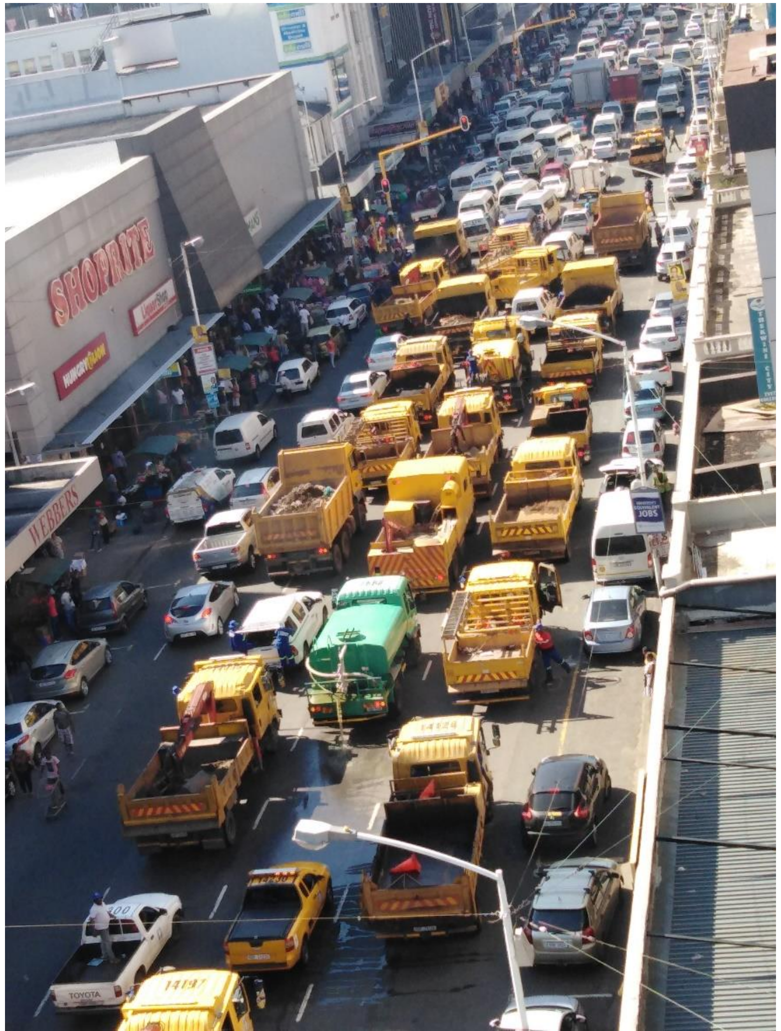
A Simulation Study on Prioritizing Connected Freight Vehicles at Intersections for Traffic Flow Optimization (Industrial Paper)

Hairuo Xie[1], Renata Borovica-Gajic[1], Egemen Tanin[1], Shanika Karunasekera[1], Udesh Gunarathna[1], Gilbert Oppy[2], and Majid Sarvi[1]

