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Recurrent and Non-recurrent Congestion Based Gridlock Detection on Chula-SSS Urban Road Network

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Paper Session 3 : **Simulator Coupling**
Place : **German Aerospace Center, Institute of Transportation Systems, Rutherfordstr. 2, 12489 Berlin, Germany**
Date and time : **14th May, 2019 (15:45 – 17:00)**

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  - The scenario used on Chula-SSS and observation results
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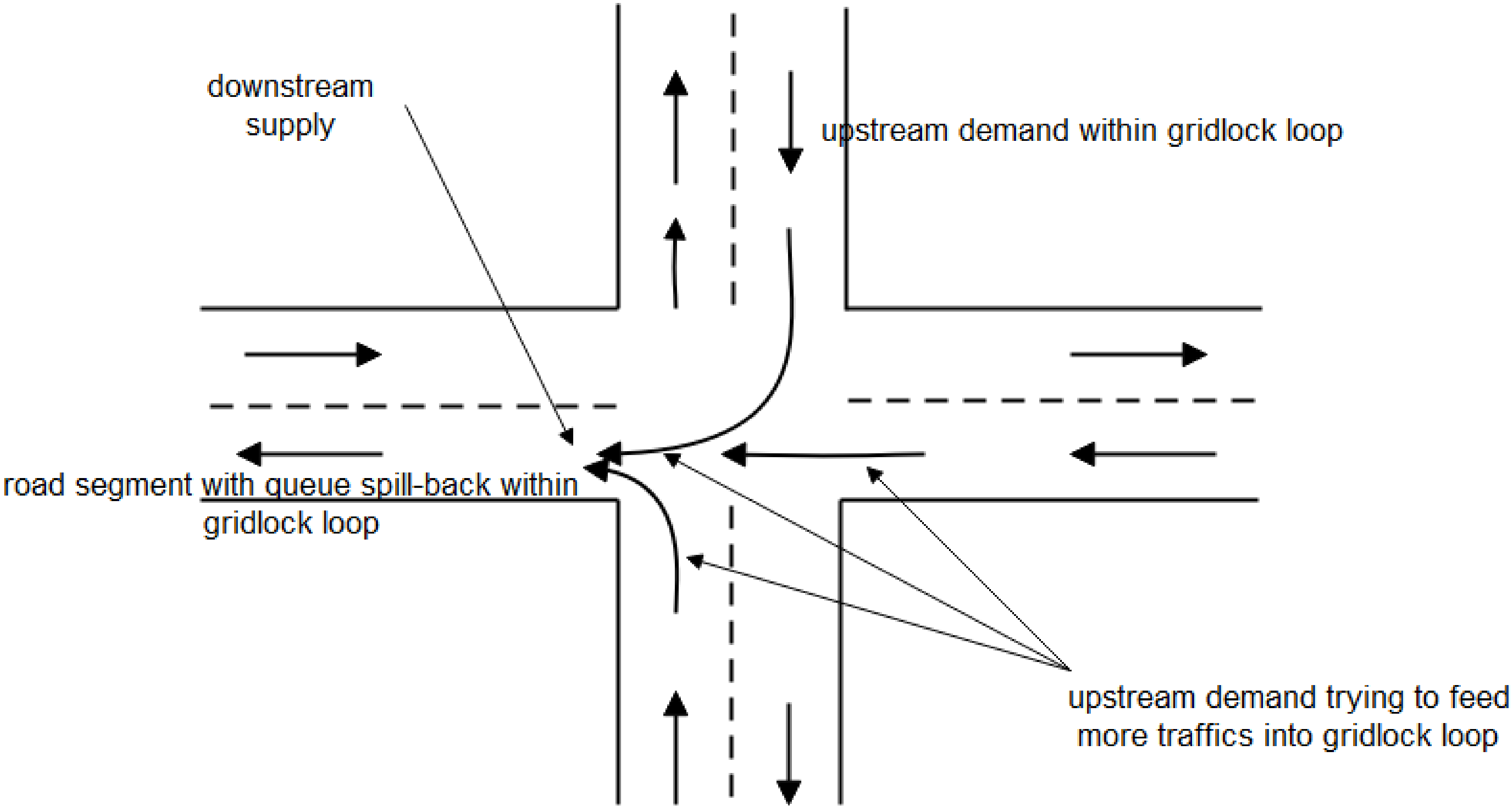
- **Acknowledgements**

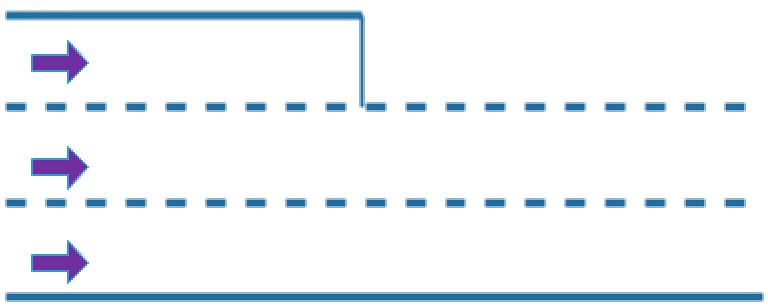
Traffic bottlenecks

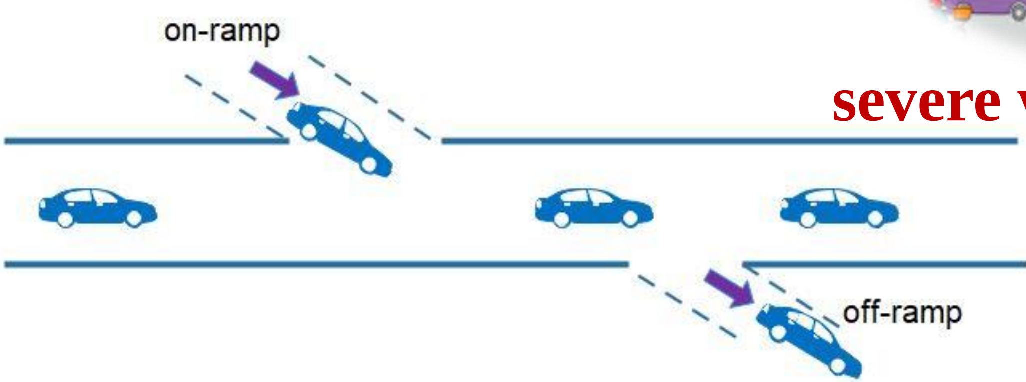


imbalance supply and demand at intersection

Traffic bottlenecks (cont'd)

