Transportation Engineering Department,
Schulich School of Engineering

Variable Speed Limits: An Overview of Safety and Operational Impacts

ITS Technology Workshop

Karan Arora
Email ID: karanarora.iitr@gmail.com

Nadia Moshahedi
Email ID: nadia.moshahedi@gmail.com

Supervised by:
Dr. Lina Kattan, Associate Professor,
Urban Alliance Professor in Transportation Systems Optimization
Civil Engineering, University of Calgary
Email ID: lkattan@ucalgary.ca

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Outline

- What is Variable Speed Limit(VSL)?
- How VSL Works?
- VSL to improve Safety
- VSL to improve Travel Time
- METANET Model for Pro Active Trigger

Introduction

- **Constructing new highways and adding lanes are not always the best option**:

Category of Area	4 Lanes Highway	6 Lanes Highway
Rural & Suburban Area	$4-$6 million per mile	$8-$10 million per mile
Urban Area	~$7 million per mile	~$11 million per mile

Source: Washington State Department of Transportation(http://www.vtpi.org/WSDOT_HighwayCosts_2004.pdf)

- Through proper management of existing transportation system, traffic condition can be improved
  - **Ramp Metering**
  - **Variable speed limit design**, etc.
- **Every expressways and urban traffic have unique characteristics of traffic movement**
  - Traffic management for one expressway can never be applied to other expressways

What is Variable Speed Limit?

Variable Speed Limit is an ITS solution that enables dynamic changing of speed limit in response to prevailing traffic, weather and incident situation

Traffic
+
Incident → Speed limit
+
Weather condition

Image Source:
https://www.deliveryquotecompare.com/news/highways-agency-open-use-hard-shoulders/

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Variable Speed Limit

- Benefits:

  - Resolving traffic breakdown

  - Safety improvements

  - Environmental benefits

- Two types:

  - Reactive: Based on current traffic measurements

  - Proactive: Predict future state of traffic

How VSL works

Congestion happens when:

Inflow > Outflow

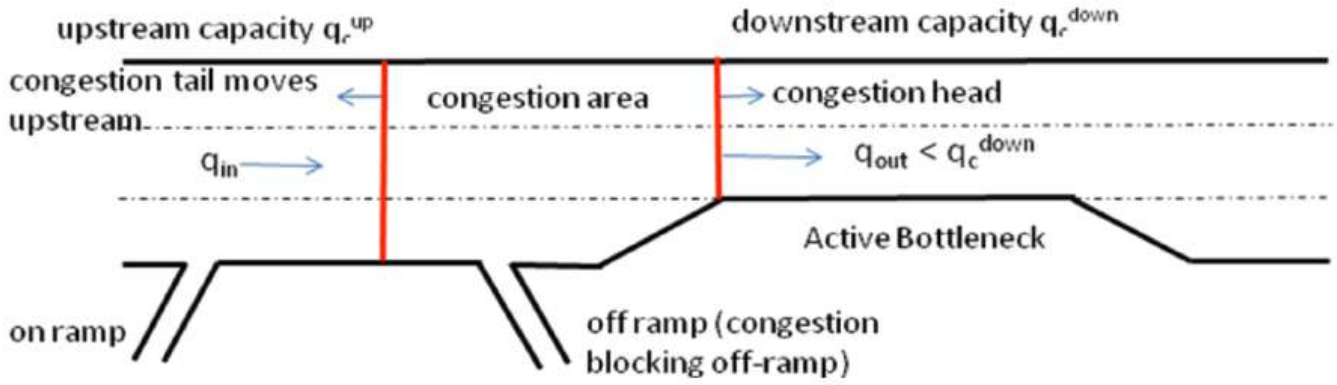


Fig 7. Active Bottleneck which causes congestion if Inflow > Outflow

Variable Speed Limit to improve Safety

Real-time Crash Prediction model

- Crash Precursors
  - Standard deviation of speed
  - Average density
  - Average speed difference between adjacent lanes
  - Average congestion (ration of real travel time to free-flow travel time)