[1] University of Melbourne, [2] Telstra

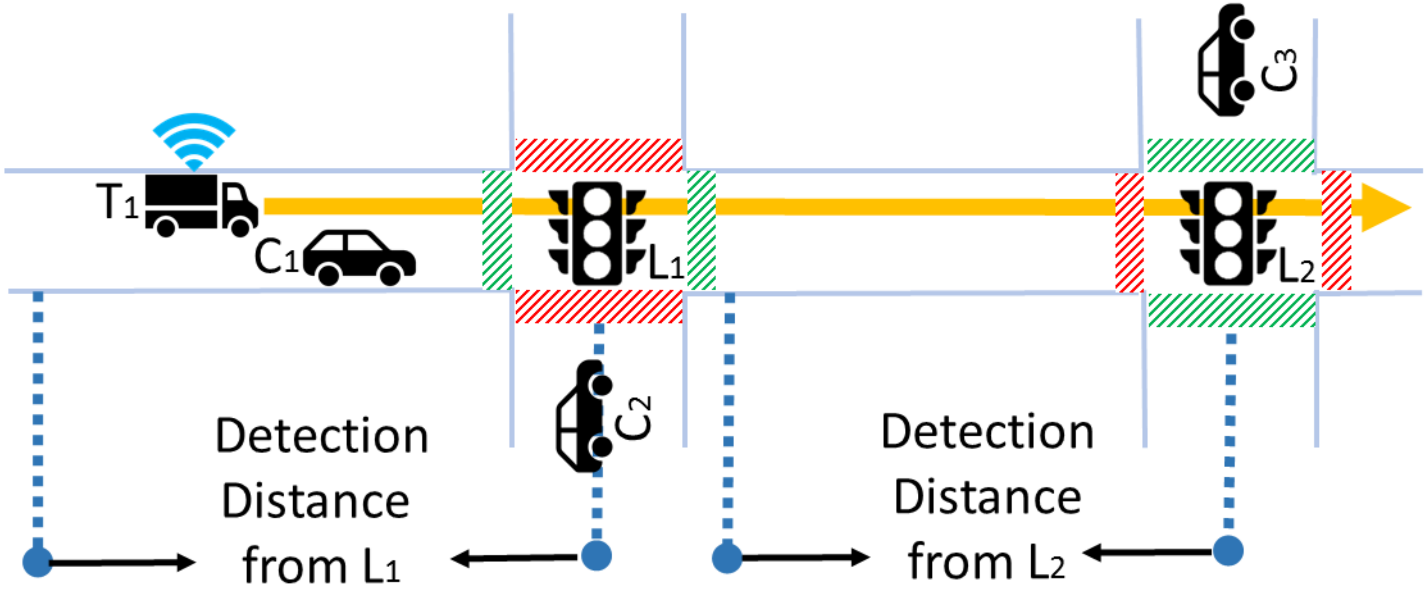
Need for Truck Delay Reduction

- Trucks play a major role in freight shipments
  - In US in 2017, trucks shipped 65% of goods by weight and 71% of goods by value
- Delay for trucks can be costly
  - E.g., truck delays on a 22-mile corridor in Georgia costs $320k a day in 2007
- A major cause of truck delay is slowdown at intersections



Autonomous Intersection Management (AIM)

- An envisaged AIM solution
  - Connected trucks are prioritized at intersections

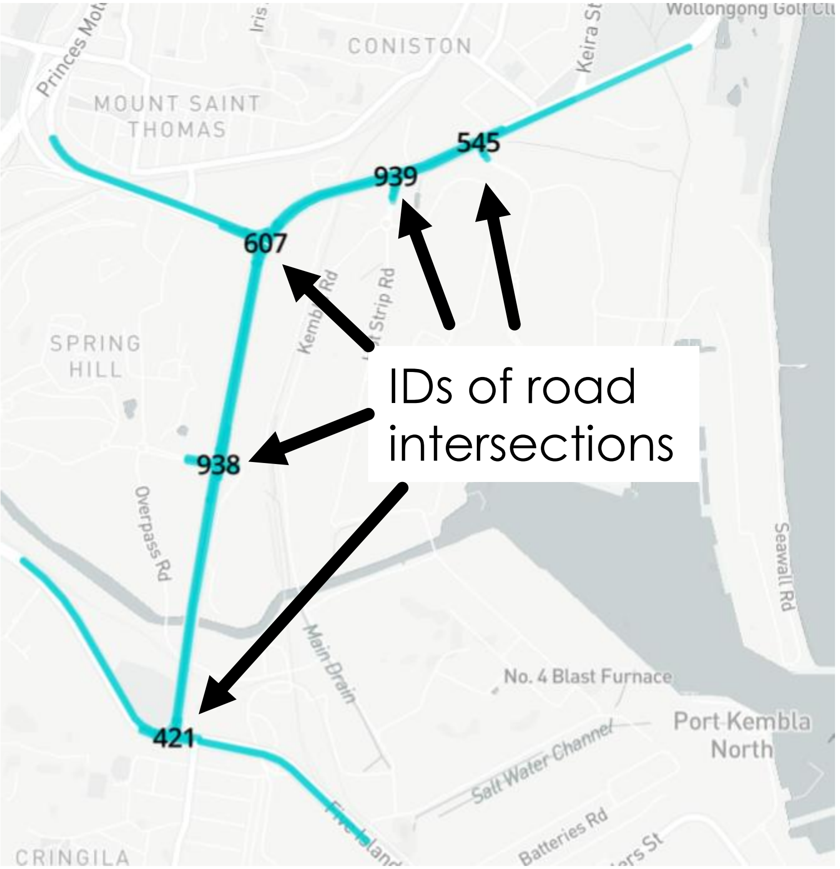


Telstra’s Connected Truck Technology

- Our industry partner (Telstra) has a 4G network covering 99.4% of Australian population
- The 4G network is used by Sydney Coordinated Adaptive Traffic System (SCATS)
- The 4G network is also used by Telstra’s subsidiary MTData for connected fleet management
  - Trucks with MTData hardware can send GPS position and other vehicle telematics via Telstra’s communication infrastructure

Telstra's Connected Truck Technology (Cont.)

