Multi-Criteria Adaptive Signal Control Theory and Practice

Joseph K. Lam
Managing Director
Delcan International Corporation

Adaptive Signal Control Technologies Workshop
San Juan, Puerto Rico
August 16, 2012

Agenda

- Introduction
- Delcan's Multiple-Criteria Adaptive Control
  - Algorithms
  - System Architecture
- York Region Pilot Study Results
- Surrey Implementation
- Conclusion

Who is Delcan?

Founded in 1953, Delcan is a 750 person multidisciplinary engineering, management and technology consulting firm focused on transportation

Moving Technology to the Future

for over 50 years - Worldwide

Integrated Systems and Infrastructure Solutions

Delcan Advanced Traffic Management Systems (Technology Integration)

WSDOT ATMS
UDOT ATMS 2000 Olympics
MoDOT Gateway Guide ATMS
IDOT TSC ATMS
IDOT TIMS
Michigan ATMS
ODOT Transport ATMS
Lake County ATMS
NJ Tollway ATMS
ODOT TATII
Caltrans D10
Caltrans D4 ATMS
NHDOT ATMS
Nebraska DOCSS Statewide ATMS
METRO RIITS
Baltimore ATMS
D7 ATMS 2000
East St. Louis
D7 ATMS 2005
MoDOT KC SCOUT
GDOT ATMS
KC SCOUT Web
D7 ATMS 2007
SR125 Tollway
GDOT NavWeb
TX SH 130
D11 ATMS 2000
Alabama Statewide
TX Statewide Plan
D11 ATMS 2005
SANDAG IMTMS

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Delcan Systems Business

- Key Office Locations in North America
  - Vienna VA, Atlanta, Chicago, Los Angeles, Oakland, Denver, Seattle, Vancouver, Toronto
- Key Services
  - Technology Integration (ITS)
  - Traffic Engineering with an emphasis on technology
  - Transportation System Planning, Engineering, and Design (all modes)
  - Program Management
  - Quality Management
  - Strategy & Policy Development
  - Public-Private Partnerships

Adaptive Control System

Users' key reasons for not implementing adaptive control:

- Communications requirements and recurrent cost to operate network
- Number of detectors required to be installed and maintained
- Complexity of the system to configure and fine tune
- Integration with legacy system and field equipment
- Dealing with over-saturation and gridlock
- Overall cost to deploy

Multiple Criteria Adaptive Control System (MAC)

The MAC Advantages:

- Open to all types of detectors
- Open to most types of communications technologies, including wireless
- Easy to integrate with legacy equipment
- Co-exists with legacy system
- Dealing with over-saturation and gridlock
- Easy and cost-effective to deploy

Detector Requirements

- Open to all types of sensor technologies
- Flexible Location Criteria
  - Stop-Line
    - At Critical Intersections (Cycle Length & Split)
  - Lane Entry
    - Intermediate Intervals along Arterial (Offset)
  - No Detector
    - Minor Intersections

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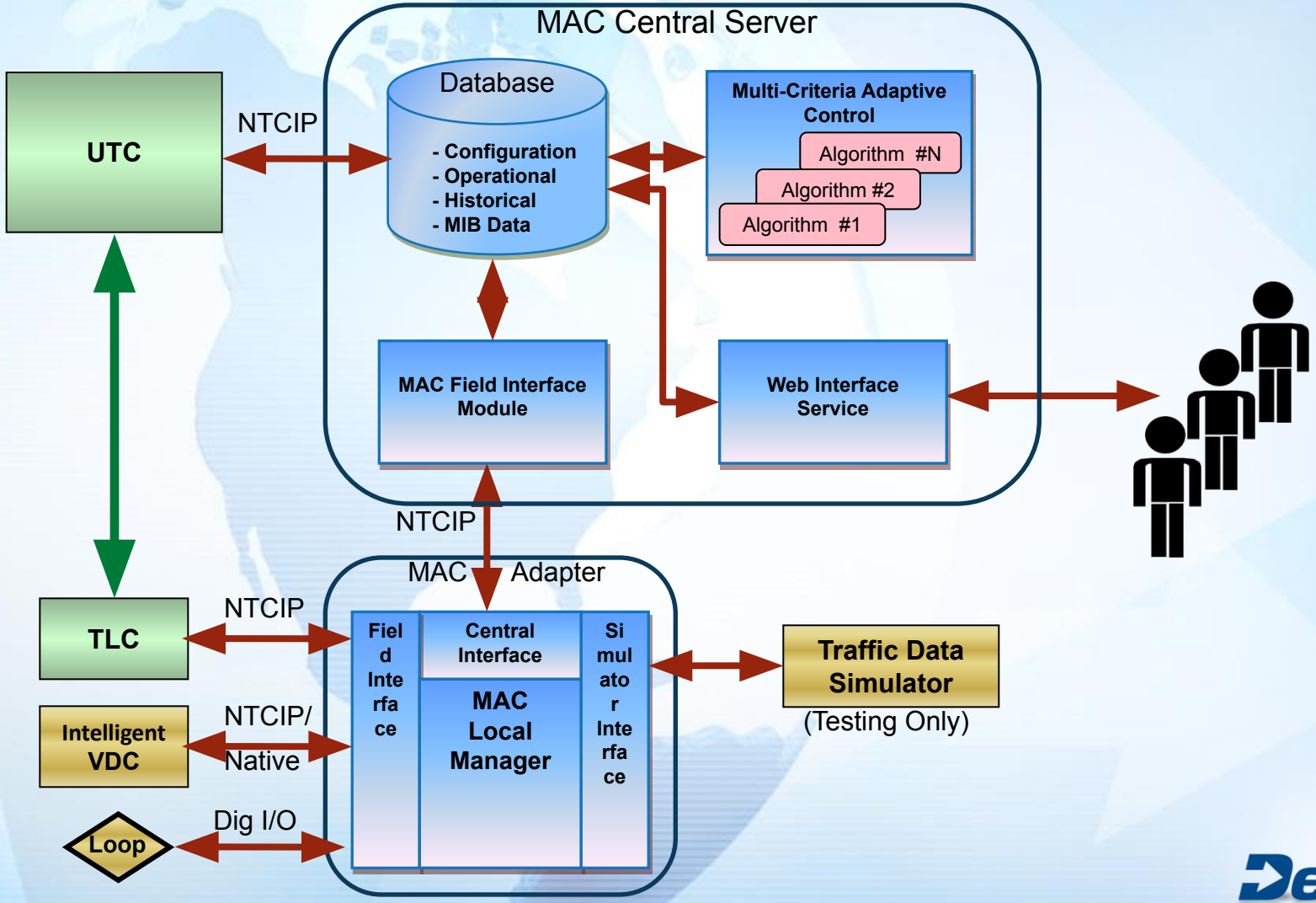
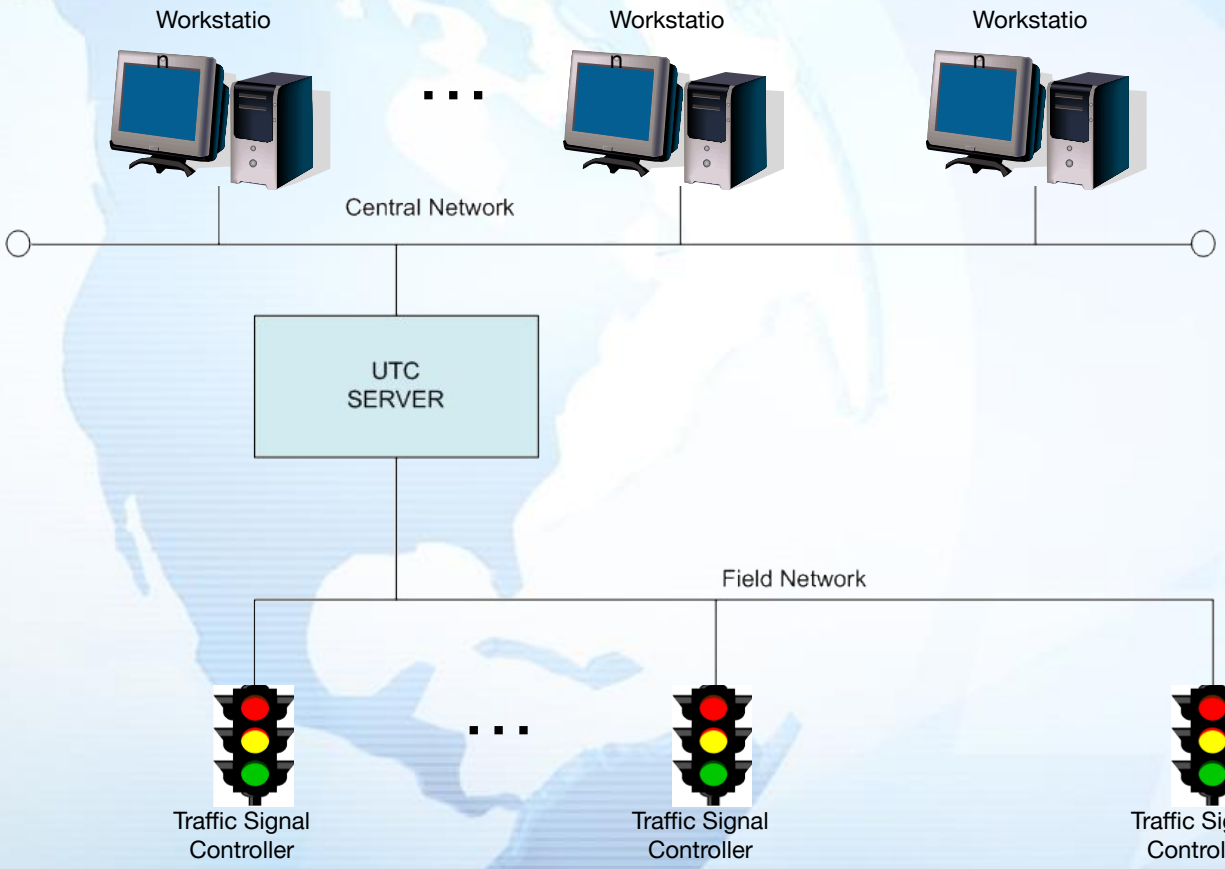
MAC Software Architecture



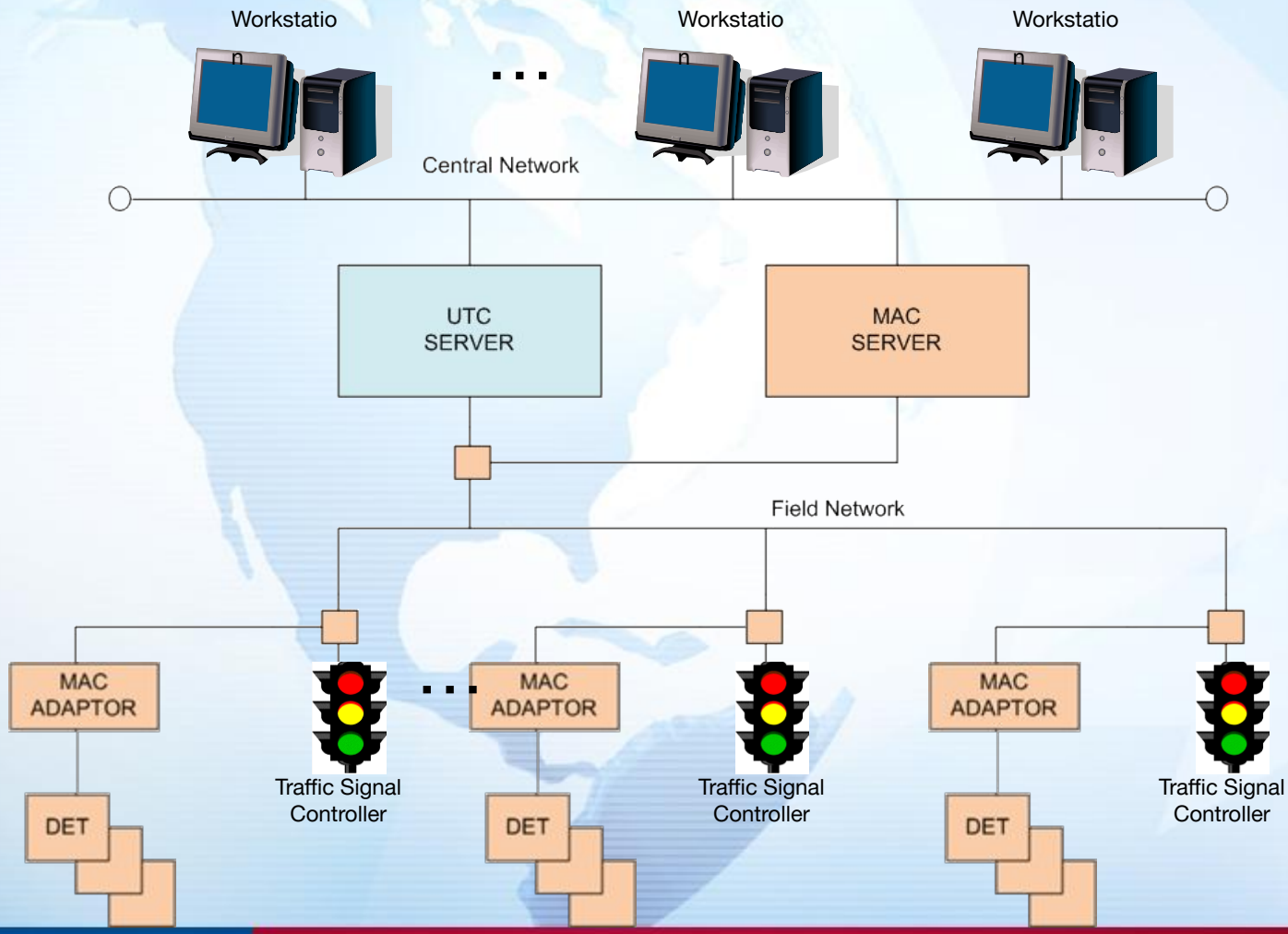
MAC Deployment

Existing Signal System



MAC Deployment

Existing with MAC



Signal Timing Changes

- Change Signal Timings Every Cycle
  - Except for Light Traffic (15 minutes)

