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Infrastructure to Enable Freight Platooning Operations in the GTHA

ABOUT ME:



Occupation:

- Project Engineer – WSP
 - Transit Planning and Engineering, Planning & Advisory Services



Education:

- Undergrad: McMaster University
- Masters: University of Toronto

Origin: Michigan, Belize



Interest & Expertise: Rail and Transit

- Alternative Finance Procurement
- Business Cases & Feasibility Studies
- Preliminary & Detailed Design
- Sustainable Technologies
- Music – Piano, Drums, Guitar





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AGENDA

01 Problem Background

- History
- Freight Platooning & Ontario

02 CACC Controller

- CACC Controller
- Research Framework

03 Infrastructure Remediation

- Merge Point Shifting
- Ramp Metering

04 Results

05 Findings and Next Steps

- CACC Controller
- Framework

01 PROBLEM BACKGROUND 🔍

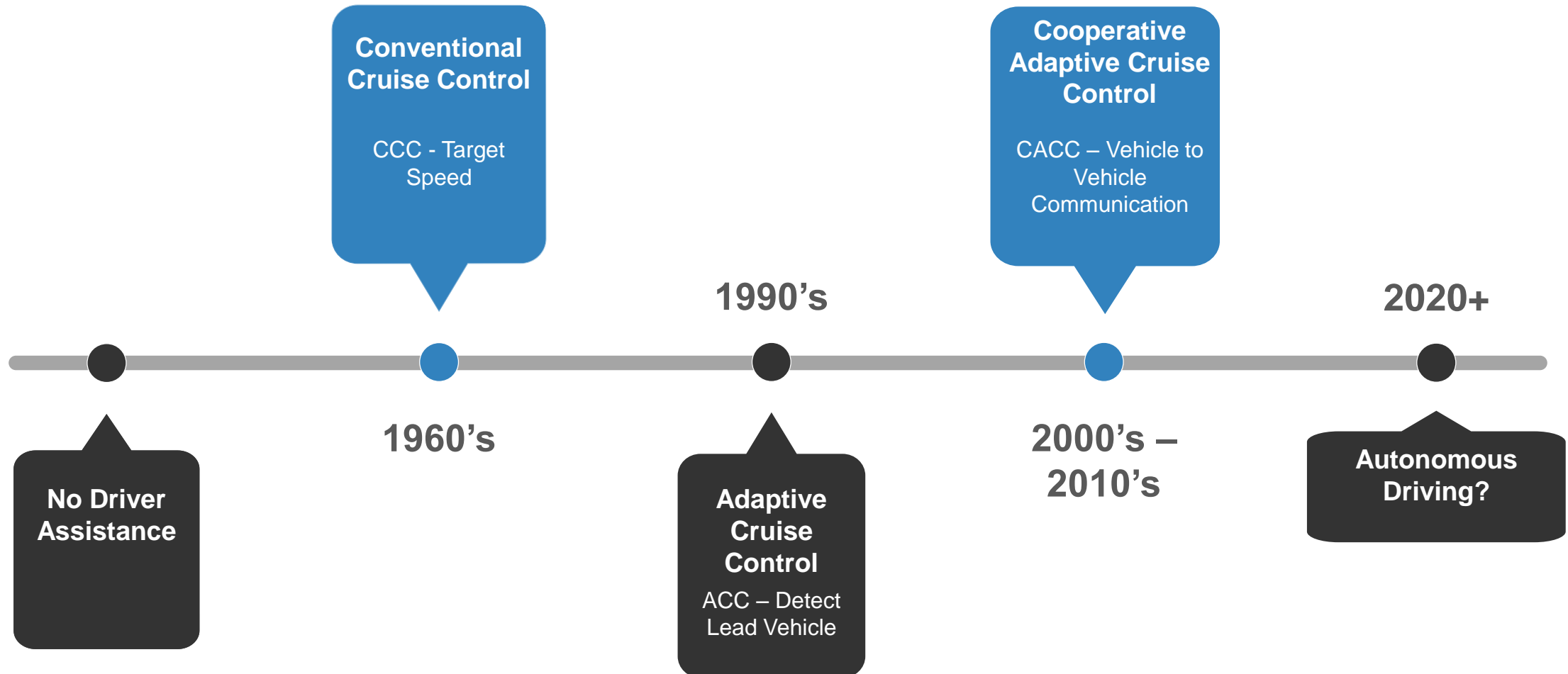
What is Freight Platooning?



- Linking of two or more trucks in convoy
- Use of connectivity technology and automated driving support systems with little to no action from drivers
- Maintain set, close distance for parts of a journey

What is CACC?

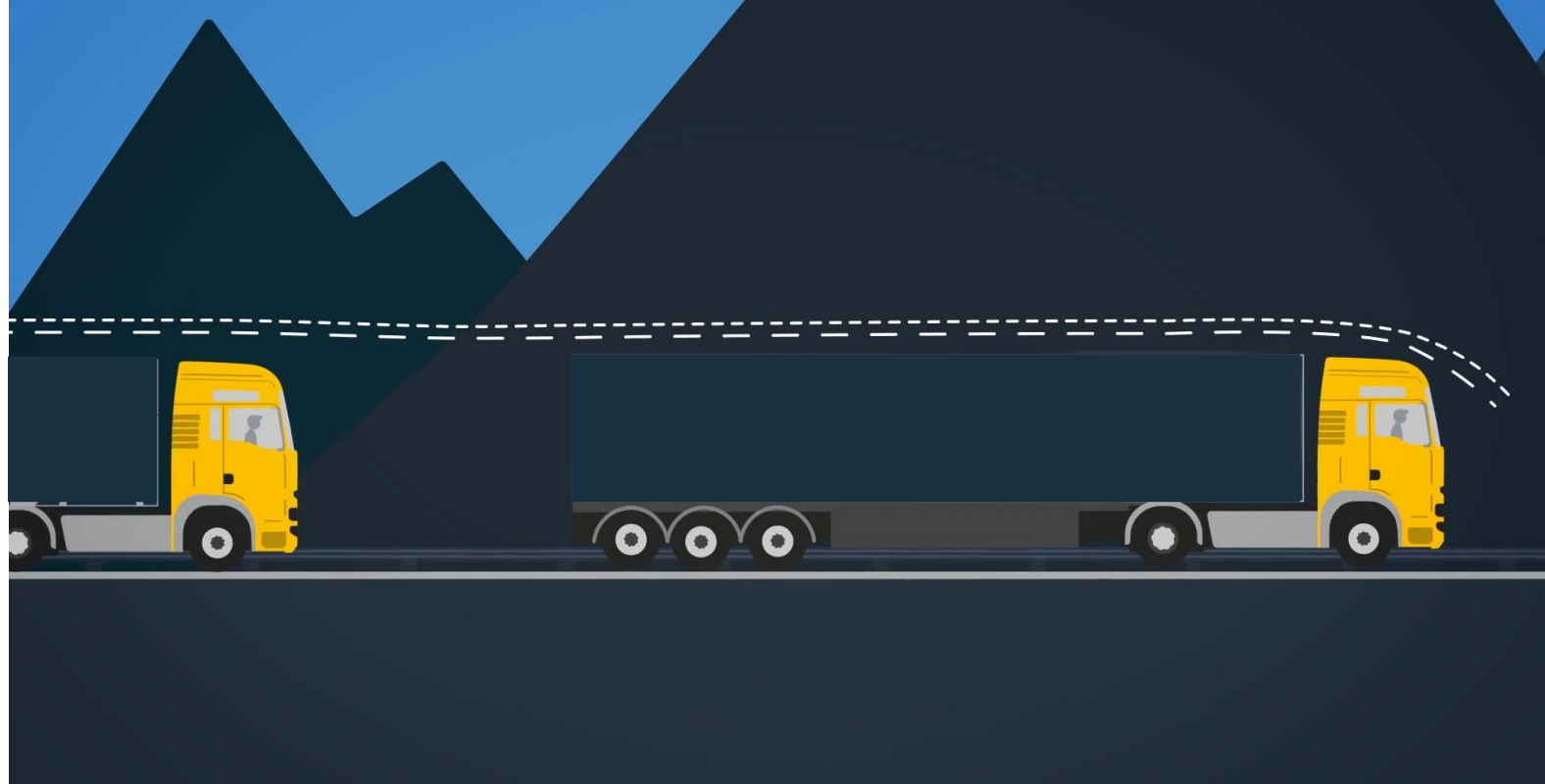
Cooperative Adaptive Cruise Control



01

Why Implement CACC:

