THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Providing bus signal priority without damaging car discharge capacities

Weihua Gu (Hong Kong Polytechnic University)
Haoyu Chen
Yiguang Xuan (University of California, Berkeley)

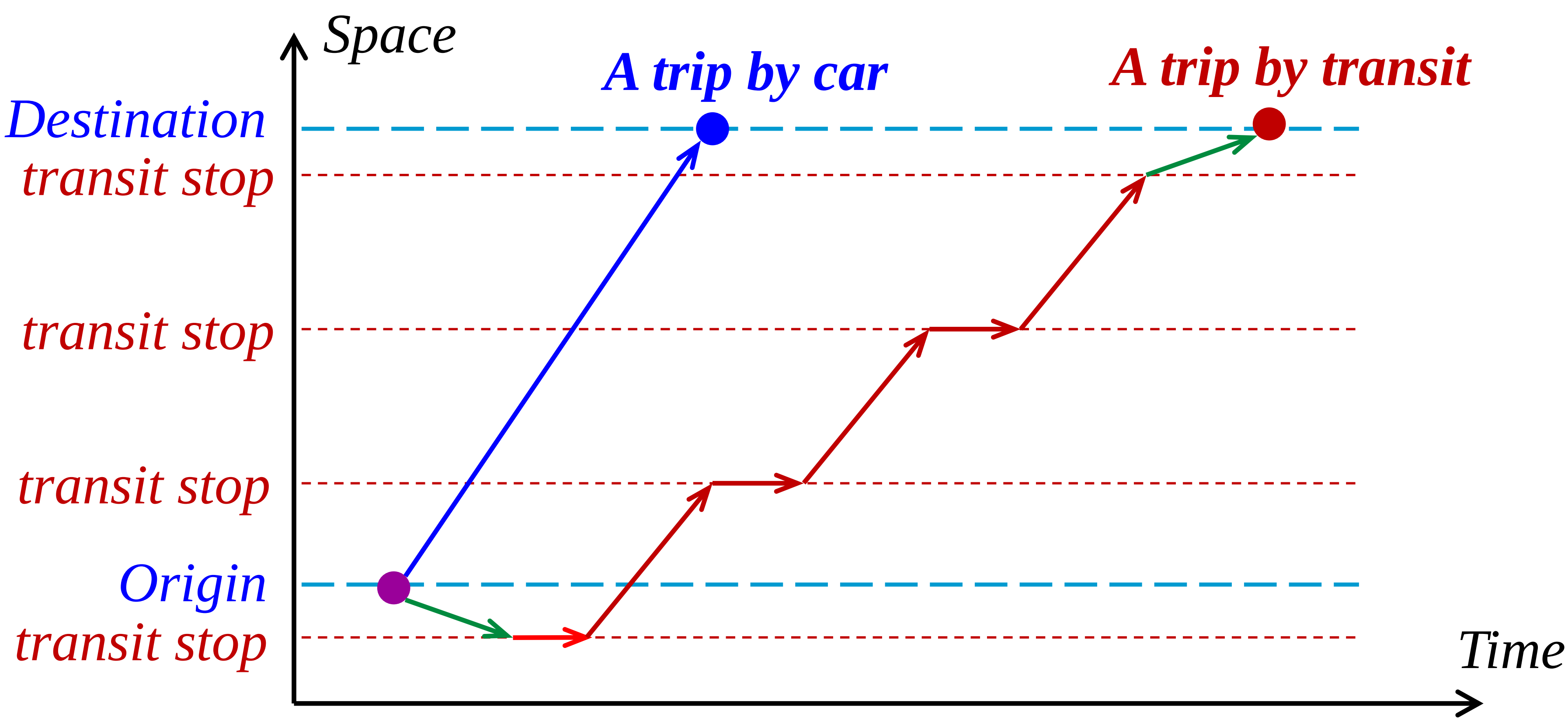
A Survey…

How many of you take more transit trips than driving?

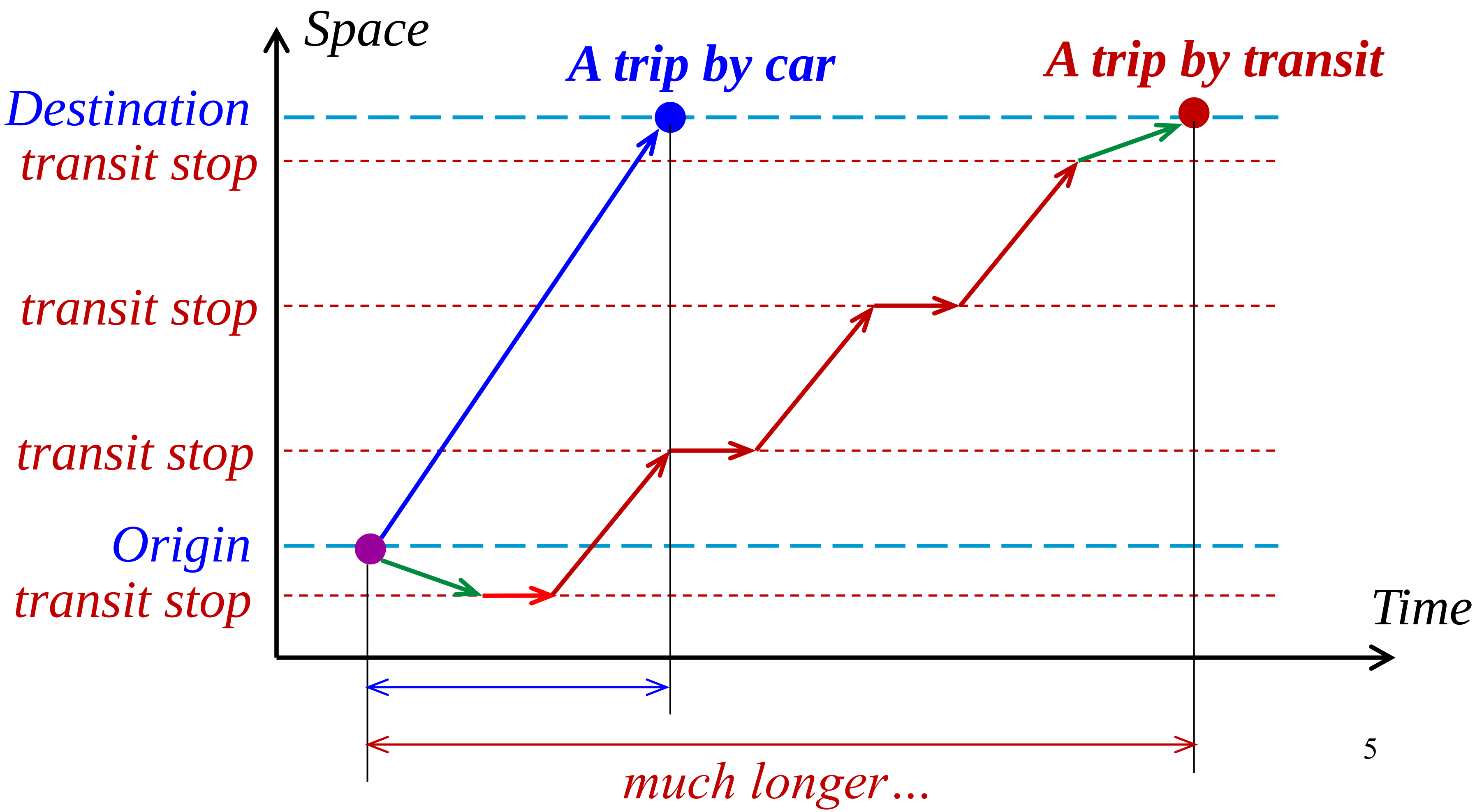
How many of you drive more than taking transit?