Variable Speed Limit to improve Safety

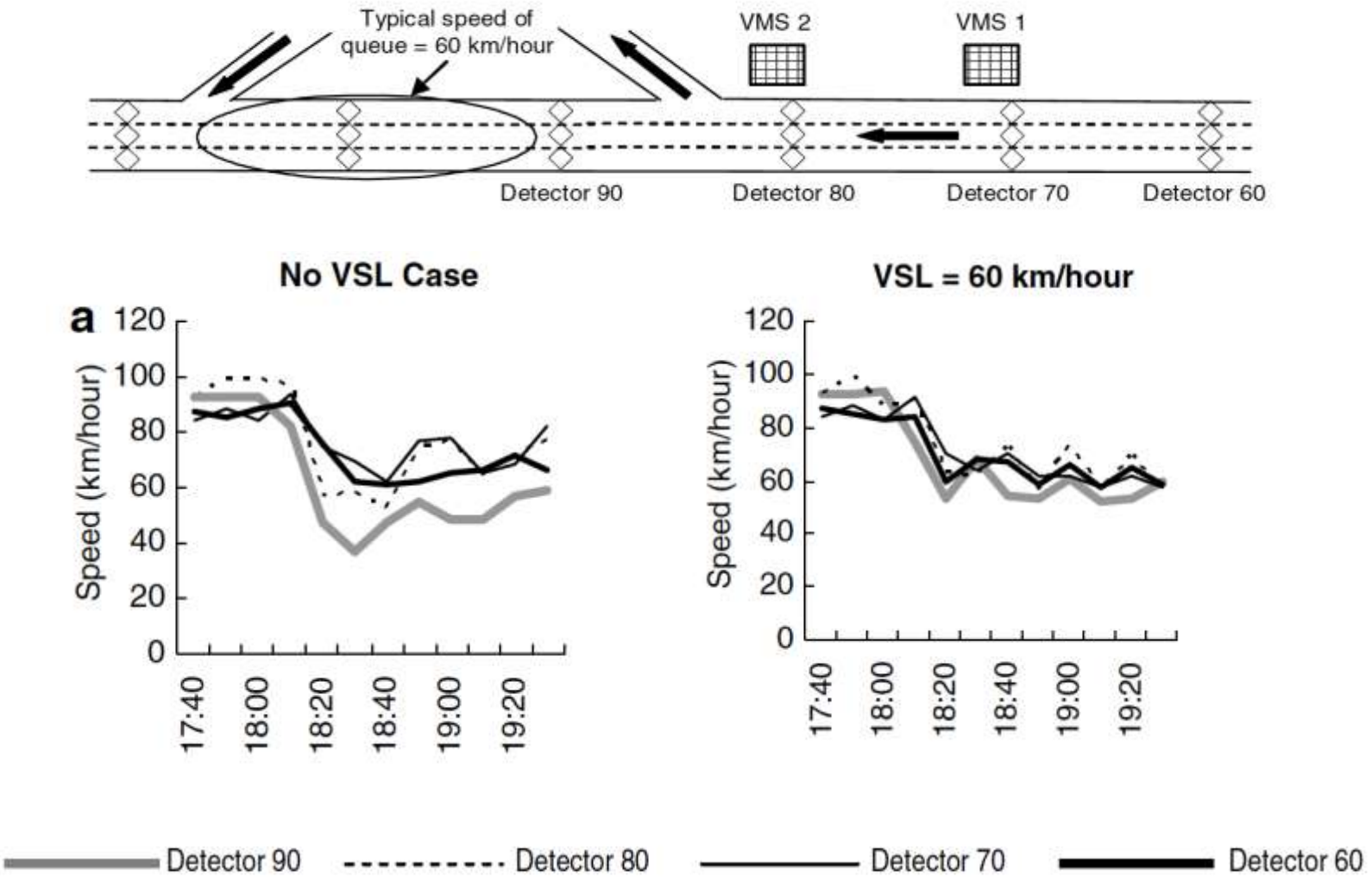


Fig 1. Comparison of fixed intervention speed limit strategies (Lee et al., 2004)

Variable Speed Limit to improve Safety

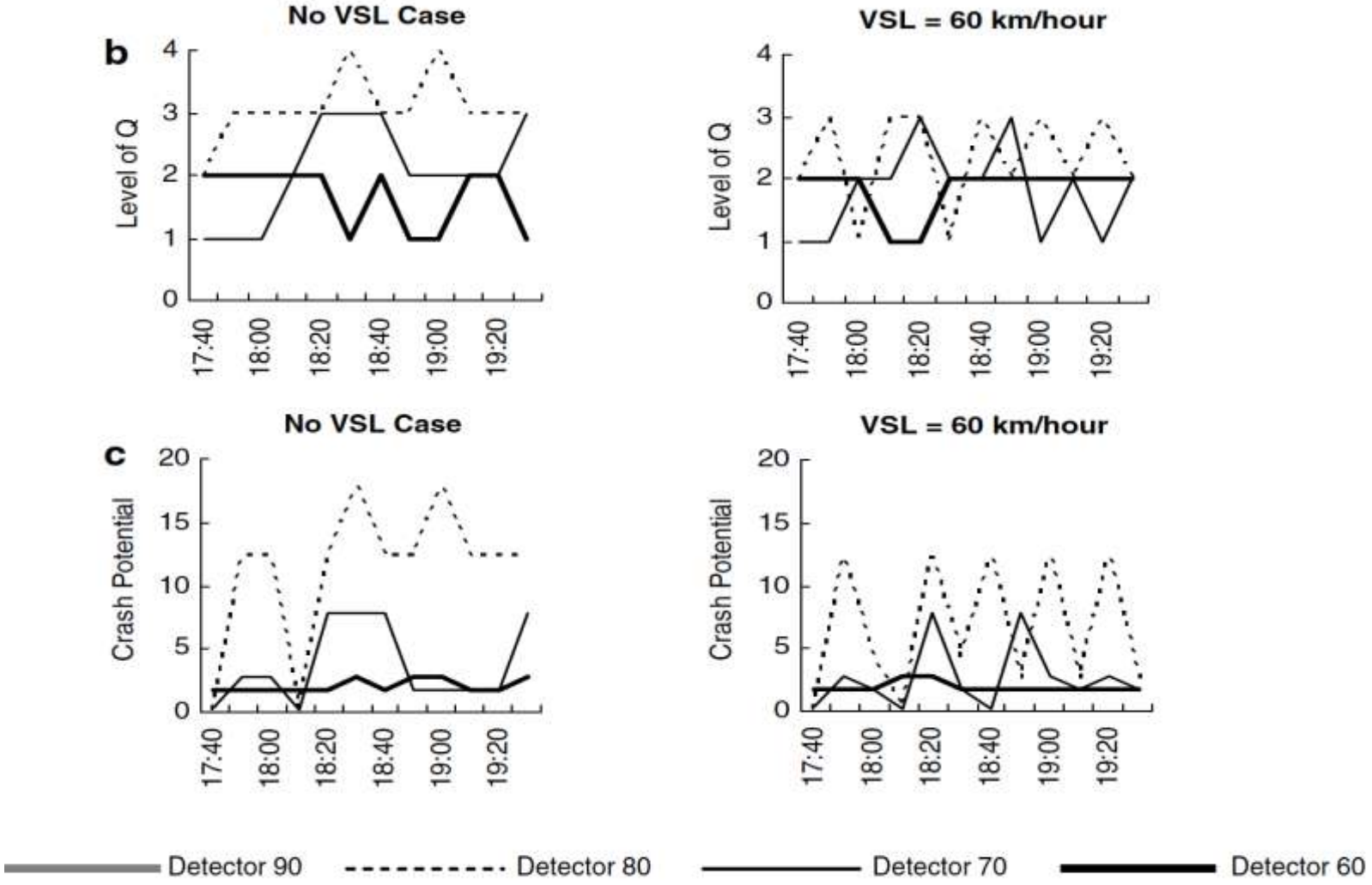


Fig 2. Comparison of fixed intervention speed limit strategies (Lee et al., 2004)