Normal traffic bottlenecks[1]





Unforeseen traffic bottlenecks

accidents

severe weather condition

road maintenance

[1] H. Qi, M. Chen, and D. Wang, "Recurrent and non-recurrent bottleneck analysis based on traffic state rank distribution," Transportmetrica B: Transport Dynamics, pp. 1-20, 2017.

Recurrent congestion

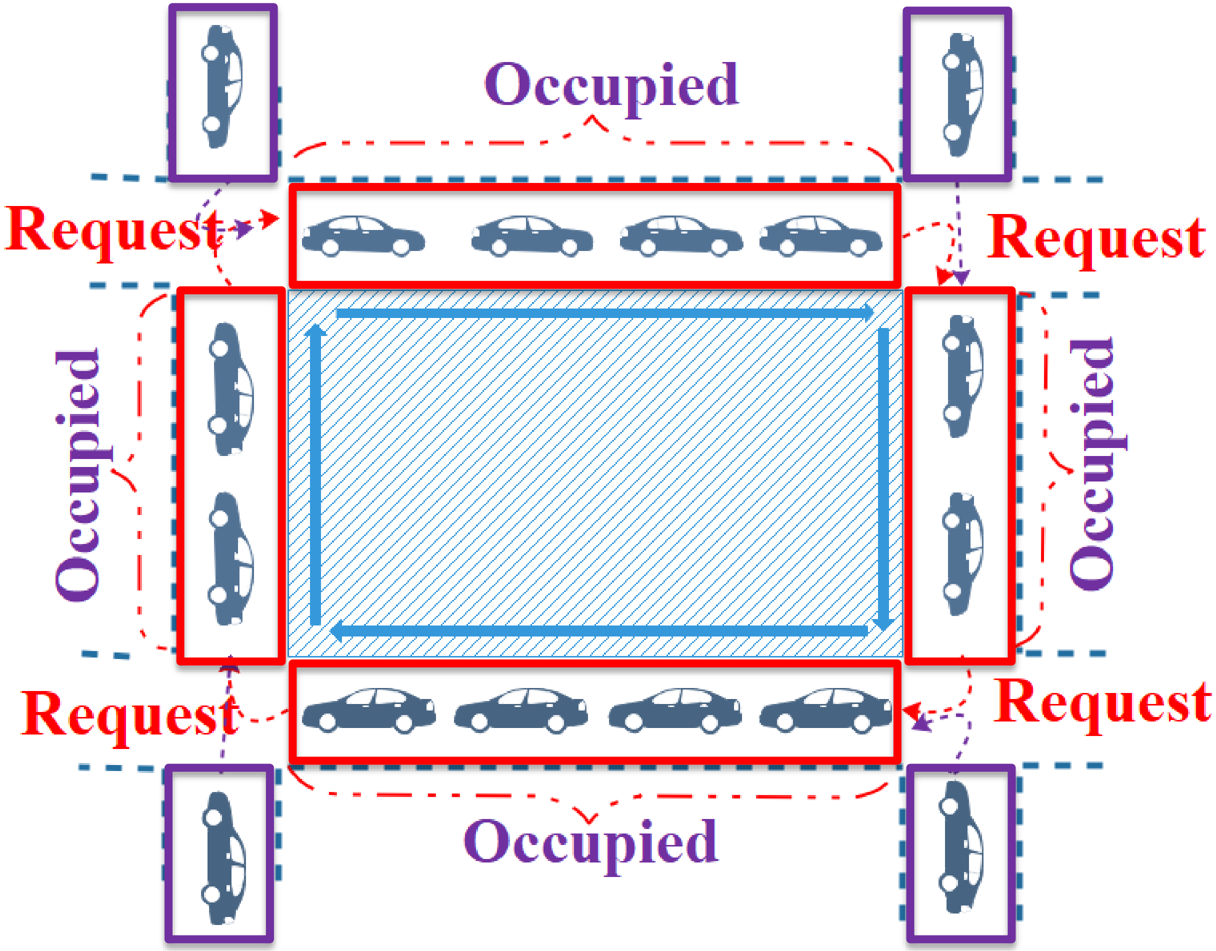
❖ Stop and go traffic pattern daily in morning and evening rush hours
e.g. from school buses and parent vehicles to drive their children to-and-from schools

Non-recurrent congestion

❖ Unforeseen, unexpected events
e.g. bad weather, vehicle collision

❖ Disorder normal traffic flows and reduce road capacity
❖ Spread negative impacts to neighbouring upstream and downstream links
❖ Reduce traffic flow efficiency in complex urban road network
❖ Lead to formation of congestion gridlock

Upstream-downstream congestion propagation



Propagation of bottlenecks can lead to a large-scale urban network gridlock [10]

[10] C. F. Daganzo, "Urban gridlock: Macroscopic modeling and mitigation approaches," Transportation Research Part B: Methodological, vol. 41, no. 1, pp. 49-62, 2007.