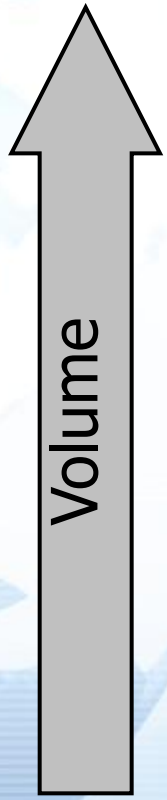
* *This supports most "intra-cycle" features (e.g. countdowns)*

- Timing Optimization Constrained to Small Changes for Smooth Transition
  - Incremental Change to Cycle Length (± 6 s)
  - Incremental Change to Offset (± 4 s)
  - Change Splits According to Demand Ratios

* *This allows for smooth transition during offset changes and avoids drastic changes in the signal operation*

Multi-Criteria Adaptive Control

Traffic Condition	Degree of Saturation
Gridlocked	1.0++
Oversaturated	0.90 – 1.0+
Heavy Demand	0.75 – 0.90
Medium Demand	0.50 – 0.75
Light Demand	0 – 0.50



Multi-Criteria Adaptive Control

Design Timings for Different Traffic Conditions

Traffic Conditi

Gridlocked	1.0++
Oversaturated	0.90 – 1.0+
Heavy Demand	0.75 – 0.90
Medium Demand	0.50 – 0.75
Light Demand	0 – 0.50

Volume

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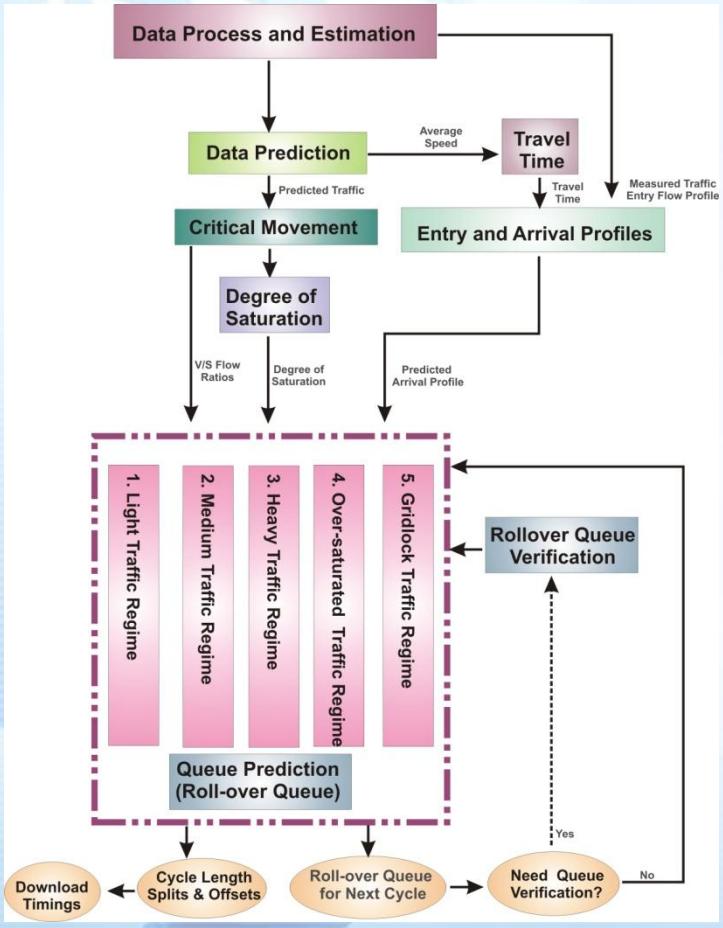
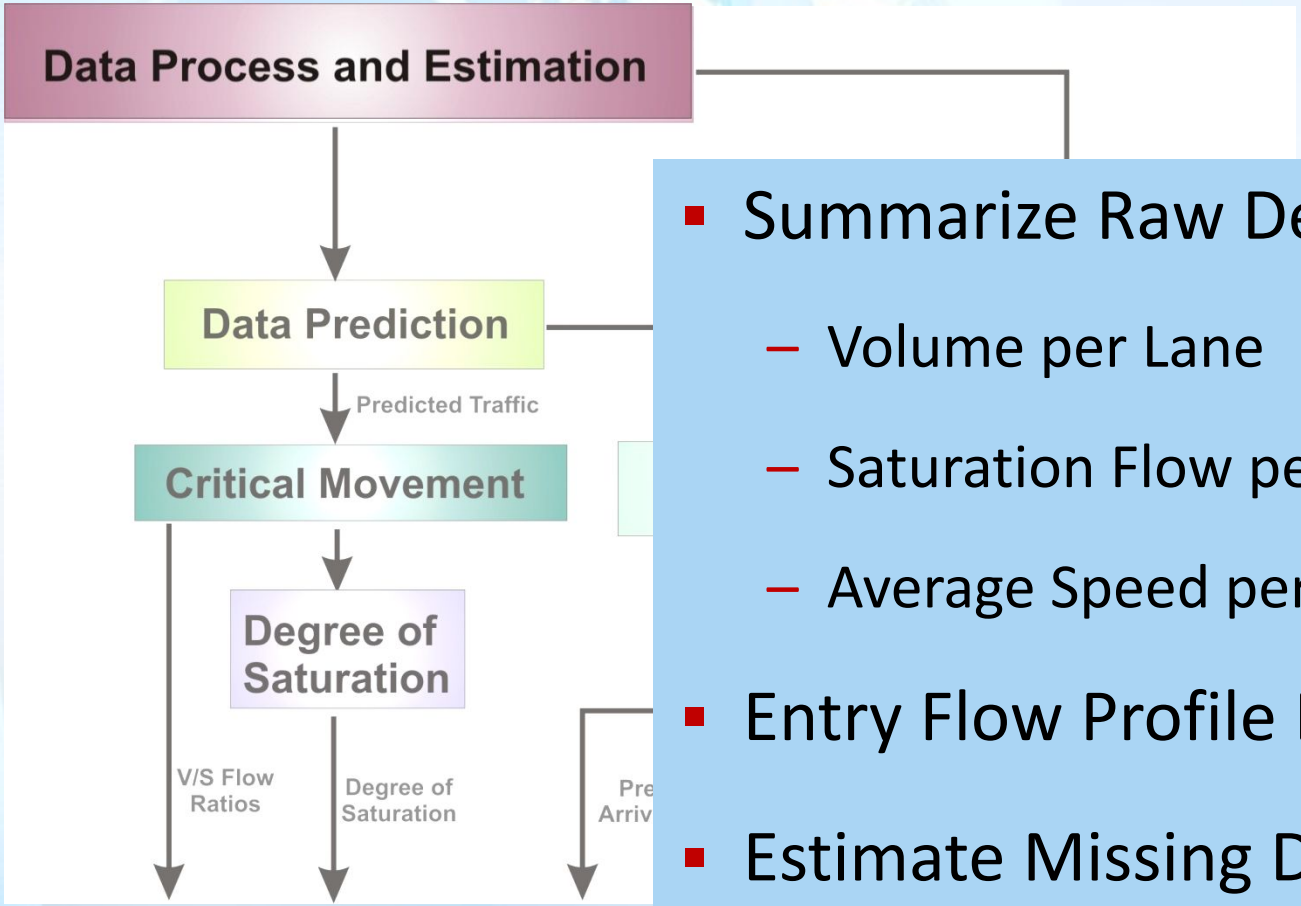
Multi-Criteria Traffic Adaptive Control Algorithms