Why do many people not want to use transit?

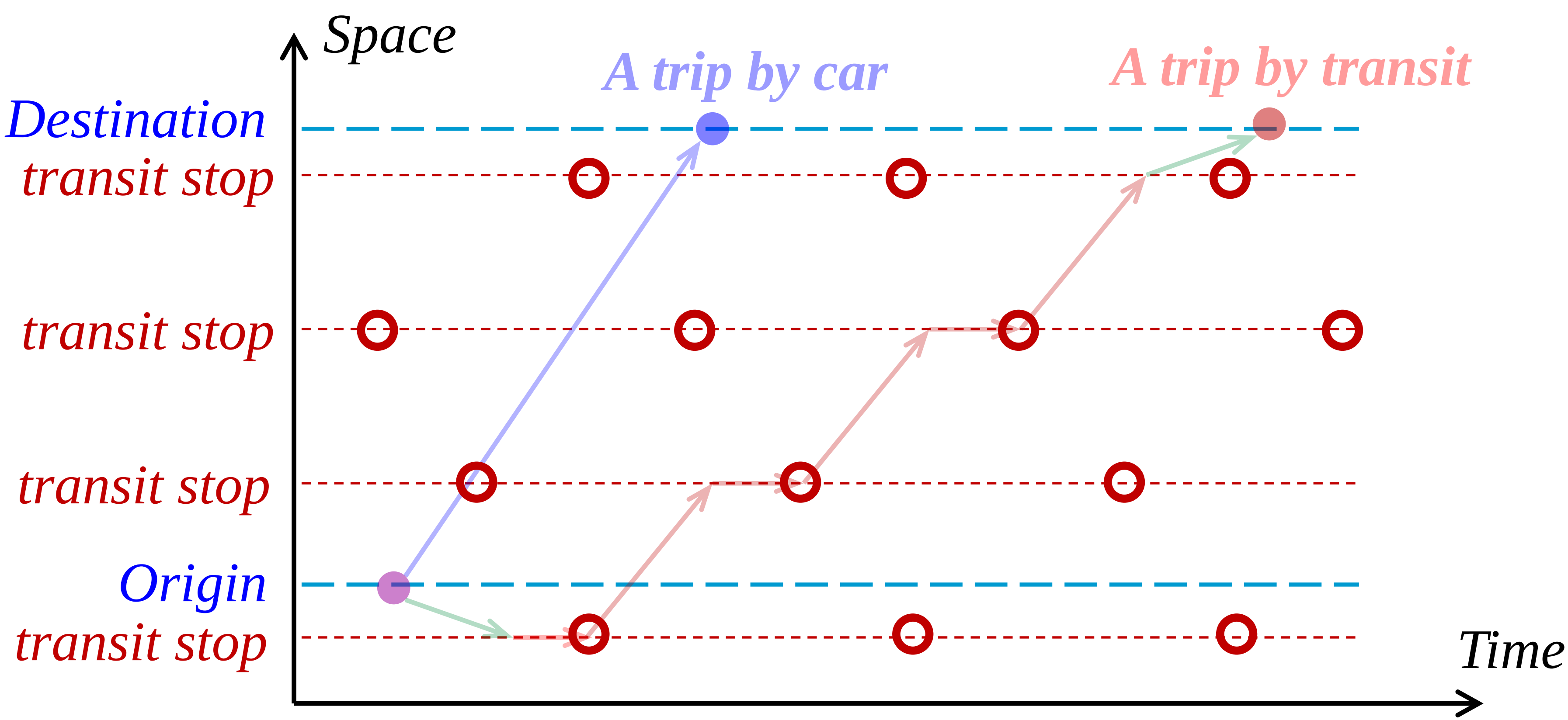
Natural defects (and advantages) of public mass transit



