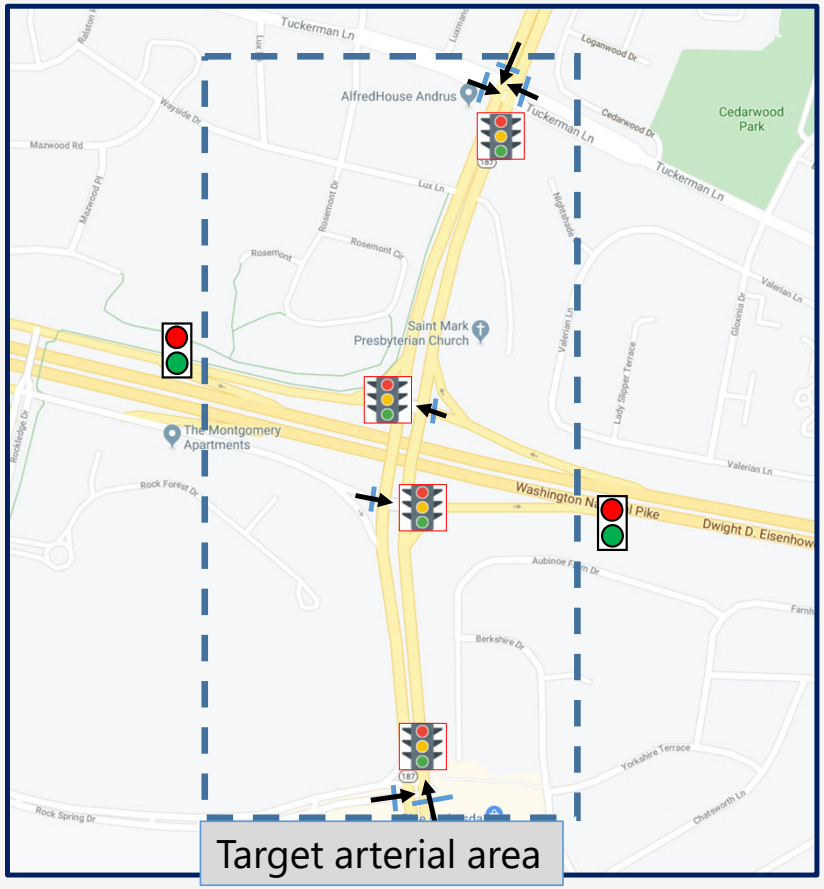
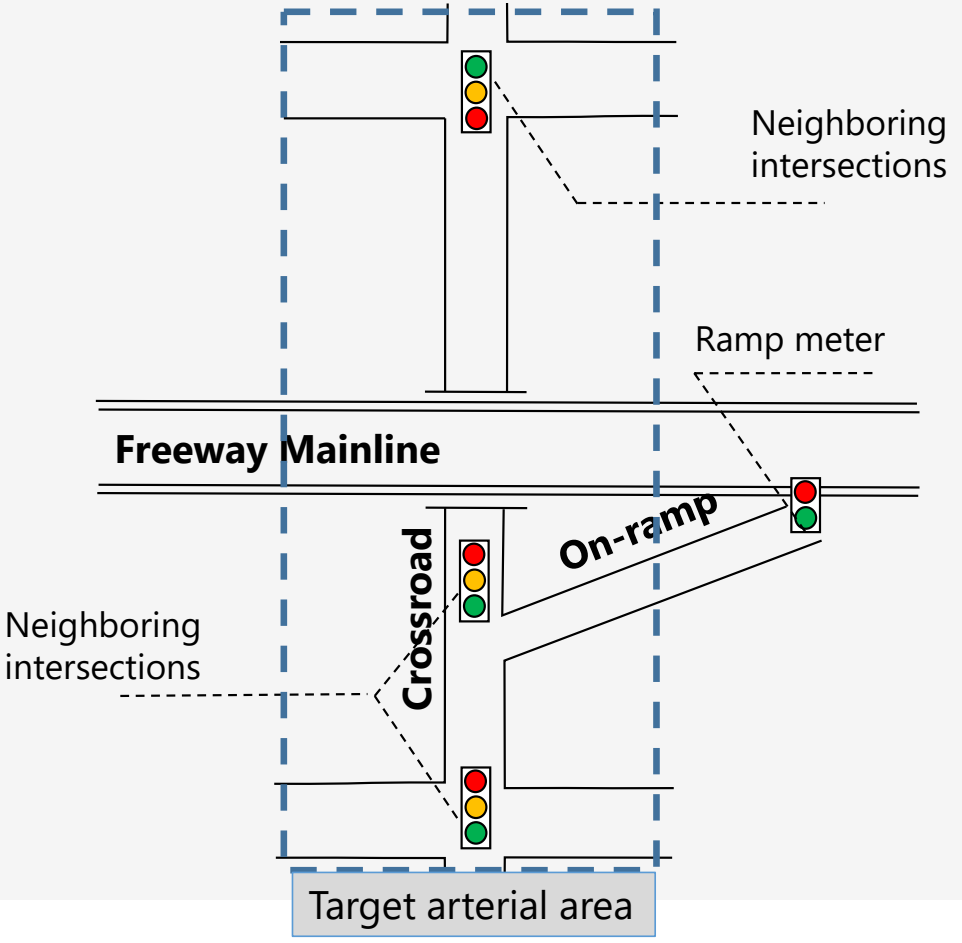
Arterial-friendly Local Ramp Metering Control