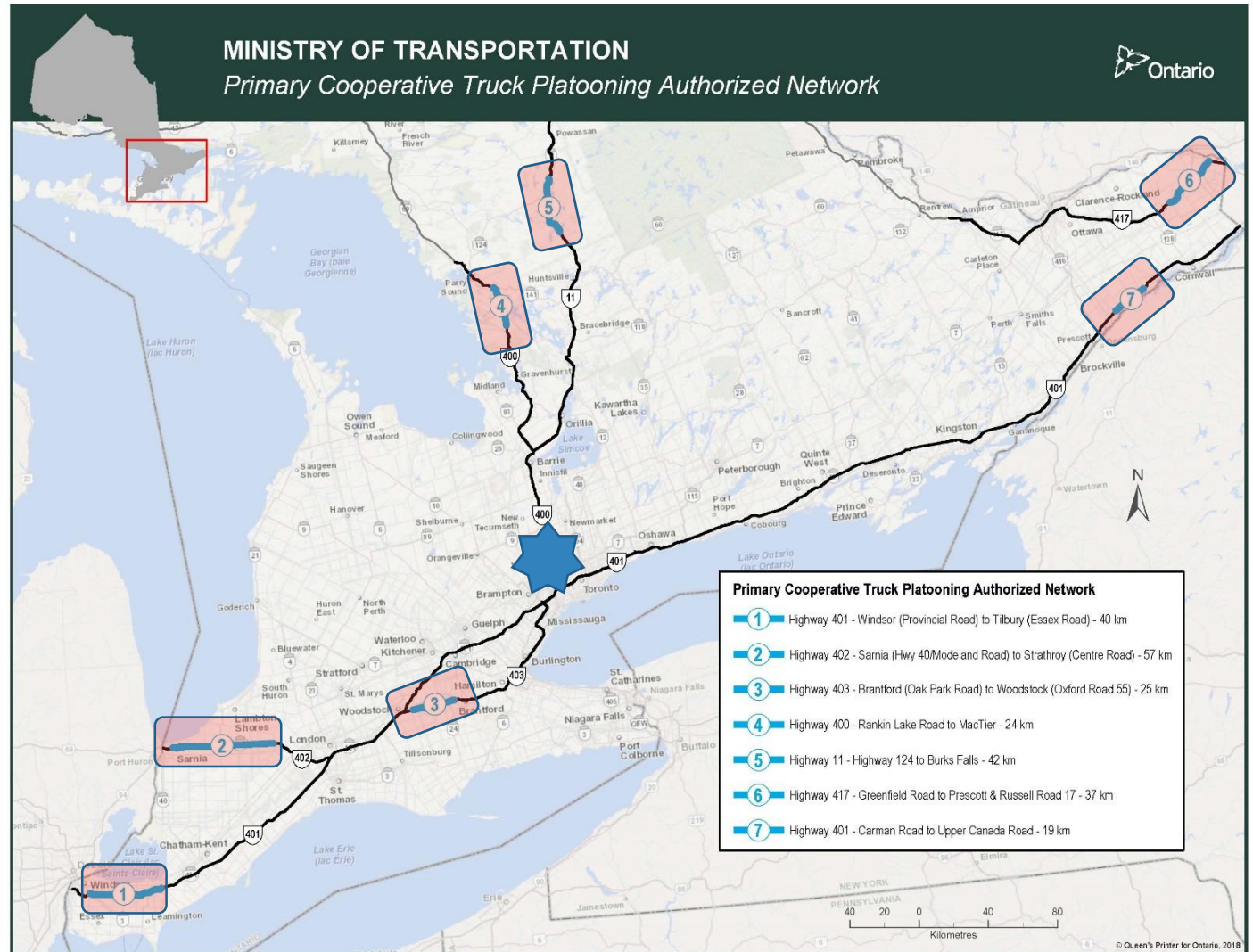
1. Improved roadway safety
2. Enhanced driver comfort
3. Cost savings (fuel and labour)
4. Increased lane capacity



Problem Background: Ontario Truck Platooning Pilot

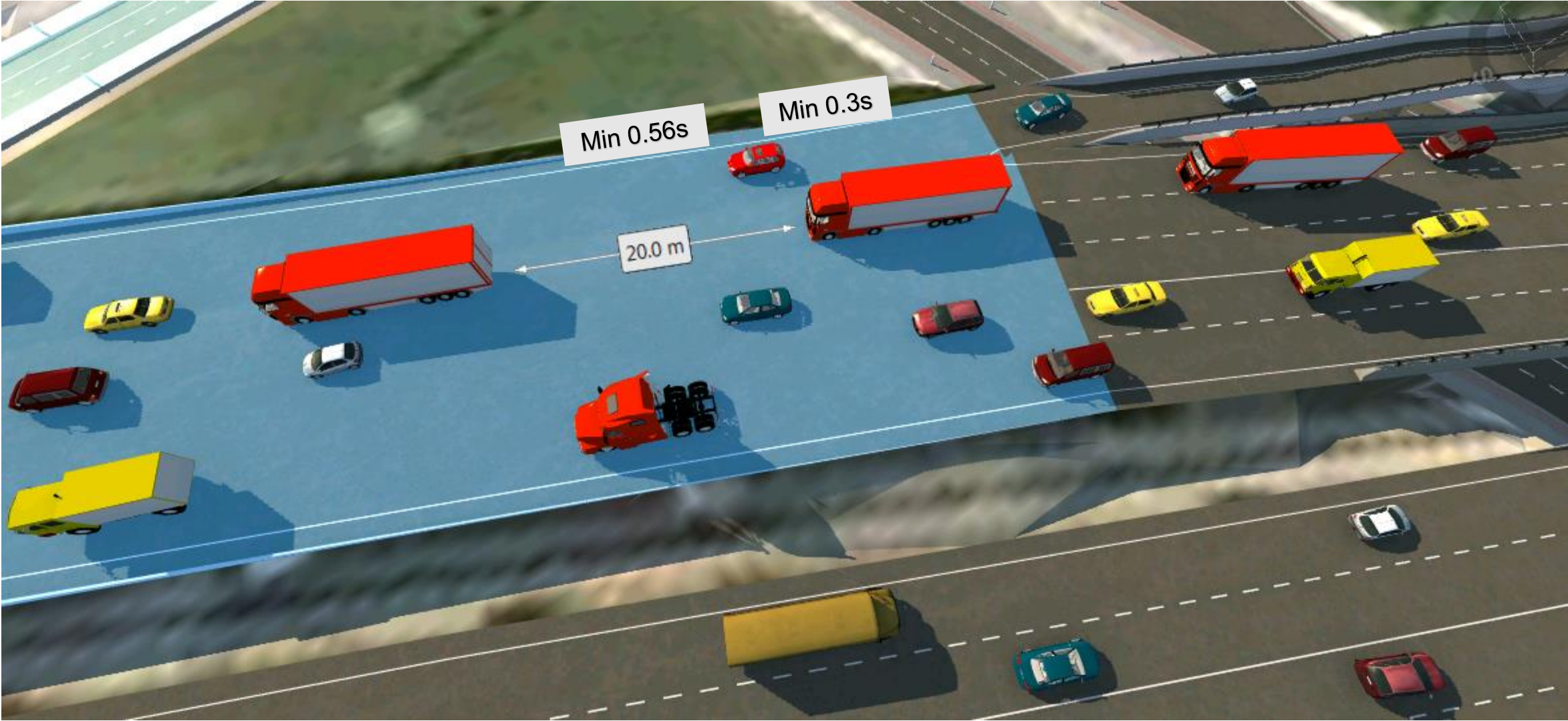
Challenges:

- ▶ Reactions to platoons
- ▶ **Roadway Infrastructure Upgrades**
- ▶ Performance in high traffic areas
- ▶ **Traffic conflicts at on-ramps in congested traffic**
- ▶ **Policy, stakeholder buy-in, insurance**