Natural defects (and advantages) of public mass transit

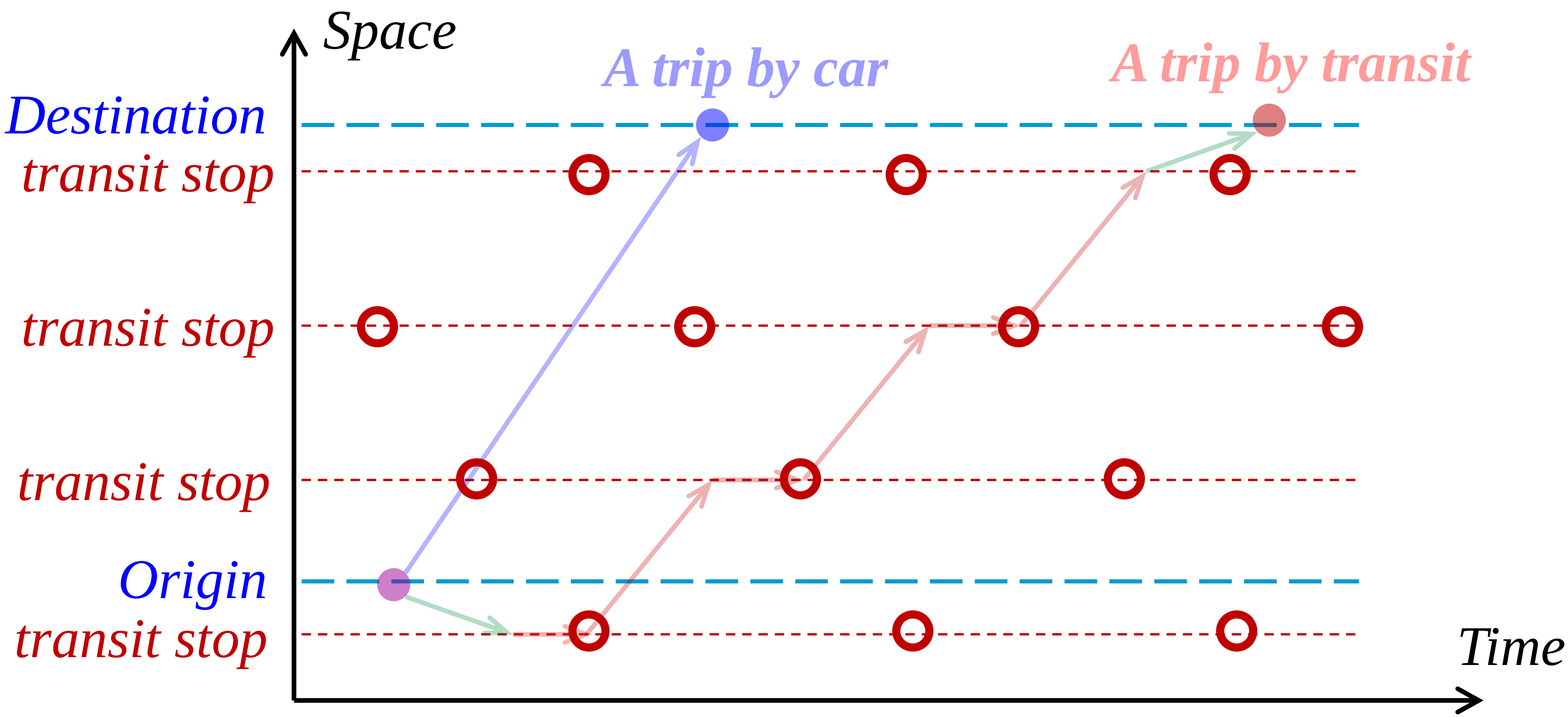


Natural defects (and advantages) of public mass transit



Spatio-temporal concentration of transit service …

Natural defects (and advantages) of public mass transit

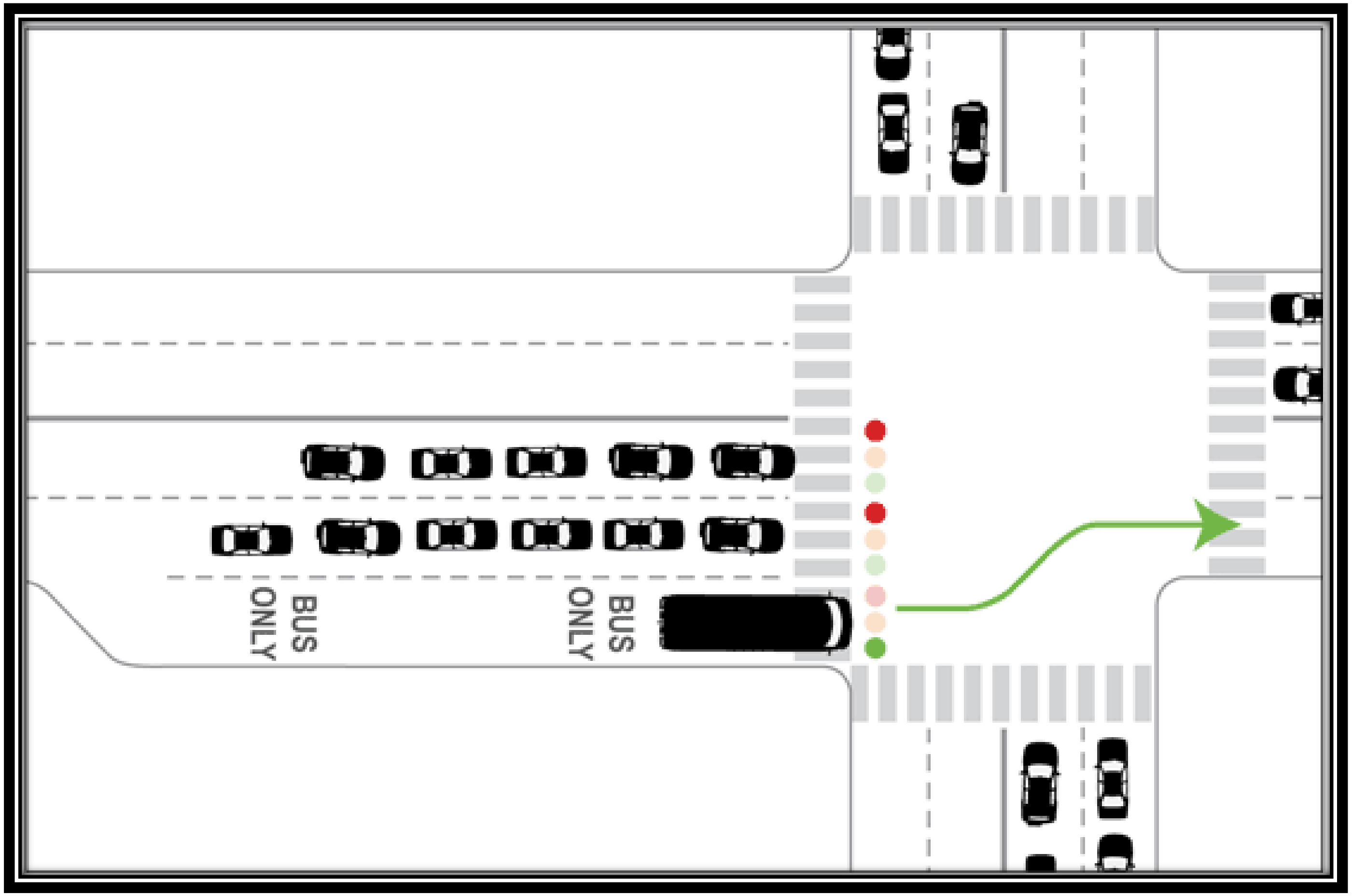


which leads to the economy of scale in cost, emission, energy consumption…

How to beat cars?

Bus lane (congested case)

Bus lane (at signalized intersections in uncongested case) – like a queue jumper lane



Bus lane + bus signal priority (bus arrival time predicted by onboard GPS)

Benefits of bus priority strategies

- ✓*Reduce bus delay*
- ✓*Improve service reliability*
- ✓*Reconcile mode conflicts*

Downside of bus priority strategies

- ✓ *Reduce car discharge capacities at intersections*
  - ✓ *Of the subject approach (cars lose a lane)*
  - ✓ *Of the cross-street traffic (green time loss)*

Why do we care about cars?

Complaints from car drivers

- ✓ *Empty bus lanes*
- ✓ *Long cross-street queues*

Practical barriers for the implementation of bus priority strategies

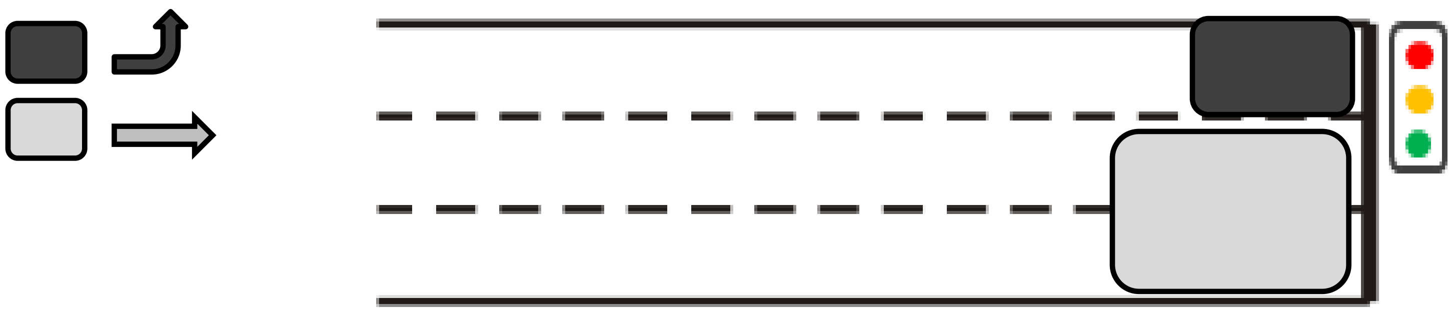
- ✓ *Not at a busy intersection (car flows can't be too large, especially the cross-street traffic)*
- ✓ *Bus flow can't be too large (for signal priority set-up)*
  (and not too small to justify the use of a dedicated lane)