Project Progress Report

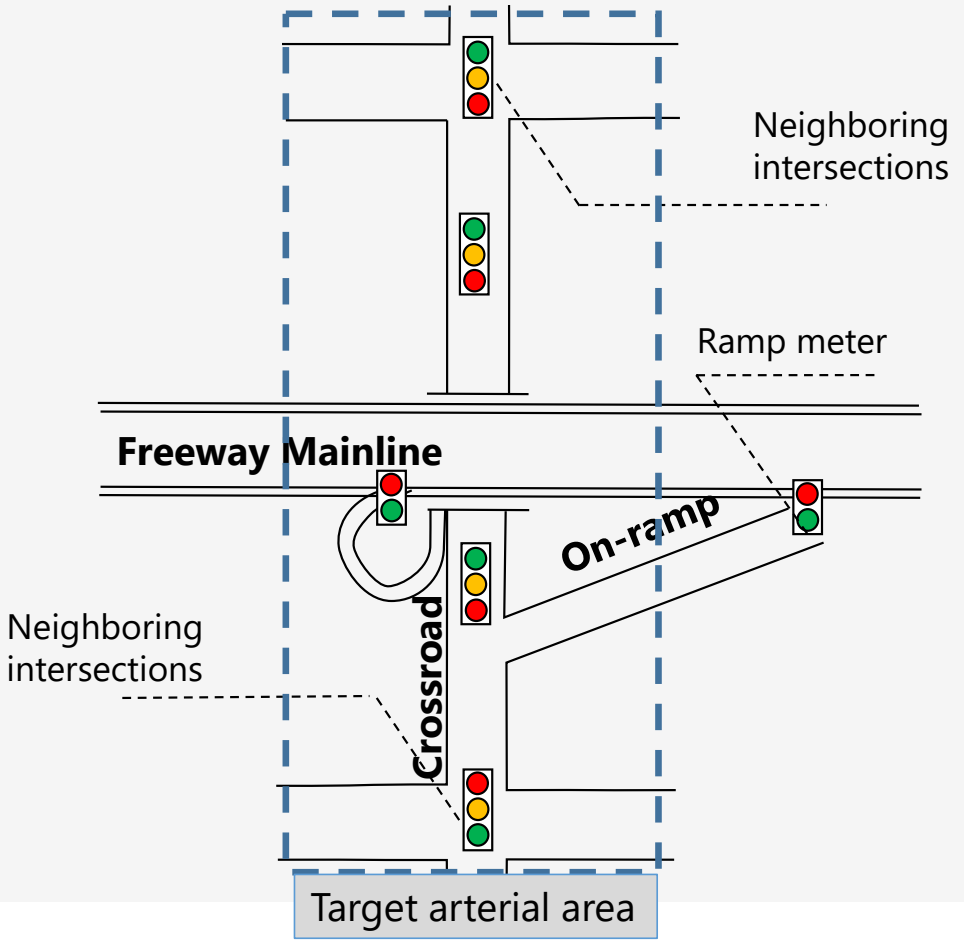
02/26/2020

Type-1 freeway on-ramp

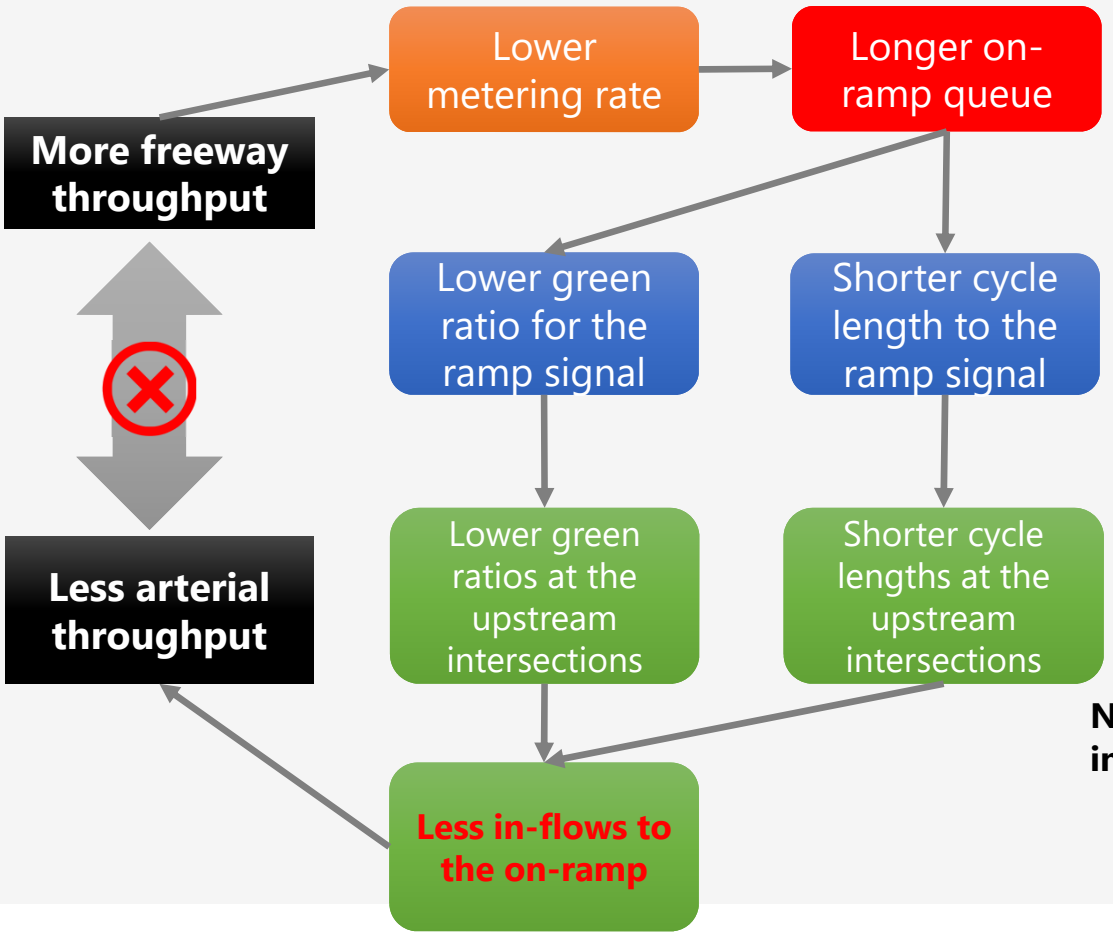


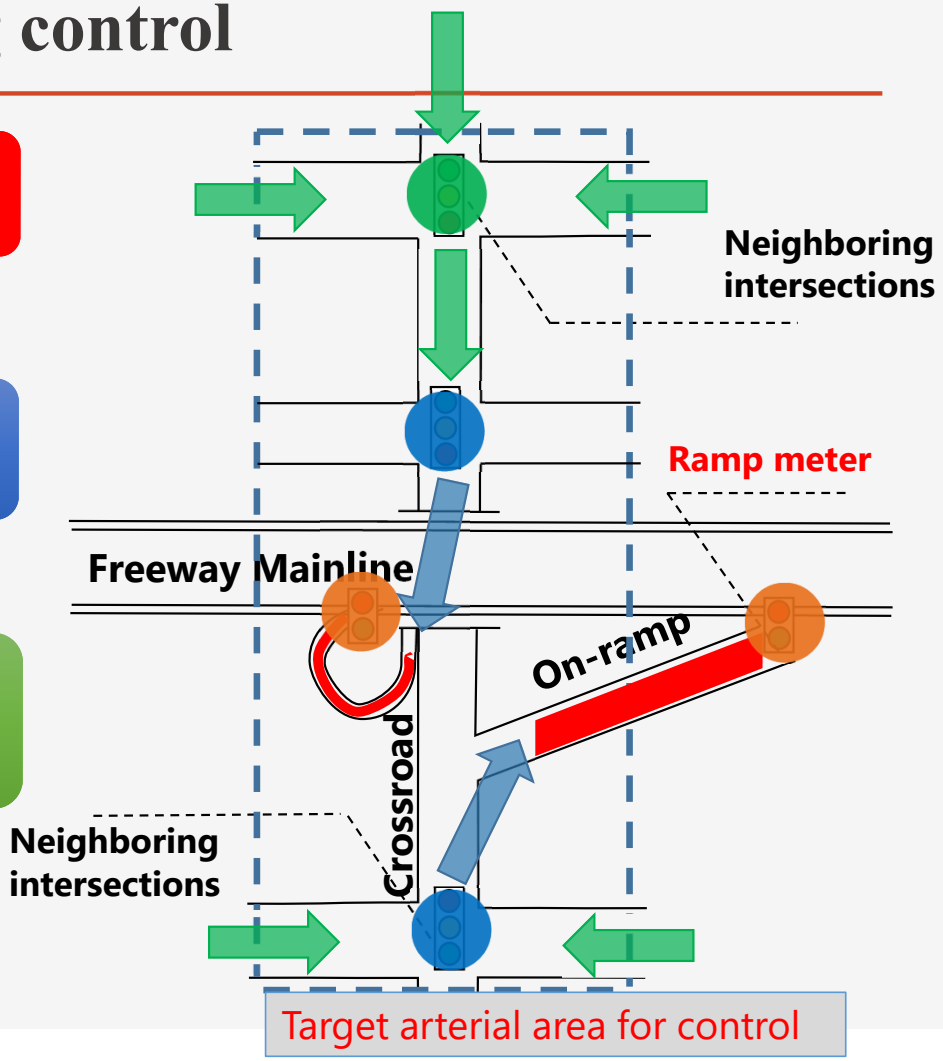


Type-2 freeway on-ramp

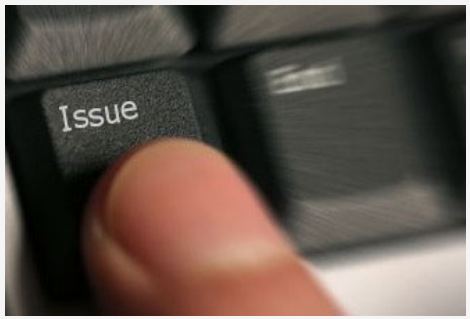


Impacts by a local-ramp metering control



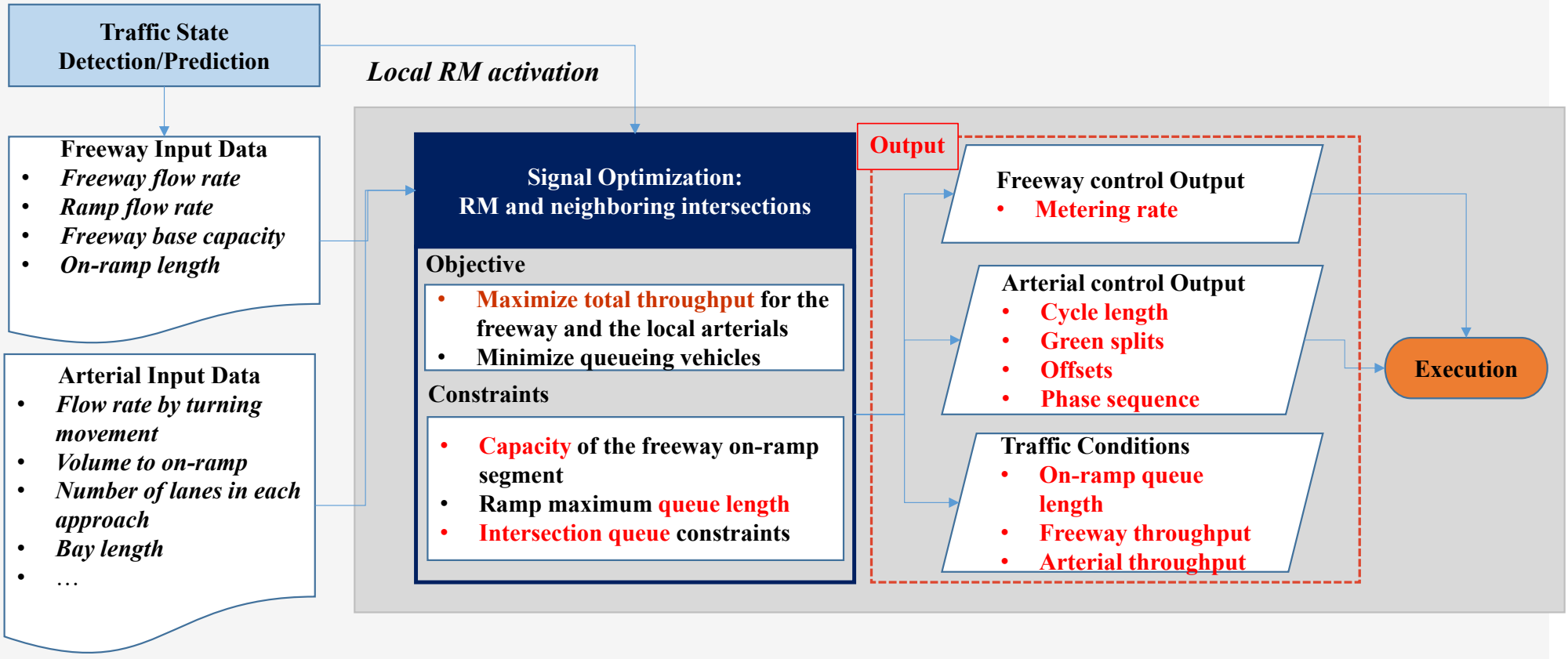


Research issues