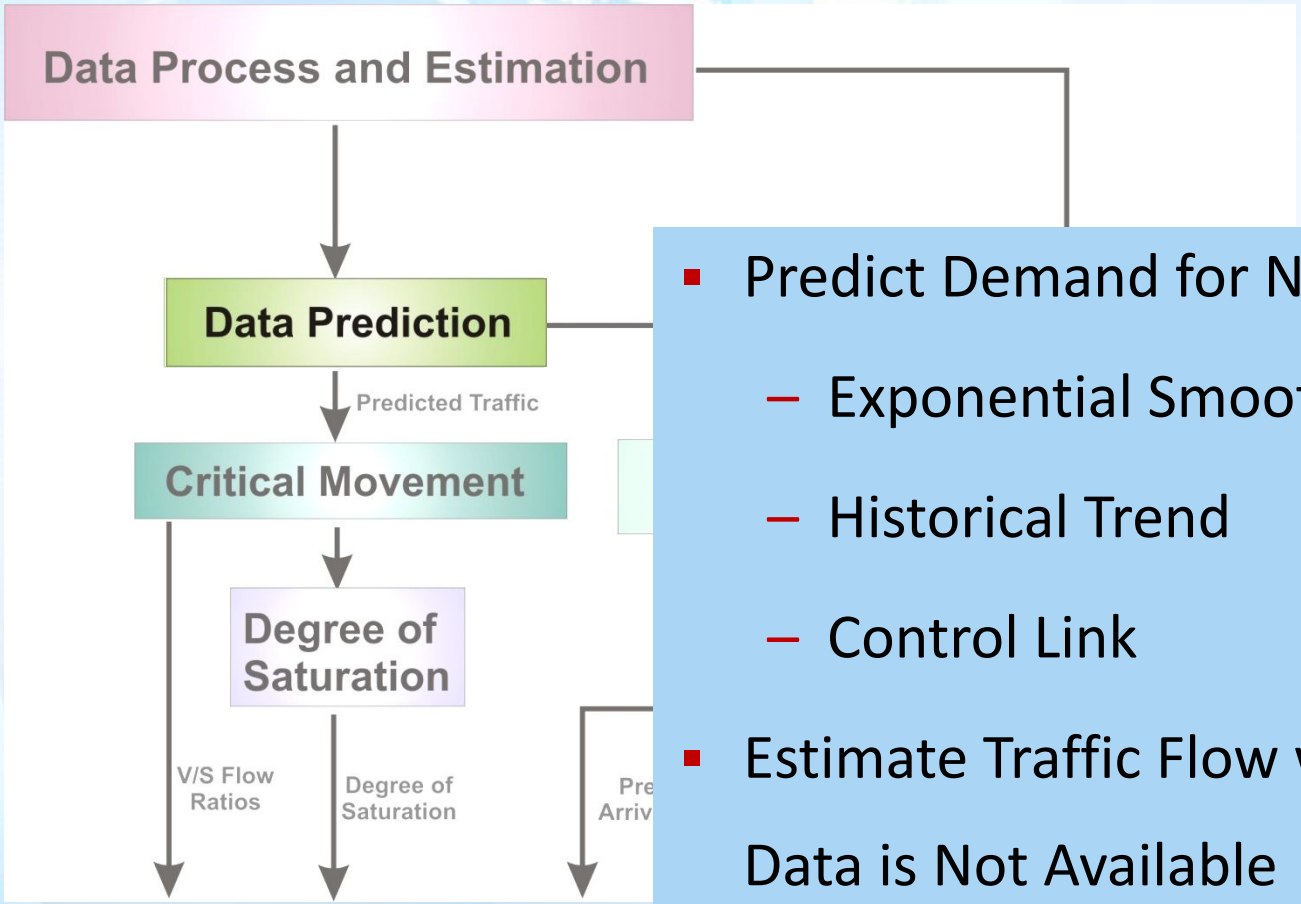


Data Process and Estimation



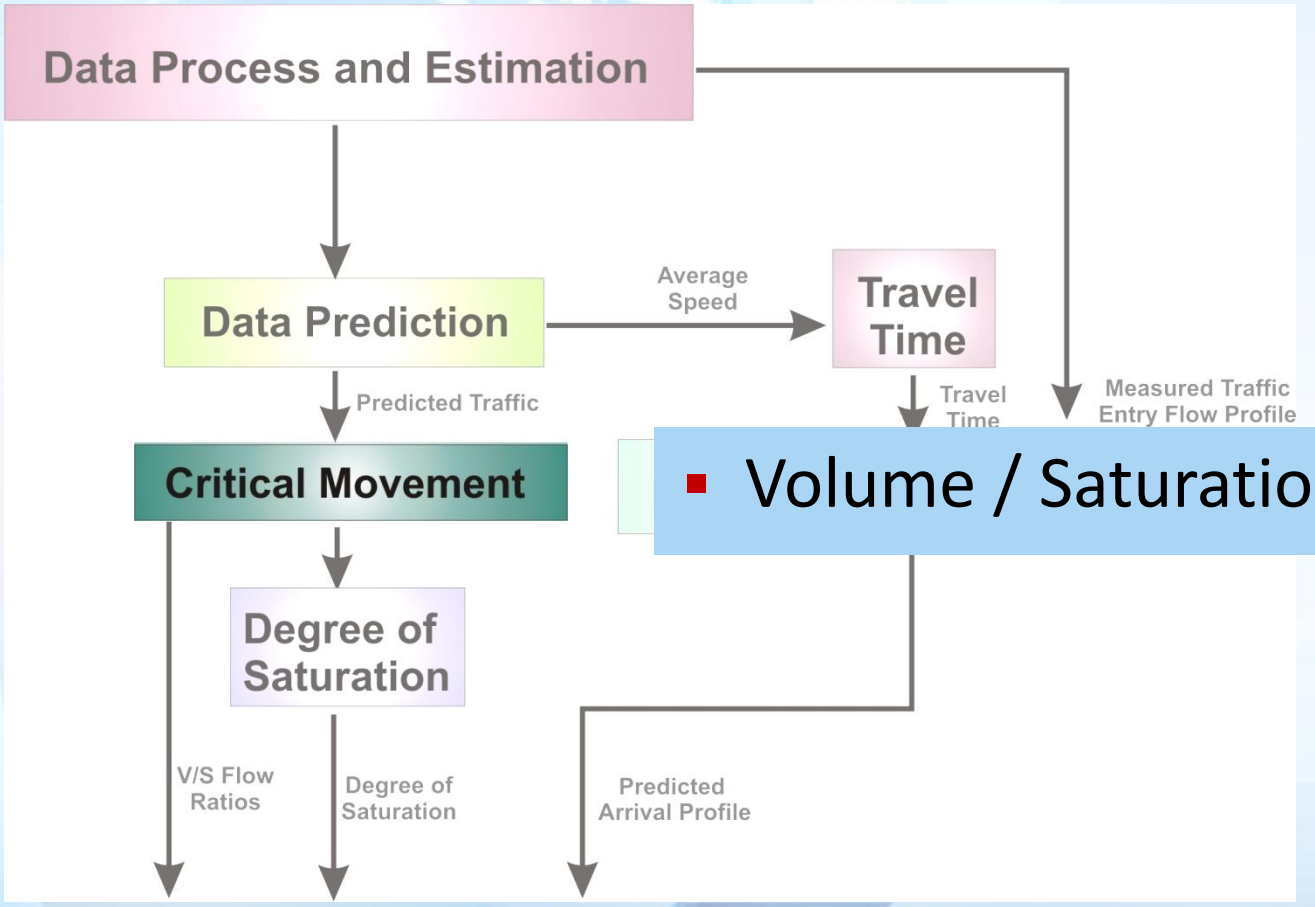
- Summarize Raw Detector Data
  - Volume per Lane
  - Saturation Flow per Lane
  - Average Speed per Link
- Entry Flow Profile Data
- Estimate Missing Detector Data

Data Prediction



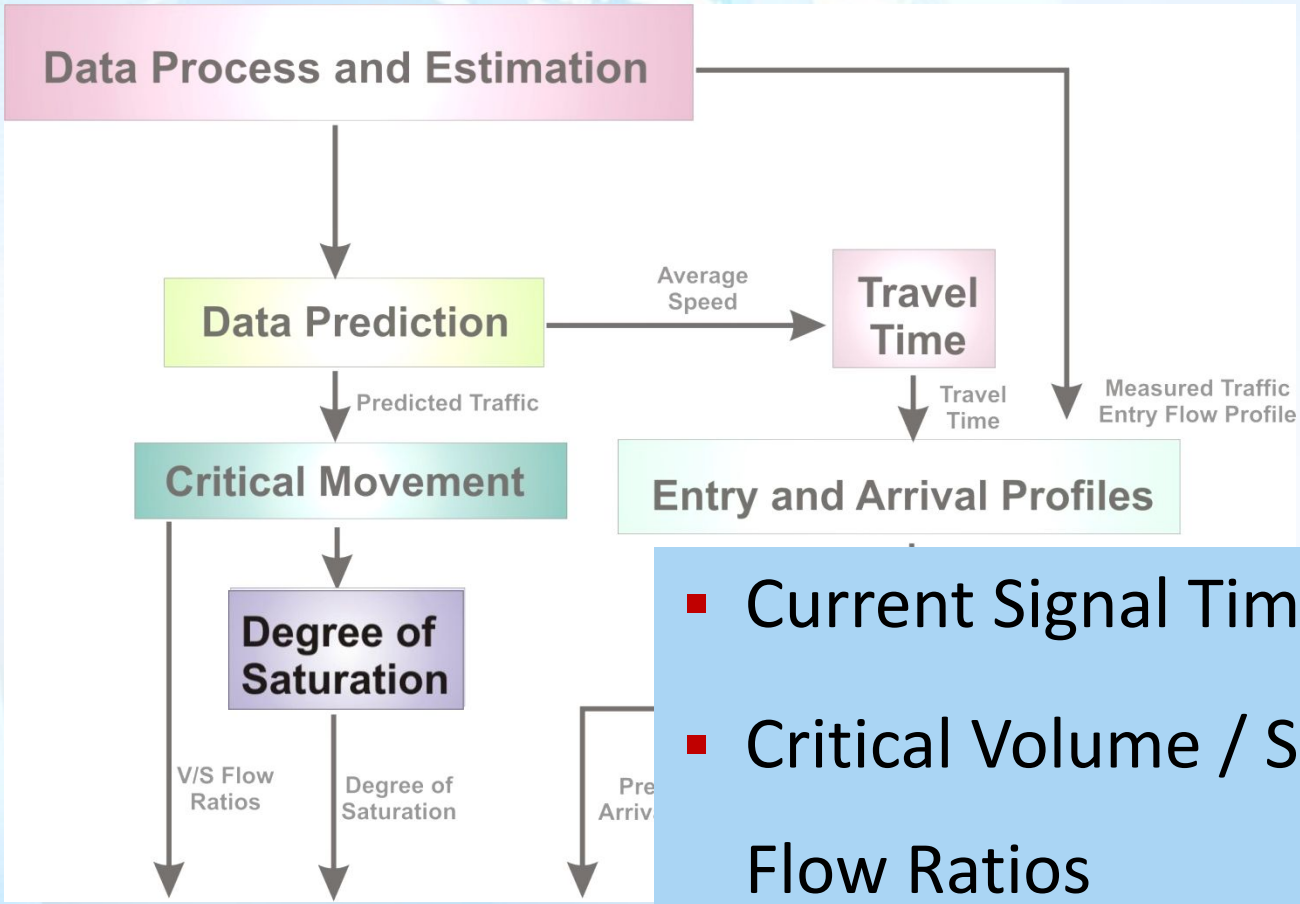
- Predict Demand for Next Cycle
  - Exponential Smoothing
  - Historical Trend
  - Control Link
- Estimate Traffic Flow when Real-time Data is Not Available

Critical Movement



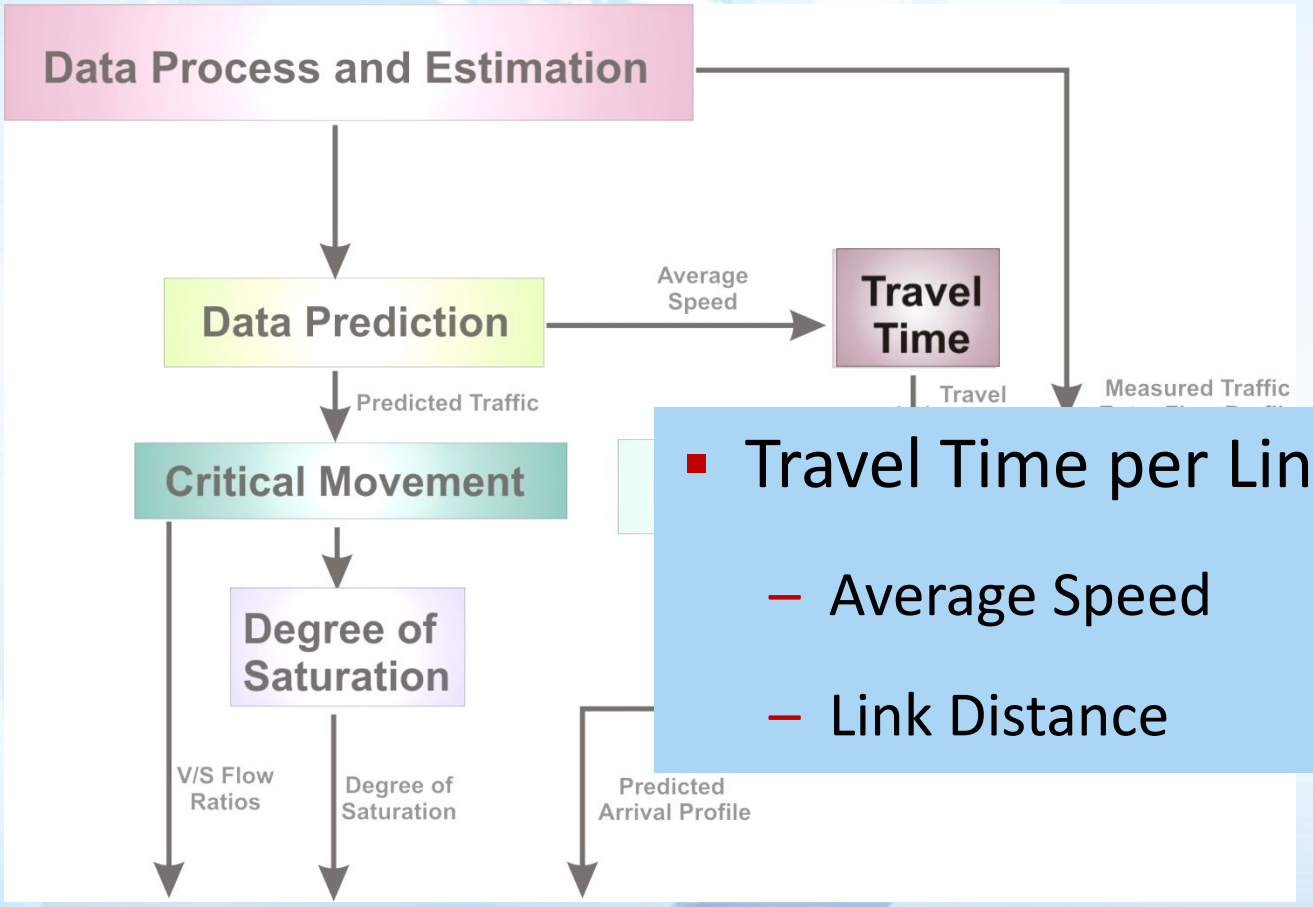
- Volume / Saturation Flow Ratios

Degree of Saturation



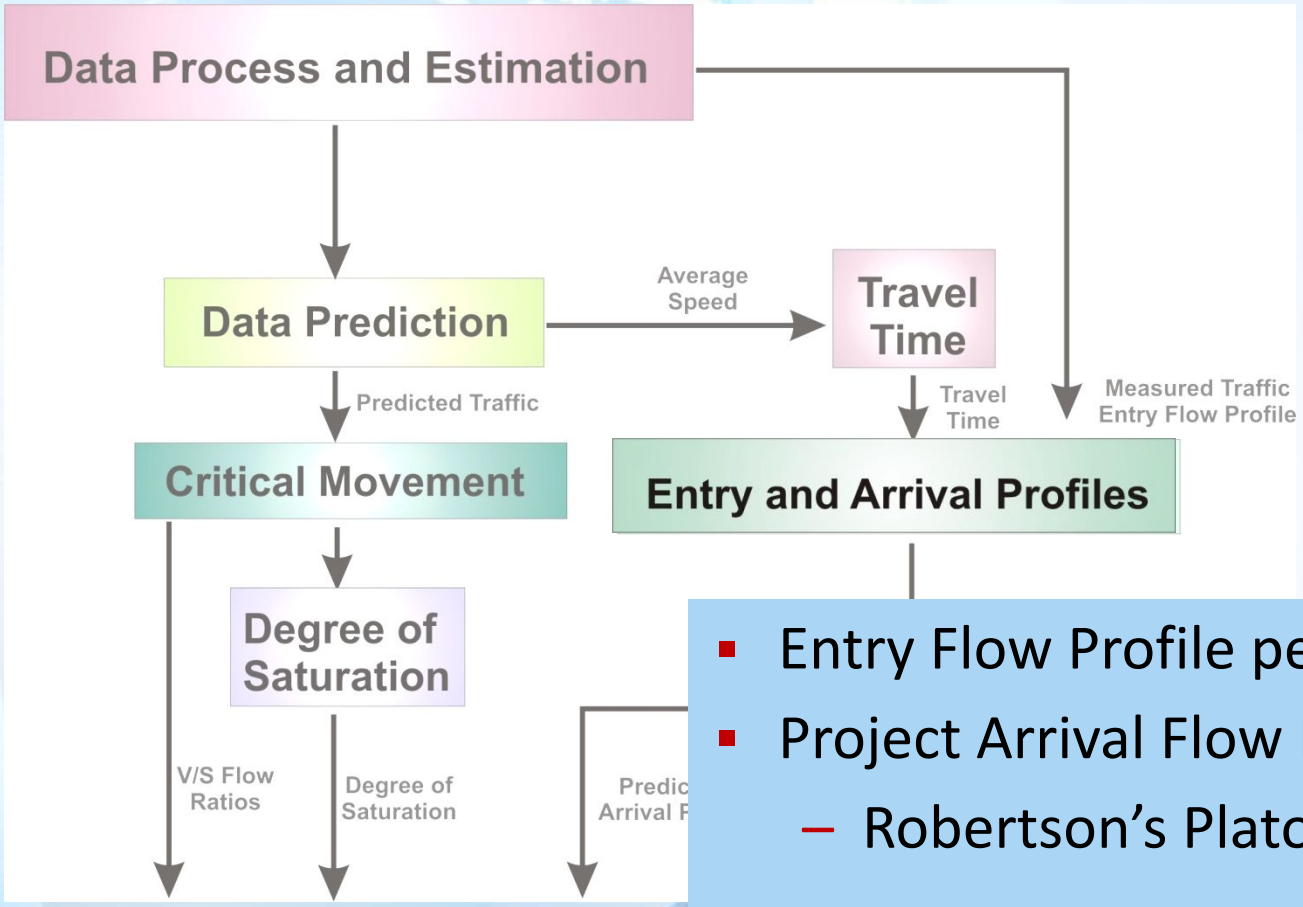
- Current Signal Timing
- Critical Volume / Saturation Flow Ratios