OUTLINE

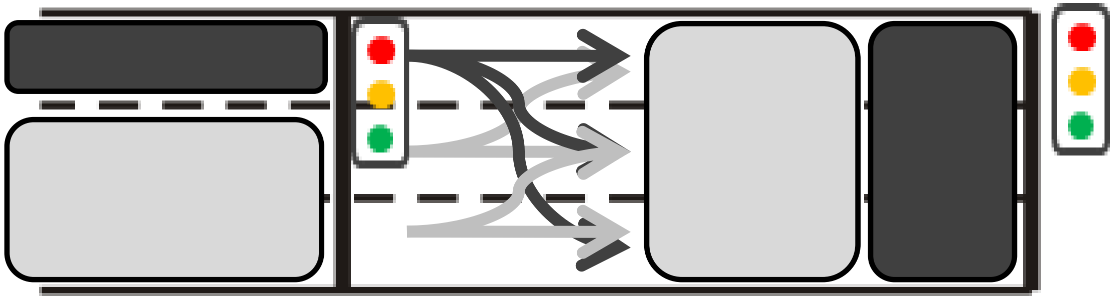
- ✓ *Background of the pre-signal concept*
- ✓ *Our strategy*
- ✓ *Models and scenarios for comparison*
- ✓ *Numerical case studies*
- ✓ *Concluding remarks*

Pre-signal to sort left-turning and through-moving traffic (Xuan et al., 2011)