- How to **balance** the benefits between the **freeway** and its local **intersections** near the on-ramps?
- How to **prevent** the on-ramp **queue spillback** during the peak hours?
- How to avoid **queue spillover** at the intersection's turning bays?
- How to provide **progression** for vehicles within the **control area**, and minimize **queues** at the **boundaries**?

System structure



Methodology

Objective

Maximize **Freeway throughput**

+ α x **Arterial throughput**

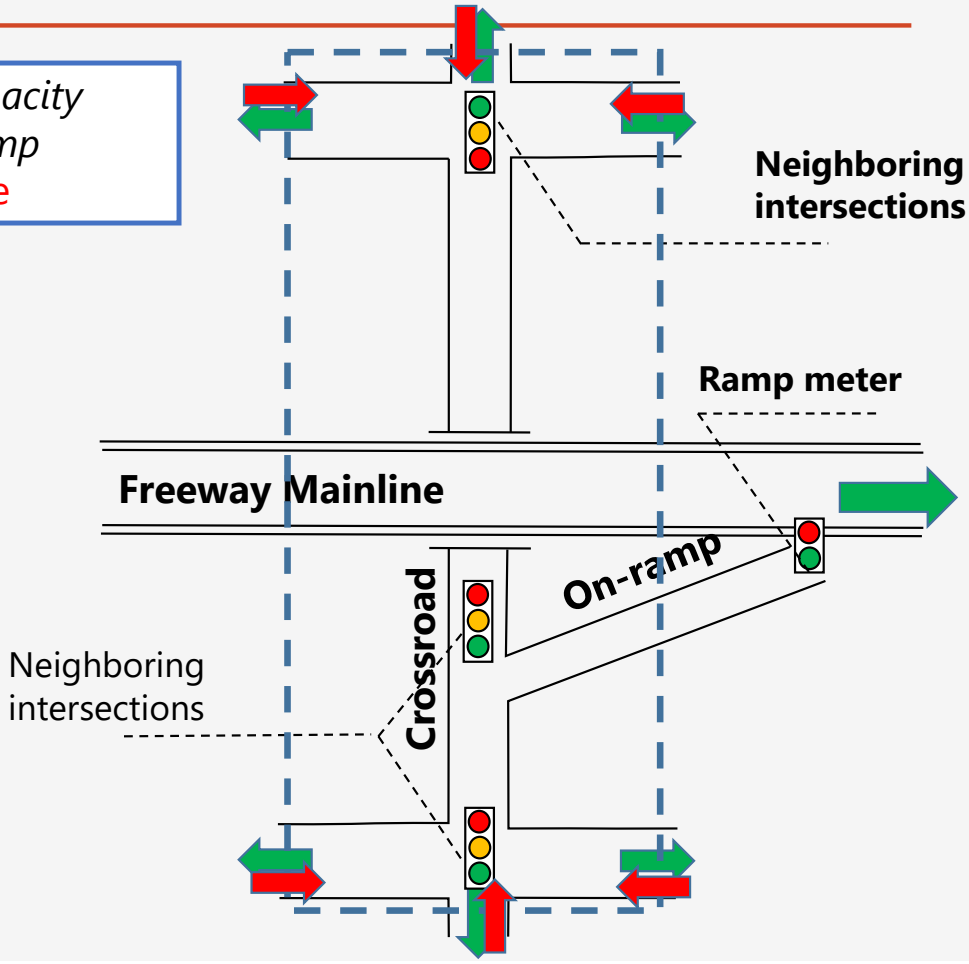
- B x **total queue vehicles**

- *Available capacity under the ramp metering rate*

Vehicles moving out of the control area (movements by green arrows), based on

- The demand that can enter the target area
- Green ratios at the boundary intersections

Queuing vehicles not within the control area (see **red arrows**)