Variable Speed Limit to improve Safety

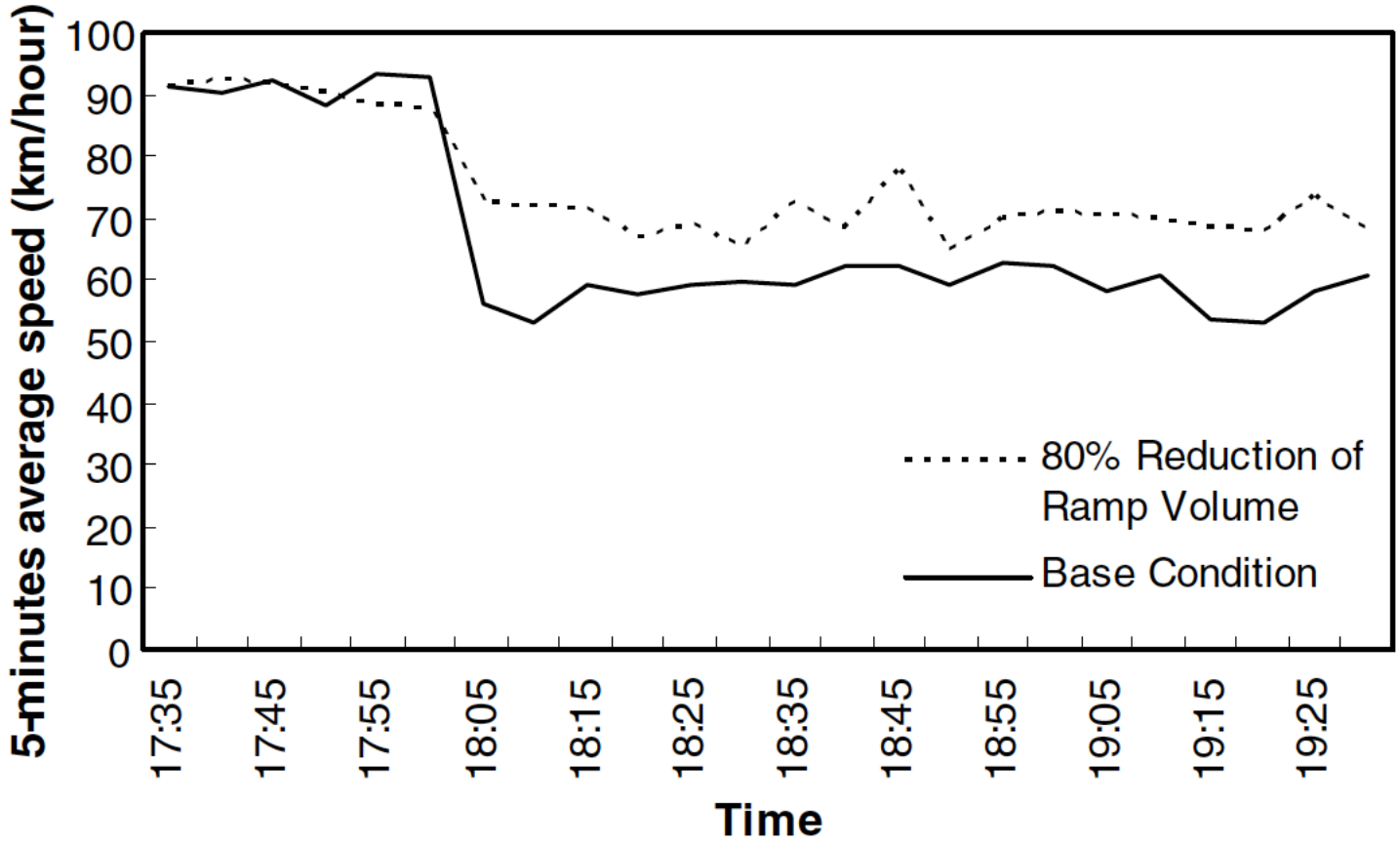


Fig 3. Speed profile immediately upstream of on-ramp (Lee et al., 2004)