✓ Conventional intersection approach

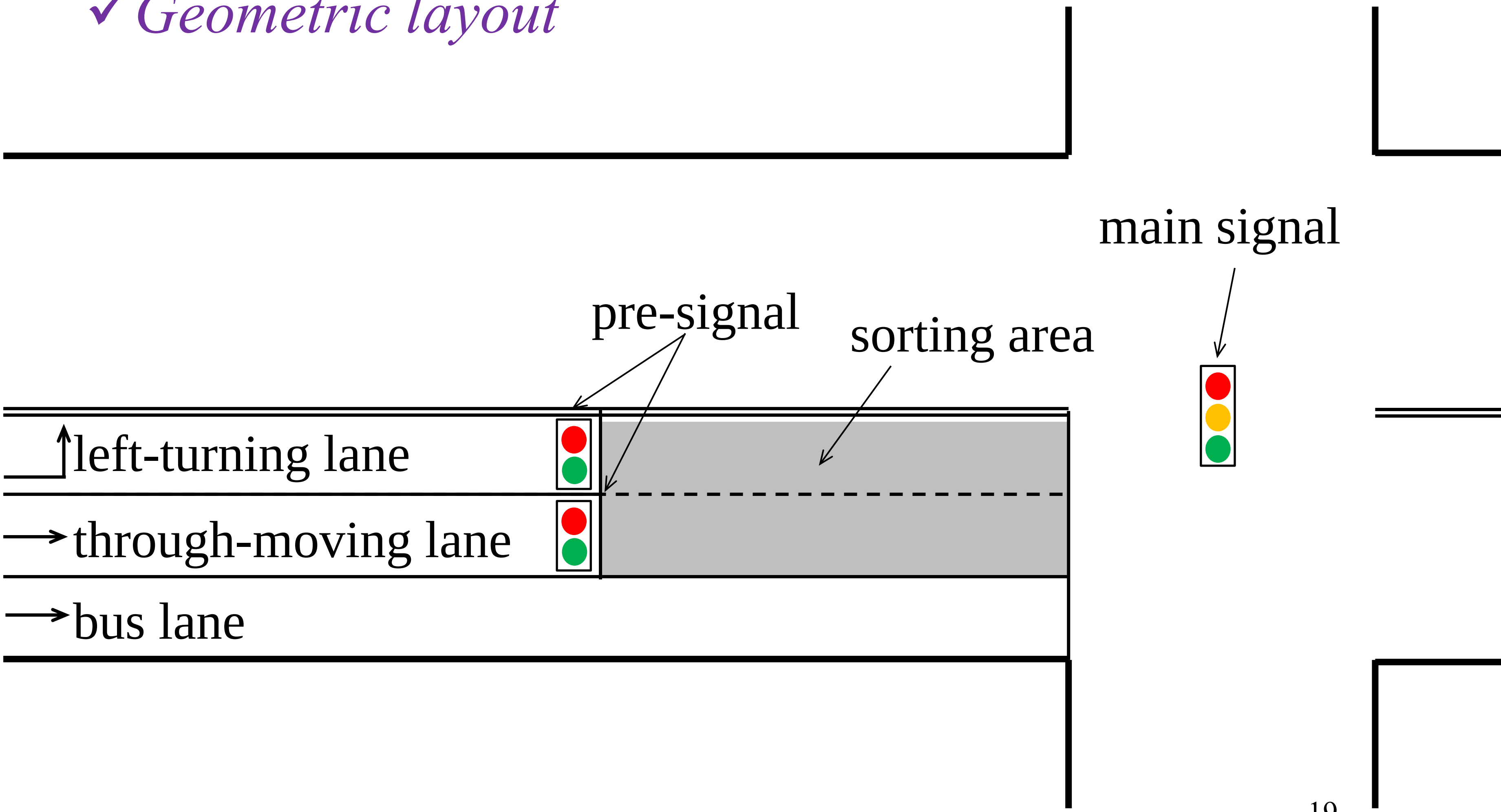


✓ With pre-signal



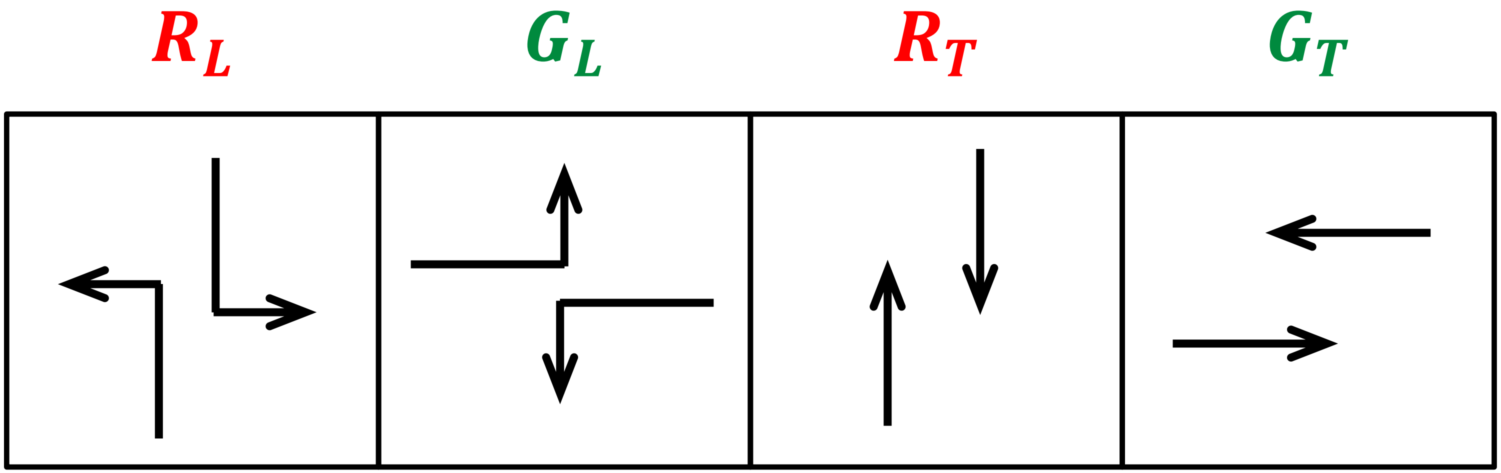
Our strategy

✓ *Geometric layout*



Our strategy

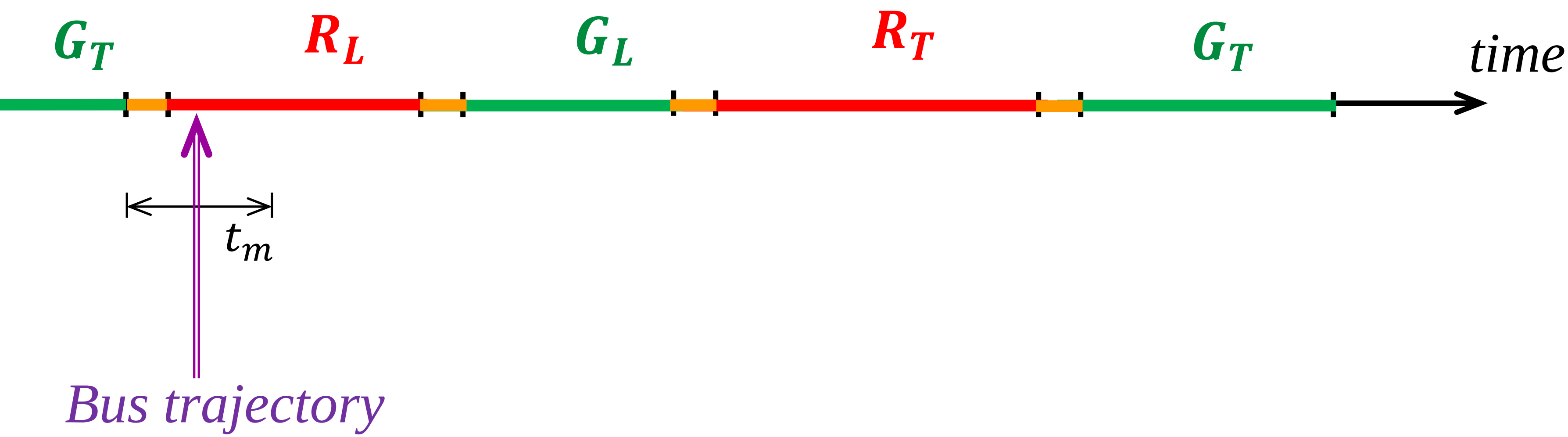
- ✓ *Main signal*
  - ✓ *Yellow time is 4 seconds*



Our strategy

- ✓ Bus signal priority – green extension only
  - ✓ Any bus that arrives to the intersection within t_m after the end of the last G_T phase will be given a green extension.

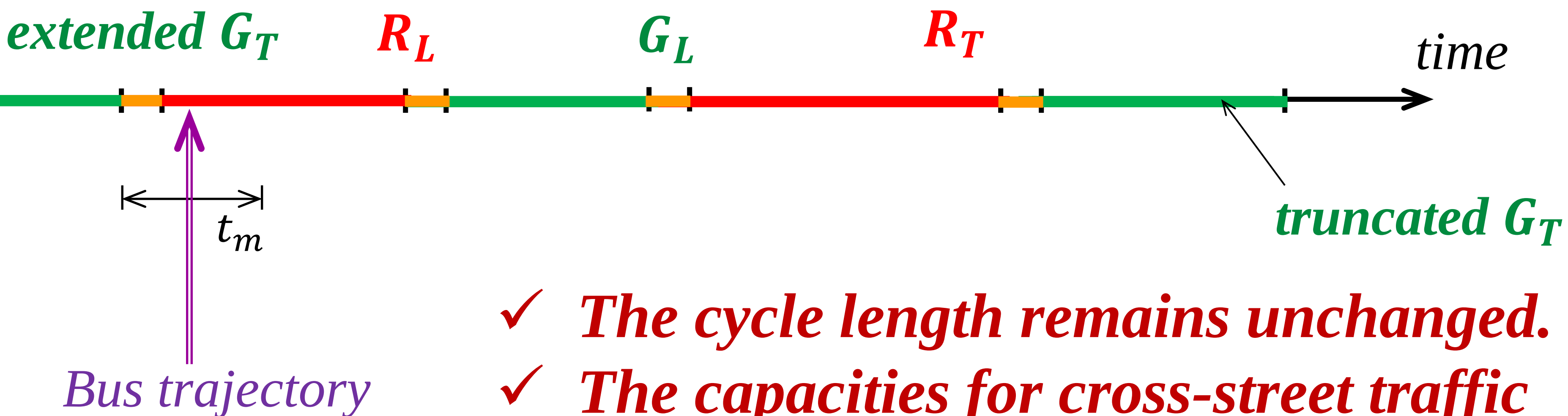
Before the change



Our strategy

- ✓ Bus signal priority – green extension only
  - ✓ Any bus that arrives to the intersection within t_m after the end of the last G_T phase will be given a green extension.