Methodology

Freeway capacity reduction due to on-ramp merging vehicles

Rear void

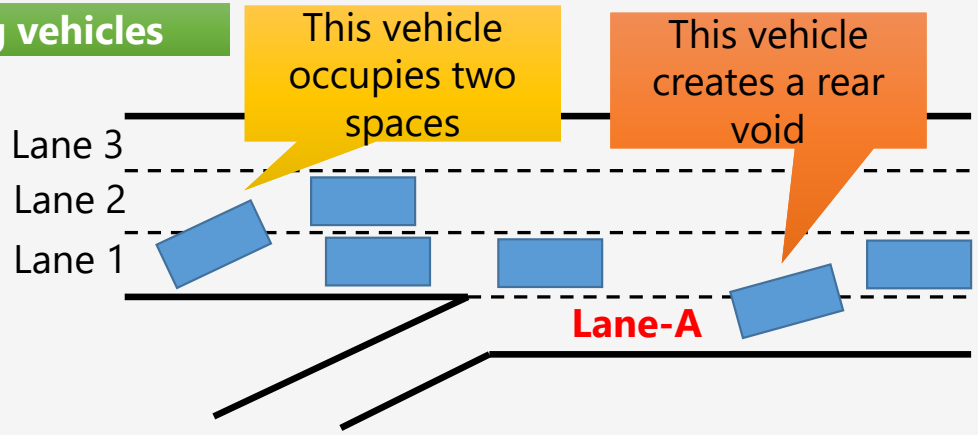
Speed difference between Lane-1 and Lane-A

Deceleration to accommodate merging flows

Create a void due to one lane change

On-ramp vehicles

Capacity reduction due to all created voids



Upstream lane change

***Assumption**: the density ratio between lanes 1 and 2 remains approximately **stable** before and after the ramp-weavings*

Density on lane 2

Density on lane 1

On-ramp merging vehicles

Number of lane-changing vehicles due to ramp flows

Capacity reduction due to vehicle weavings

Methodology

Constraints

On the on-ramp

Type A: Queues caused by excessive volumes

Type B: Queues caused by vehicles per cycle from the upstream intersections

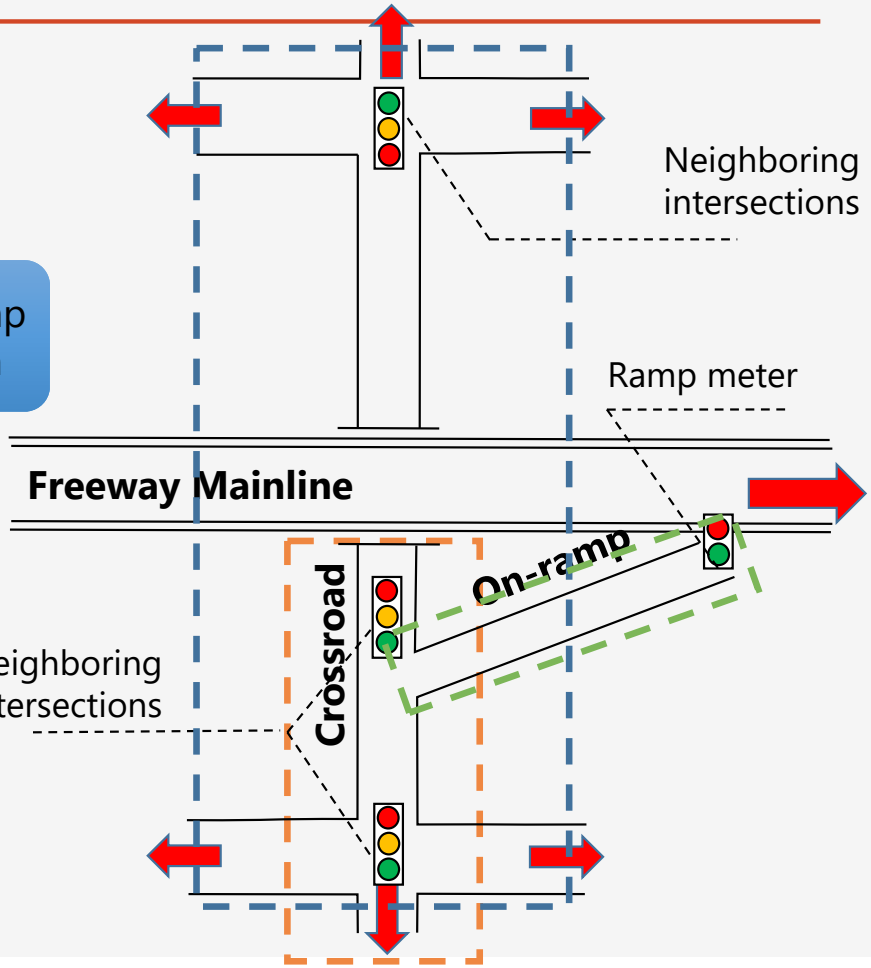
On-ramp queues $\leq$ On-ramp length

On the arterial links

Vehicle queues on an arterial link $\leq$ Bay length/ link length

Vehicles entering a link $\leq$ Discharging capacity

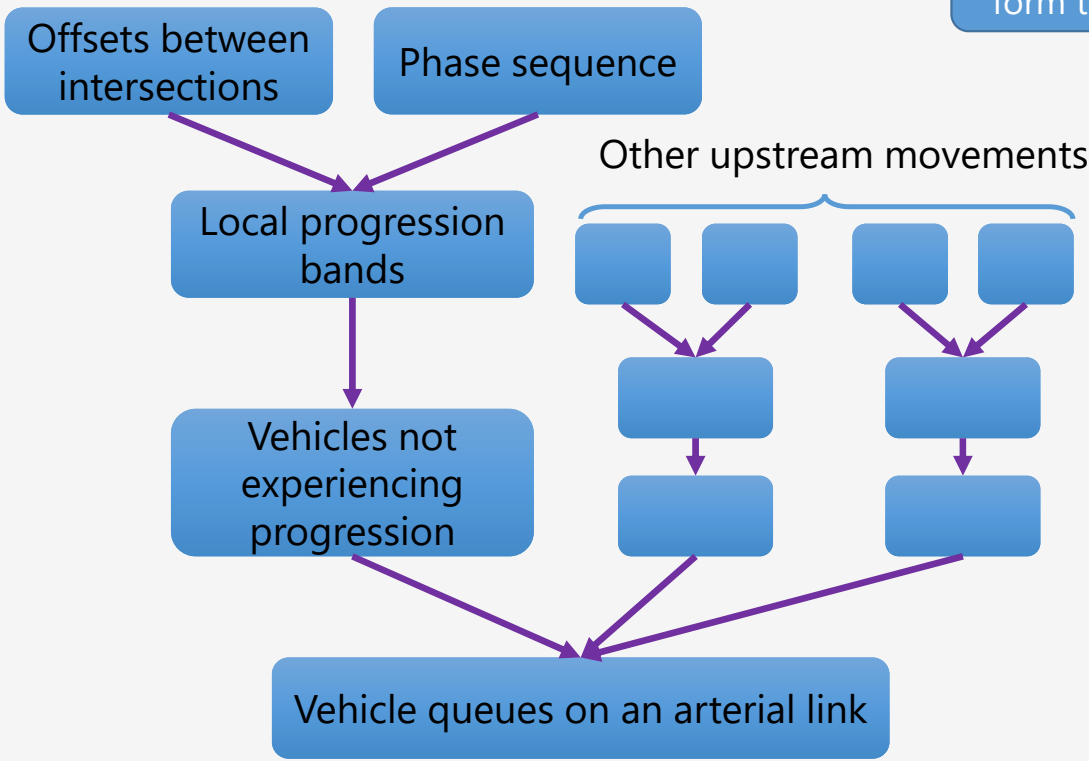
Vehicles not experiencing local progression $=$ Queueing vehicles