01

Infrastructure Remediation: Merging



01

Infrastructure Remediation: Merging



02

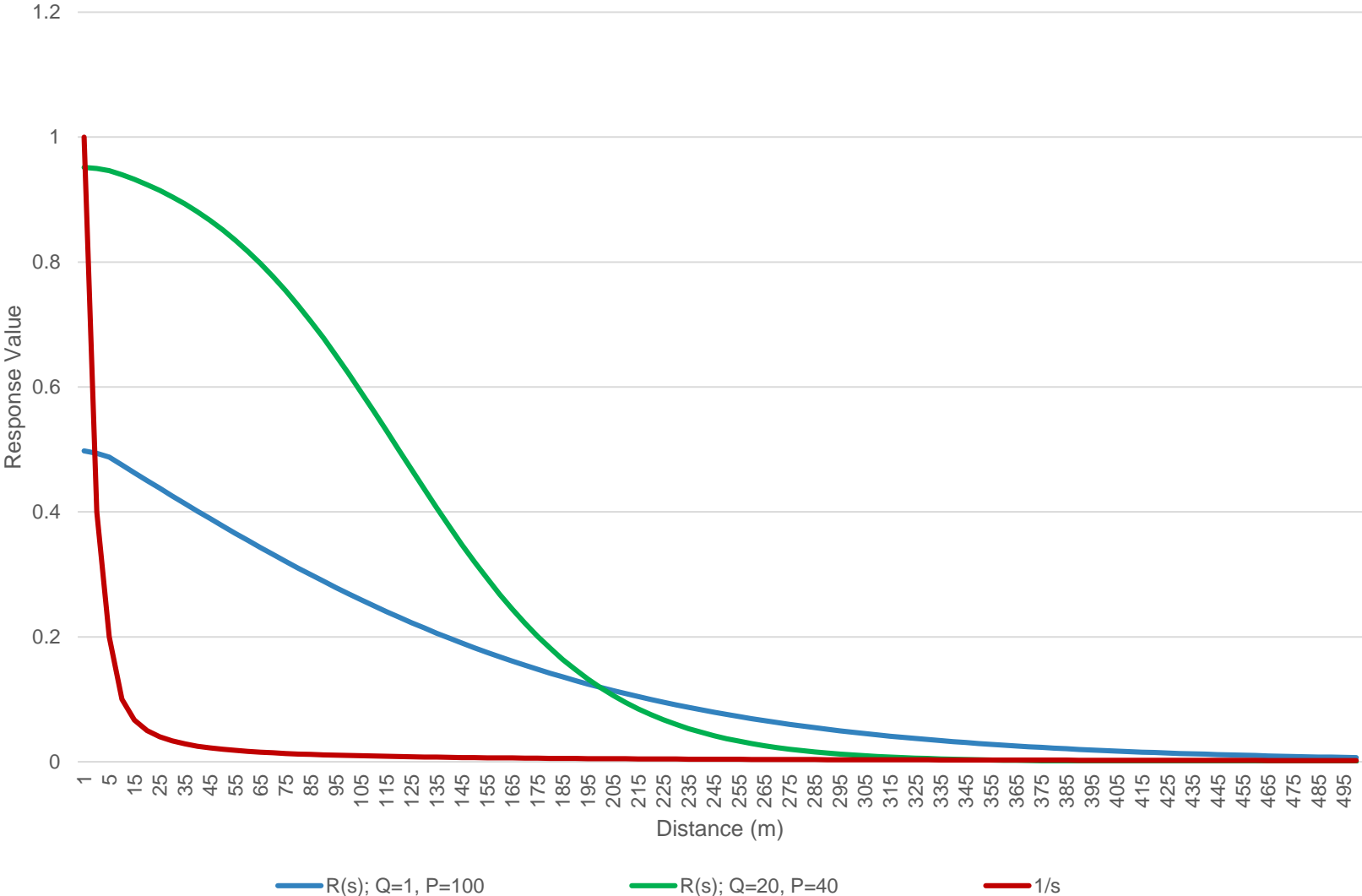
CACC CONTROLLER



CACC MODEL

Response Function Comparison

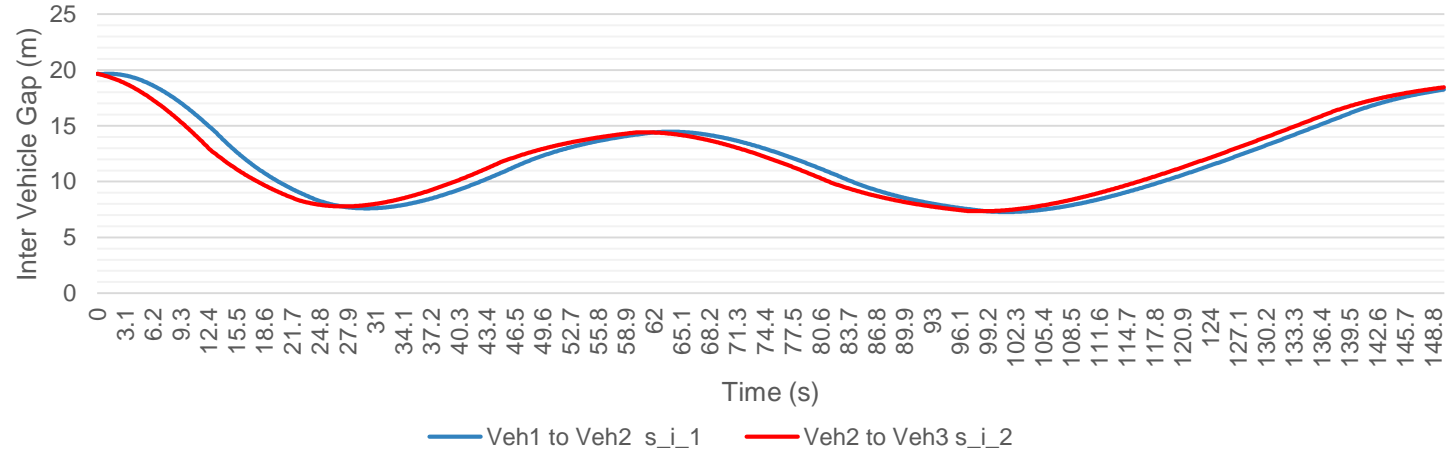
- ▶ Extension of ACC System Tested via PATH
 - ▶ Response Function
- ▶ **Collision Avoidance**
- ▶ Tuned for Freight Vehicles
- ▶ Implemented within **VISSIM**, coded in **C++**