After the change

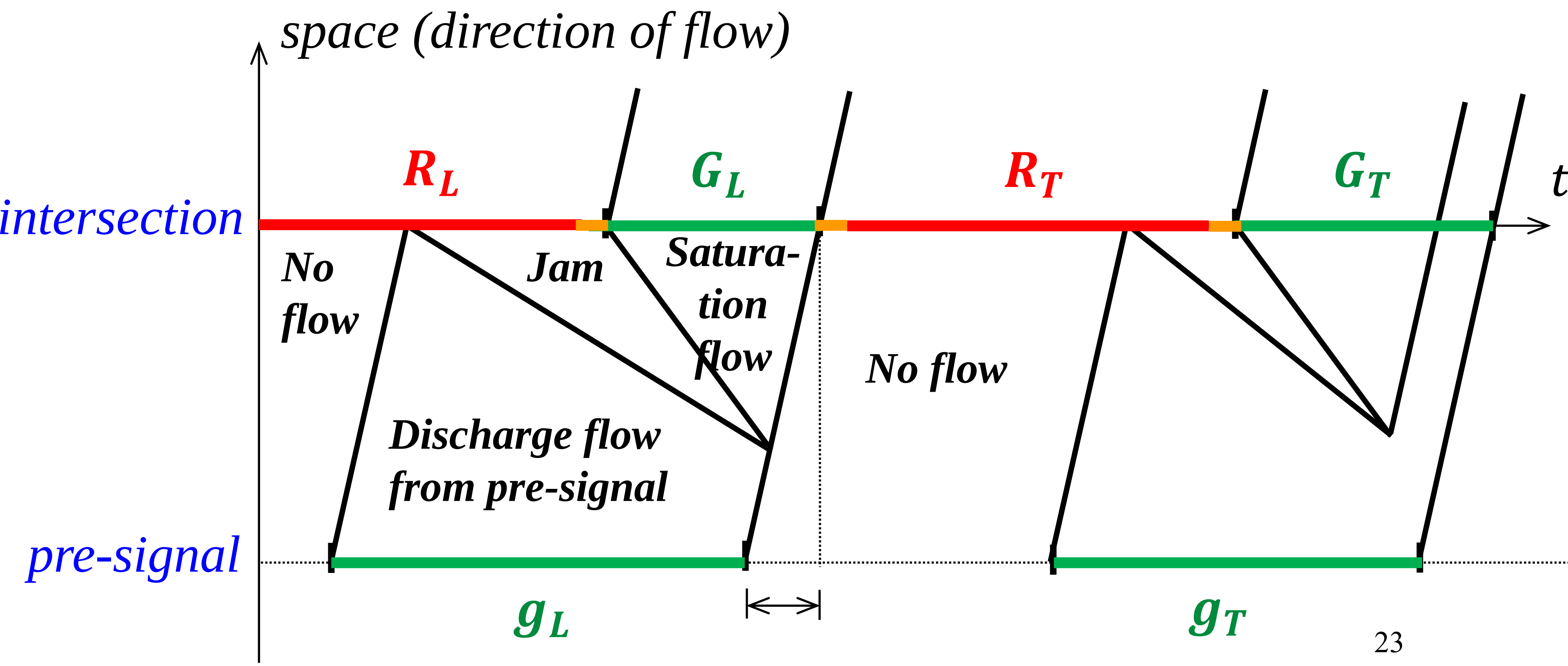


✓ **The cycle length remains unchanged.**

✓ **The capacities for cross-street traffic are not compromised.**

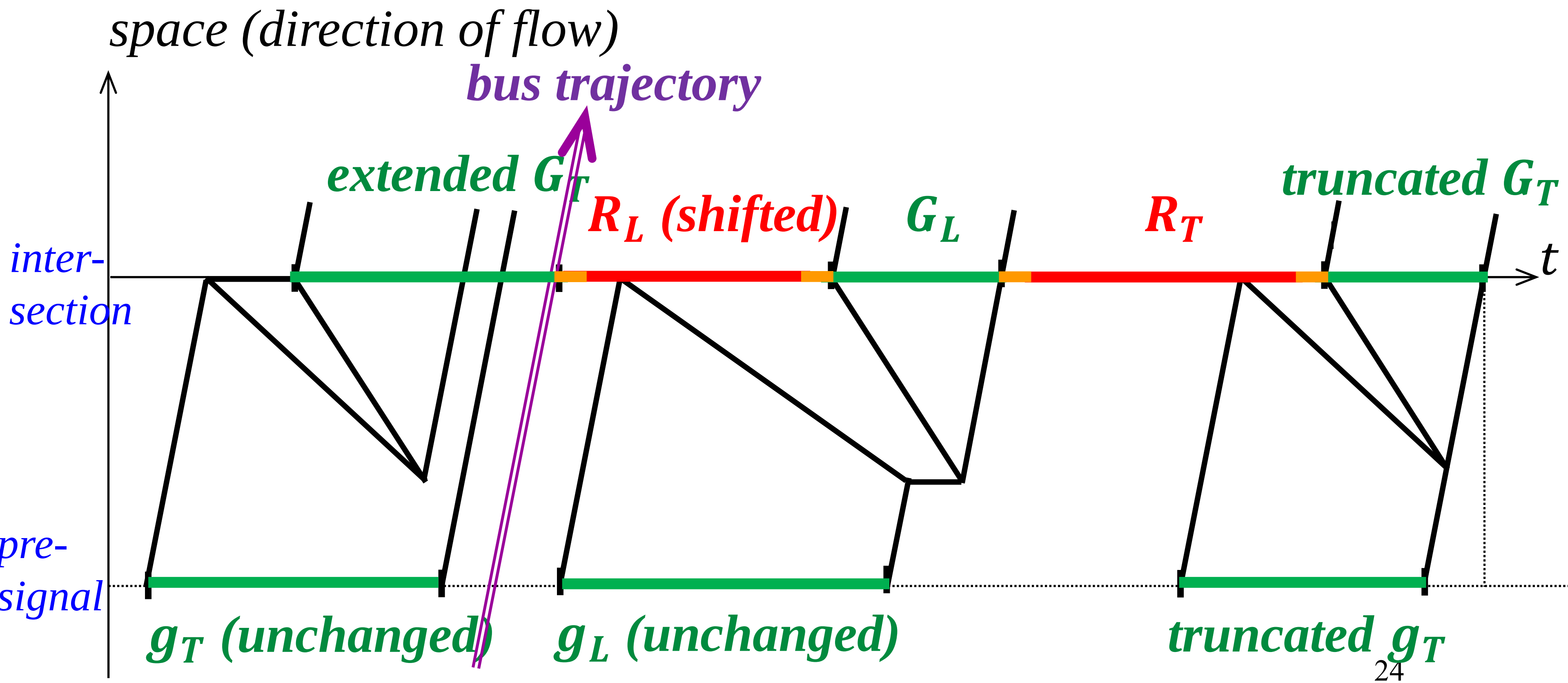
Our strategy

- ✓ *Pre-signal plan*
  - ✓ *Based upon kinematic wave theory of traffic flows*



Our strategy

- ✓ Coordinating pre-signal with bus priority at main signal



Models

- ✓ *Objectives:*
  - ✓ *Maximizing (expected) car discharge capacity of the subject approach*
  - ✓ *Minimizing expected bus delays*

Models

- ✓ *Two-step approach:*
  - ✓ *Step 1 – Determining the optimal assignments of lanes and signal times (to left-turning and through-moving traffic streams) that maximizes car discharge capacity given:*
    - ✓ *Left-turning ratio*
    - ✓ *Signal cycle length*
    - ✓ *Total green time per cycle allocated to the subject approach*
  - ✓ *Step 2 – Find the* ***Pareto frontier*** *between expected bus delay and expected car capacity*