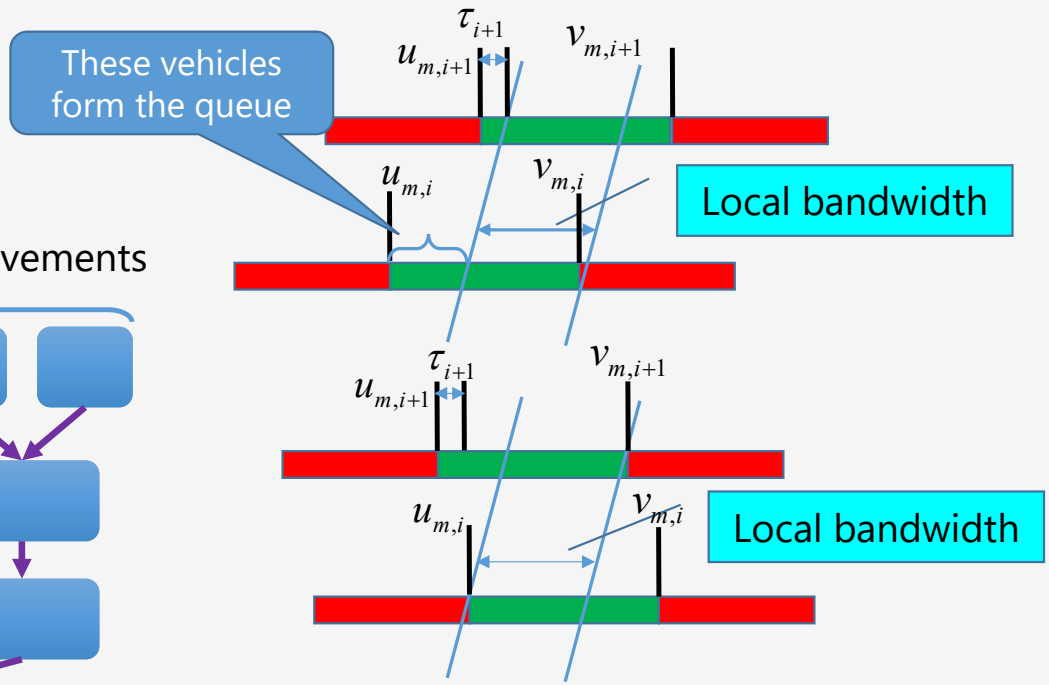


Key control logic –providing progression for vehicles of all movements within the control area

Constraints

Local progression bands





u, v: start, and end of a green phase

For Type-2 ramps

Additional Constraints

Dual on-ramp Control

Freeway Flow rate$_{upstream}$ - (off-ramp flow rate) + total on-ramp flow rate <= Freeway Capacity$_{downstream}$

