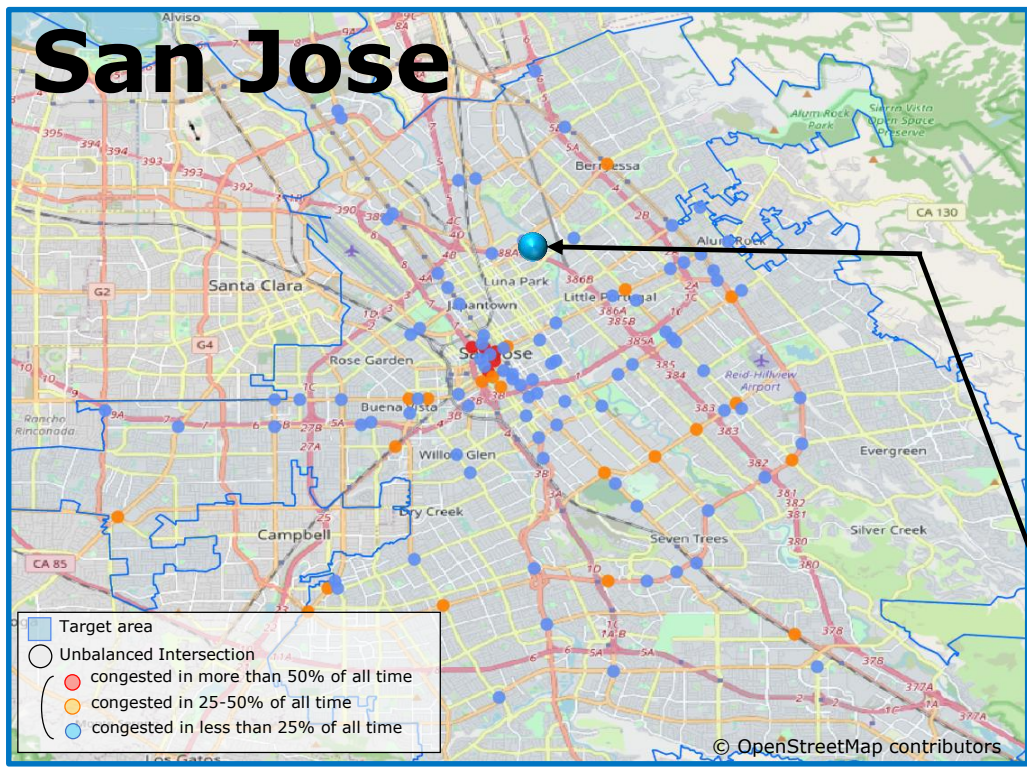
2) TS34 : How Technology Impacts Transportation I, Sep.20th 03:00-04:30 PM, Room 402B

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Signalized intersection analysis (Case in USA)

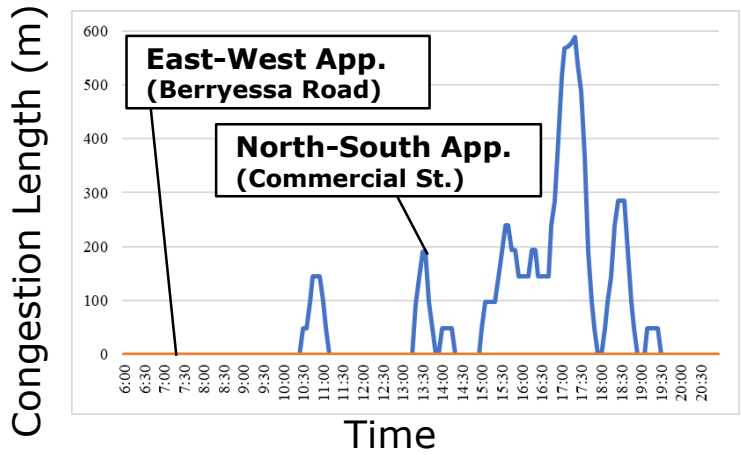
Sorting out unbalanced congestion intersections



* **Period:**
1 - 5, Aug., 2022

* **Unbalanced Intersections:**
116 / 1052 (about 11%)