Objective

- **To detect recurrent and non-recurrent cases based gridlock with upstream ~ downstream nearby detectors at every intersection in the loop by using different combinations of traffic jam length and mean speed conditions during the green time**

Literature review on recurrent and non-recurrent congestion

- **Analysis congestion bottleneck core link and its neighbouring links by clustering links based on link speed ranks [1]**

- **Regression model for urban traffic networks by using the combinations of traffic indicators like link traffic flows, link lengths and signal phase cycle time [2]**

- **Non-recurrent congestion detection method with spatio-temporal clustering on high link journey time [3]**

[1] H. Qi, M. Chen, and D. Wang, "Recurrent and non-recurrent bottleneck analysis based on traffic state rank distribution," Transportmetrica B: Transport Dynamics, pp. 1-20, 2017.
[2] F. Ahmed and Y. E. Hawas, "A threshold-based real-time incident detection system for urban traffic networks," vol. 48, pp. 1713-1722, Elsevier, 2012.
[3] B. Anbaroglu, B. Heydecker, and T. Cheng, "Spatio-temporal clustering for non-recurrent traffic congestion detection on urban road networks," Transportation Research Part C: Emerging Technologies, vol. 48, pp. 47-65, 2014.

Literature review on recurrent and non-recurrent congestion (cont'd)

- **Percentile and space-time scan statistics for non-recurrent incident detection with link journey time lognormal distribution [4]**
- **Travel demand effects on non-recurrent incident detection methods by using estimated link journey time [5]**
- **Data mining approach to define traffic volume parameters and analyze impact duration with time and season features [6]**

[4] B. Anbaroglu, T. Cheng, and B. Heydecker, "Non-recurrent traffic congestion detection on heterogeneous urban road networks," Transportmetrica A: Transport Science, vol. 11, no. 9, pp. 754-771,2015.
[5] B. Anbaroglu, B. Heydecker, and T. Cheng, "How travel demand affects detection of non-recurrent traffic congestion on urban road networks," in XXIII ISPRS Congress, Commission II, vol. 41, pp. 159-164, Copernicus Gesellschaft MBH, 2016.
[6] C. Sun, J. Hao, X. Pei, Z. Zhang, and Y. Zhang, "A data-driven approach for duration evaluation of accident impacts on urban intersection traffic flow," in Intelligent Transportation Systems (ITSC), 2016 IEEE 19th International Conference on, pp. 1354-1359, IEEE, 2016.

Literature review on recurrent and non-recurrent congestion (cont'd)

- **An automatic traffic incident detection and locating method on urban road segment in consideration of lane-changing characteristics [7]**

[7] J. Ren, Y. Chen, L. Xin, J. Shi, and H. Mahama, "Detecting and locating of trac incidents in a road segment based on lane-changing characteristics," Transportmetrica A: transport science, vol. 13, no. 10, pp. 853-873, 2017.

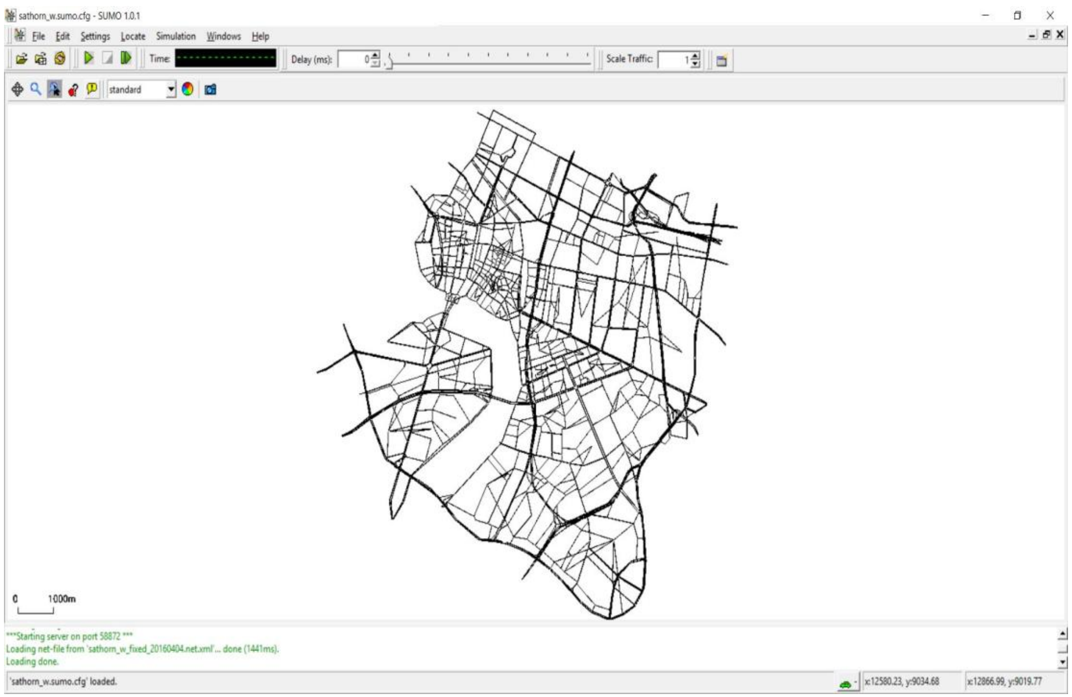
Bangkok (Thailand)

- TomTom Traffic Index (Aug, 2016)
  - Bangkok is the most congested city in Asia
  - 2nd most congested city globally
  - Extra travel time 64 min per day
- Workers based outside the city drive to and from work with different vehicle types (cars, bus, motorbikes)
- Rush hours from 6:00 to 9:00 in morning and 3:00 to 7:00 in evening

Sathorn Area

- Densely populated part of city
- Link between residential area and business area
- 150,000 vehicles ~ every weekday
- 55,000 traveling vehicles ~ morning/evening rush hours
- Spillover effect on nearby streets and surrounding areas