Variable Speed Limit to improve Safety

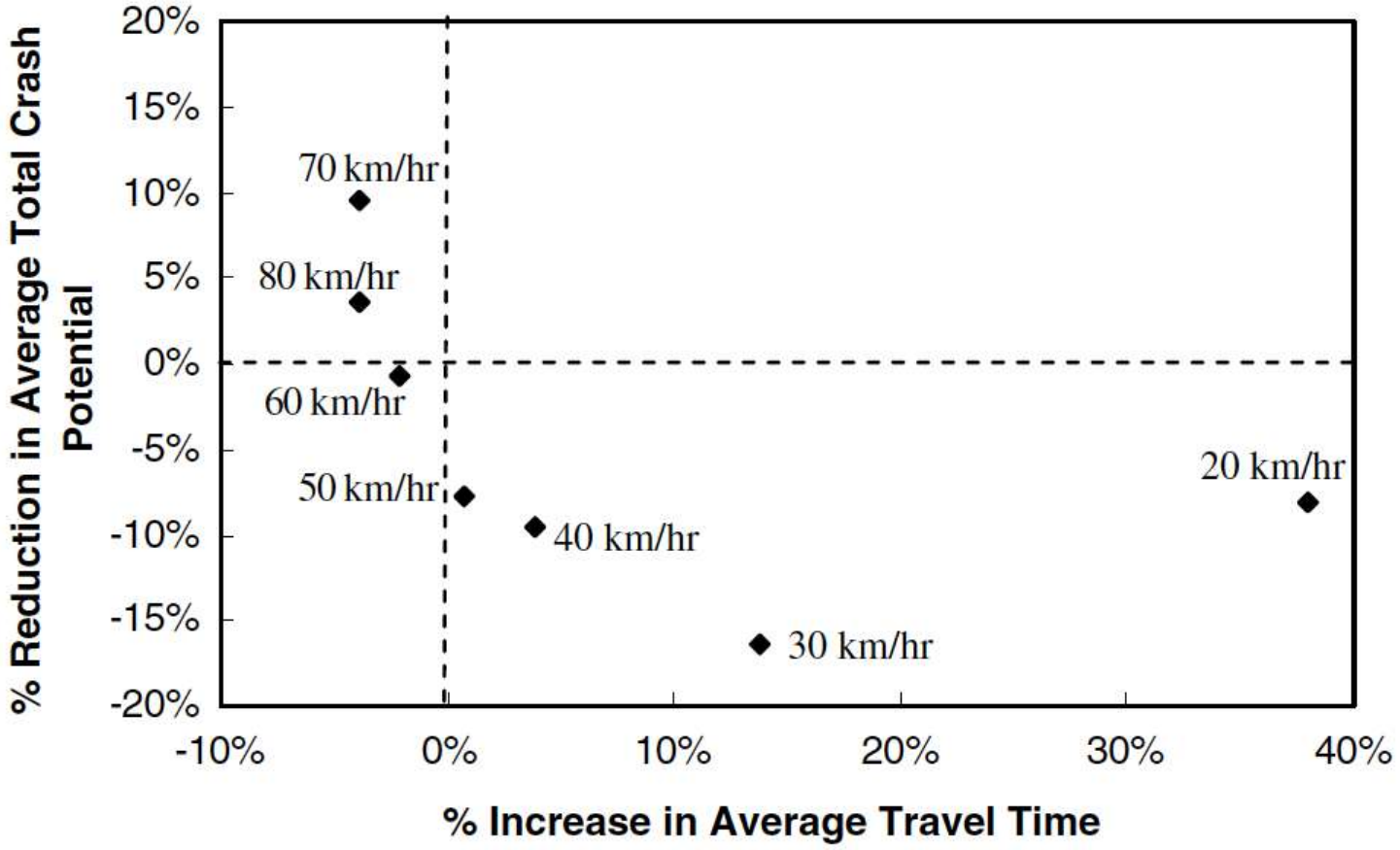
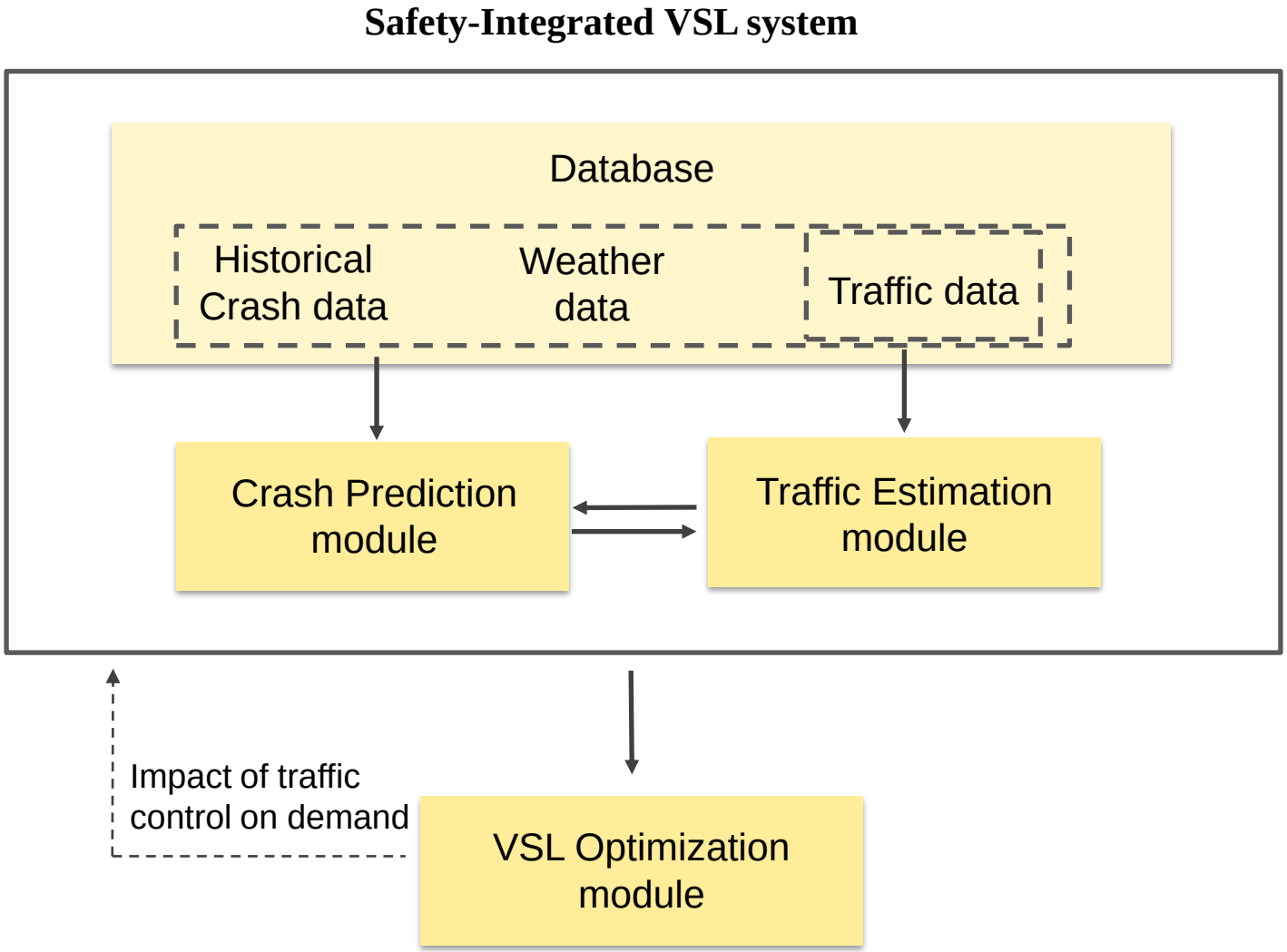


Fig 4. Effect of speed limit on crash potential and travel time (Lee et al., 2004)