On-ramp demand = actual volume on link x turning ratio to the ramp

Prior to the control by signals

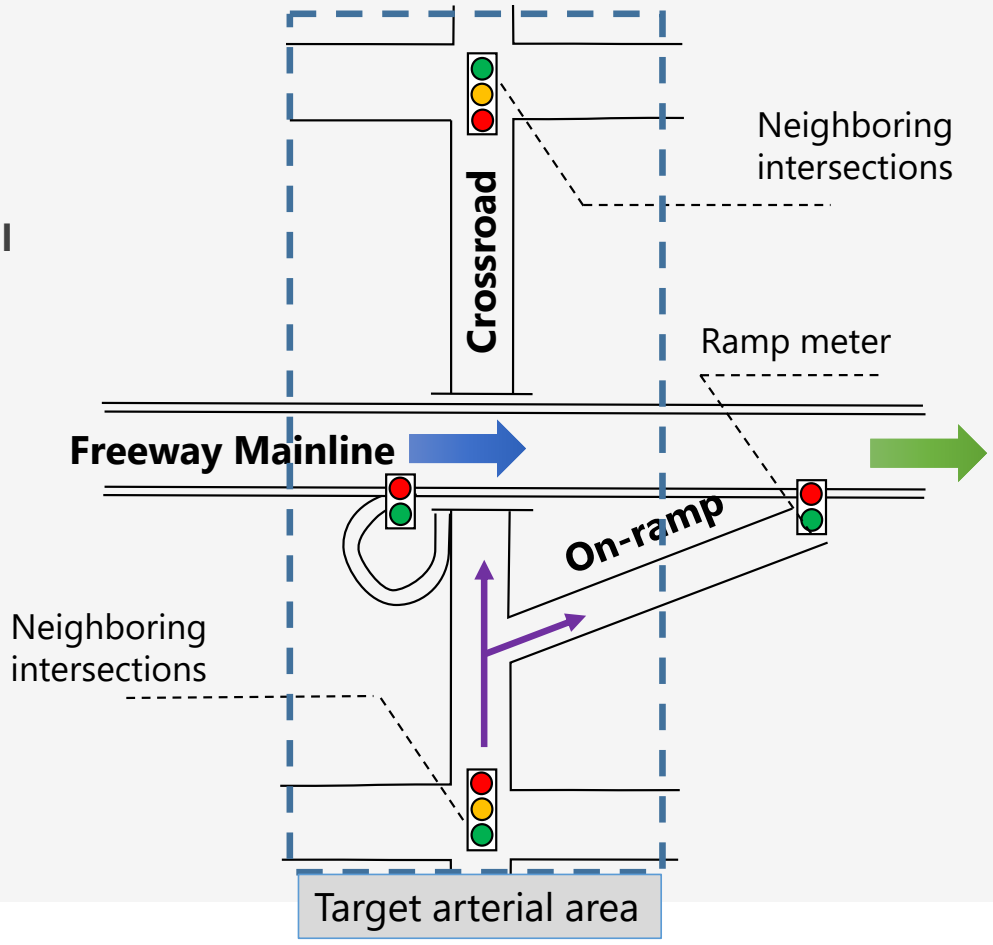
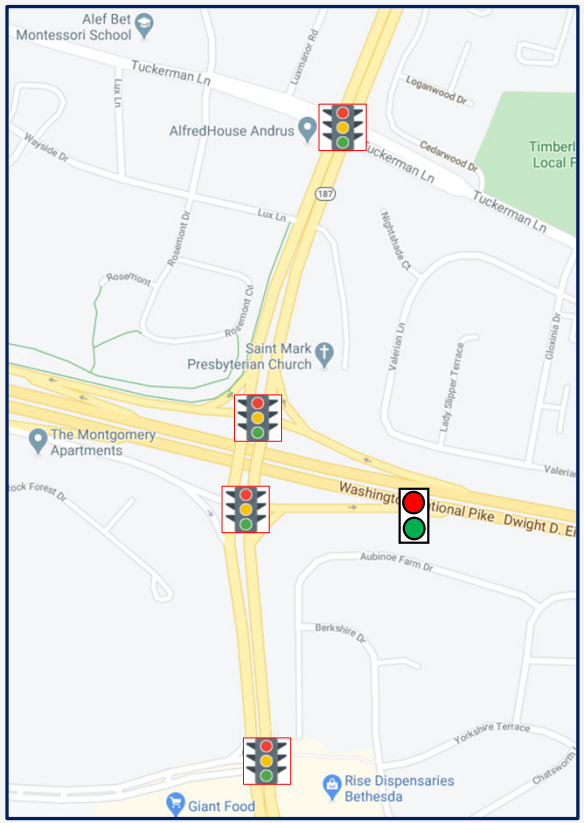


Illustration of model application



I-270 @ Exit 1, EB on-ramp

Freeway mainline:

- ***2 lanes (excluding HOV lane), 3000 vph***

Metered on-ramp:

- ***792 ft, one lane***

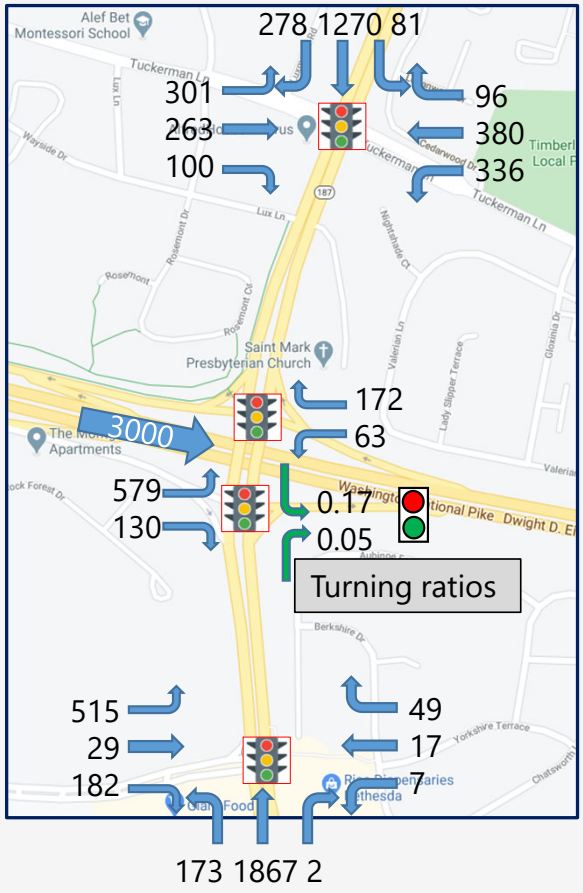
Intersection volume input and turning ratios obtained from ITMS.