Ex) 1 Aug., 2022

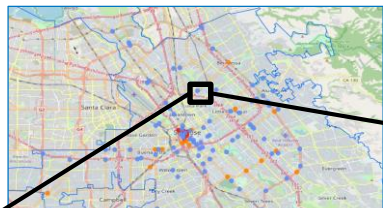


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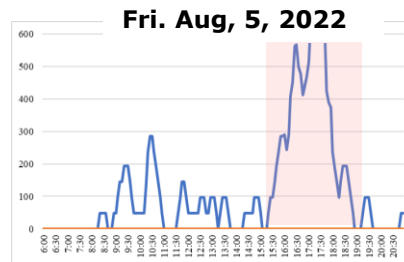
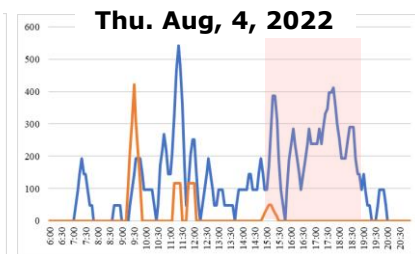
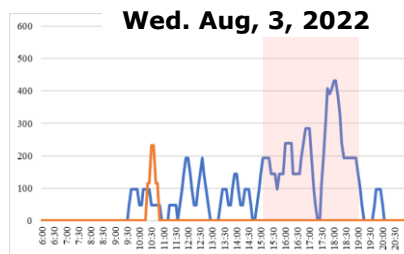
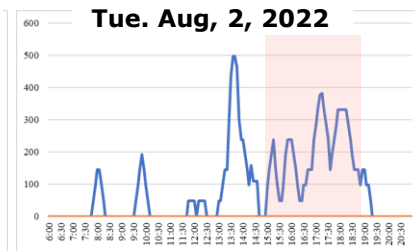
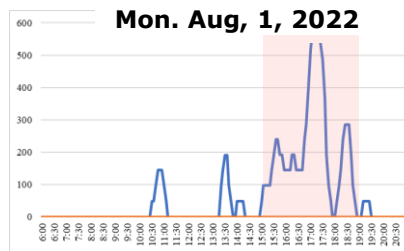
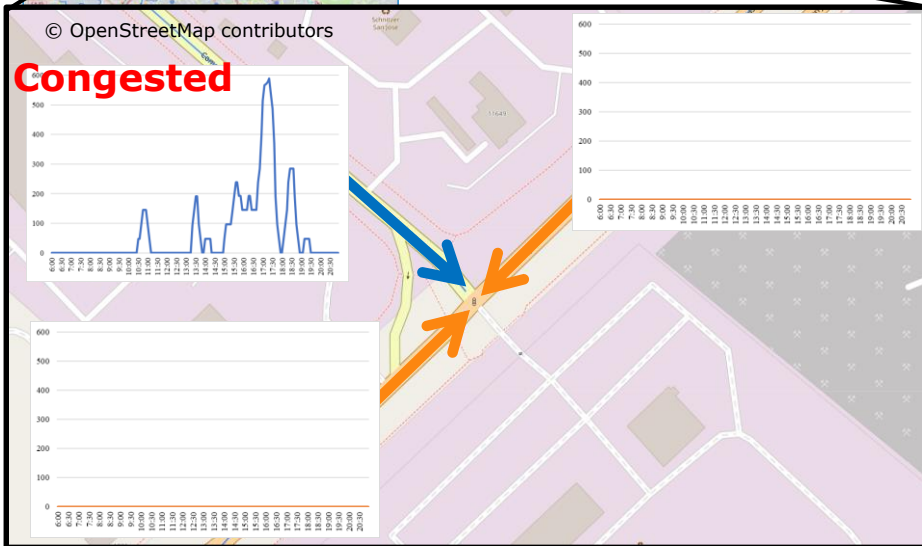


Signalized intersection analysis (Case in USA)