Variable Speed Limit to improve Safety



Greenshield's theory

Basic Theoretical Model

Newell's Triangular Model

Generalized Model

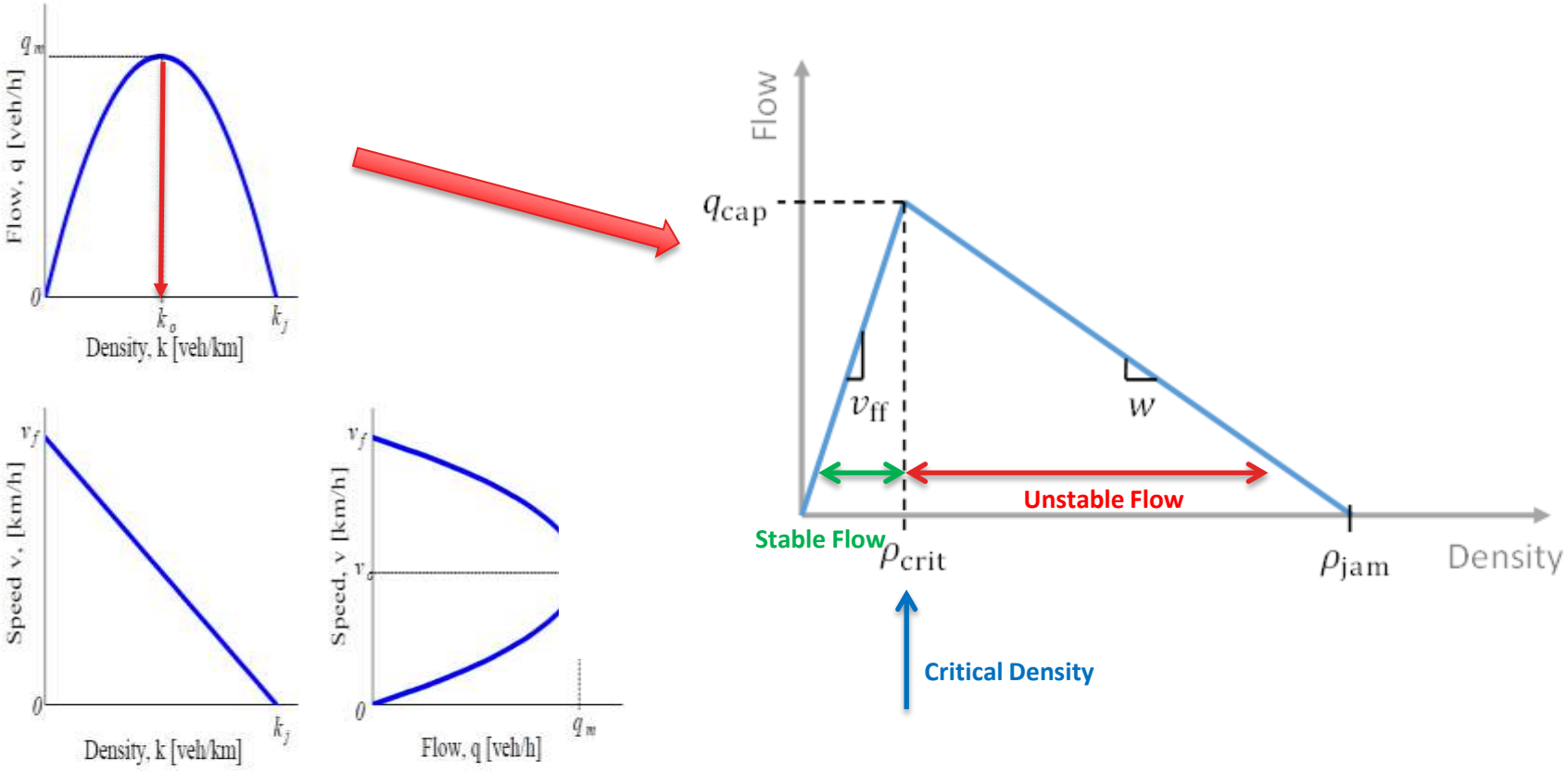


Fig 5. Fundamental Diagrams of Greenshield Traffic Flow Mode (Greenshield et al., 1933)

Deerfoot Data

- **Freeway section** of the Queen Elizabeth II Highway (Highway 2) in Calgary, Alberta, Canada