Travel Time



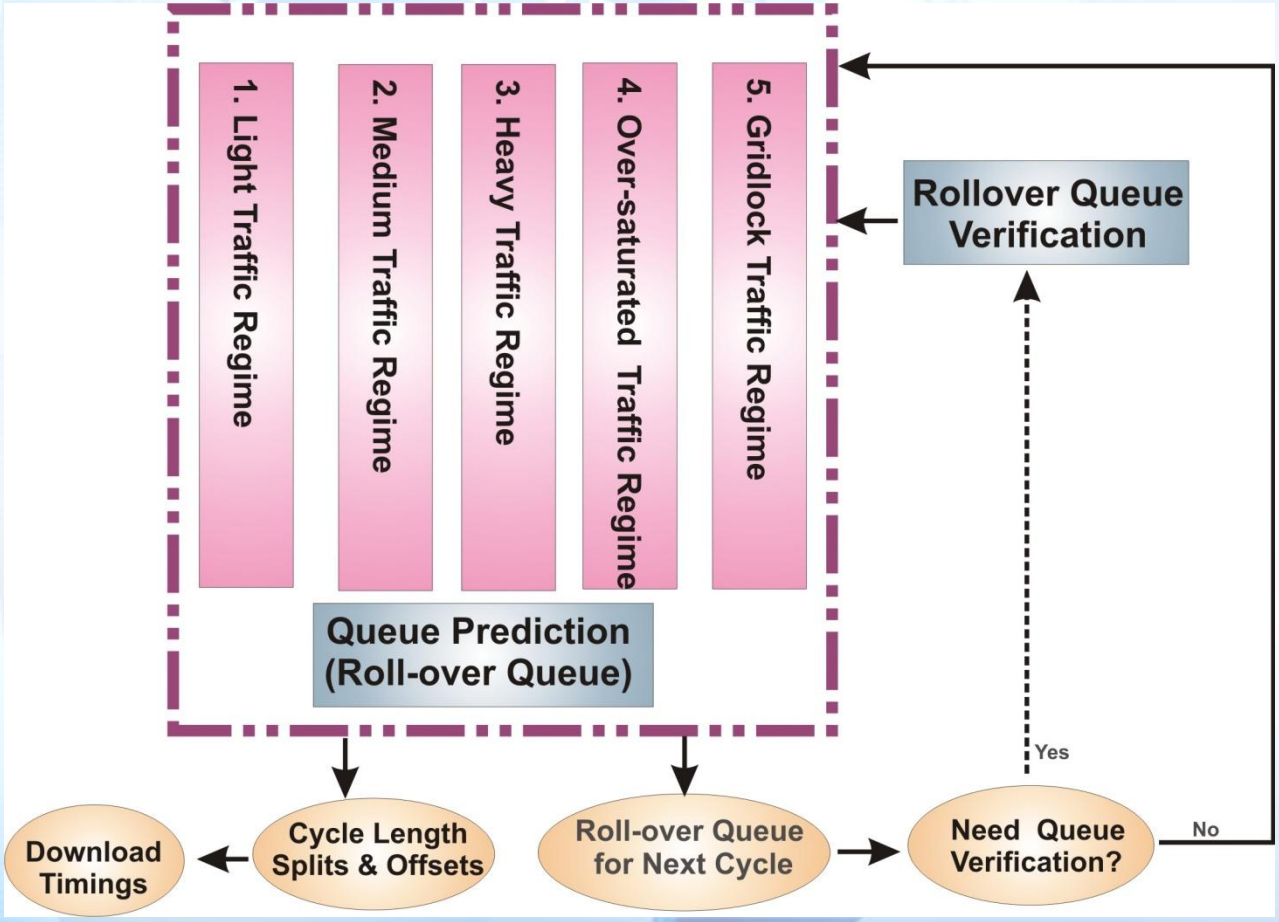
- Travel Time per Link
  - Average Speed
  - Link Distance

Entry and Arrival Profiles



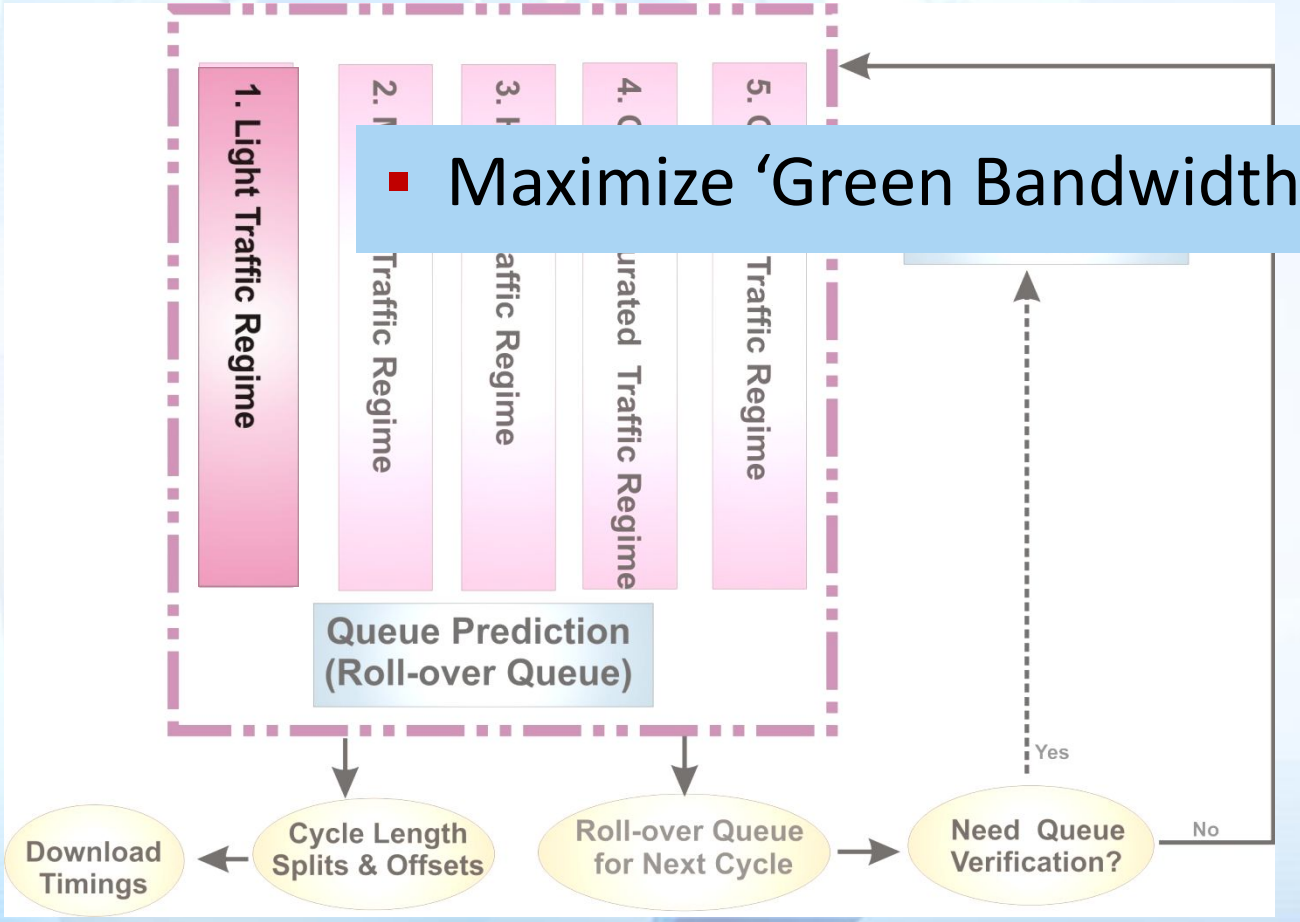
- Entry Flow Profile per Link
- Project Arrival Flow Profile
  - Robertson's Platoon Dispersion

Multi-Criteria Adaptive Control Algorithms



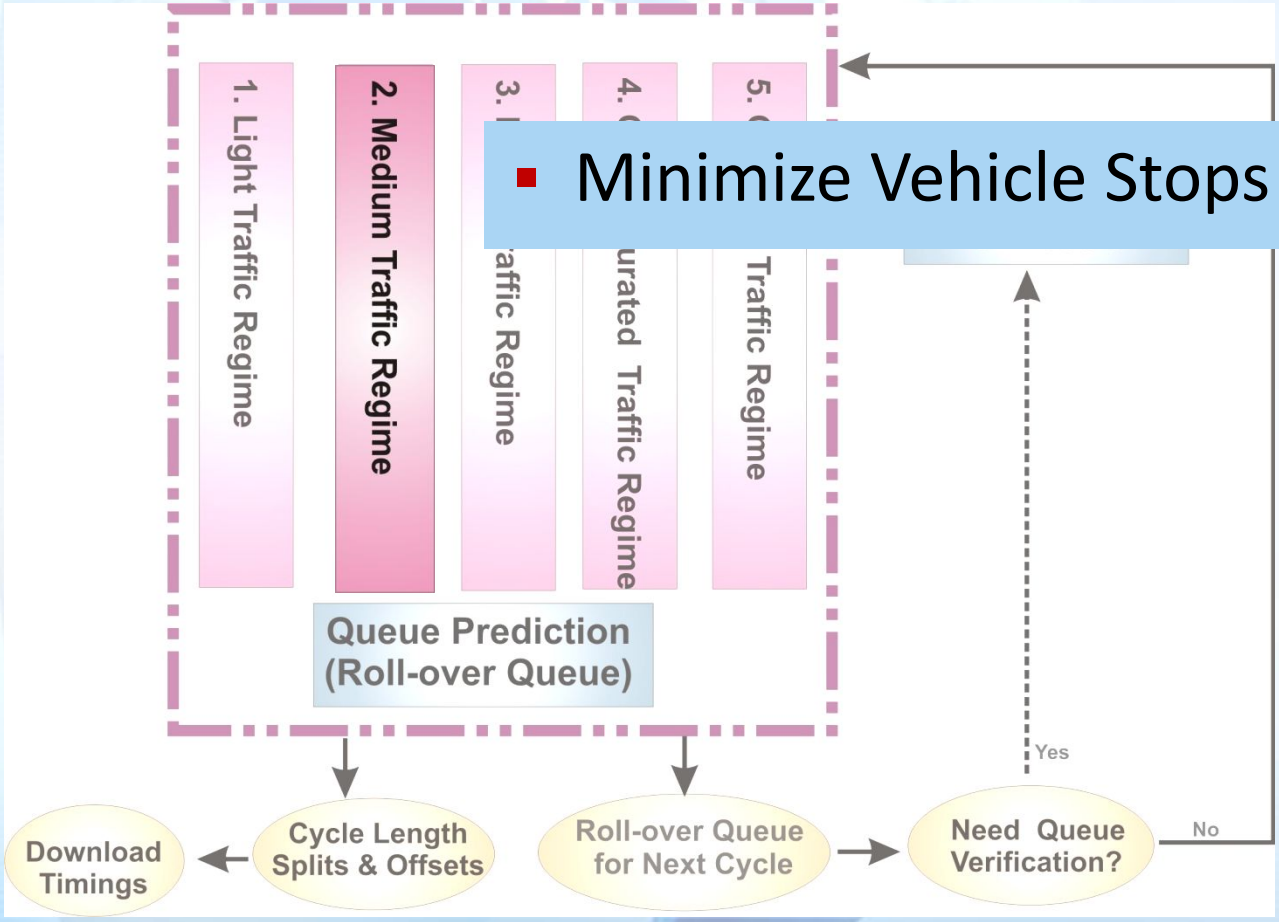
Multi-Criteria Adaptive Control Algorithms

- Maximize ‘Green Bandwidth’