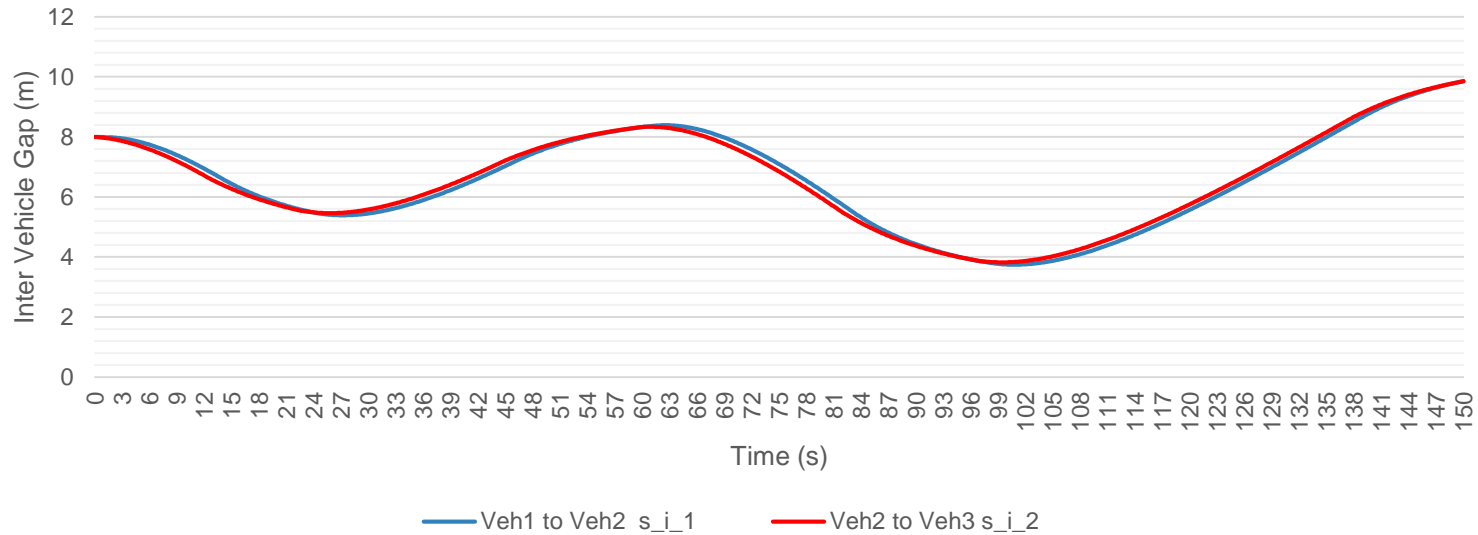
CACC Controller

02

Vehicle Spacing – 0.6s CTG



Vehicle Spacing – 0.9s CTG



03 INFRASTRUCTURE REMEDIATION MEASURES

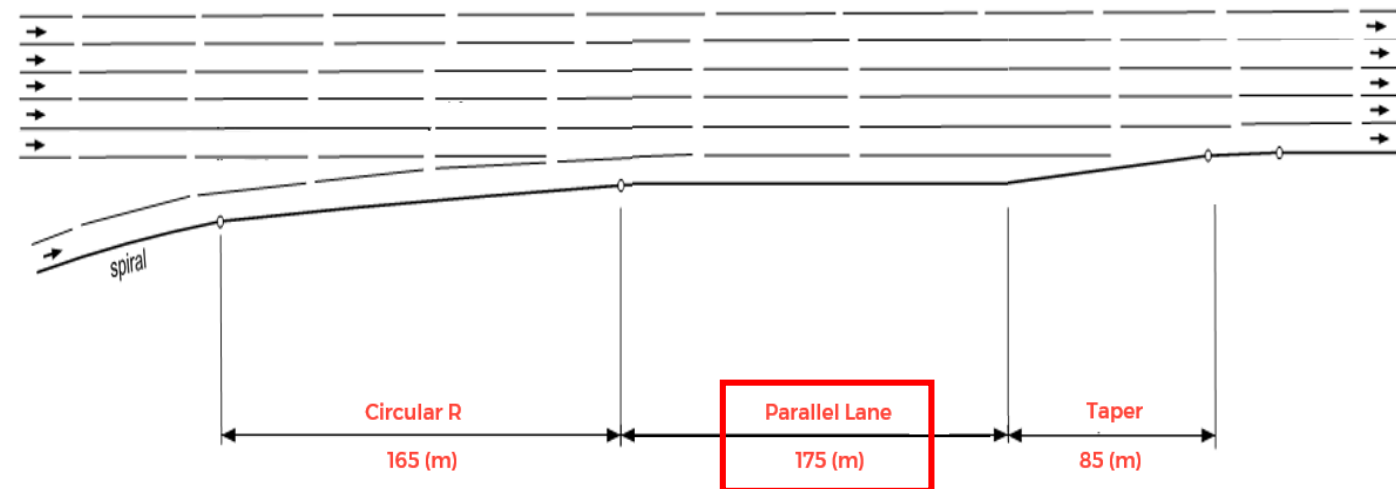
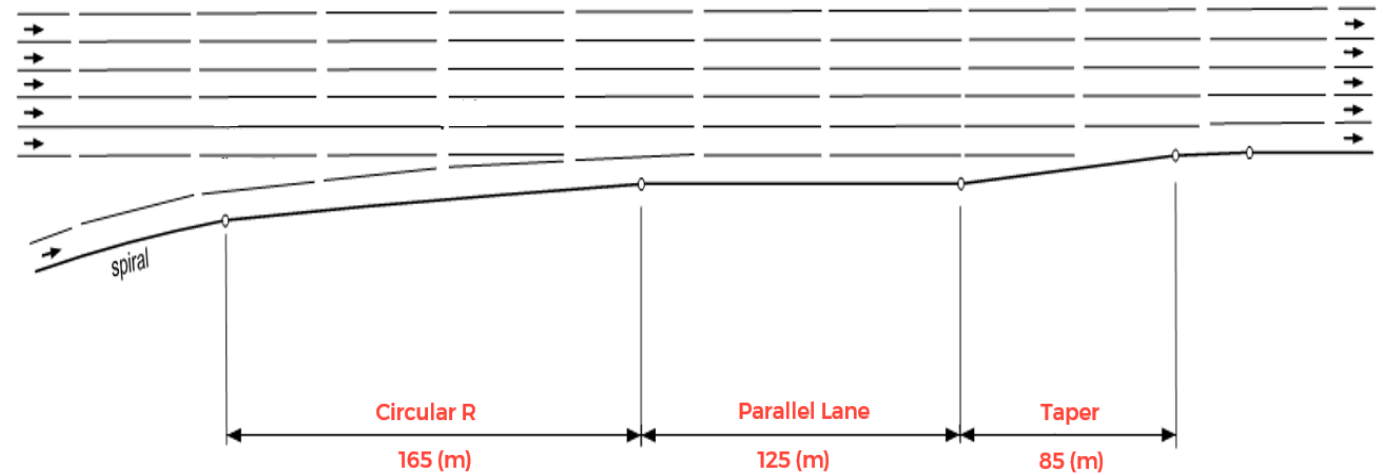
Study Area – Highway 401



03 Remediation Measures: Lane Extension

Merge Point Shifting

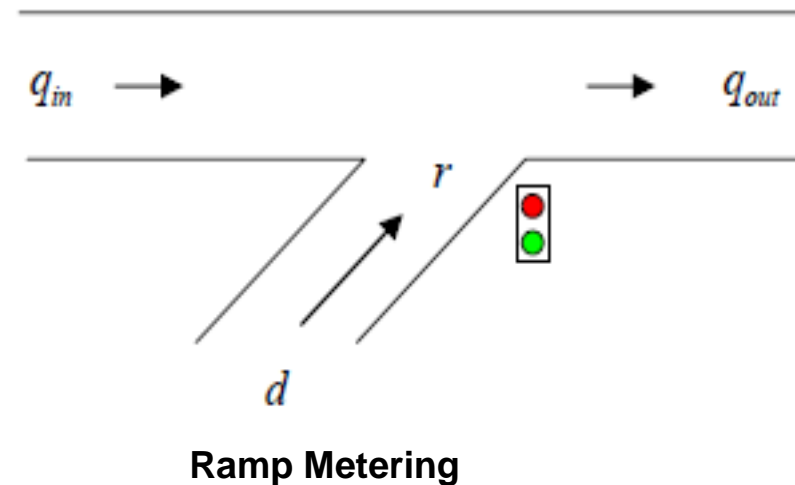
- ▶ Late merging
- ▶ Keep traffic in merging lane
- ▶ Utilize capacity of both lanes



Remediation Measures: Ramp Metering

Ramp Metering

- ▶ Two-state signal
- ▶ Traffic Responsive Control Strategy
 - ▶ Vehicle-to-Infrastructure
- ▶ Real time information from on-board systems to signal infrastructure
- ▶ Calibrated similar to optimize highway and ramp flow