Image Source: Snapshot from Google Earth

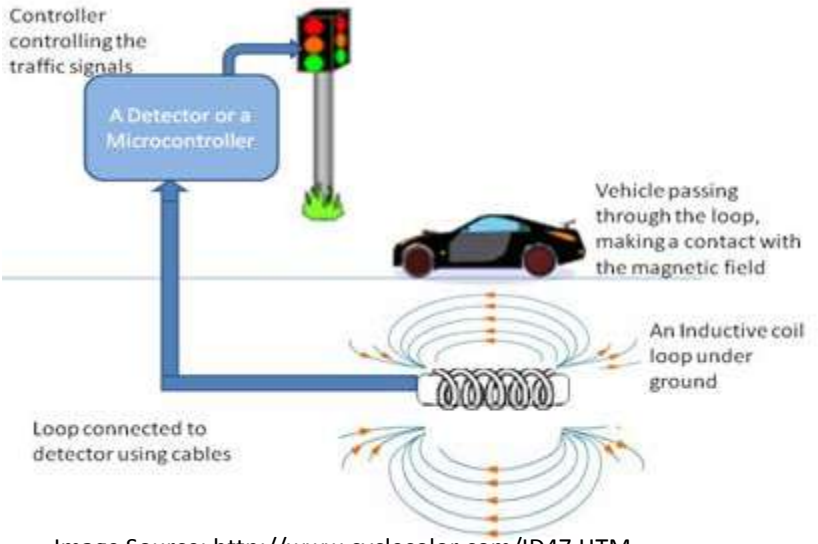


Image Source: http://www.cyclecolor.com/ID47.HTM

Detectors for RTMS Data

Capacity Drop

Existence of Capacity Drop at Bottleneck Locations

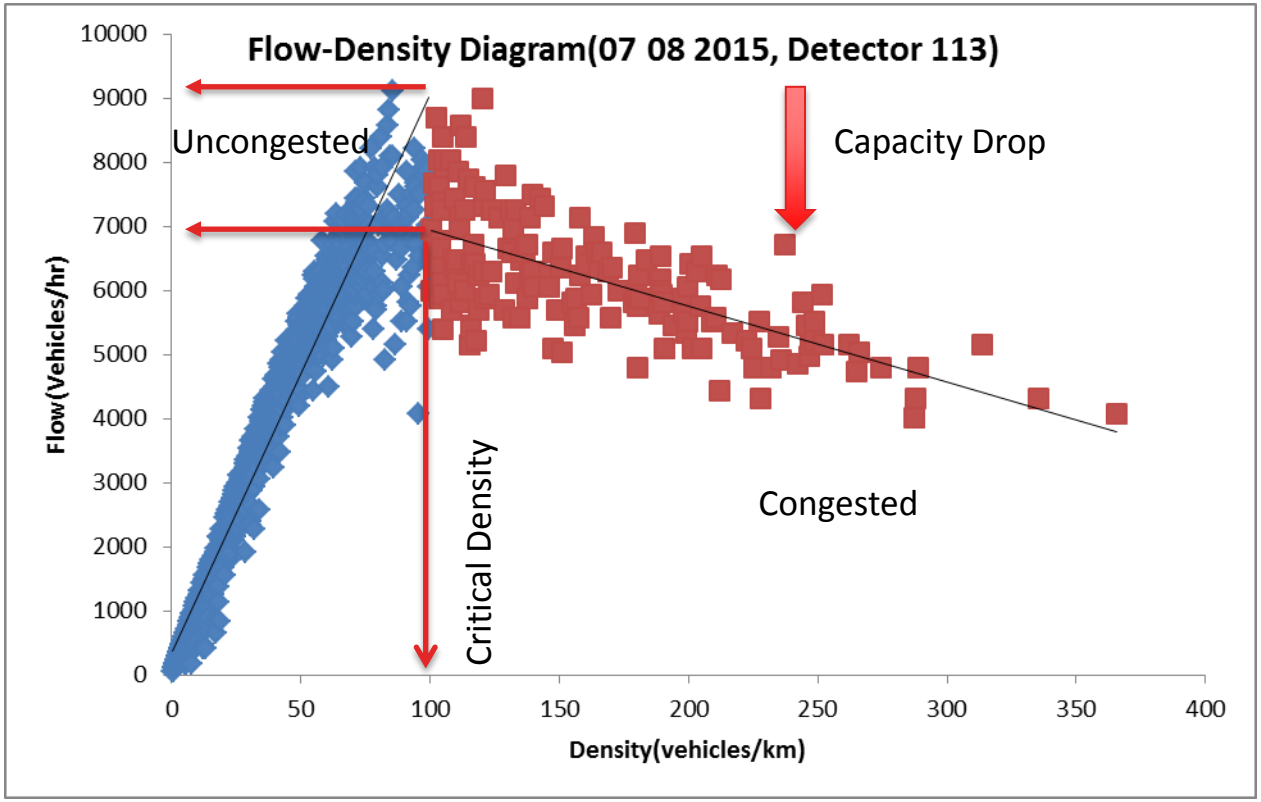


Fig 6. Existence of Capacity Drop at Bottleneck Locations

Congestion happens when:

Inflow > Outflow

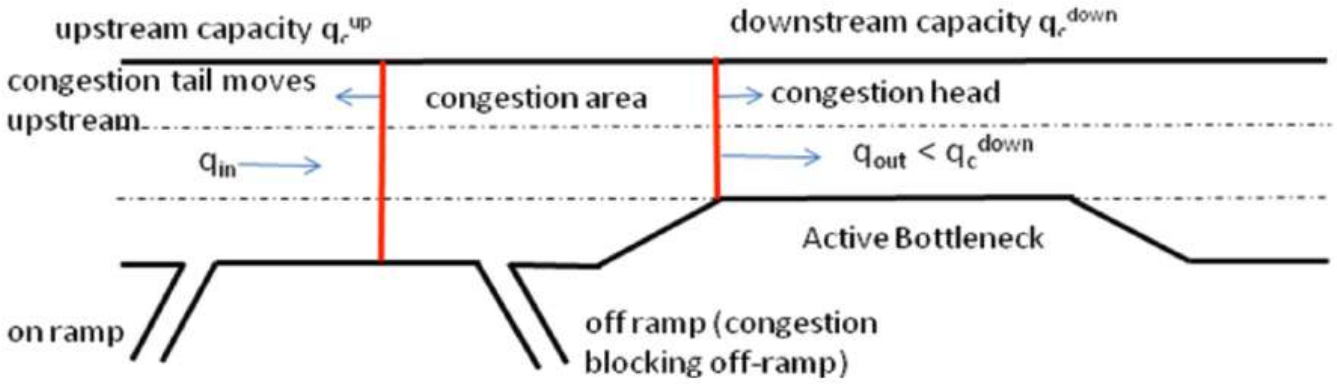


Fig 7. Active Bottleneck which causes congestion if Inflow > Outflow

Capacity Drop Vs Smooth traffic

VIDEO: https://www.youtube.com/watch?v=8G7ViTTuwno

Source: Doug MacDonald, Washington State Department of Transportation

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Fundamental Diagrams with different speed limits