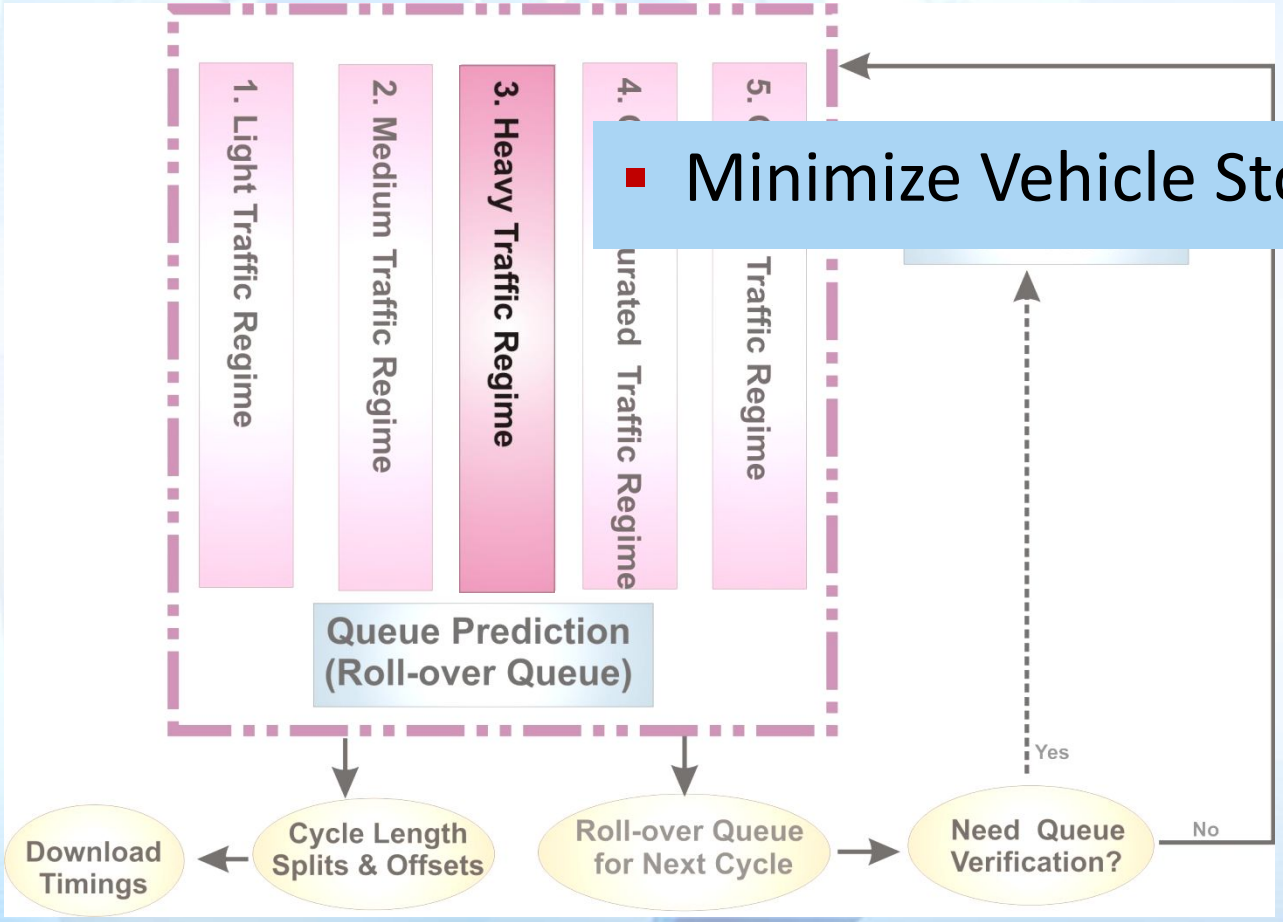
Multi-Criteria Adaptive Control Algorithms

- Minimize Vehicle Stops

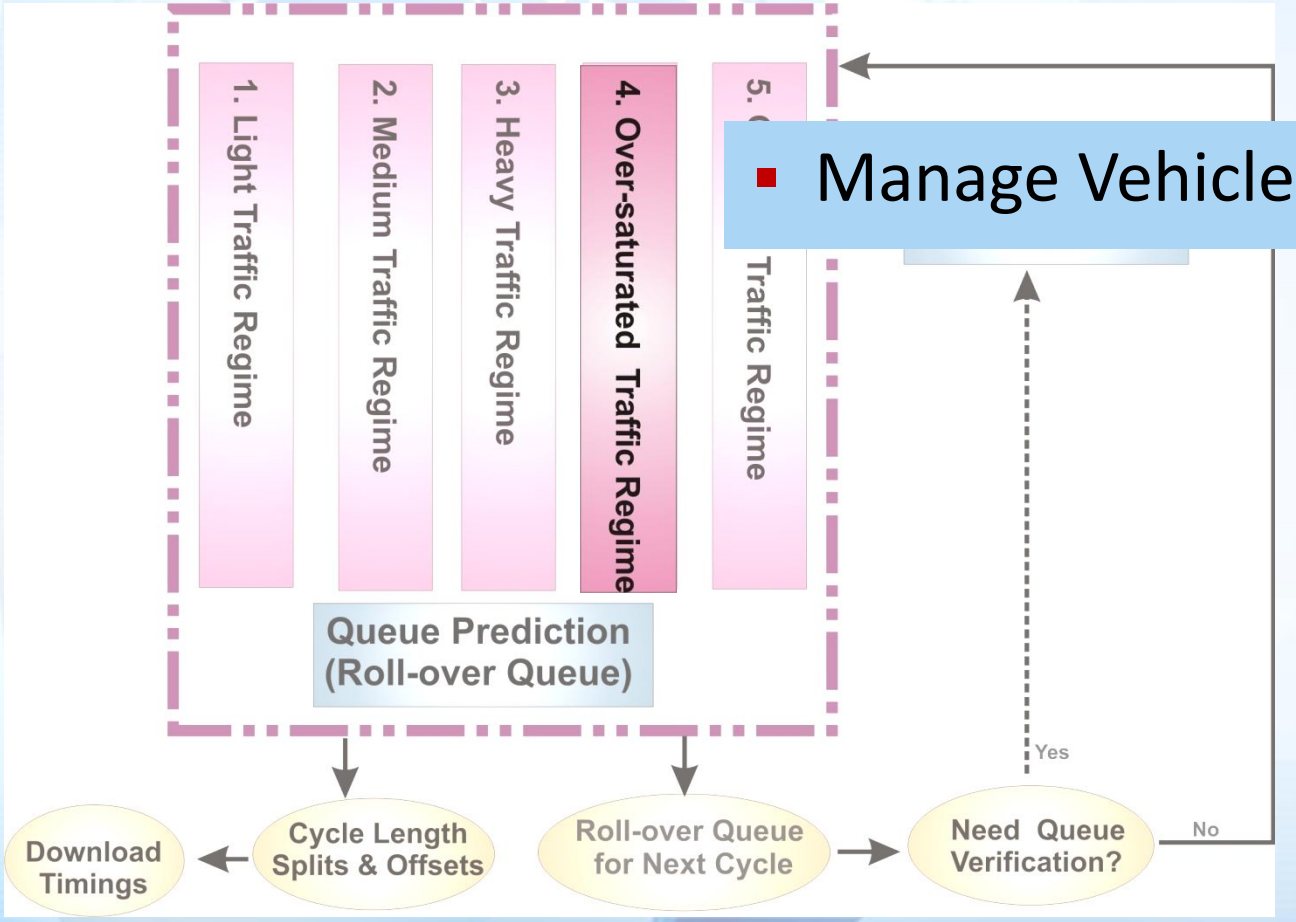


Multi-Criteria Adaptive Control Algorithms

- Minimize Vehicle Stops & Delays

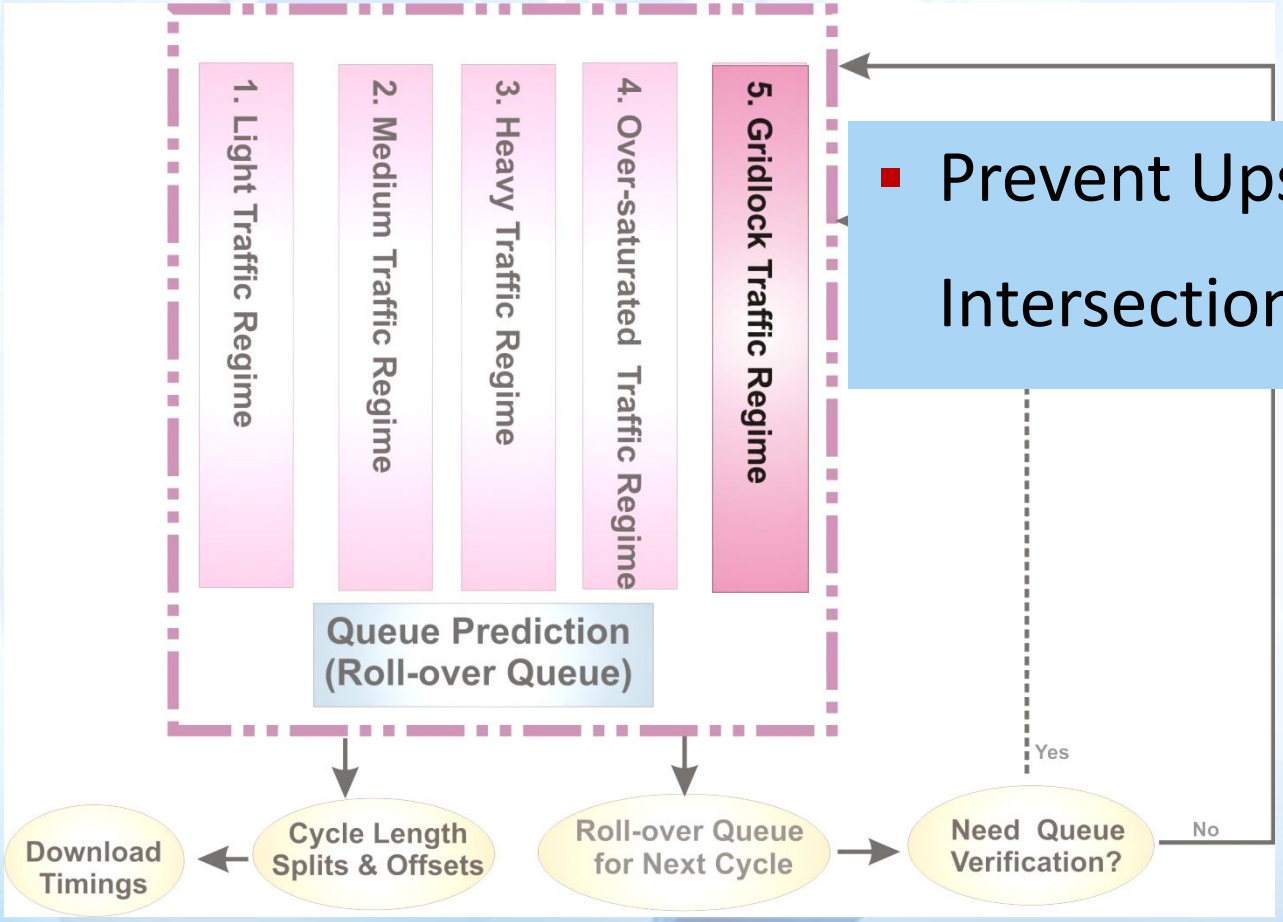


Multi-Criteria Adaptive Control Algorithms



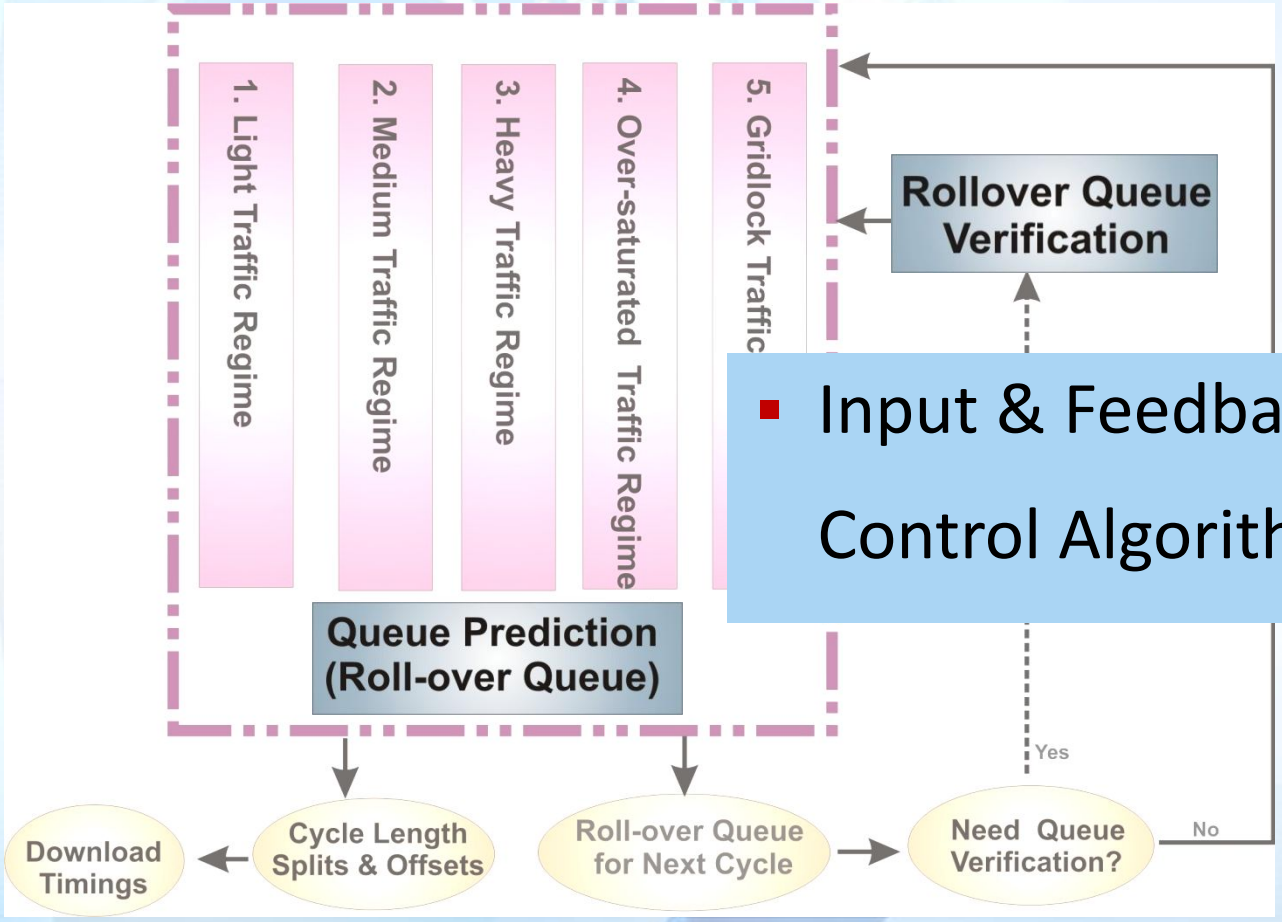
- Manage Vehicle Queues

Multi-Criteria Adaptive Control Algorithms



- Prevent Upstream Intersection Blocking

Adaptive Control Algorithms



- Input & Feedback to Adaptive Control Algorithms

York Region

- A ‘County’ in the Greater Toronto Area
- Population – 1 Million and fast growing
- 600+ signals
- Multi-protocol System (CTCS) - Supports 16 protocols on 4 controller brands
- Flexible communication supports leased lines, radio, 1xRTT, etc.