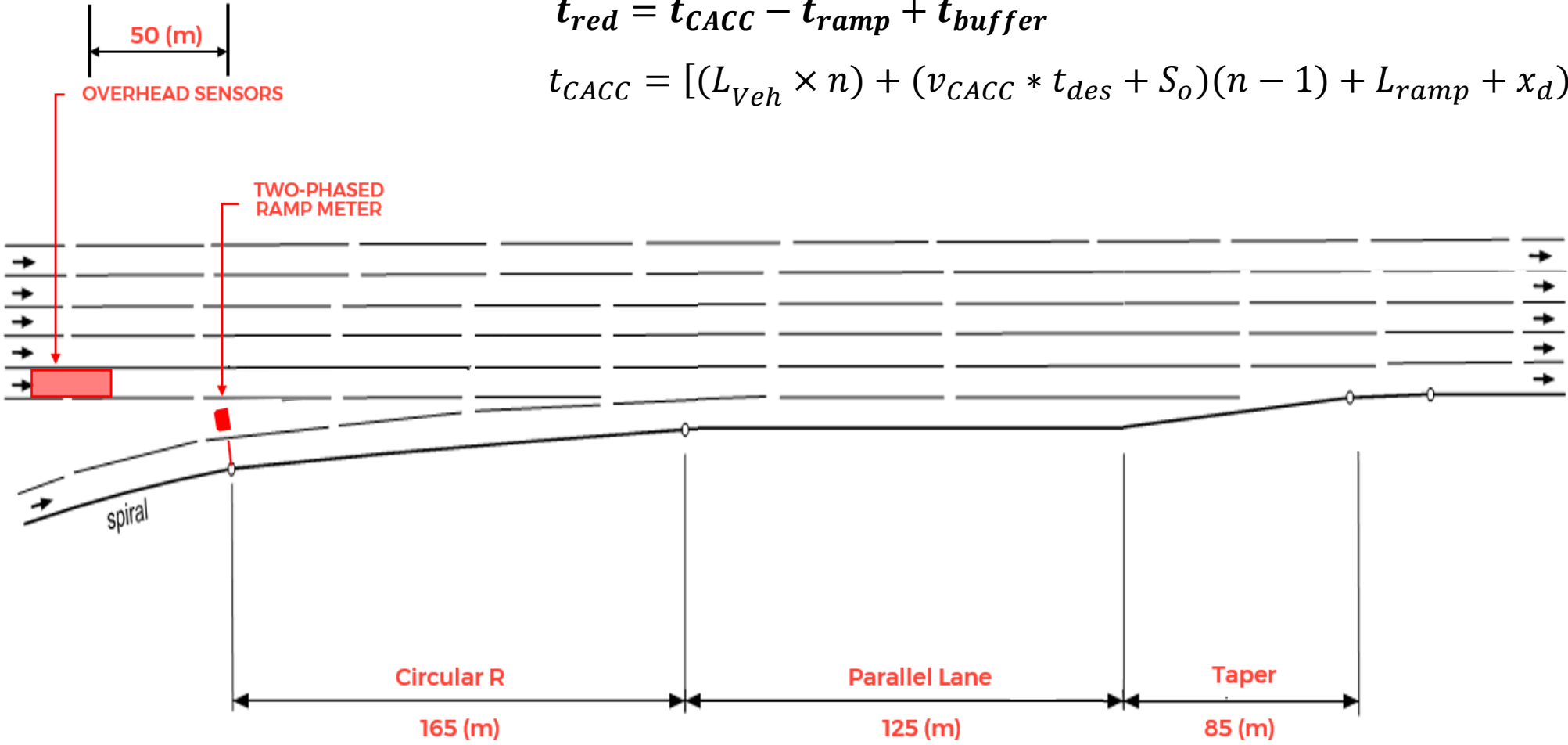
Remediation Measures: Ramp Metering

Ramp Metering

- ▶ Two-state signal
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Remediation Measures: Ramp Metering



$$t_{red} = t_{CACC} - t_{ramp} + t_{buffer}$$

$$t_{CACC} = [(L_{Veh} \times n) + (v_{CACC} * t_{des} + S_o)(n - 1) + L_{ramp} + x_d] / v_{CACC}$$



Model Application: Scenarios

NUMBER OF PLATOONED FREIGHT	TRAFFIC CONDITIONS (C – CONGESTED, H – HIGH, M – MEDIUM)	FOLLOWING DISTANCE (SECONDS)	DESIRED SPEED (KM/HR)	MERGE LANE LENGTH (M)	MARKET PENETRATION RATE	LANE METERING (Y/N)
2	C, H, M	0.6	100	Standard, Extended	25%, 50%	N
2	C, H, M	0.6	100	Standard	25%, 50%	Y
3	C, H, M	0.6	100	Standard, Extended	25%, 50%	N
3	C, H, M	0.6	100	Standard	25%, 50%	Y