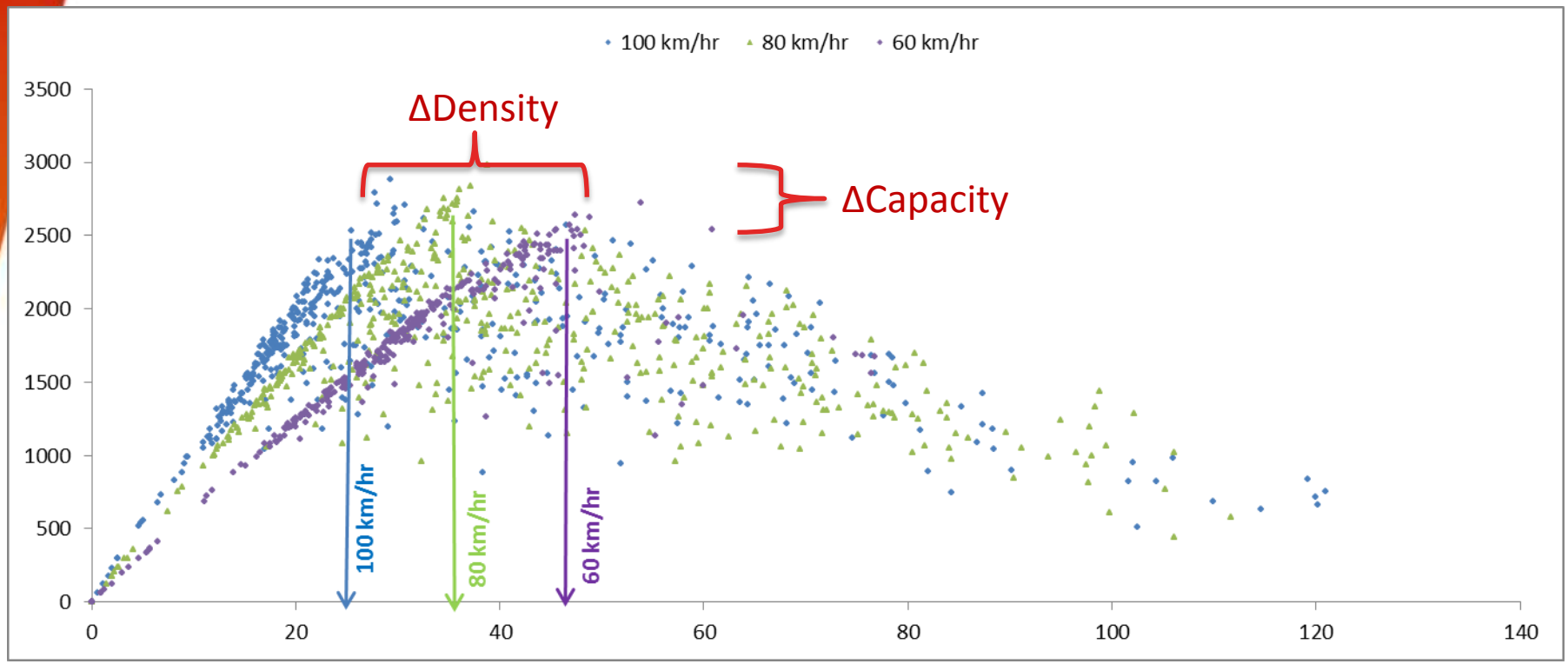

Fig 7. Fundamental Diagrams with different speed limits

If we reduce the speed of vehicles approaching bottleneck, inflow would decrease and congestion can be prevented

VISSIM Simulation

- Calibration of VISSIM Deerfoot Model
- Testing of Different VSL algorithms
- Scenarios:

Scenarios	Prediction Horizon	Objective Function
1	No VSL	
2	Reactive(No Prediction)	Distributing Vehicles(Density Uniformity)
3	Reactive(No Prediction)	Optimizing TTT and TTC
4	Proactive(5 minutes Prediction)	Distributing Vehicles(Density Uniformity)
5	**Proactive(5 minutes Prediction)**	**Optimizing TTT and TTC**

Fig 8. Snapshot from PTV VISSIM

No Variable Speed Limit

Vs

Scenario 1

Reactive VSL aimed at Density Uniformity

(Most basic VSL technique)