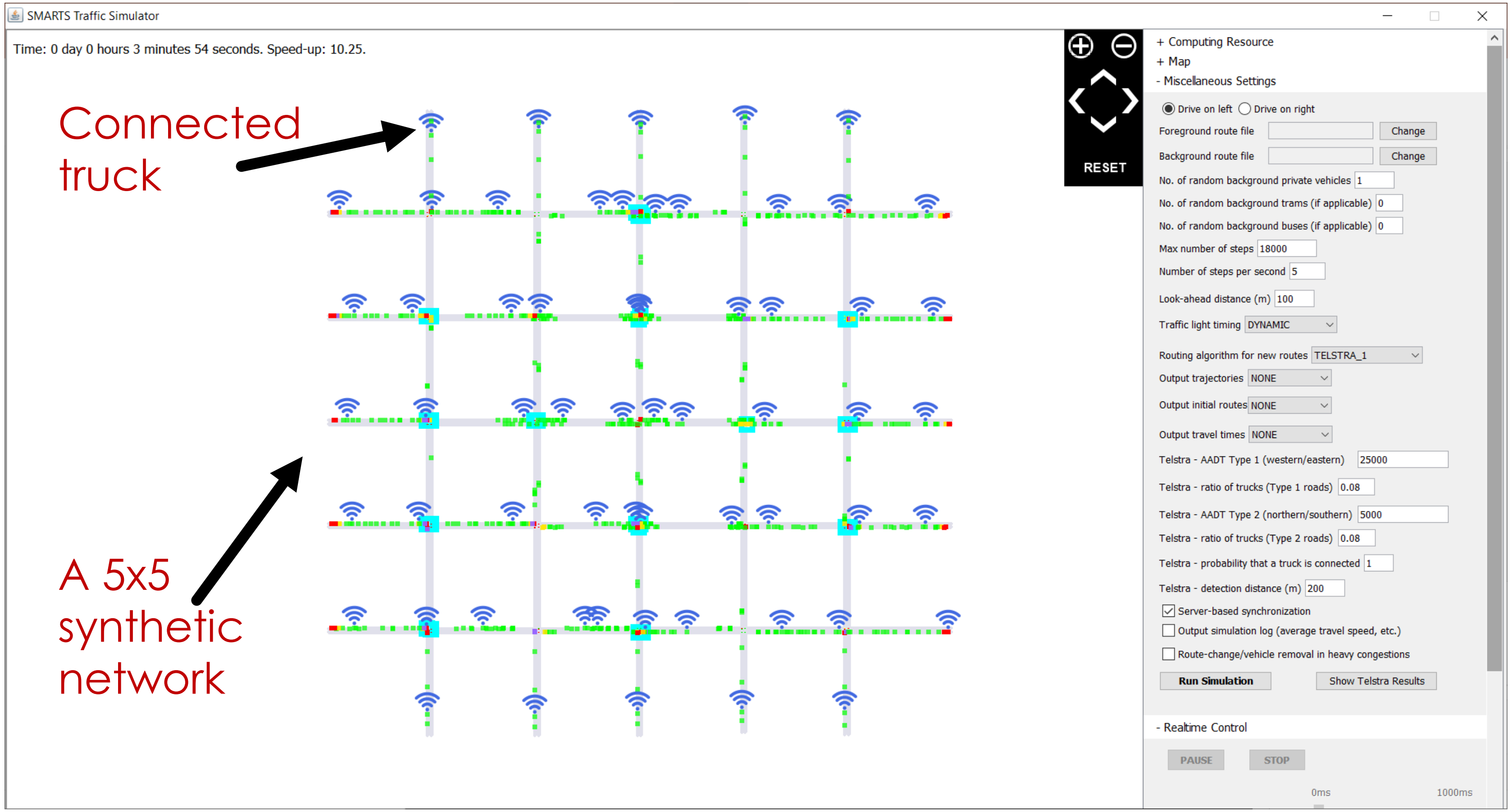
- Telstra conducted a trial of connected trucks in Wollongong, Australia
  - Trucks with MTData hardware send Signal Request Extended Message (SREM) to traffic lights in the SCATS system
  - The technology for implementing AIM is ready
- Need for comprehensive understanding of AIM's impacts
  - We ran a simulation study for this