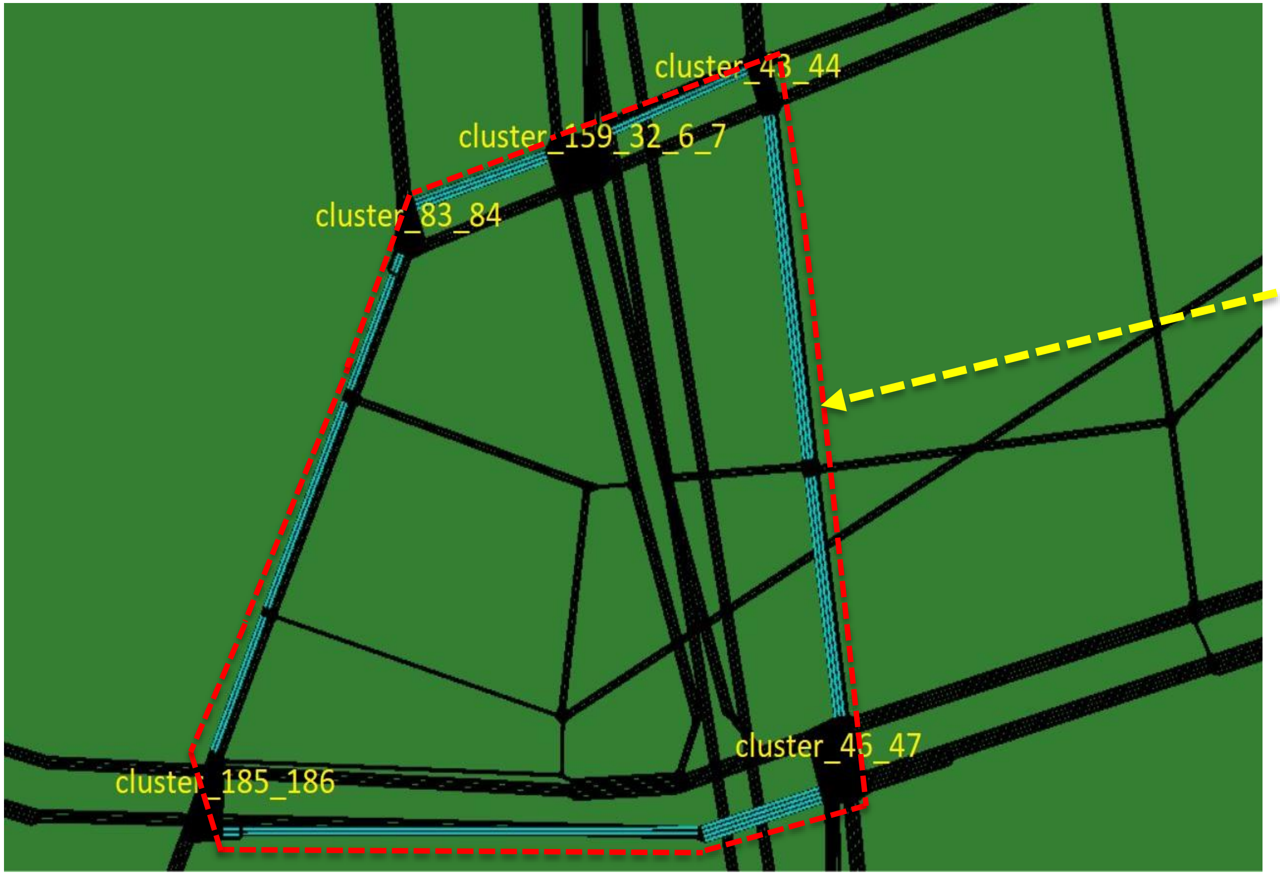
Chula-Sathorn SUMO Simulator (Chula-SSS)



- **Chulalongkorn University's Sathorn Model project**
- **Calibrated datasets cover morning and evening rush-hour periods with over 55,000 simulated vehicles**
- **2375 intersection nodes**
- **4517 edges with left-handed driving**
- **10 signalized intersections**

[8] C. Aswakul, S. Watarakitpaisarn, P. Komolkiti, C. Krisanachantara, and K. Techakittiroj, "Chula-sss: Developmental framework for signal actuated logics on sumo platform in over-saturated sathorn road network scenario," in SUMO 2018- Simulating Autonomous and Intermodal Transport Systems, vol. 2 of EPiC Series in Engineering, pp. 67-81, EasyChair, 2018.