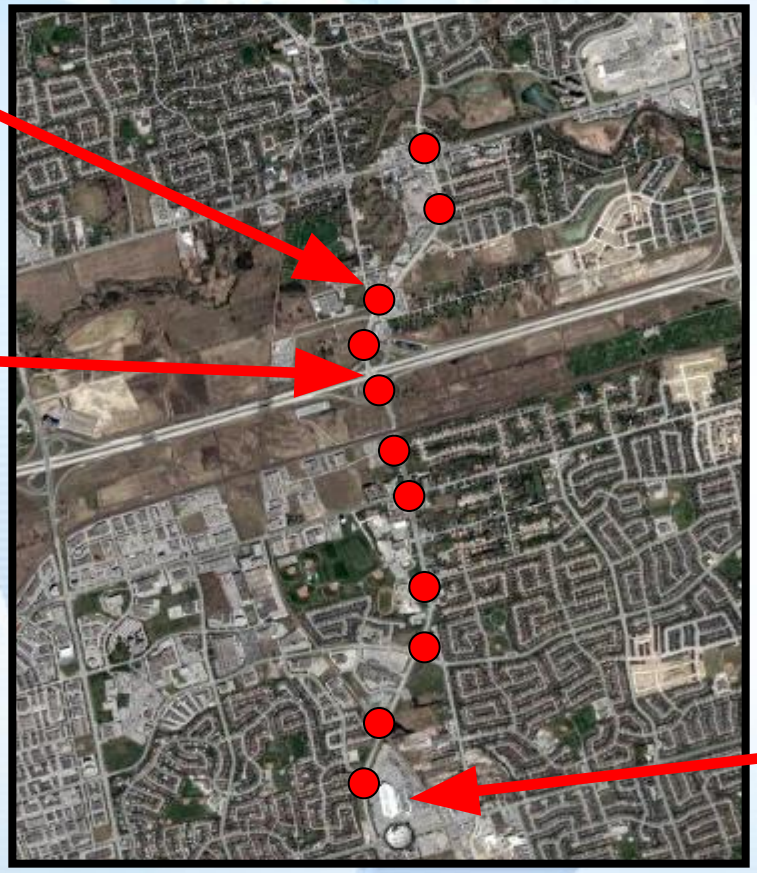
Region's System Objectives

- Accurately Predict Traffic Patterns and Optimize Signal Timings
- Use Cost-effective Vehicle Detectors
- Minimize Communications Dependency (wireless)
- Use Distributed, Open System Architecture
- Effectively Deal with Wide Range of Traffic Conditions
- Open to a variety of controllers and systems

Pilot Network Selection

Major Commuter Transit Parking

Highway Interchange



Major Shopping Centre

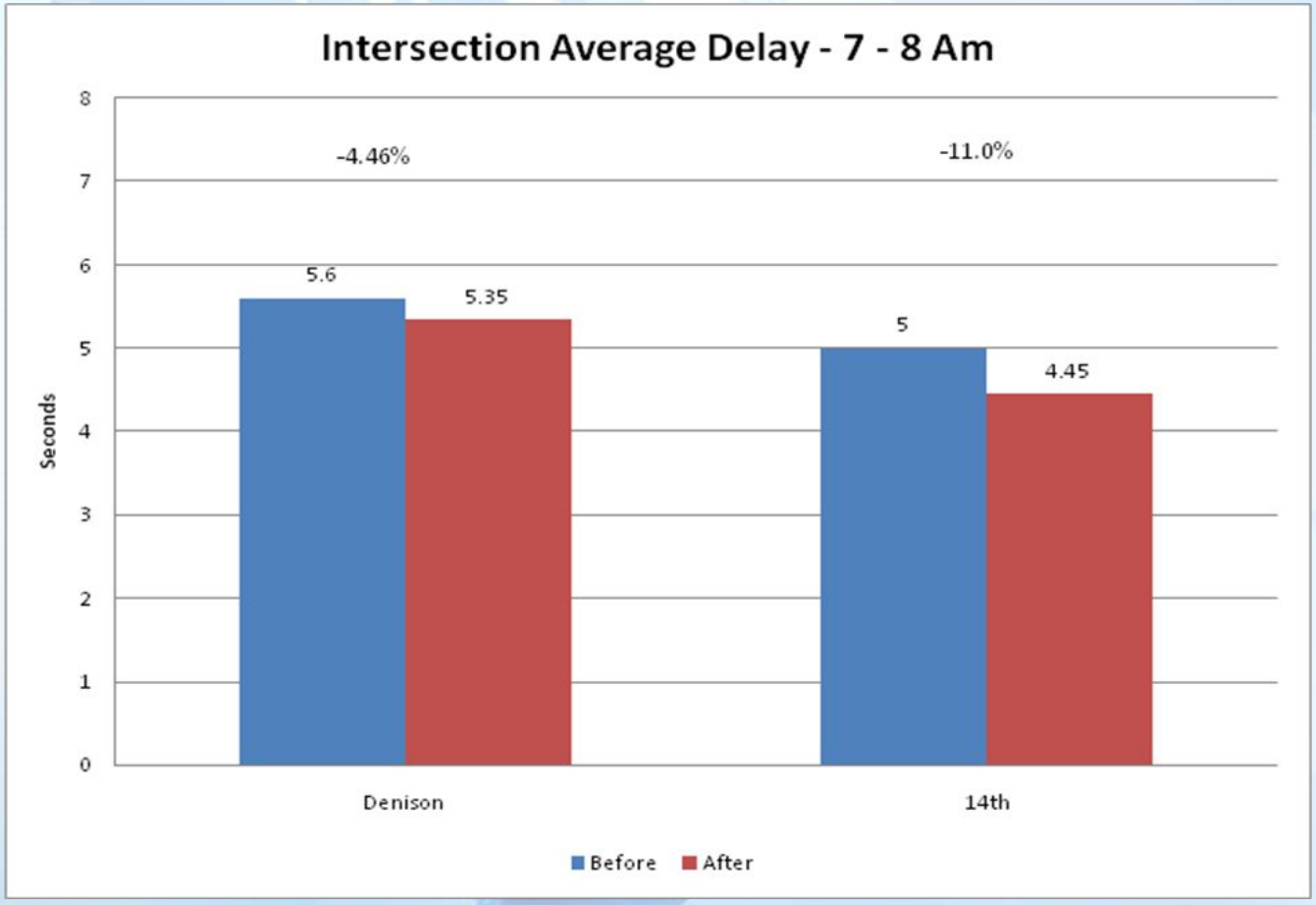
- 40,000 AADT
- 11 traffic control signals

System Assessment

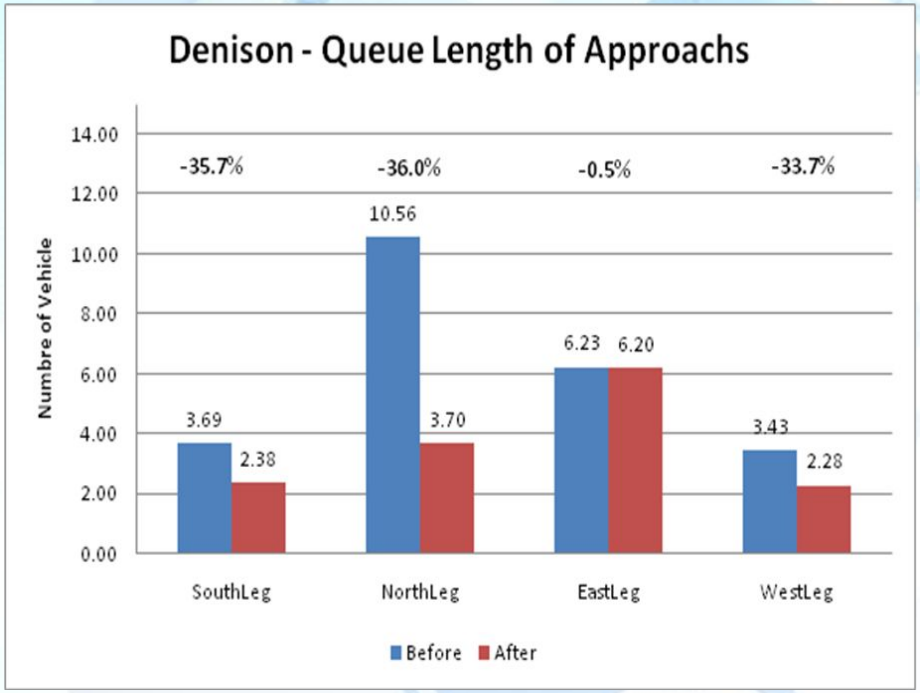
- Micro-simulation Test
  - AM Peak (Base Model)
  - Traffic Diversion From Highway 407
  - Incident, etc
- On-street System Evaluation
  - Conduct “Before & After” Study
  - Evaluate System Performance
    - Delay
    - Queue Length, etc

Micro-simulation Results – Delay Reduction

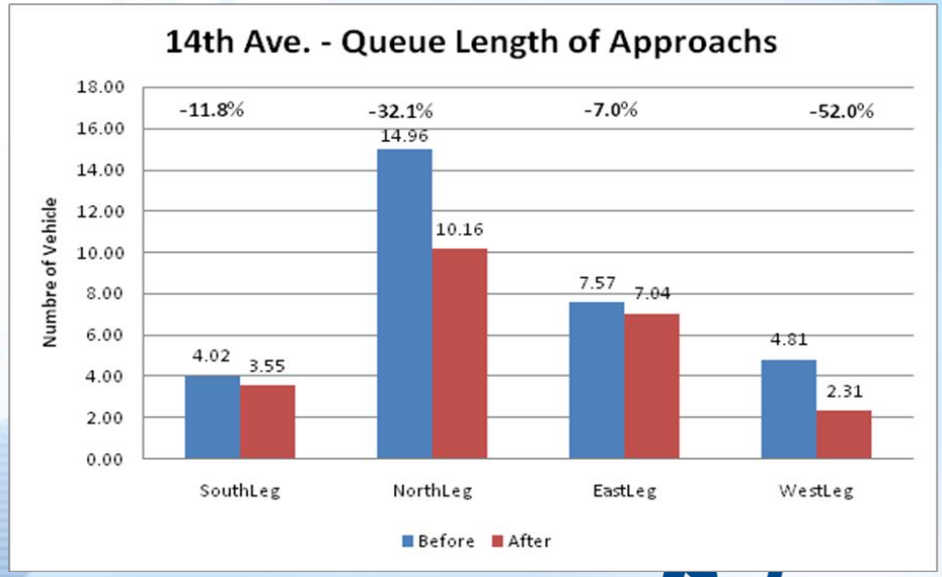
Intersection Average Delay Reduction up to 11%