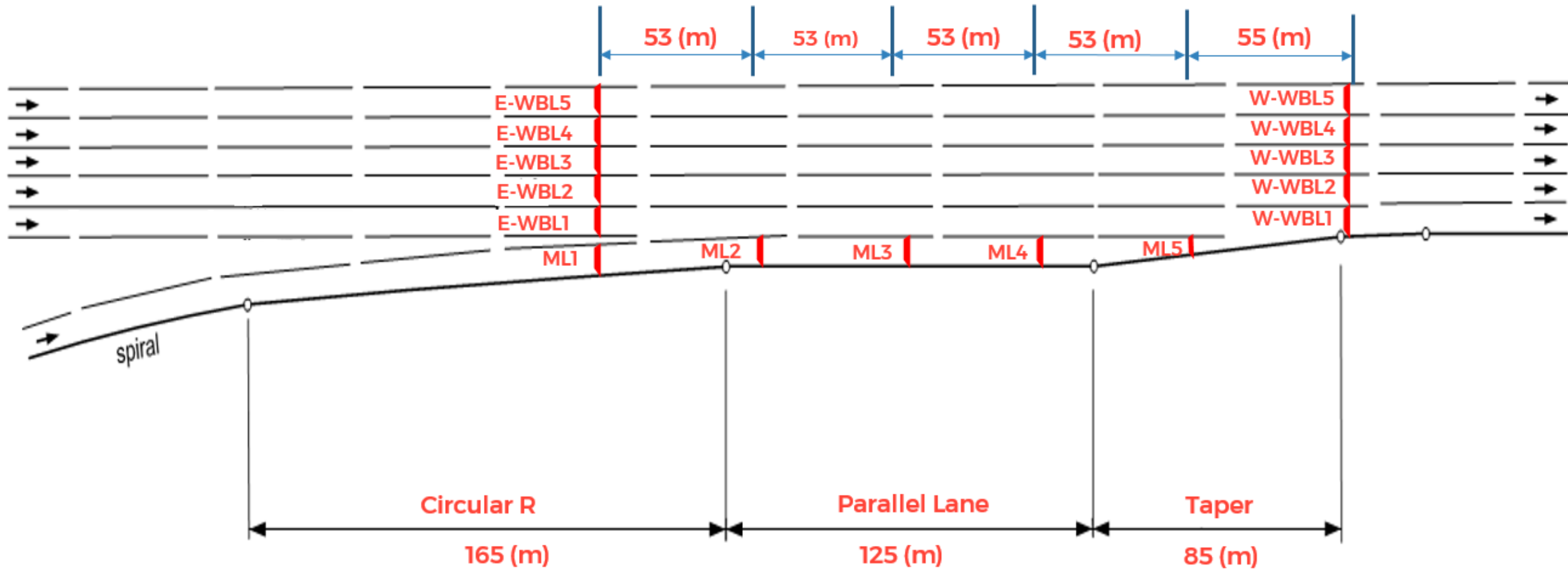


04

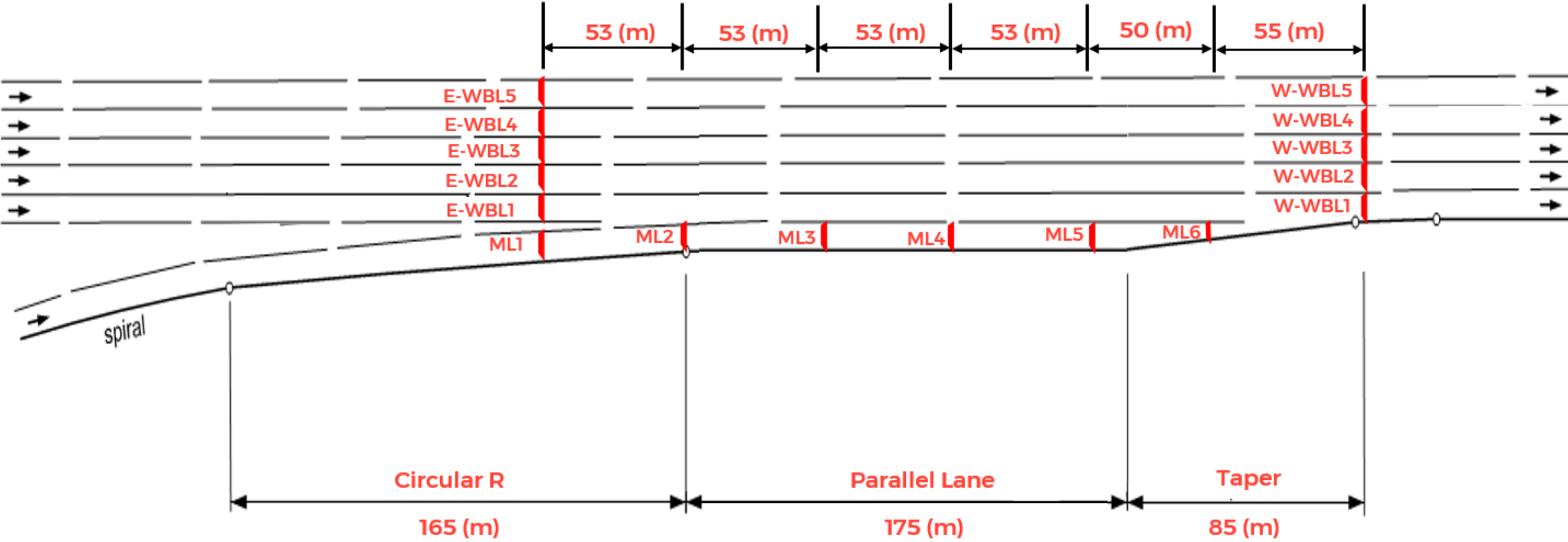
RESULTS

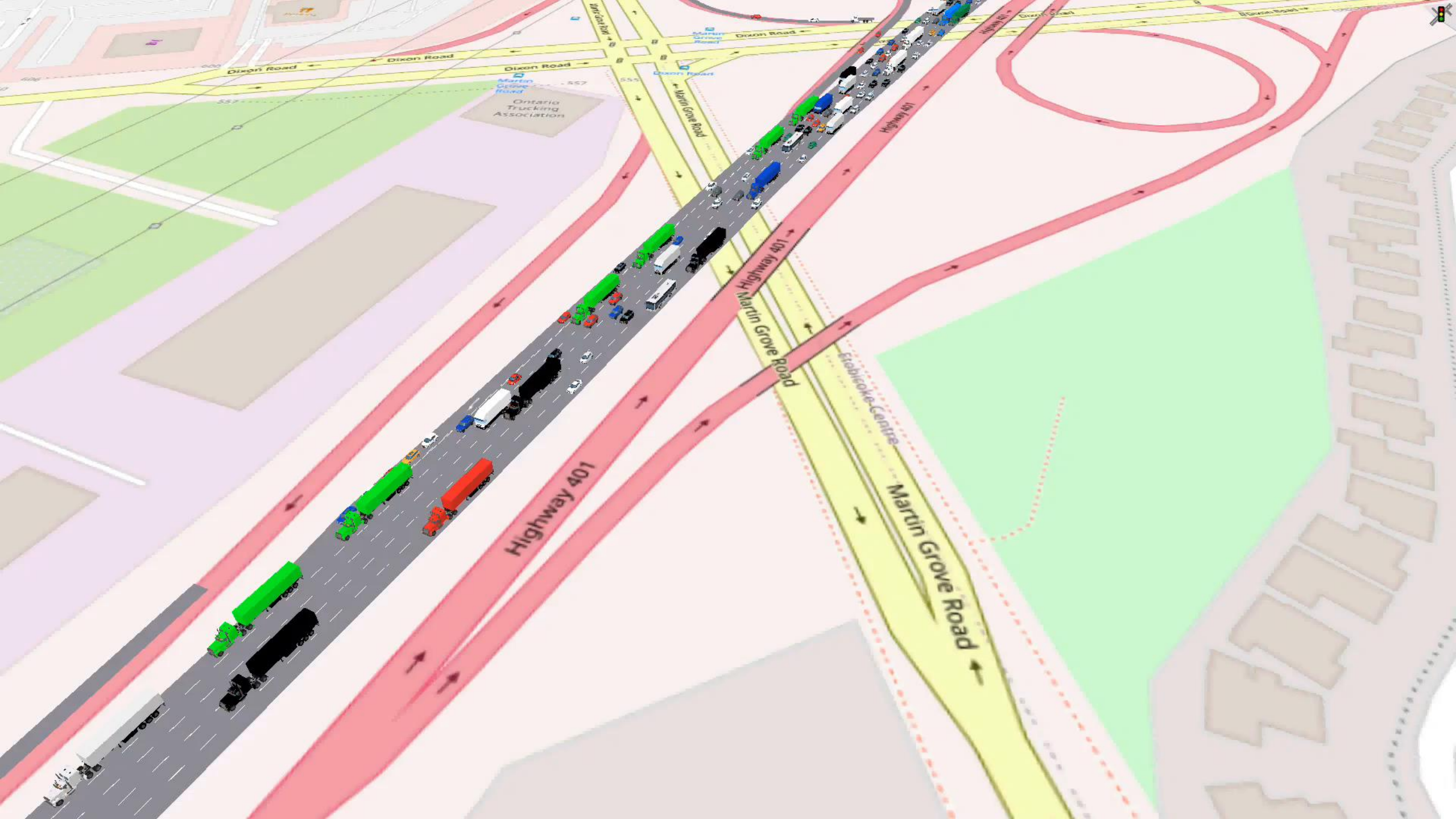


Data Collection Points: Standard Length



Data Collection Points: Extended Length





Dixon Road

Dixon Road

Dixon Road

Martin Grove Road
Ontario Trucking Association

Martin Grove Road

Highway 401

Highway 401

Etobicoke Centre

Martin Grove Road

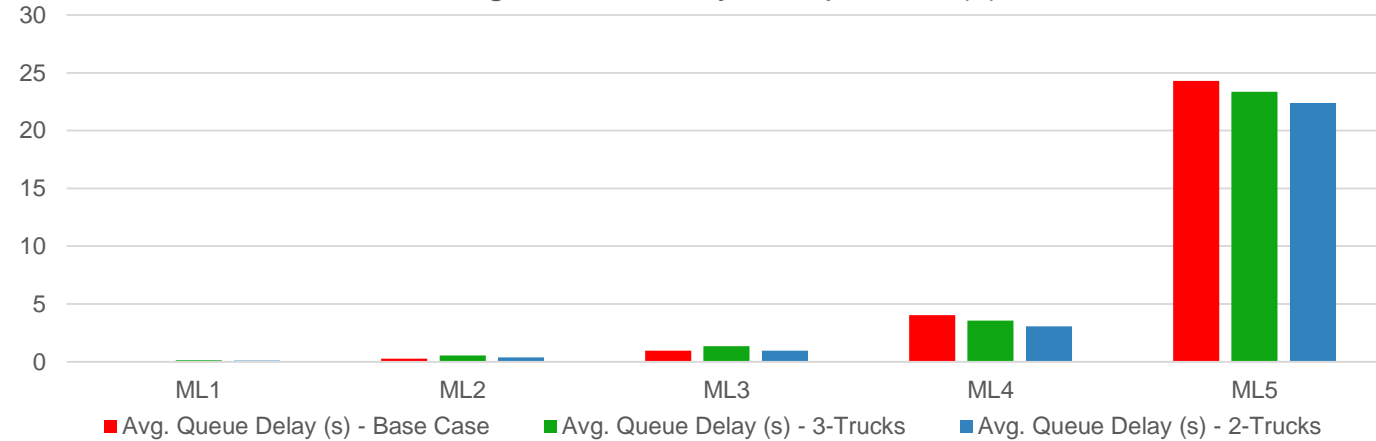
Results: 25% MPR

04

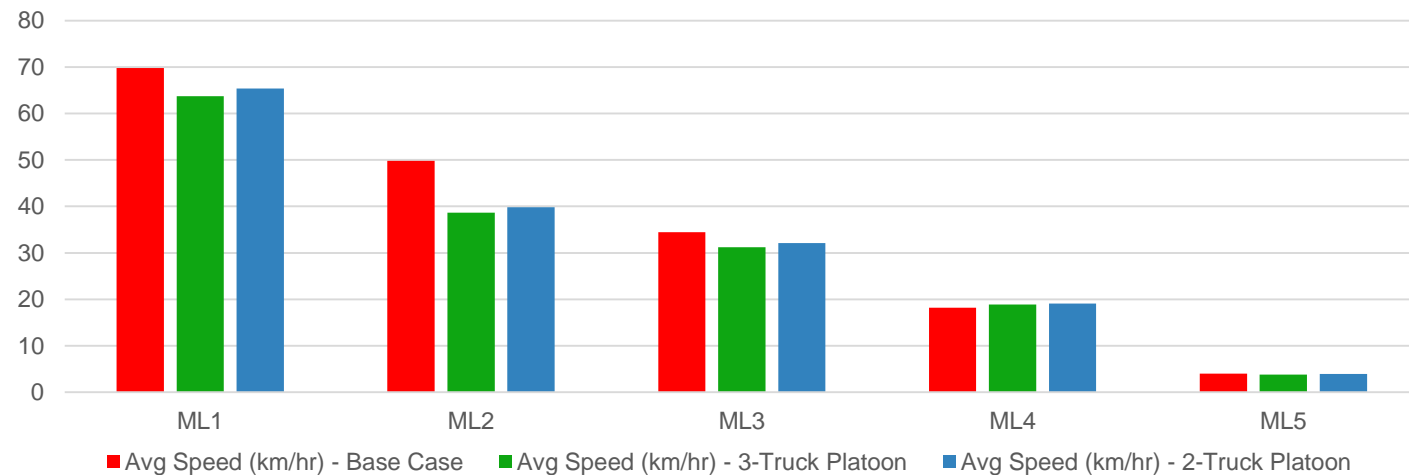
Congested Traffic – Merge Lanes

- ▶ Overall network performance relatively unchanged
- ▶ Slight decrease in average merge speed for 2 and 3-truck platoons