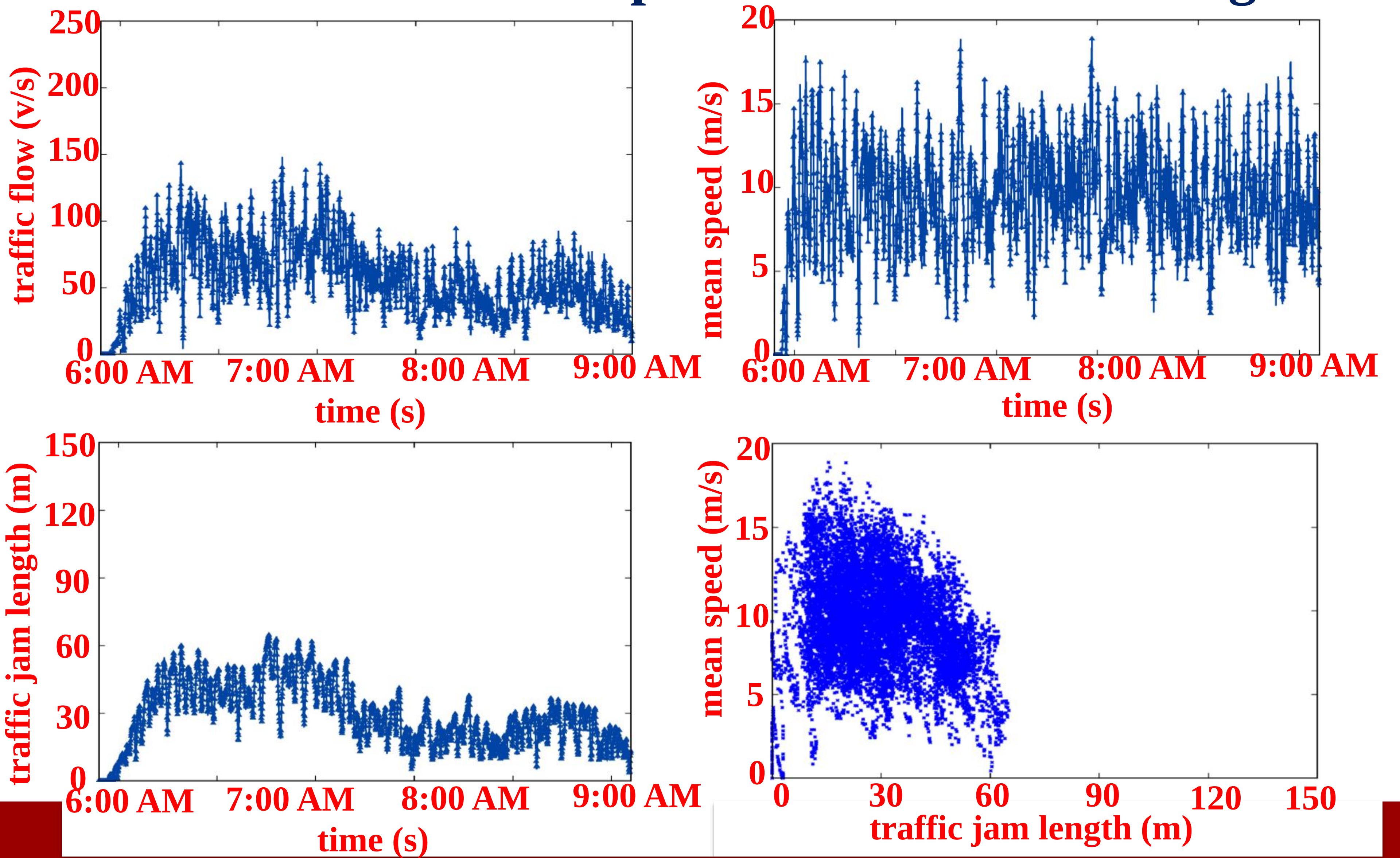
Critical region in simulated Sathorn road network



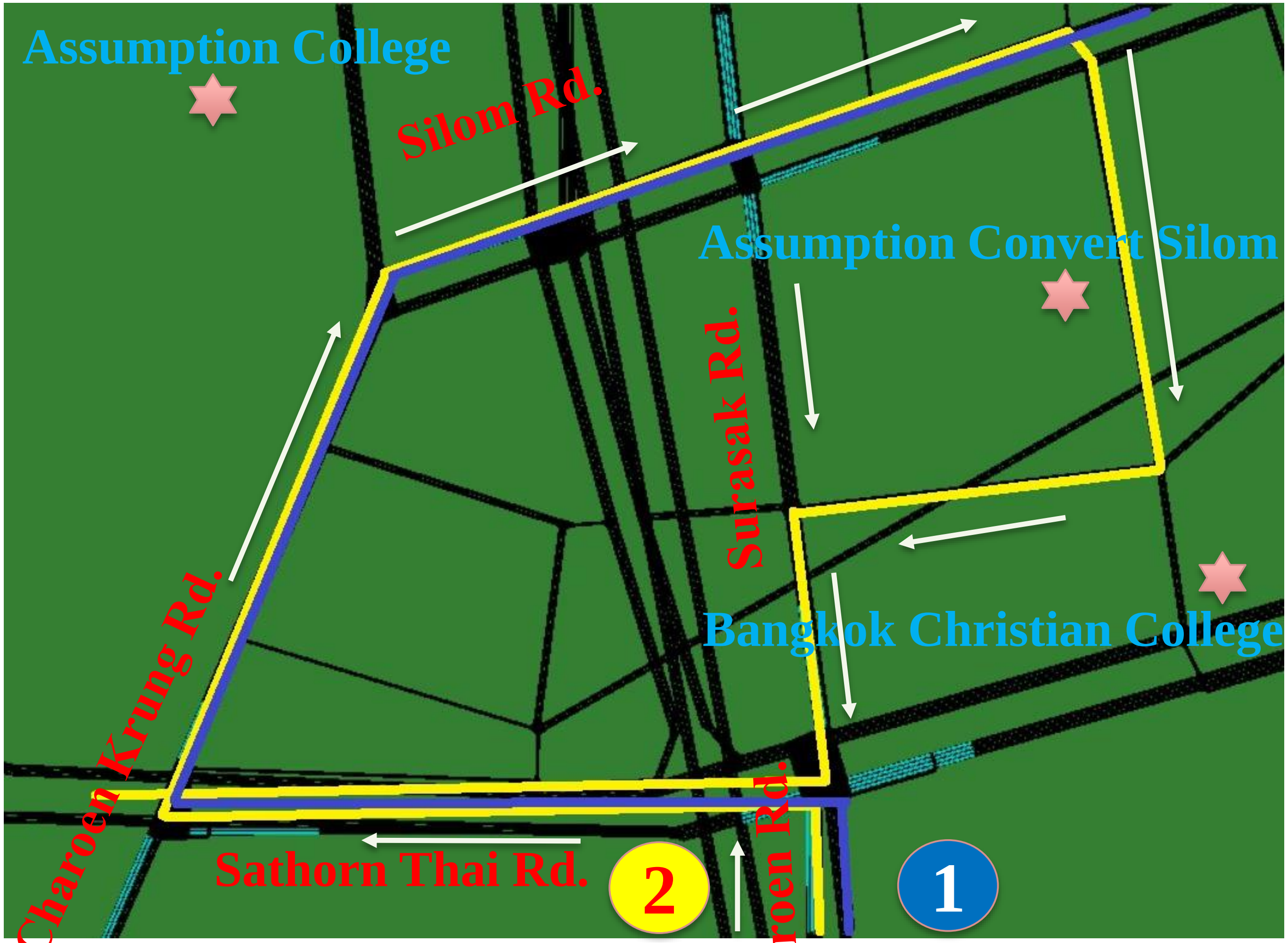
- ❖ Sathorn critical region with 5 intersections
- ❖ Accumulate summed data during simulation time ~ traffic flow, mean speed, jam length from lane area detectors [9] in the whole loop

[9] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "Sumo - simulation of urban mobility," in The Third International Conference on Advances in System Simulation (SIMUL 2011), Barcelona, Spain, vol. 42, 2011.