Micro-simulation Results - Average Queue Lengths

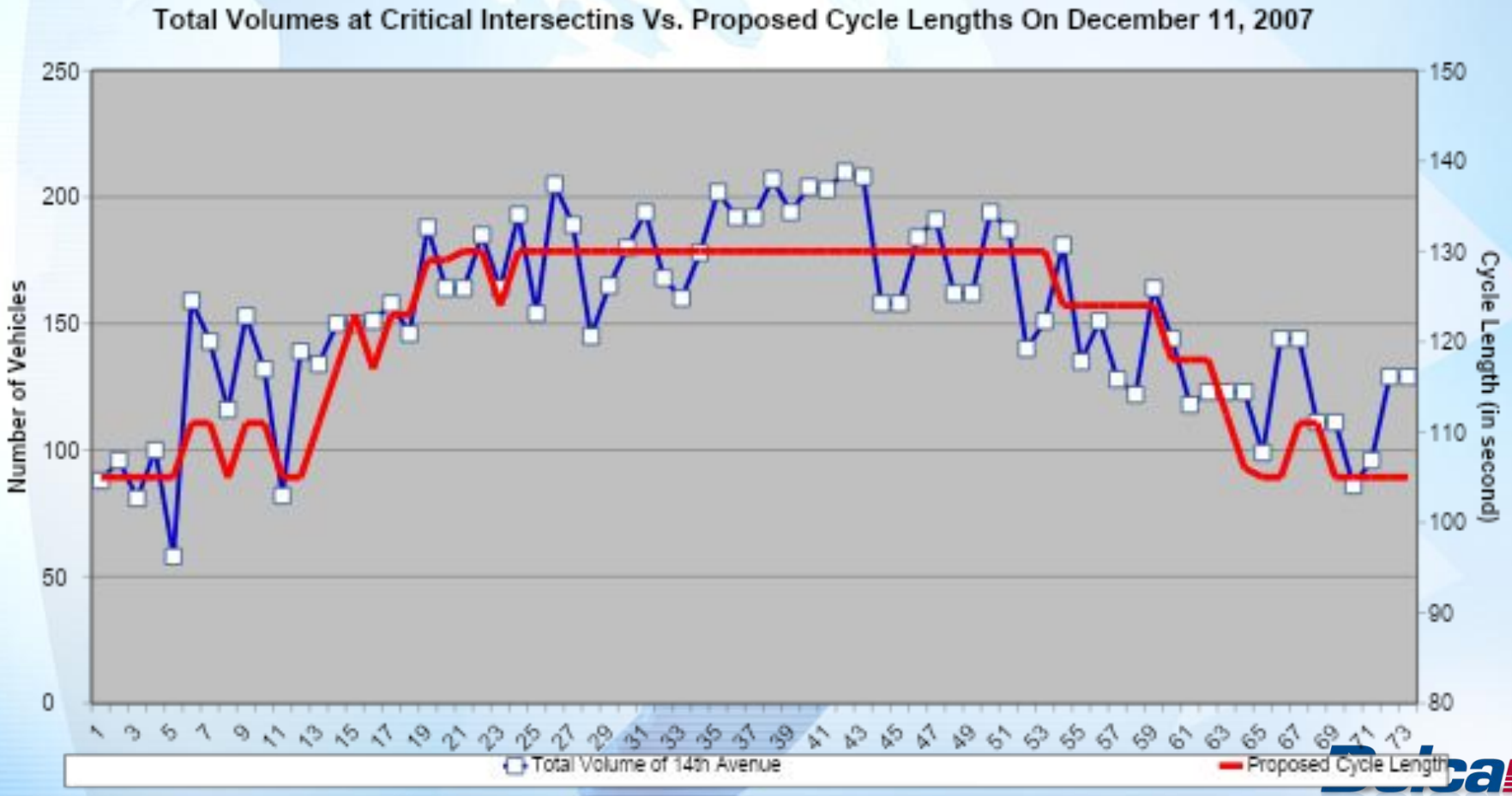


Consistent Reductions of Queue Lengths



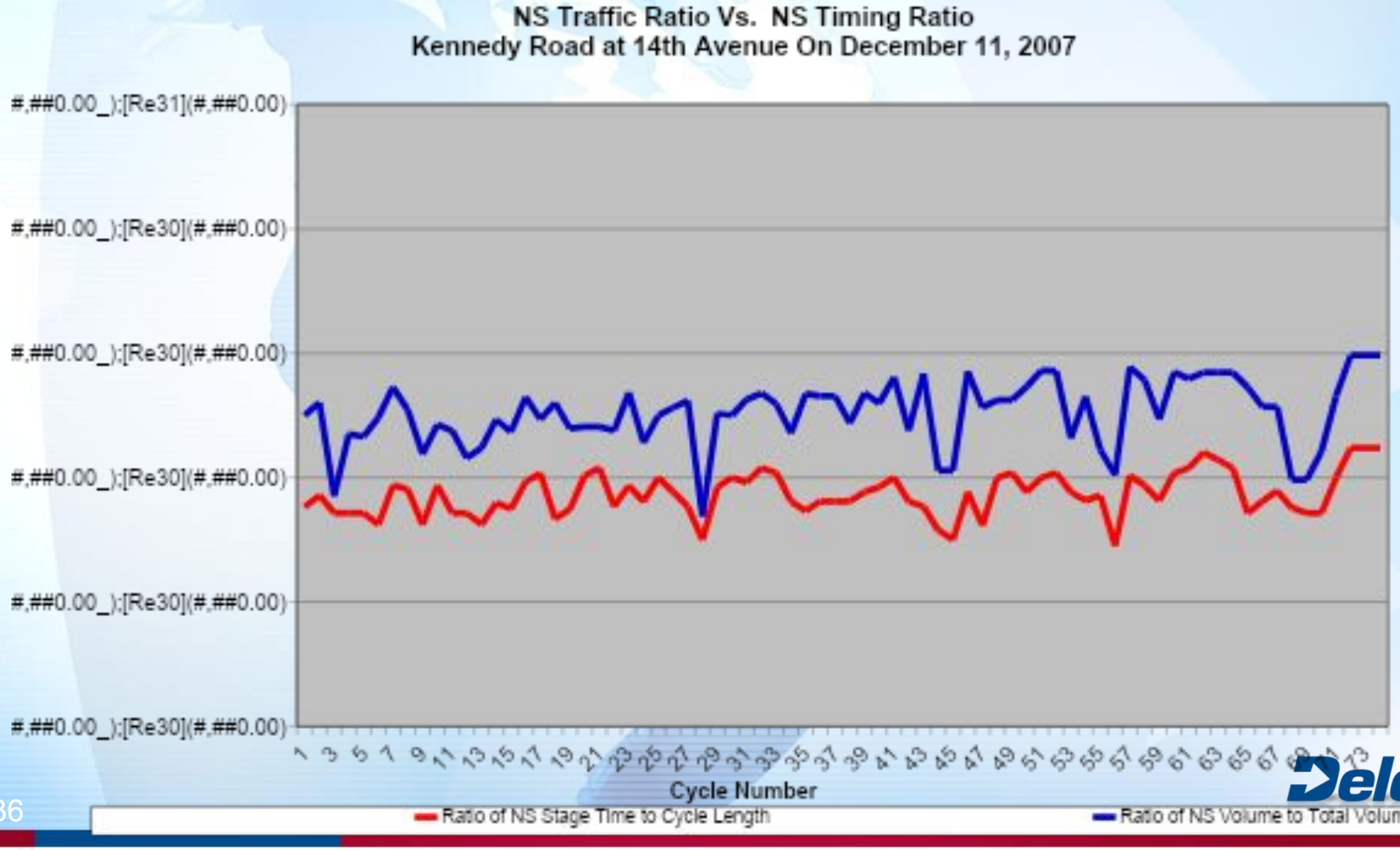
On-Street System Evaluation – Cycle Length

System Cycle Lengths Tracks Volume Trend



On-Street System Evaluation - Green Splits

Green Splits Track Traffic Volume Ratios



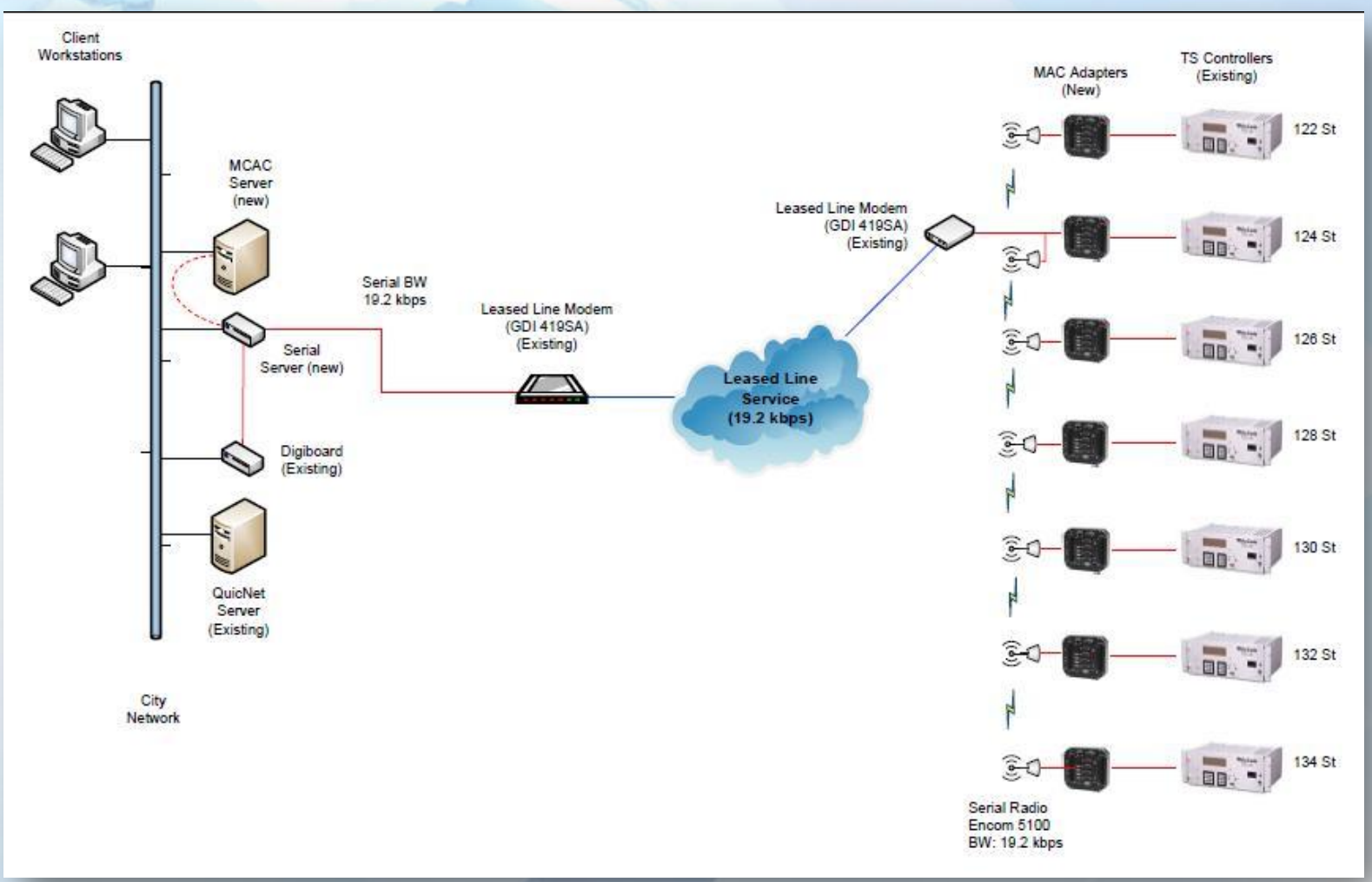
Conclusions of the Pilot Network Testing

- The open system architecture design provided for seamless integration of the adaptive traffic control package with the Region's existing CTCS
- The adaptive traffic control package was successfully integrated and proven to work with the Region's legacy signal controllers
- The use of 3G wireless data communications technology provided a reliable, sustainable and cost effective solution
- MAC performed well compared to the fixed-time operation

City of Surrey Implementation

- Test site -- 7 intersections along 72 Avenue in Surrey BC
- Average link distance = 2400 feet
- BI Tran 170 traffic signal controllers (serial communication protocol)
- QuickNet central system
- Central MAC server
- MAC adapters (one unit per intersection)
- Communication network (leased line + radio modems)

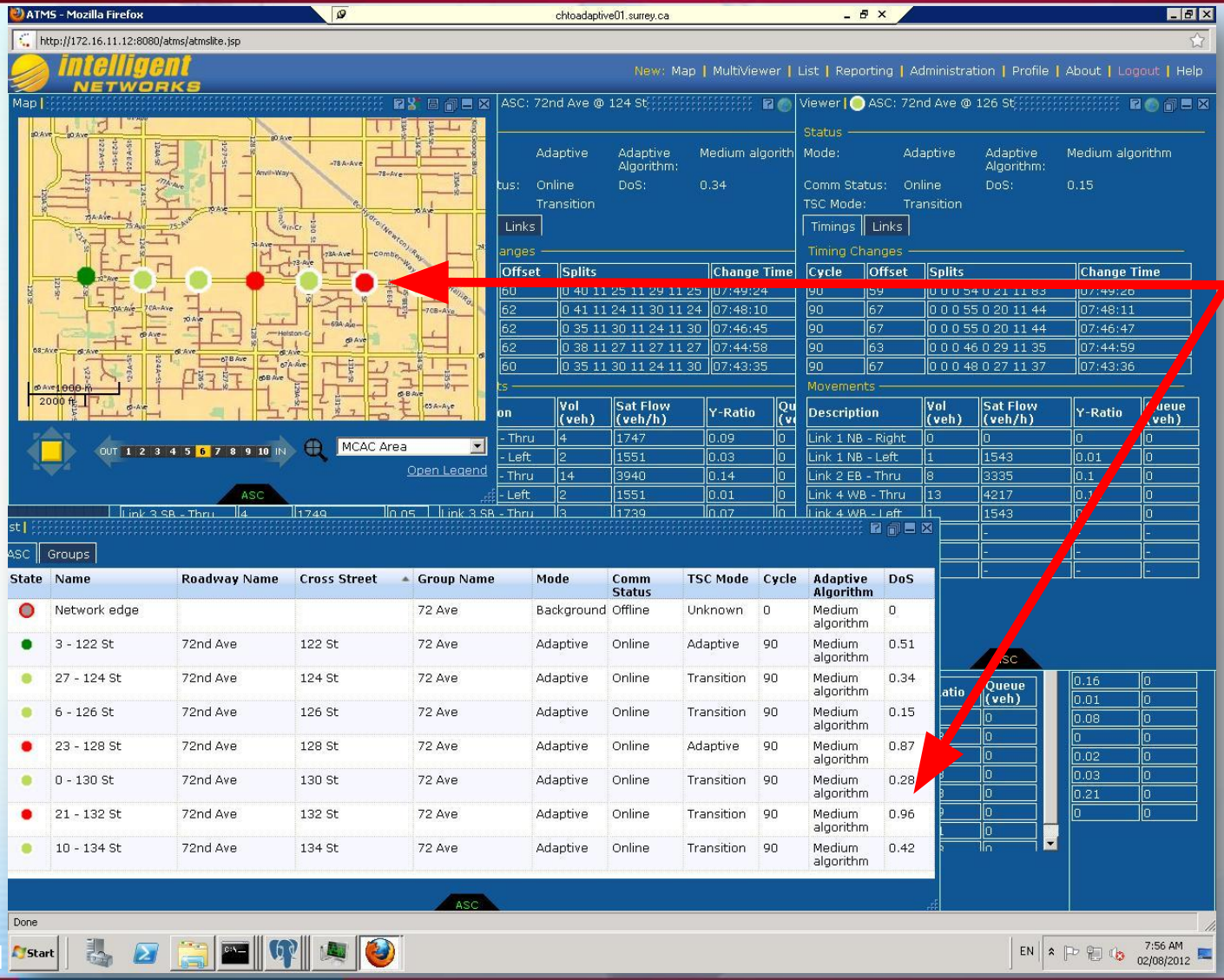
City of Surrey System Layout



City of Surrey – AM Peak Test

- Initial cycle parameter set implemented:
  - Algorithm: medium traffic
  - Cycle length: 90 seconds
  - Phase splits: 25 seconds EW / 40 seconds NS
- Peak cycle parameter set implemented at 8:35 AM
  - Algorithm: heavy traffic
  - Cycle length: 102 seconds
  - Phase splits: 35 seconds EW / 42 seconds NS
- Cycle length variation step: +/- 6 seconds