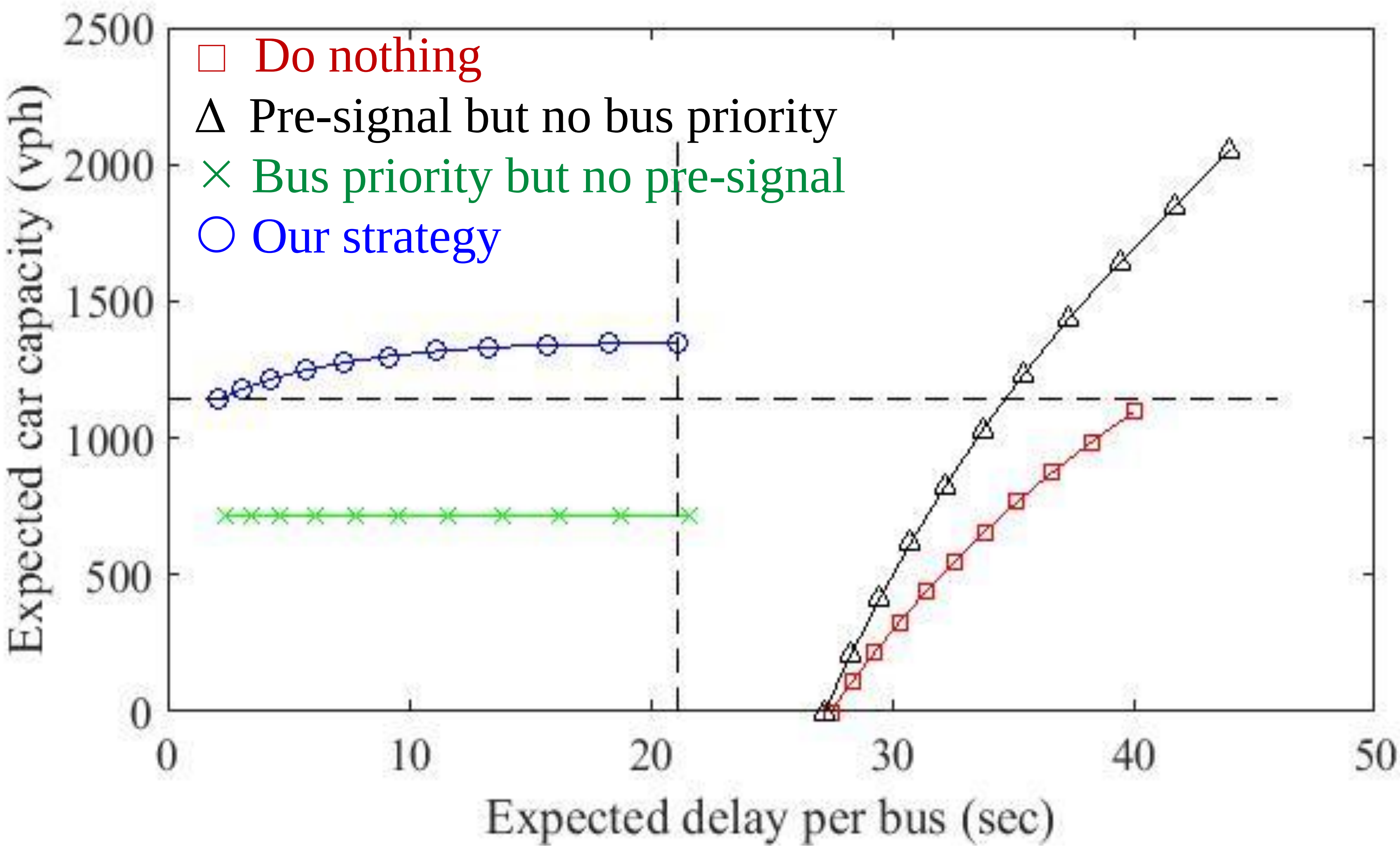
Scenarios for comparison

	Pre-signal?	***Bus lane?***	***Signal priority?***	
1	×	×	×	*Baseline 1*
2	×	×	√	*Infeasible*
3	×	√	×	*No use*
4	×	√	√	*Baseline 3*
5	√	×	×	*Baseline 2*
6	√	×	√	*Infeasible*
7	√	√	×	*Special case of our strategy* ($t_m = 0$)
8	√	√	√	*Our strategy*

Numerical case studies

- ✓Parameters:
  - ✓Three lanes
  - ✓Left-turning ratio: 0.2
  - ✓Signal cycle length: 120 sec
  - ✓Green time for the subject approach: 60 sec
  - ✓Saturation flow per lane: 0.5 veh/sec
  - ✓Bus flow: 30 bus/hr (low-bus-flow case)

Results


□ Do nothing
Δ Pre-signal but no bus priority
× Bus priority but no pre-signal
○ Our strategy
Expected car capacity (vph)
Expected delay per bus (sec)
0
500
1000
1500
2000
2500
0
10
20
30
40
50