- ▶ Vehicle-to-Infrastructure
- ▶ Queue delays at end of ramp reduced
- ▶ Lateral behaviour remains relatively unchanged

Avg Queue Delay Comparison (s)



Avg Speed Comparison (km/hr)

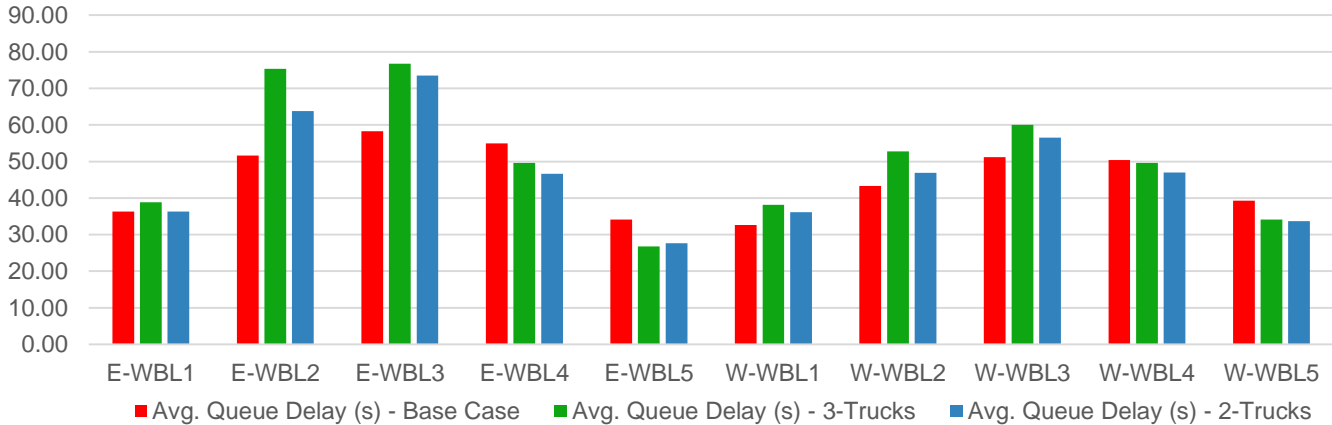


Results: 25% MPR

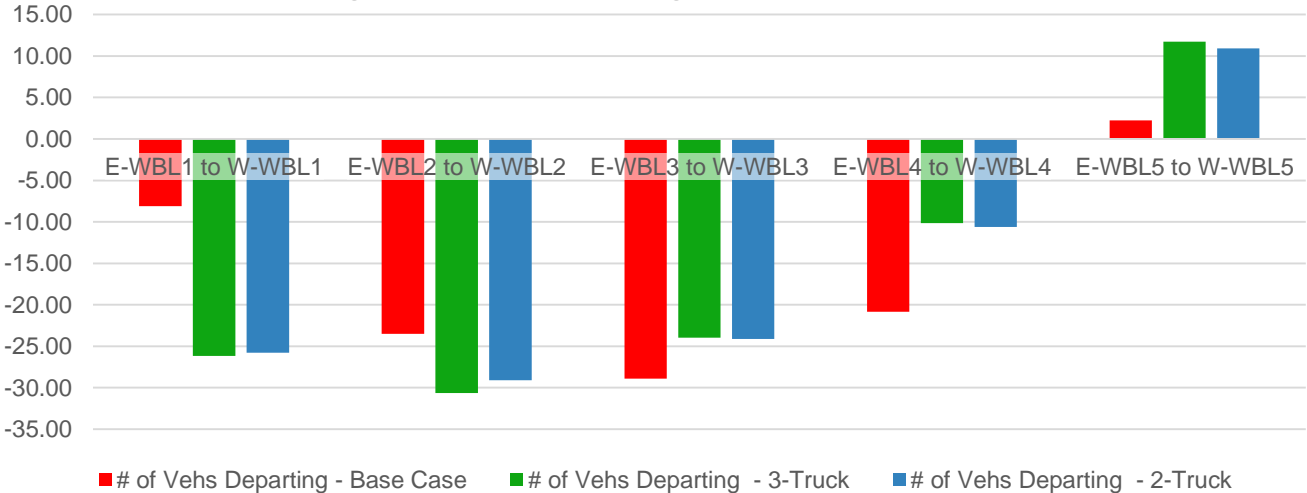
Congested Traffic – Highway Lanes

- ▶ Negligible impact to overall network performance
- ▶ Slightly higher queue observed in lanes upstream of merge ramp.
- ▶ Significant change in lateral behaviour
- ▶ No impact to highway speeds

Avg Queue Delay Comparison (s)



Avg Vehicles Departing Comparison (count)