VIDEO: https://www.youtube.com/watch?v=ebXAp9n-AUs

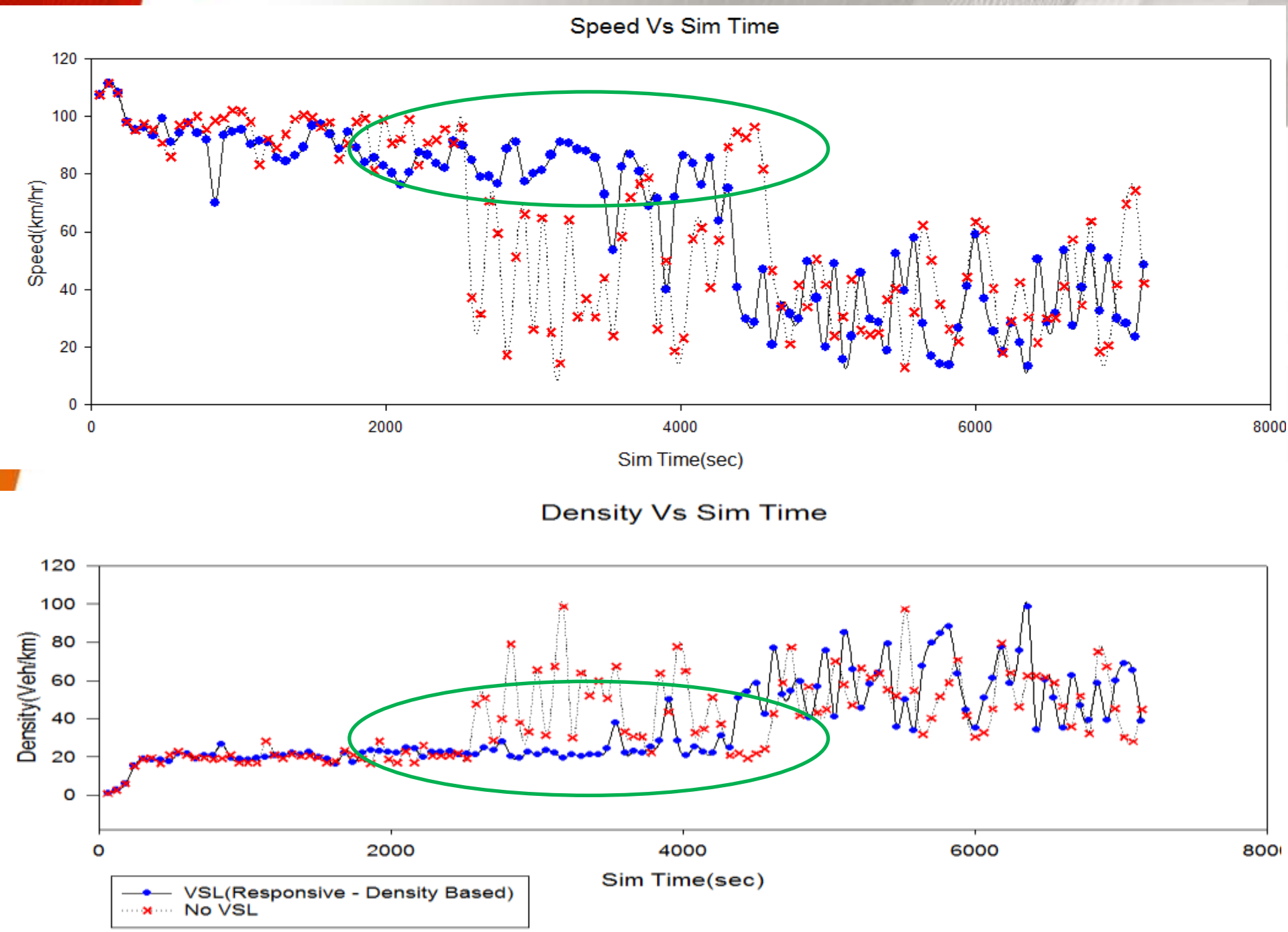

Fig 9. Results (1. Speed Vs Simulation Time, 2. Density Vs Simulation Time)

Results

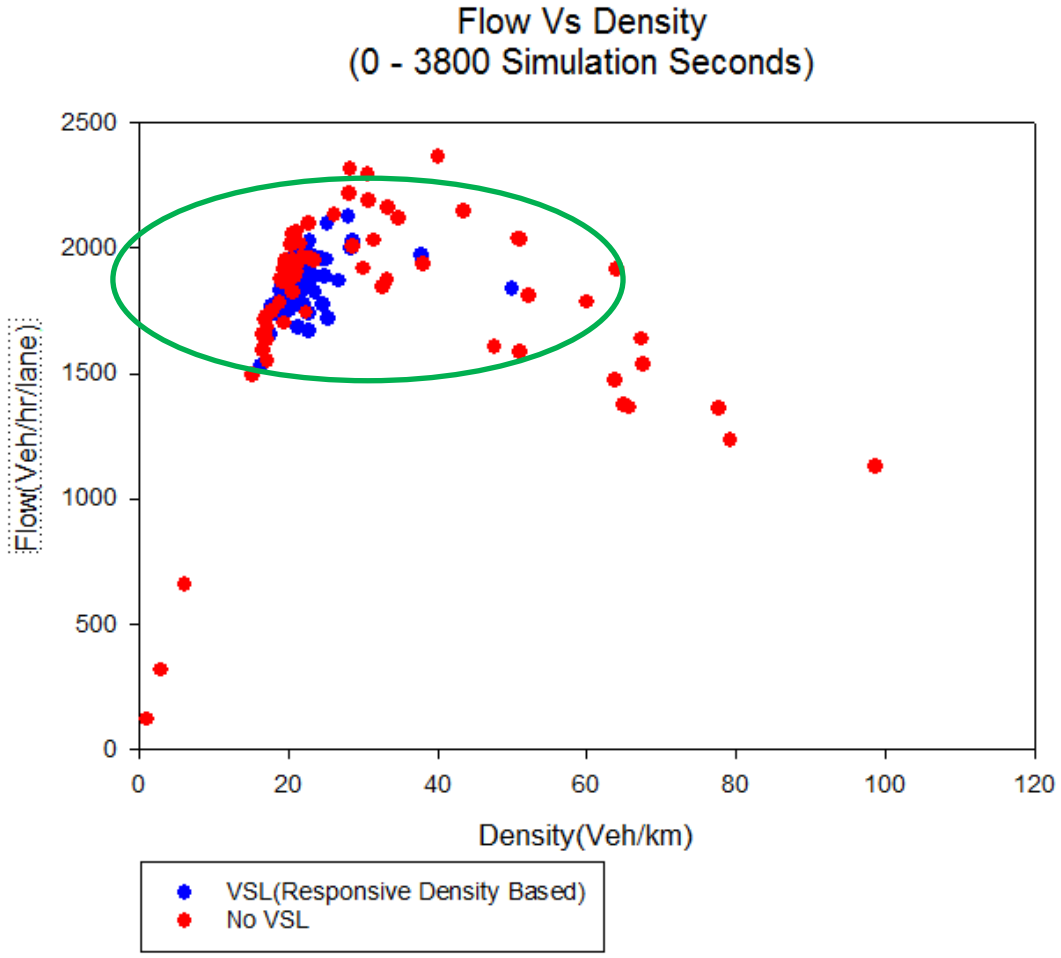

Fig 9. Results (Flow Vs Density Comparison)

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Results

VEHICLE NETWORK PERFORMANCE					
	TIME INTERVAL	AVERAGE DELAY	AVERAGE STOPS	AVERAGE SPEED	AVERAGE DELAY DUE TO STOPS
NO VSL	*0-1800*	53.43	1.14	66.37	13.29
	1800-3600	85.45	2.12	60.02	18.41
	3600-5400	107.41	3.16	55.51	19.62
	5400-7200	166.88	6.27	45.49	33.17
VSL (RESPONSIVE DENSITY BASED)	*0-1800*	48.1	0.9	75.79	10.2
	1800-3600	74.12	1.48	68.01	15.21
	3600-5400	100.7	2.56	59.92	16.54
	5400-7200	160.16	6.03	46.66	29.35
COMPARISON	*0-1800*	5.33	0.24	-9.42	3.09
	1800-3600	11.33	0.64	-7.99	3.2
	3600-5400	6.71	0.6	-4.41	3.08
	5400-7200	6.72	0.24	-1.17	3.82

Table: Vehicle Network Performance

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Conclusion

- ✓ High-level crash precursors generally contribute to higher crash rates
- ✓ Variable Speed Limit generally reduces crash potential
- ✓ Variable Speed Limit with crash reduction purpose might increase travel time
- ✓ By developing proper optimization algorithm VSL can improve travel time as well as safety
- ✓ Traffic condition can made smoother

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Thank You !

QUESTIONS ?