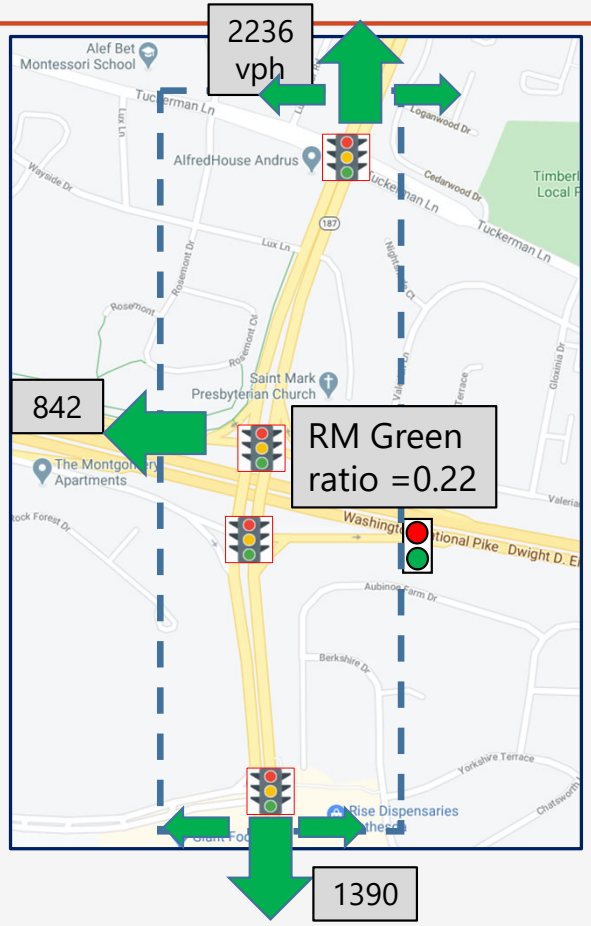
Arterial signals

- ***90s<cycle<180s***
- ***Lost time: 2 s, Minimum phase duration: 9 s***

Study period: 1 hr

Model application: Max. total throughput out of the control area





Signal Cycle length =95s

Arterial throughput = 6537 veh/hr

Freeway throughput = 3222 veh/hr

Type A on-ramp queue = 587 ft(27 veh)

Type B on-ramp queue = 205 ft(9 veh)

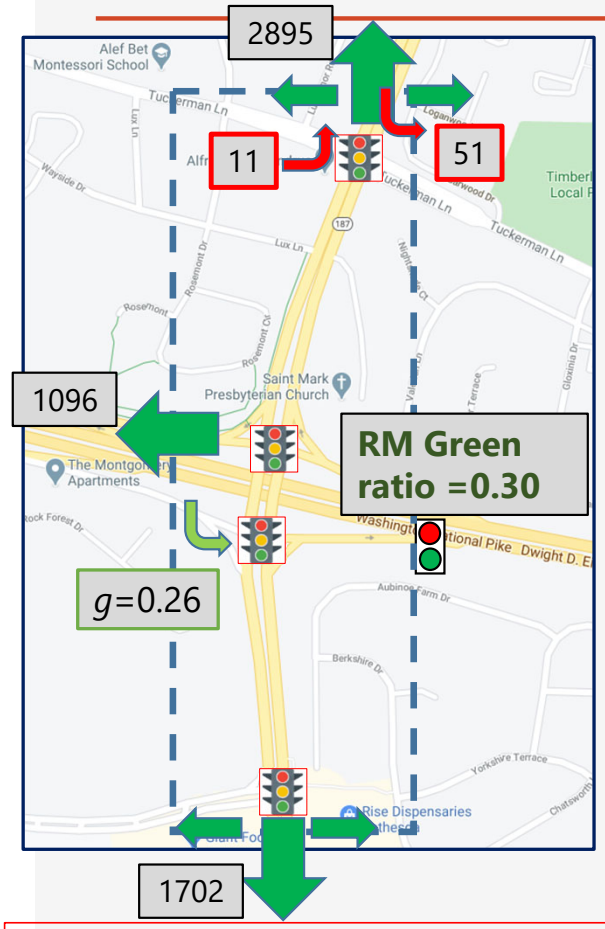
On-ramp inflow = 353 veh

Total restrained vehicles = 0 veh

Input Volume (total=6890 veh)

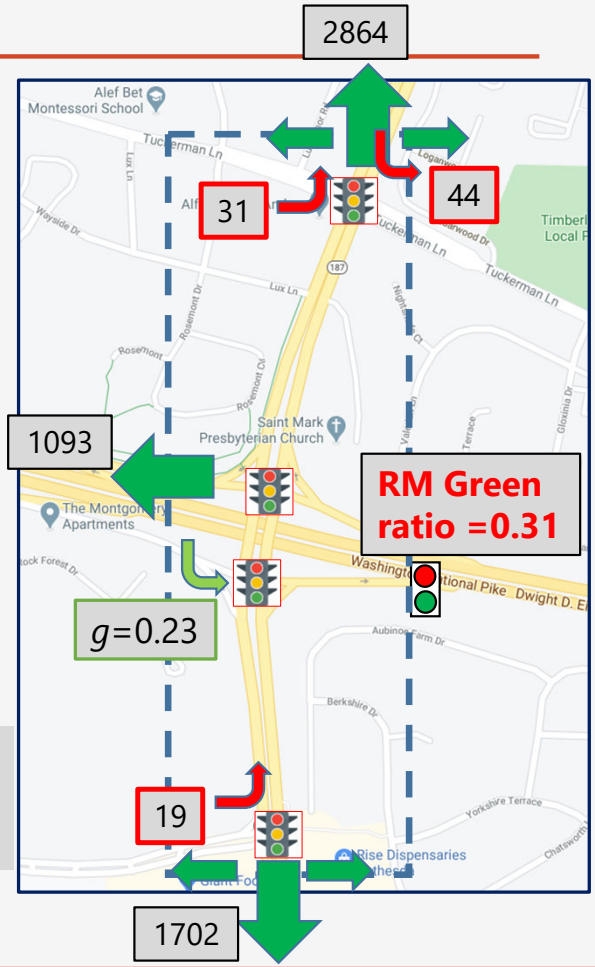
Major throughput under Optimized results

Primary model output



180	Cycle length (s)	160
8436	*Arterial throughput (veh/hr)*	8405
3083	*Freeway throughput (veh/hr)*	3069
13	*On-ramp residual queues (veh)*	0
23	*Ramp queues from arriving vehicles per cycle (veh)*	20
458	*Vehicles entering the on-ramp under the signal plan (vph)*	458
62	*Total restrained vehicles (veh)*	94
90	*Suggested RM cycle length (s)*	80

- **Shorter on-ramp length → shorter intersection cycle length, and higher RM green ratio**



1.3 * vol, ramp length = 972 ft

1.3 * vol, ramp length = 450 ft

Upgrading the system to real-time operation