Area of the connected truck trial

SMARTS Simulator

- SMARTS
  - Light weight
  - Microscopic
  - Open source
  - Developed in Java



Simulating connected trucks and normal vehicles on a 5x5 network

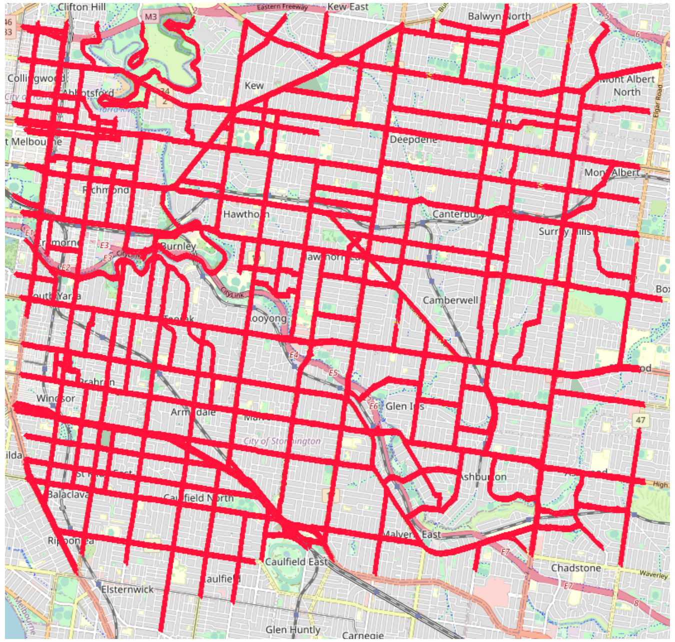
Parameters

- We considered 8 parameters
  - E.g., **motion factor** affects acceleration globally – lower motion factor leads to lower acceleration such as in bad weather
  - E.g., **maximum cycle length** is the longest possible time of a complete dynamic light cycle, which covers colour phases of green, yellow and red
  - E.g., **look-ahead distance** controls how far a driver can see front vehicles and traffic lights

- Parameter values are based on real data if possible

Methodology

- Part I: Simulation of a real road network
  - A 12kmx12km Melbourne area with 650km road and 338 signalled intersections
  - This part estimates AIM's impact in realistic scenarios
- Part II: Parameter scan
  - A total of 1944 parameter value combinations
  - A 5x5 synthetic network
  - This part finds settings where AIM is the most/least beneficial
- Part III: Individual parameter study
  - An extended set of synthetic networks
  - This part evaluates the impact of individual parameters
  - Default parameter settings are from the best cases in Part II