Results: Congested Traffic Intensity

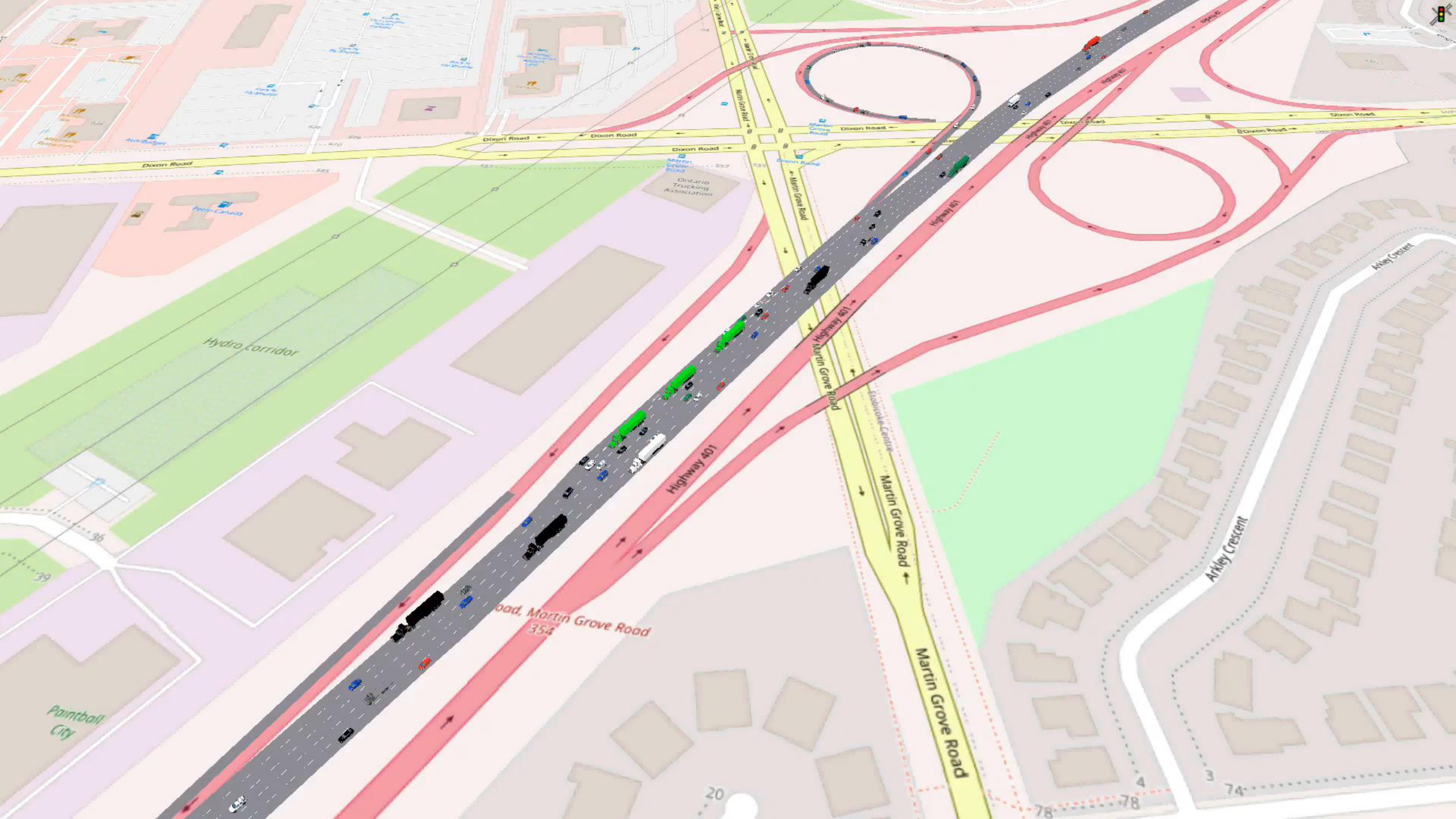
▶ **Extension of Acceleration Lane:**

- ▶ Higher merge speeds
 - ▶ Particularly for 2-truck platoons
- ▶ Reduction in queue delays
- ▶ Vehicles enter highway earlier
- ▶ Slight increase in highway lane speeds
- ▶ Reduce upstream and downstream highway lane queues

▶ **Ramp Metering not a viable option**

- ▶ High frequency of arrival times leaves little time for vehicles to enter highway
 - ▶ Reduce on-ramp capacity





hydro corridor

oad, Martin Grove Road
354

Paintball
City

Highway 401

Martin Grove Road

Arkley Crescent

Arkley Crescent

20

78

78

74

4

39

39

Dixon Road

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Results: High Traffic Intensity

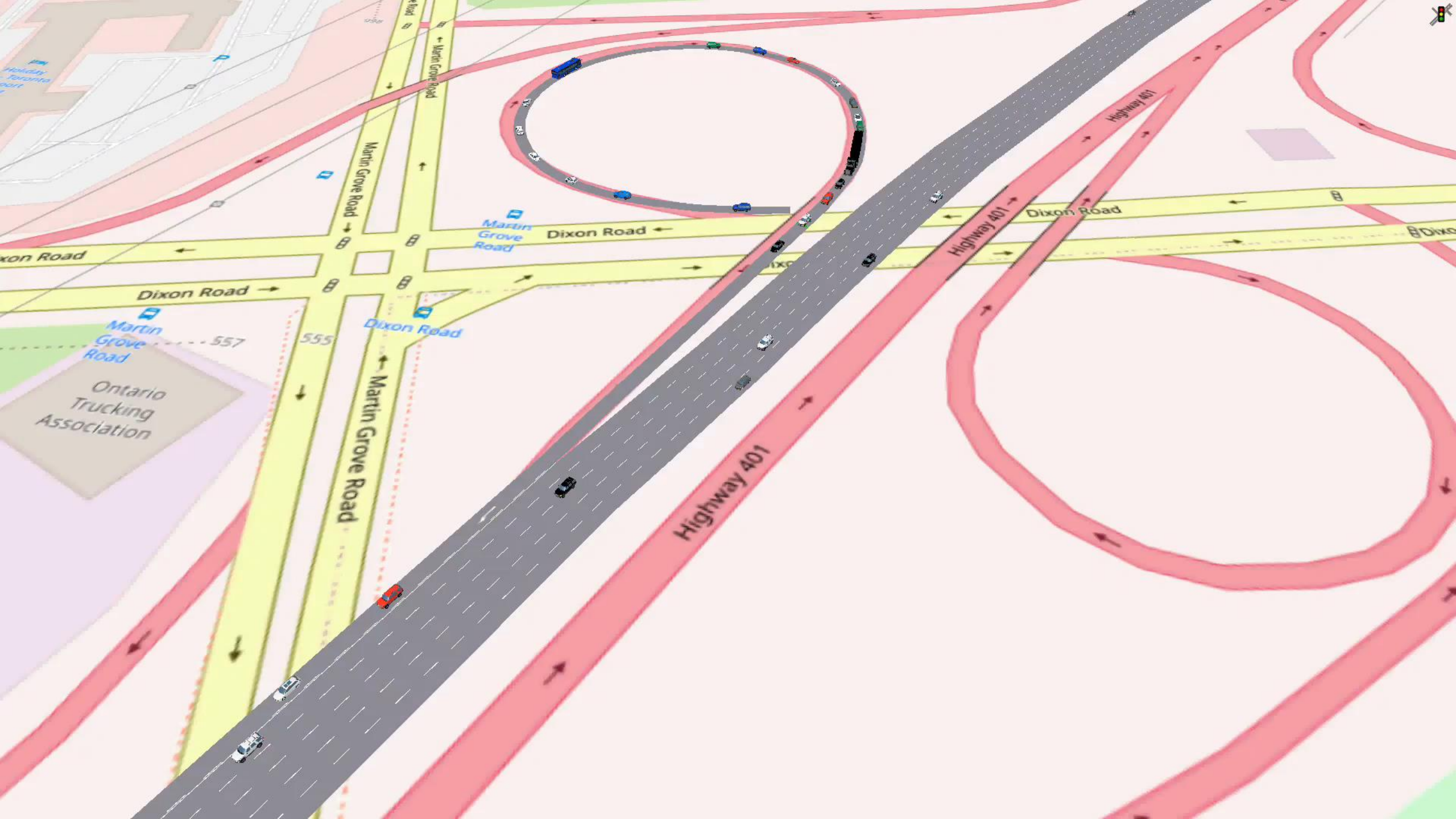
Extension of Acceleration Lane:

- ▶ Higher merge speeds halfway through ramp
- ▶ Reduction of queue delays for both platoon sizes
- ▶ Minimal impact of lateral behaviour along ramp, greater distribution
- ▶ Improved average speed and reduced queue delay along highway lanes

Ramp Metering:

- ▶ More effective for 2-truck platoons
- ▶ Improved average vehicle speed on ramps, highway lanes
- ▶ Improved highway flow for both 2- and 3-truck platoons
- ▶ Sometimes jeopardized ramp capacity





Dixon Road

Dixon Road

Dixon Road

Dixon Road

Dixon Road

Highway 401

Highway 401

Highway 401

Martin Grove Road

Ontario Trucking Association

557

555

Holiday Toronto port

Results: Medium Traffic Intensity

Extension of Acceleration Lane:

- ▶ Not completed for medium traffic intensities

Ramp Metering:

- ▶ Merge speeds improved by 13 to 24% for 2- and 3-truck platoons
- ▶ Improved average vehicle speed on ramps, highway lanes
- ▶ Minimal impact to lateral behaviour on highways



05 FINDINGS AND NEXT STEPS





Findings

Next Steps:



1. Determine maximum market penetration rate where platoons impact network performance



2. Determine threshold for traffic intensity at on-ramps and along highways

a. Level of effectiveness of Ramp Metering utilizing vehicle-to-infrastructure communication



3. Test additional intervals of extended acceleration lanes (75m, 100m)

Next Steps

Policies

1. Public Awareness – Signage, platoon stickers/logos
2. Market Penetration Rate – Track number of vehicles allowed to operate as platoons
3. Time of Day of Operation – Regulate use of platooning technology as a traffic responsive strategy

Pilot Programs

1. Freight Platoons not recommended for highways in urban areas during high-congested traffic for MPR ~ 50%
2. Ramp Metering incorporating Vehicle-to-Infrastructure as a viable option for intermediate traffic congestion levels





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Thank You!