Sorting out unbalanced congestion intersections



Intersection of
* Commercial St.
* Berryessa Road

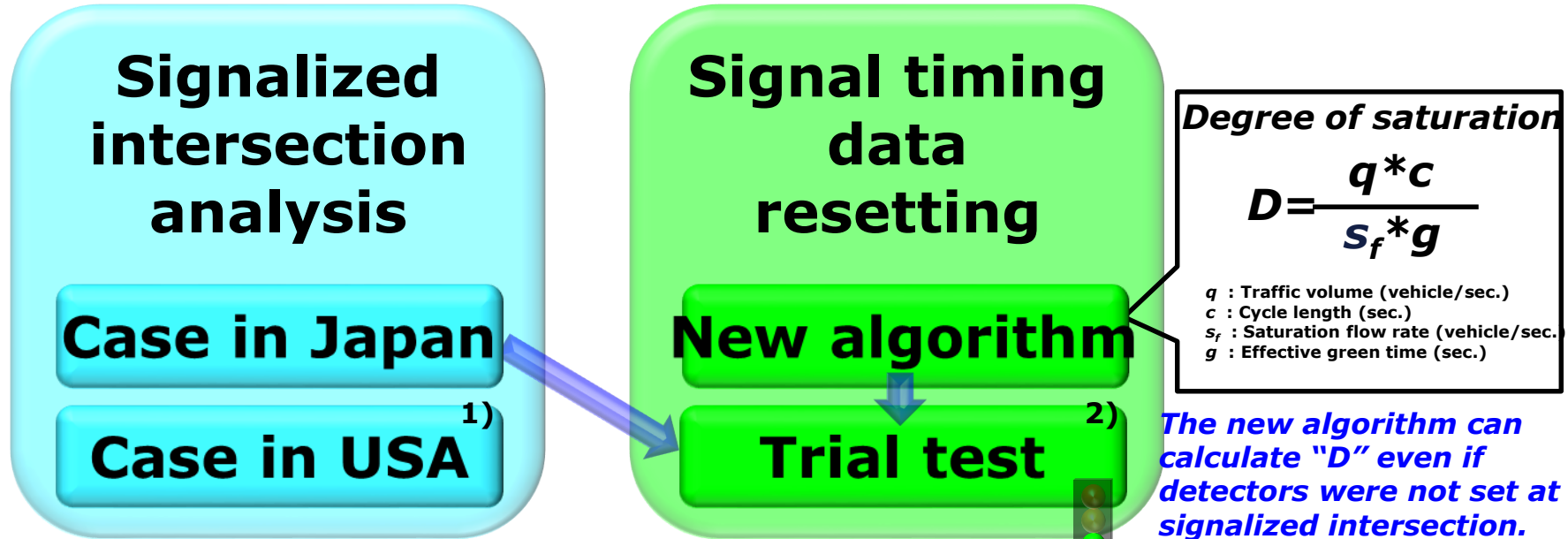


Room for signal
retiming in the
evening peak hours
every weekday

Intelligent Traffic Management using Probe Data

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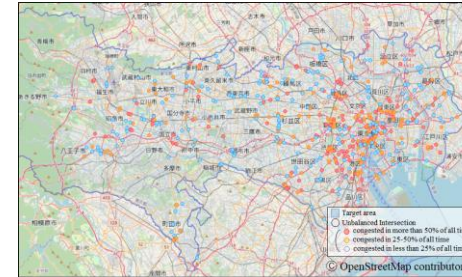
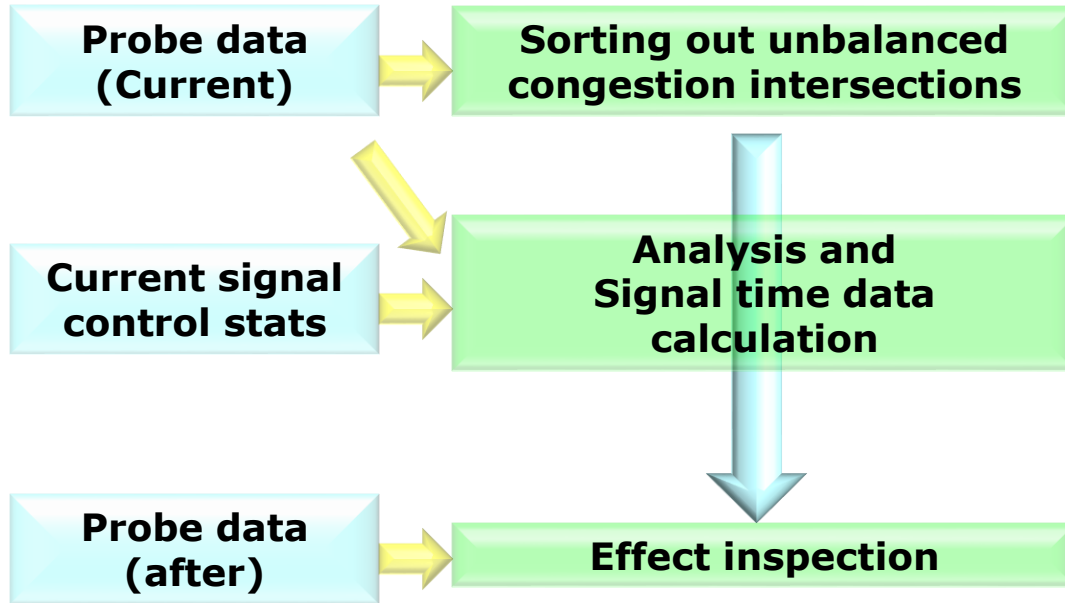
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Work flow for making safe and smooth traffic flow with probe data analysis



If $w \leq (c-g)/2$ Under-saturation

$$q = \{1 - (c-g)^2 / (2wc)\} s_f$$

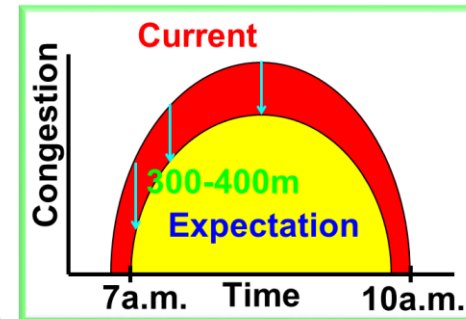
If $w > (c-g)/2$ Over-saturation

$$q = (1 - (c-g)/c) s_f$$

$$v_q = \left[\frac{w - (c-g)/2}{(c-g)} \right]^* \{1 - (c-g)/c\} s_f$$

$$L_f = \frac{q + k^* v_q}{s_f}$$

k : Usage ration of j
 V_q : Vehicles in queue (veh./sec.)
 c : Cycle length (sec.)
 g : Effective green time (sec.)
 s_f : Saturation flow rate (vehicle/sec.)



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