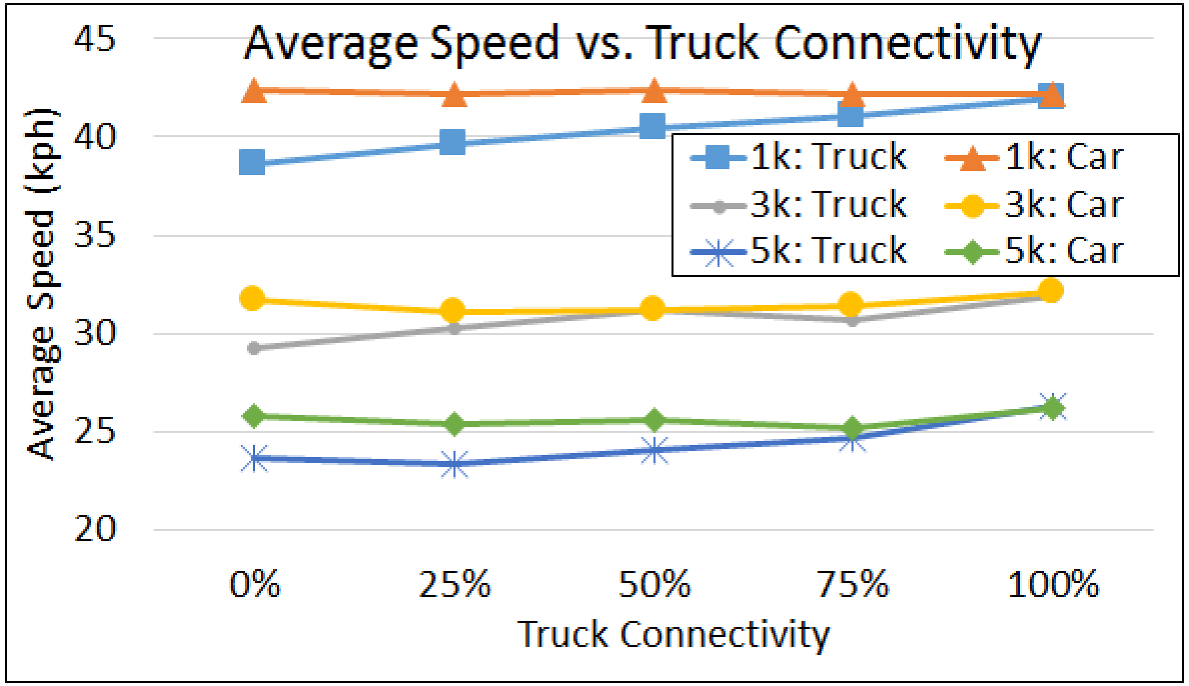
The real road network in Melbourne

Metrics

- Impacts of the parameters were evaluated using 3 metrics
  - **Trip counts**: total number of vehicles that arrived at their destination
  - **Average speed:** aggregated travel distance divided by aggregated travel time
  - **Average number of stops**: aggregated number of stops divided by total number of vehicles (a stop is a period when speed is under 5kph)
- We collected results for specific categories and also for the whole road network
  - The categories are based on vehicle type, road type or both
    - Based on vehicle type: truck and car (real and synthetic networks)
    - Based on road type: major and minor (synthetic networks)
    - Based on both: truck on major, truck on minor, car on major, car on minor (synthetic networks)

Results on Real Network

- AIM is beneficial in realistic scenarios under different traffic loads (1k-3k)
  - When more trucks are connected (higher **truck connectivity**), truck speed improves while car speed keeps steady

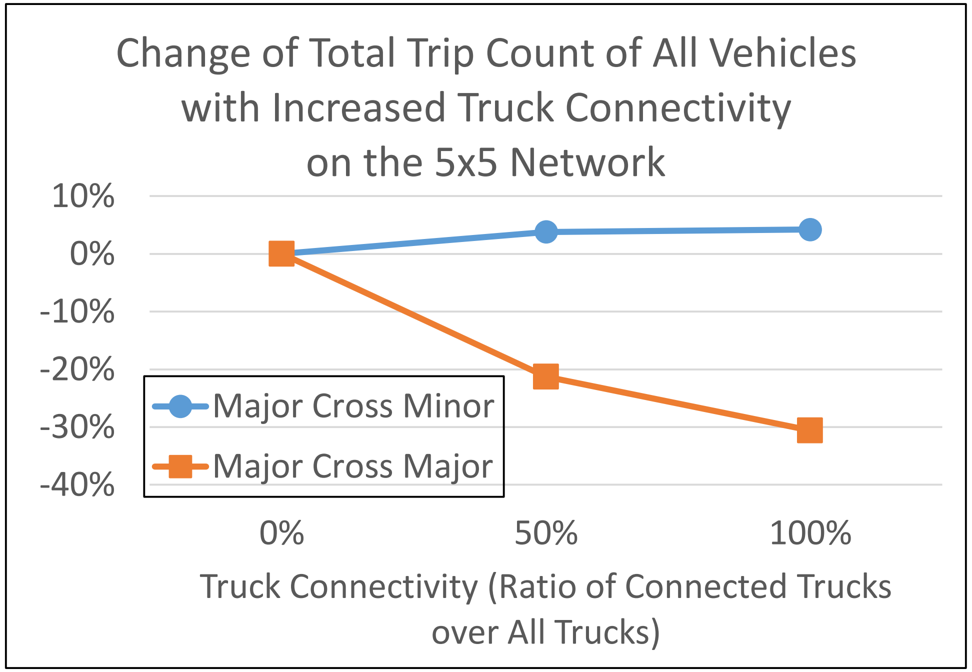


Results on Parameter Scan

- There are patterns in the best cases and patterns in the worst cases
- The highest truck improvement is achieved where trucks only travel on minor roads that intersect major roads
  - In such scenarios, AIM can improve truck performance by 16-31% while decreasing car performance by only 1-5%