Calibrated Chula-SSS loop-based fundamental diagrams



Recurrent-case with two extra routes



Turning movements at intersection in real case

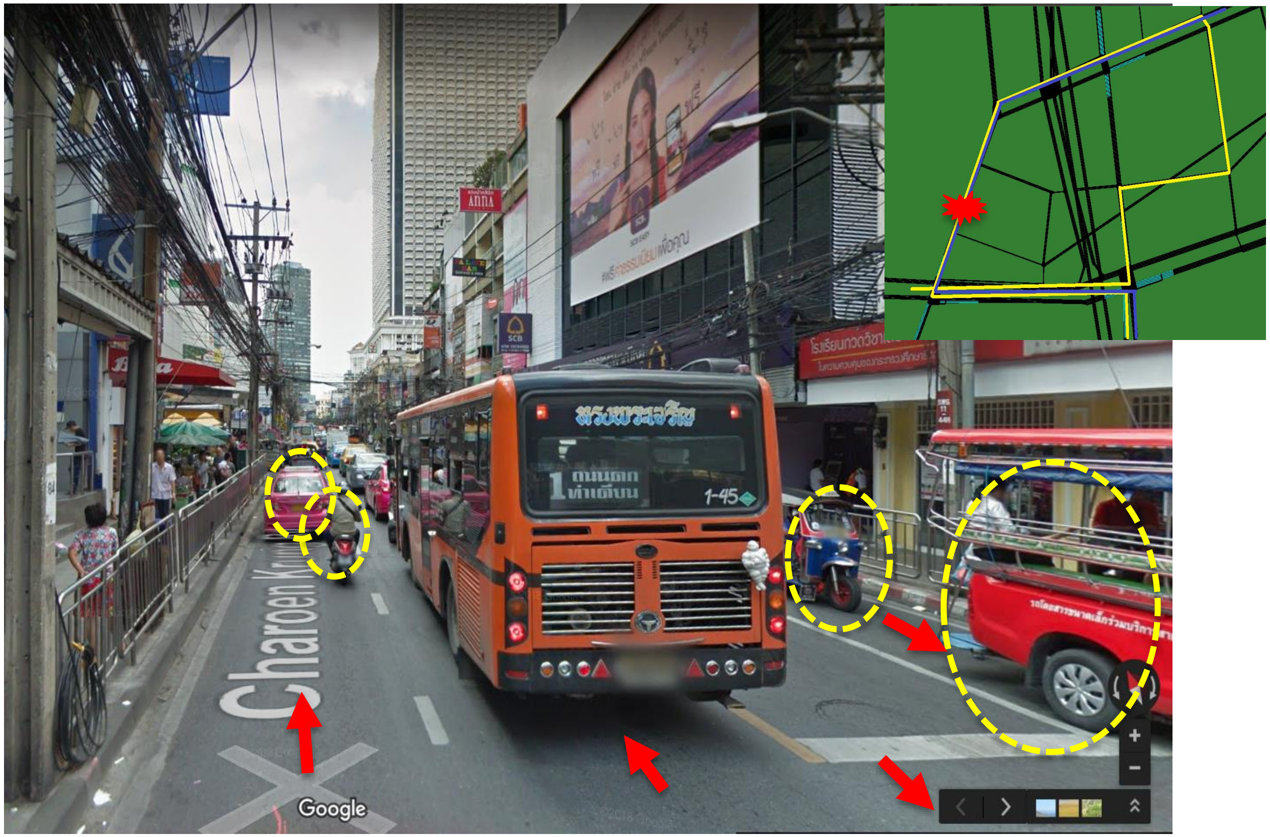
Original Chula-SSS with two extra routes to create recurrent-case

Route	Time	Flow (v/h)	Total Vehicles
1	7:00 AM - 8:15 AM	425	531
2	6:15 AM – 6:45 AM	300	150
3	6:45 AM - 7:15 AM	300	150