City of Surrey System - User Interface
AM Peak – 90 Seconds Cycle



Red colored symbols represent high degree of saturation values

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City of Surrey System - User Interface
AM Peak – 102 Seconds Cycle

ATMS - Mozilla Firefox — chtoadaptive01.surrey.ca

http://172.16.11.12:8080/atms/atmslite.jsp

intelligent NETWORKS

New: Map | MultiViewer | List | Reporting | Administration | Profile | About | Logout | Help

Map

MCAC Area

Open Legend

ASC

Light colors on the map symbolize low degree of saturation values reflecting the adaptive algorithm efficiency

List

ASC | Groups

State	Name	Roadway Name	Cross Street	Group Name	Mode	Comm Status	TSC Mode	Cycle	Adaptive Algorithm	DoS
	Network edge			72 Ave	Background	Offline	Unknown	0	Heavy algorithm	0
	3 - 122 St	72nd Ave	122 St	72 Ave	Adaptive	Online	Transition	102	Heavy algorithm	0.36
	27 - 124 St	72nd Ave	124 St	72 Ave	Adaptive	Online	Transition	102	Heavy algorithm	0.49
	6 - 126 St	72nd Ave	126 St	72 Ave	Adaptive	Online	Transition	102	Heavy algorithm	0.34
	23 - 128 St	72nd Ave	128 St	72 Ave	Adaptive	Online	Transition	102	Heavy algorithm	0.77
	0 - 130 St	72nd Ave	130 St	72 Ave	Adaptive	Online	Adaptive	102	Heavy algorithm	0.25
	21 - 132 St	72nd Ave	132 St	72 Ave	Adaptive	Online	Adaptive	102	Heavy algorithm	0.53
	10 - 134 St	72nd Ave	134 St	72 Ave	Adaptive	Online	Transition	102	Heavy algorithm	0.28

ASC

Done

Start

EN 8:34 AM 02/08/2012

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City of Surrey System – PM Peak

- Illustrative example of efficient management of heavy traffic during special events using adaptive control

- Test Case: Surrey 2 August, 2012
  - PM peak extended by Ramadan celebration
  - Mosque located close to one of the test intersections

- Traffic detected: from 35 vehicles / cycle (at 90 sec.)
  to 110 vehicles / cycle (at 120 sec.)

City of Surrey System – PM Peak

- Test conducted between 3:00 PM and 8:30 PM
- Initial cycle parameter set implemented:
  - Algorithm: medium traffic
  - Cycle length: 90 seconds
  - Phase splits: 20 seconds EW / 45 seconds NS
- Peak cycle parameter set implemented at 5:35 PM
  - Algorithm: heavy traffic
  - Cycle length: 120 seconds
  - Phase splits: 45 seconds EW / 43 seconds NS
- Cycle length variation step: +/- 6 seconds

City of Surrey System - User Interface
PM Peak – 120 Seconds Cycle

ATMS - Mozilla Firefox — chtoadaptive01.surrey.ca

http://172.16.11.12:8080/atms/atmslite.jsp

intelligent NETWORKS

Map

Viewer | ASC: 72nd Ave @ 122 St

Status

Mode:	Adaptive	Adaptive Algorithm:	Medium algorithm
Comm Status:	Online	DoS:	0.77
TSC Mode:	Transition		

Timings | Links

Timing Changes

Cycle	Offset	Splits	Change Time
114	21	0 45 11 43 20 25 11 43	17:30:53
114	25	0 45 11 43 20 25 11 43	17:28:33
114	21	0 45 20 34 20 25 20 34	17:26:47
108	17	0 45 20 28 20 25 20 28	17:24:03

Movements

Description	Vol (veh)	Sat Flow (veh/h)	Y-Ratio	Queue (veh)
Link 1 NB - Thru	3	1739	0.05	0
Link 1 NB - Left	2	1551	0.03	0
Link 2 EB - Thru	47	8127	0.18	0
Link 2 EB - Left	2	1551	0	0
Link 3 SB - Thru	15	1749	0.21	0
Link 3 SB - Left	19	1551	0.39	0
Link 4 WB - Thru	28	5103	0.17	0
Link 4 WB - Left	10	2398	0.05	0

Viewer | ASC: 72nd Ave @ 128 St

Status

Mode:	Adaptive	Adaptive Algorithm:	Medium algorithm
Comm Status:	Online	DoS:	0.64
TSC Mode:	Transition		

Timings | Links

Cycle	Offset	Splits	Change Time
120	52	11 29 11 51 11 29 11 51	17:32:46
114	52	20 34 11 31 20 34 11 31	17:30:58
114	52	11 60 11 21 11 60 11 [illegible]	17:28:38
114	52	11 38 11 36 11 38 11 36	17:26:53
114	52	11 24 11 50 11 24 11 50	17:25:05

Movements

Description	Vol (veh)	Sat Flow (veh/h)	Y-Ratio	Queue (veh)
Link 1 NB - Thru	19	3477	0.17	0
Link 1 NB - Left	6	1442	0.04	0
Link 2 EB - Thru	58	5734	0.32	0
Link 2 EB - Left	1	1532	0	0
Link 3 SB - Thru	20	3601	0.18	0
Link 3 SB - Left	4	1562	0.02	0
Link 4 WB - Thru	42	4687	0.28	0

Viewer | ASC: 72nd Ave @ 132 St

Status

Mode:	Adaptive	Adaptive Algorithm:	Mediu algorithm
Comm Status:	Online	DoS:	0.72
TSC Mode:	Transition		

Timings | Links

120	7	11 47 11 33 11 47 11 33	17:32 49
114	5	11 38 11 36 11 38 11 36	17:31 02
114	111	11 40 11 34 11 40 11 34	17:28 43
114	5	15 41 11 29 15 41 11 29	17:26 56
114	111	13 31 11 41 13 31 11 41	

Movements

Description	Vol (veh)	Sat Flow (veh/h)
Link 1 NB - Right	0	0
Link 1 NB - Thru	15	2915
Link 1 NB - Left	3	1550
Link 2 EB - Thru	36	4962
Link 2 EB - Left	4	1551
Link 3 SB - Thru	17	1660
Link 3 SB - Left	5	1533
Link 4 WB - Thru	36	6388

List | ASC | Groups

State	Name									
	Network edge			72 Ave	Background	Offline	Unknown	0	Medium algorithm	0
	3 - 122 St	72nd Ave	122 St	72 Ave	Adaptive	Online	Transition	120	Medium algorithm	0.77
	7 - 124 St	72nd Ave	124 St	72 Ave	Adaptive	Online	Transition	114	Medium algorithm	0.61
	6 - 126 St	72nd Ave	126 St	72 Ave	Adaptive	Online	Adaptive	114	Medium algorithm	0.44
	23 - 128 St	72nd Ave	128 St	72 Ave	Adaptive	Online	Transition	114	Medium algorithm	0.64
	0 - 130 St	72nd Ave	130 St	72 Ave	Adaptive	Online	Transition	114	Medium algorithm	0.3
	21 - 132 St	72nd Ave	132 St	72 Ave	Adaptive	Online	Transition	114	Medium algorithm	0.72
	10 - 134 St	72nd Ave	134 St	72 Ave	Adaptive	Online	Adaptive	114	Medium algorithm	0.52

Done

Start | EN | 5:34 PM 02/08/2012

Light colors symbolize low degree of saturation values reflecting the adaptive algorithm efficiency

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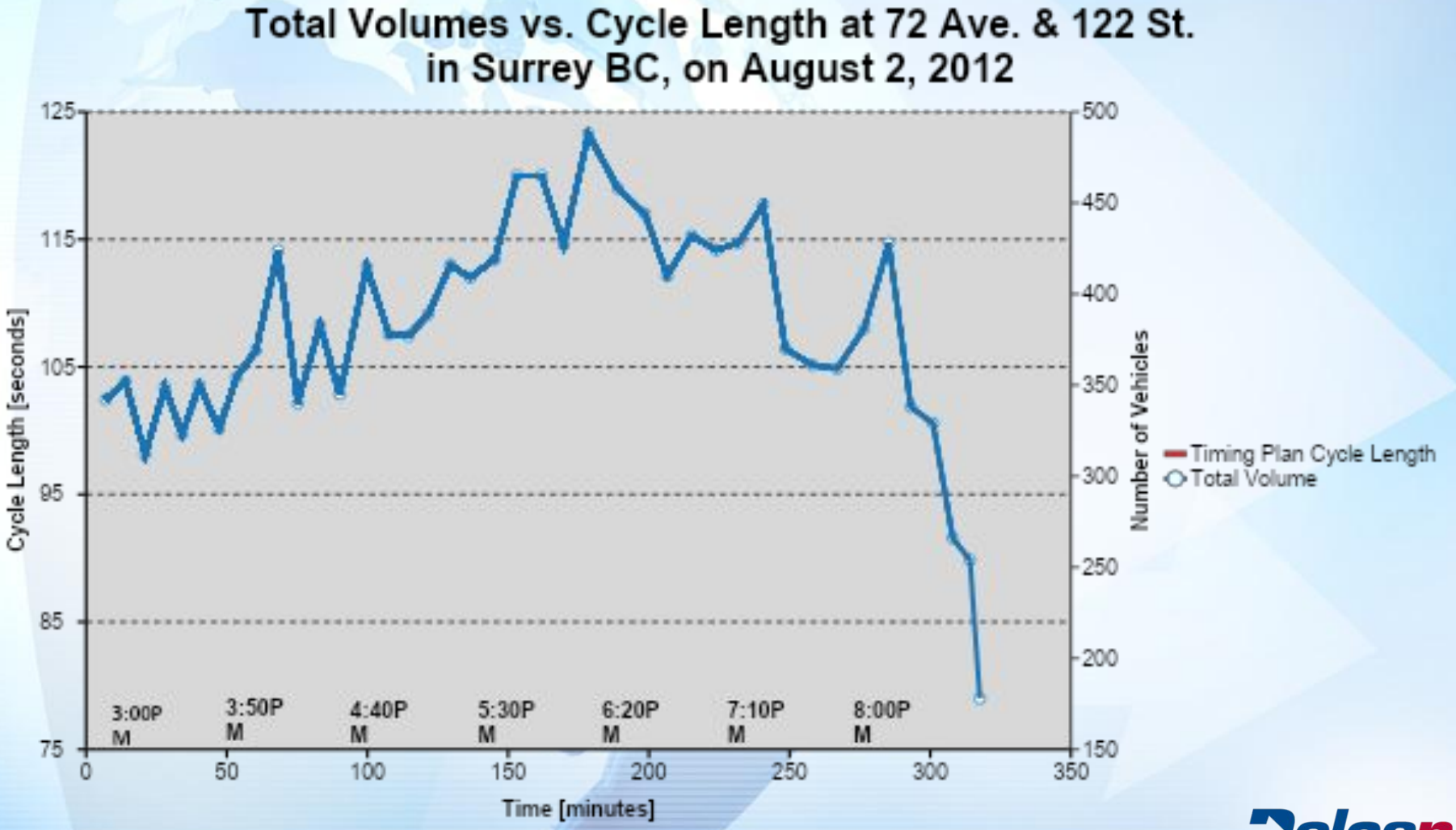
City of Surrey System – PM Peak



City of Surrey System

- AM And PM Peak Test Conclusions:
  - Adaptive control efficiently managed the traffic in
    - Normal conditions (AM peak interval)
    - Exceptional conditions (PM peak interval + Ramadan event)
  - Adaptive control extended cycle lengths and phase splits ensuring
    - Smooth traffic flow
    - No residual queues at end of cycles under heavy traffic conditions

Key Benefits of Delcan MAC System

- Smooth integration with existing legacy systems
- Management of oversaturated and gridlocked traffic (as well as heavy traffic)
- Multi-protocol interface and ability to work with multiple controller manufacturers/types
- Flexible (and minimal) detector requirements
- Low data transmission requirements (and hence low communications cost ~ 70% reduction)
- Robust and highly efficient communications scheme – supports a variety of wireless technologies

Questions and Answers

For further information, please contact:

Joseph Lam
j.lam@delcan.com

THANK YOU

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