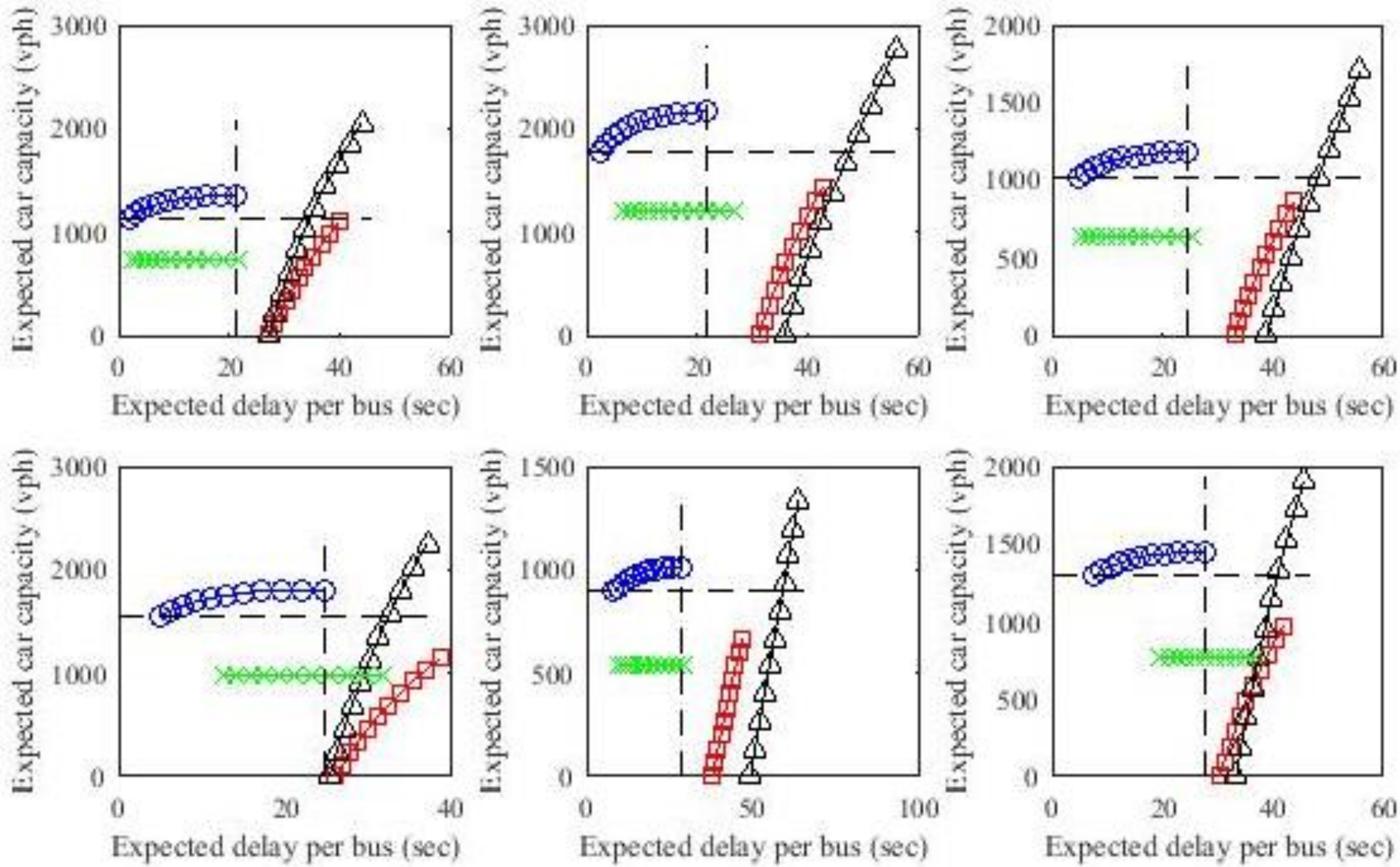
Numerical case studies

- ✓ *Parameters:*
  - ✓ *Three or four lanes*
  - ✓ *Left-turning ratio: 0.2, 0.3, 0.4*
  - ✓ *Signal cycle length: 120 sec*
  - ✓ *Green time for the subject approach: 60 sec*
  - ✓ *Saturation flow per lane: 0.5 veh/sec*
  - ✓ *Bus flow: 30 bus/hr (low-bus-flow case)*

Left-turning ratio: 0.2 0.3 0.4

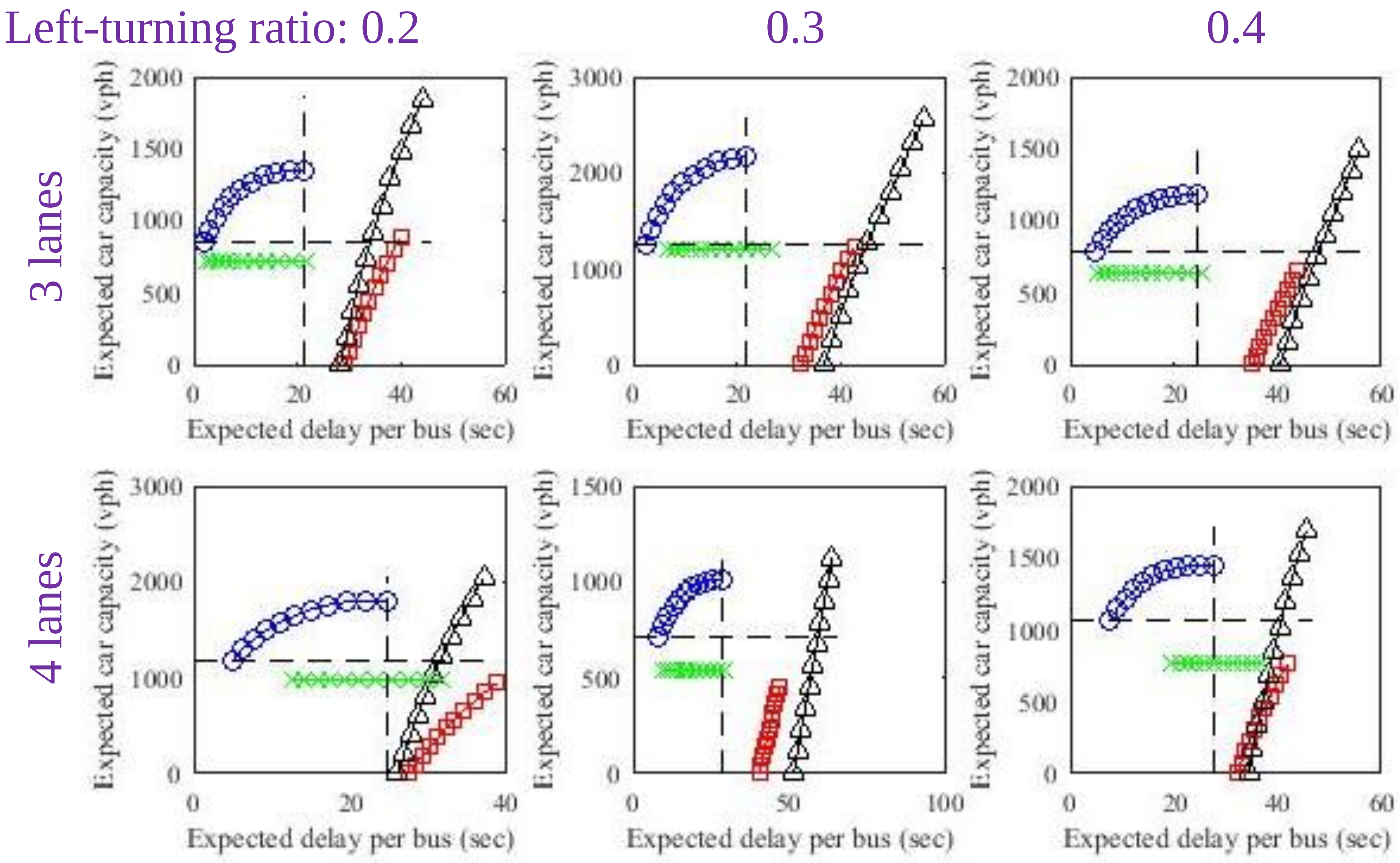
3 lanes

4 lanes



Numerical case studies

- ✓ *Parameters:*
  - ✓ *Three or four lanes*
  - ✓ *Left-turning ratio: 0.2, 0.3, 0.4*
  - ✓ *Signal cycle length: 120 sec*
  - ✓ *Green time for the subject approach: 60 sec*
  - ✓ *Saturation flow per lane: 0.5 veh/sec*
  - ✓ *Bus flow: 90 bus/hr (high-bus-flow case)*


Left-turning ratio: 0.2
0.3
0.4
3 lanes
4 lanes
Expected car capacity (vph)
Expected delay per bus (sec)

Concluding remarks

- ✓ *We show by a simple strategy that bus and car operations at a busy intersection can be both improved. Though simple and conservative, the strategy's benefit is huge.*
- ✓ *Our strategy can be applied for busy intersections with high car and bus flows.*
- ✓ *Possible extensions:*
  - ✓ *More efficient bus signal priority schemes*
  - ✓ *Make the bus lane intermittently available for cars*
  - ✓ *Accommodate left-turning buses*
  - ✓ …

Concluding remarks

- ✓ *Limitations:*
  - ✓ *Heterogeneity in vehicle kinematics*
  - ✓ *Bounded acceleration*
  - ✓ *Neighboring bus stops*
- ✓ *Simulation tests underway*
- ✓ *Applications*

Questions?

Weihua Gu

weihua.gu@polyu.edu.hk