Route 1 ~ 2125 v/h

Route 2 ~ 1500 v/h

Non-recurrent case with lane closure



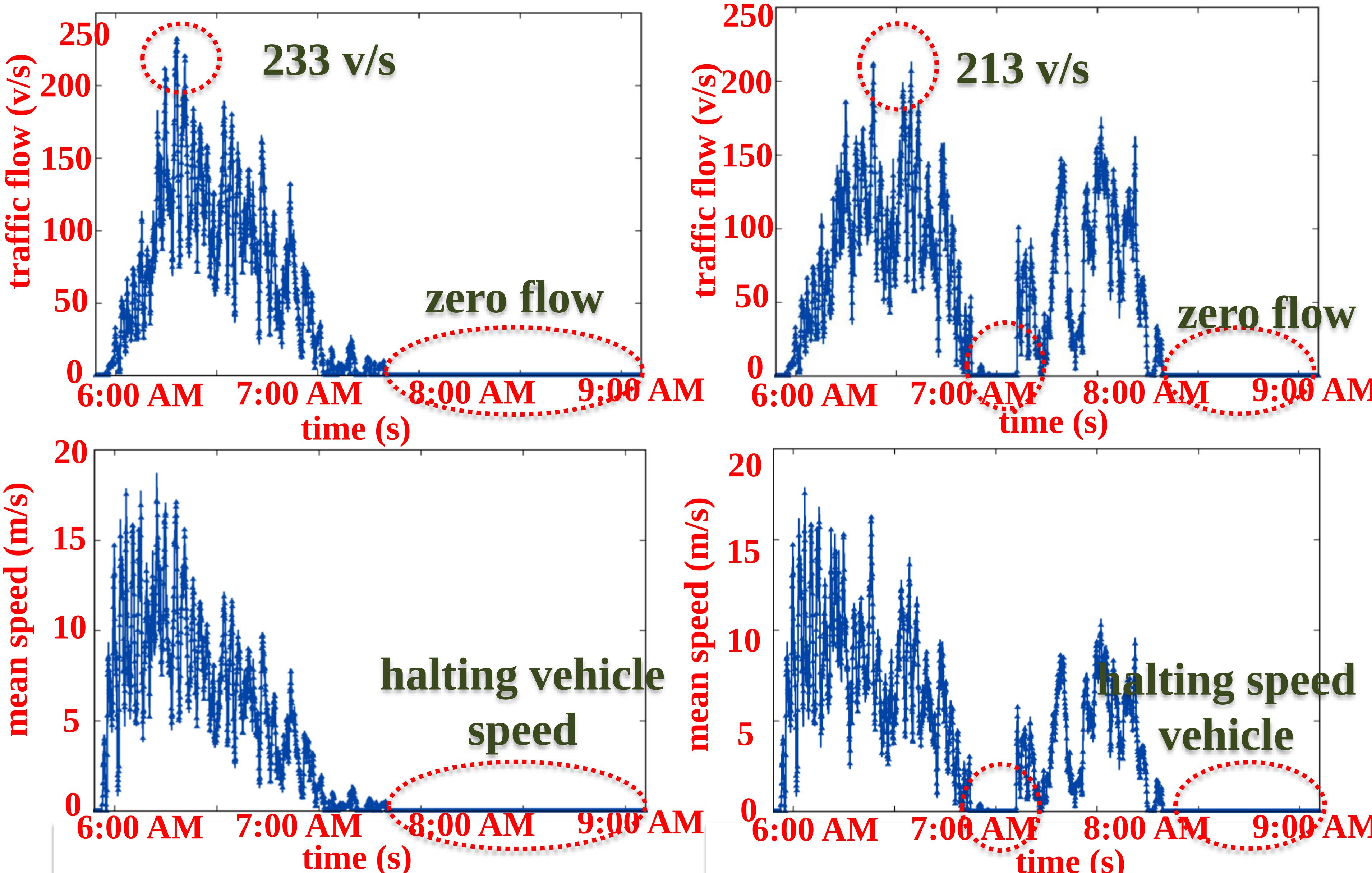
https://www.google.com/maps/

- 2 lanes for each direction
- Blockages
  - Bus stops
  - Illegal parking ~ taxis , tuktuks
- One out of two lanes (160 m) on the road segment for two times (22500 s to 23700 s and 25200 s to 26400 s) with the duration of 20 mins each

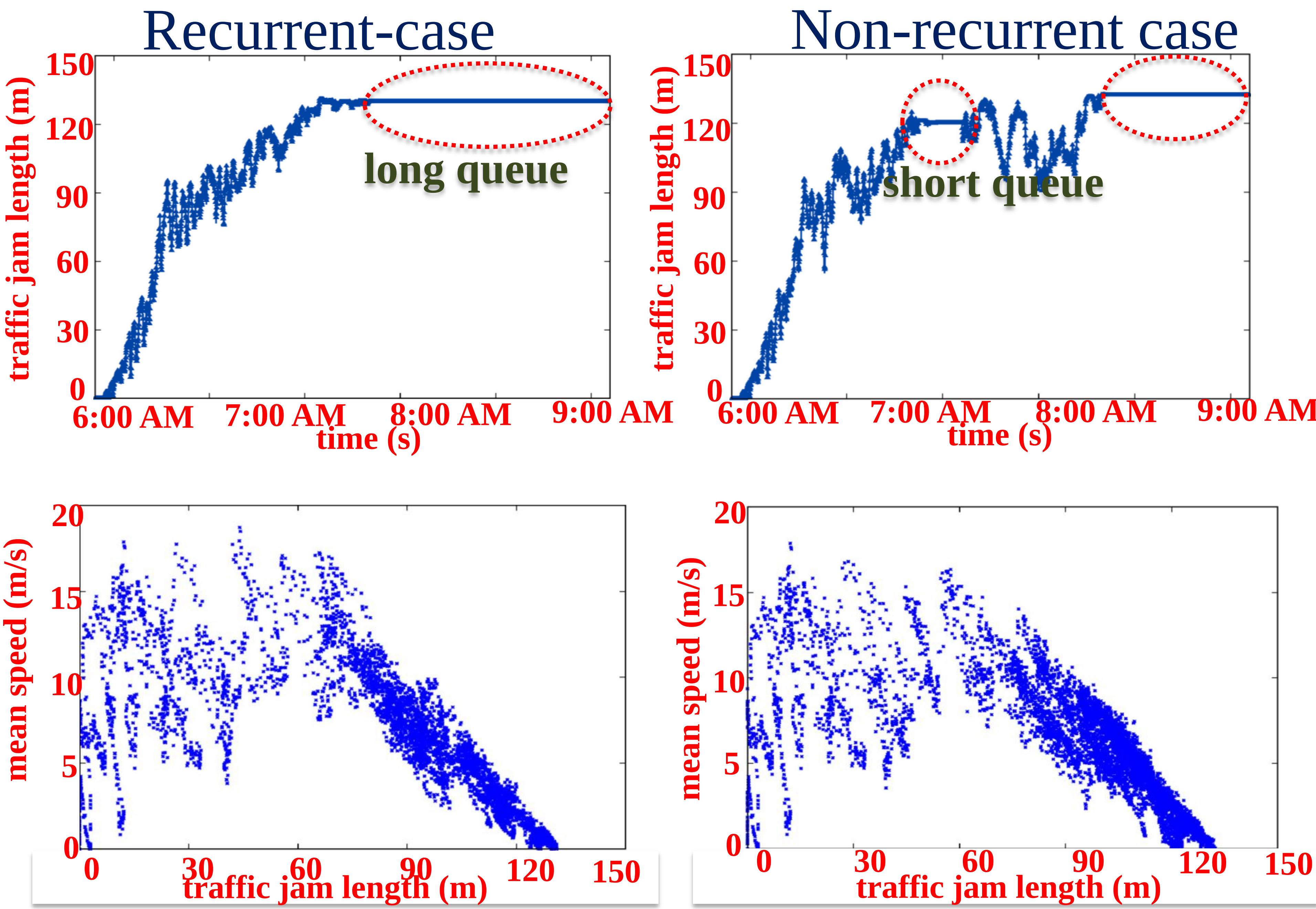
Comparison of loop-based fundamental diagrams