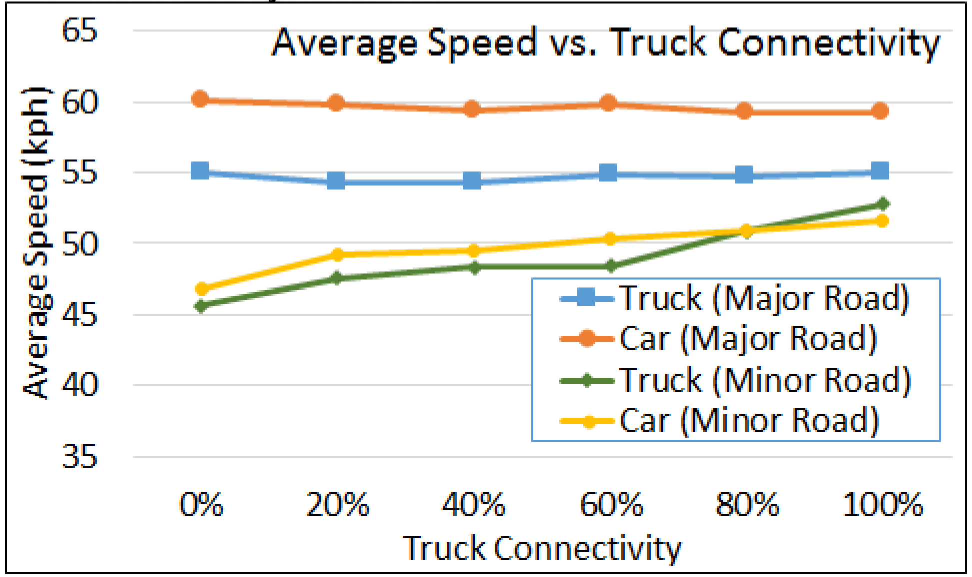
Results on Parameter Scan (Cont.)

- Regarding overall traffic performance, such as the total trip count of all vehicles, AIM is generally not suitable where **major** roads cross **major** roads but it can help where **major** roads cross **minor** roads
  - Major roads cross major roads: Extending green time for any road breaks the equality of traffic flow from different directions, causing significantly longer queues.
  - Major roads cross minor roads: Extending green time for major roads speeds up a major portion of traffic. Meanwhile, extending green time for minor roads does not slow down major roads much because minor roads can clear up vehicle queue quickly in general.

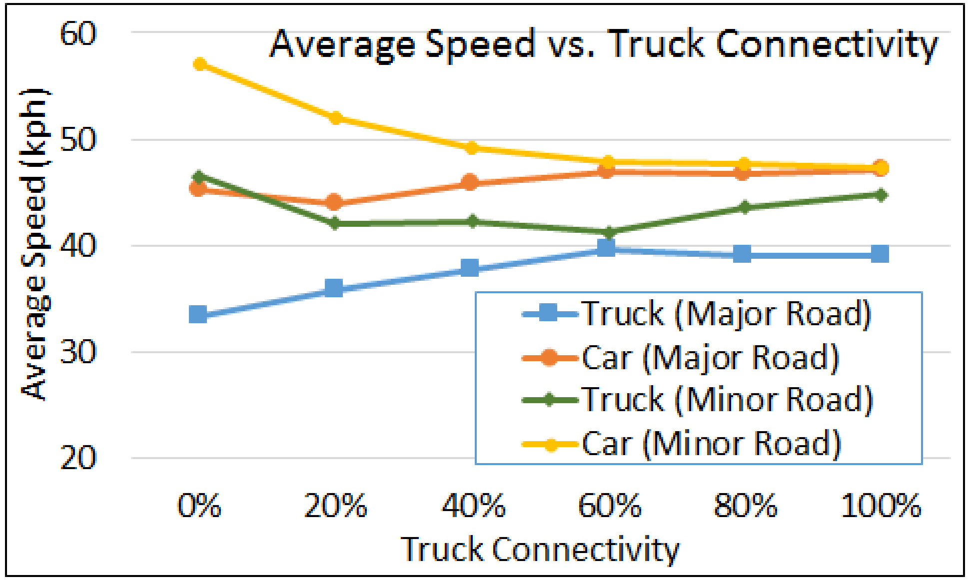


Thoughts on Results

- Due to combinational effects of multiple parameters, traffic engineers should analyse AIM's impact case by case
  - E.g., When more trucks are connected where major roads cross minor roads, we see different trends in two cases. In Case 1, AIM's benefit is more visible to minor roads. In Case 2, AIM's benefit is more visible to major roads.



Case 1: 1.5 motion factor, 120s maximum cycle length, 100m look-ahead distance



Case 2: 0.5 motion factor, 60s maximum cycle length, 300m look-ahead distance

Conclusion

- AIM can help reduce truck delay in certain scenarios
- AIM is not a universal solution for reducing truck delays
- We plan to further collaboration with Telstra on studying connected trucks
- More information about SMARTS simulator at https://projects.eng.unimelb.edu.au/smarts/