Recurrent-case

Non-recurrent case

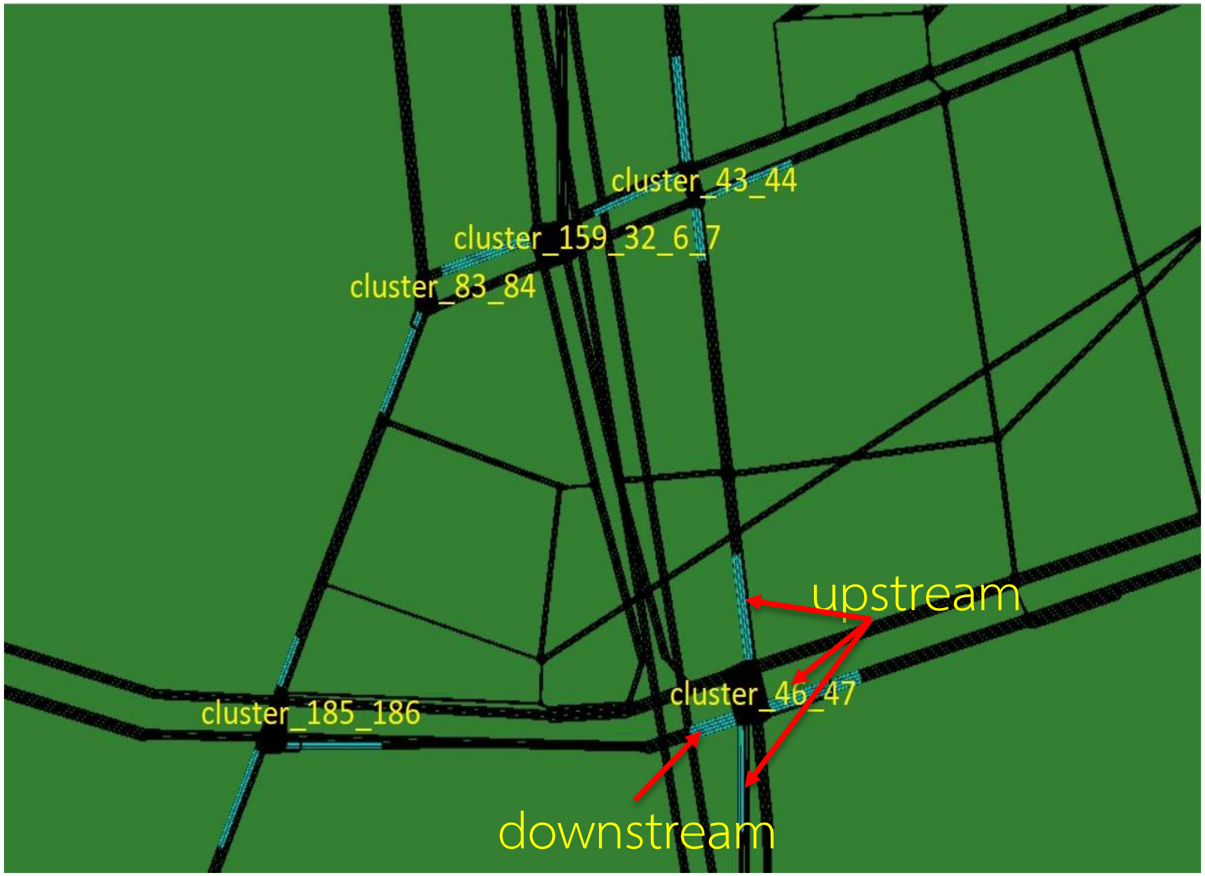


Comparison of loop-based fundamental diagrams (cont'd)



- **Overall network capability**
  - **233 v/s ~ recurrent case**
  - **213 v/s ~ non-recurrent case (incident injection)**
- **Incident injection does not hurt the jam situation significantly higher that its norm**

How to characterize gridlock in practice?



- upstream-downstream detectors **in all intersections** within potential gridlock loop **are in jam state**
- 100 m ~ upstream
- 50 m ~ downstream

How to characterize gridlock?

- *jam state of* **each intersection** *i in the whole loop L,*
    - *meanspeed <= 5 km/h*
    - *jamlength > 80% of detector length for each upstream and downstream pair*

gridlock status 1 ~ all intersections i ∈ L are in the jam state during green time

gridlock status 0 ~ otherwise

Number of time steps with gridlock detected by each condition in every 5s of simulation

	Recurrent	Non-recurrent
upstream-speed, downstream-speed	103	70
upstream-speed, downstream-jam	105	70
upstream-speed, downstream-speed+jam	103	70
upstream-speed+jam, downstream-speed	103	70
upstream-speed+jam, downstream-jam	104	70
upstream-speed+jam, downstream-speed+jam	103	70
upstream-jam, downstream-speed	110	80
upstream-jam, downstream-jam	120	87
upstream-jam, downstream-speed+jam	110	78

Conclusion

- Recurrent and non-recurrent based gridlock
- Measurable gridlock characteristics in terms of traffic jam length and speed from both upstream and downstream links of corresponding intersections
- Investigating gridlock detection and prediction conditions with machine learning based classification algorithms (**ongoing work**)

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