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A Practical Application of Artificial Intelligence in Traffic Responsive Signal Control

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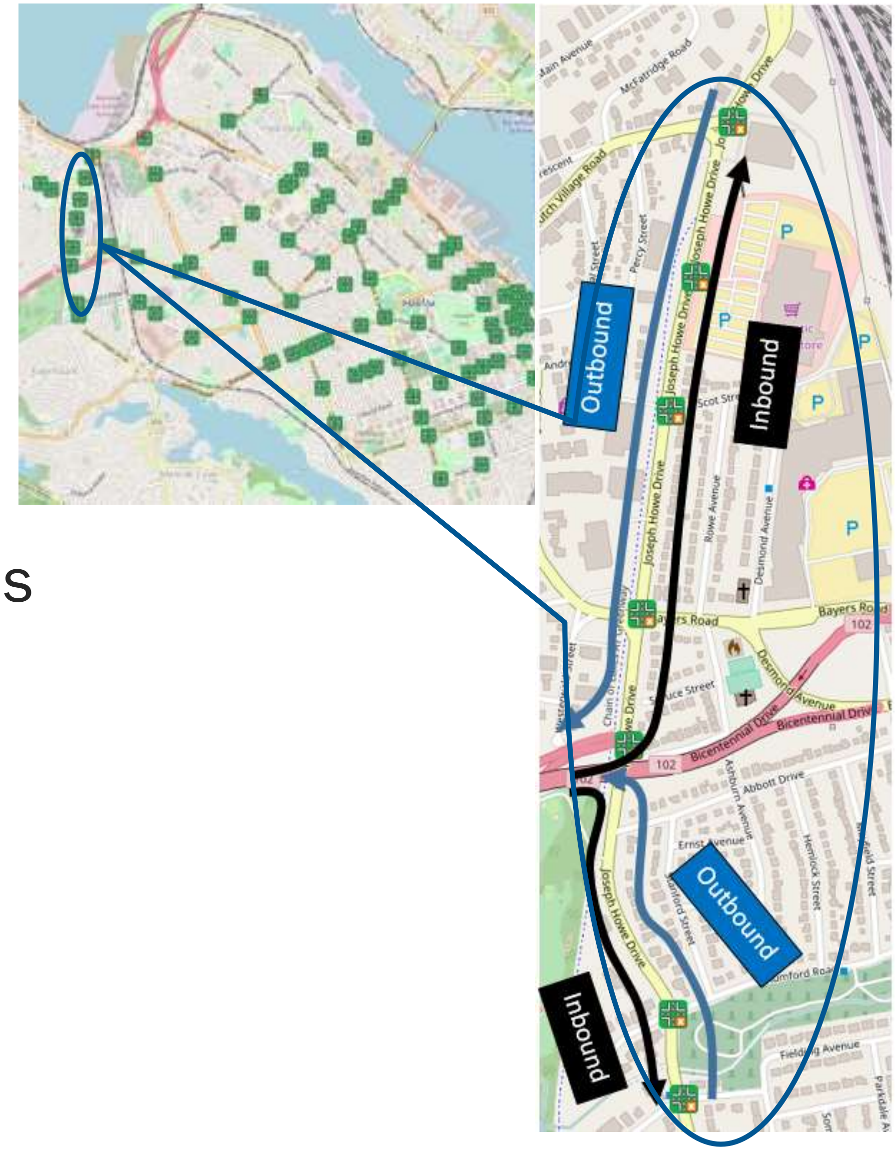
Presentation Objectives

- Review a representative responsive control area
- Explain how baseline reference traffic conditions are maintained to inform responsive decision making
- Explain how simulated reasoning (AI) is being applied to select traffic responsive signal timing patterns
- Describe how system stability and feedback control is achieved
- Present a case study illustrating a typical response scenario
- Discuss current and planned deployments

Responsive Control Area

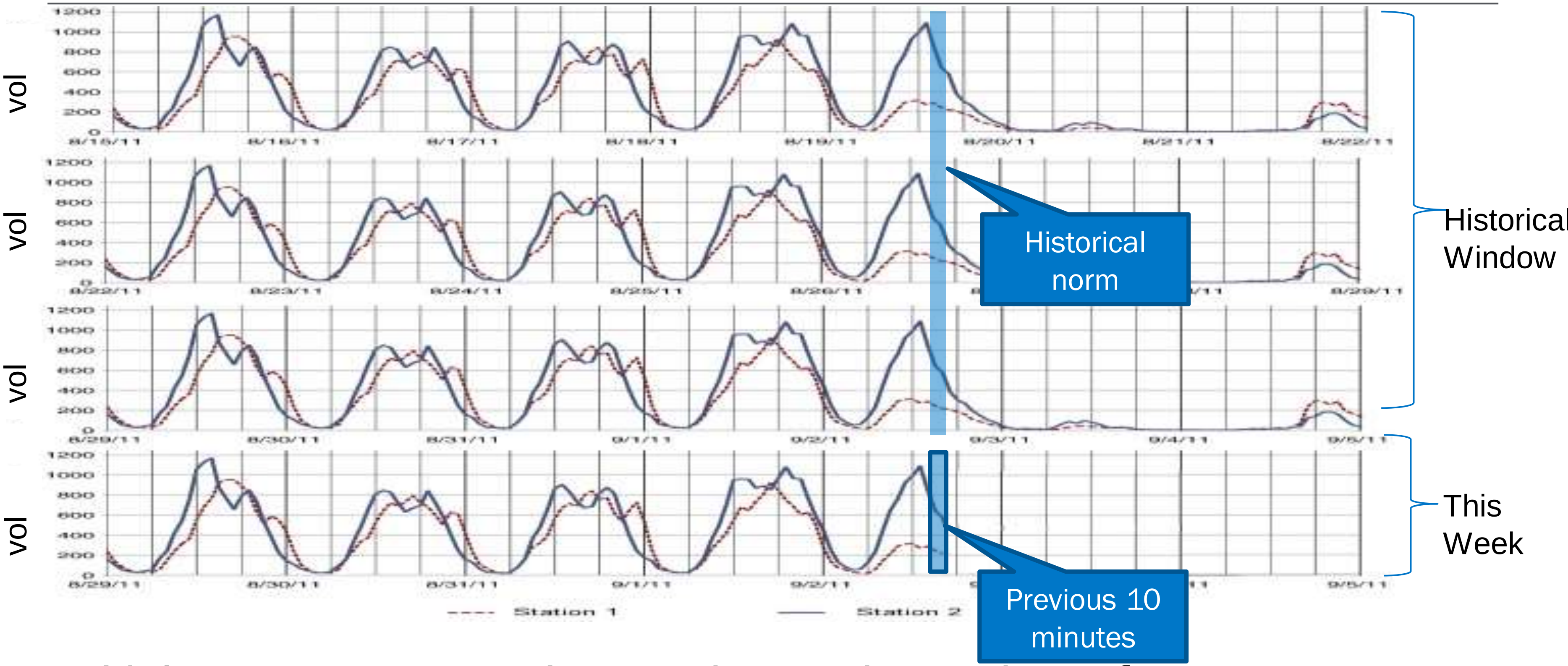
- Halifax, Nova Scotia
- 7 Signals on Joseph Howe Drive between Springvale Ave and Dutch Village Rd
- "Coordination corridor" with high volumes, several major intersections and ramp signals
- Connects alternate routes entering and leaving the downtown area
- Therefore, traffic is heavily affected by incidents on the adjoining highways and crossing arterials



Sensor Stations

- Four strategically-placed stations; two in each direction
- Placed to capture flows exiting the intersection, upstream of the normal back of queue
- Microwave technology

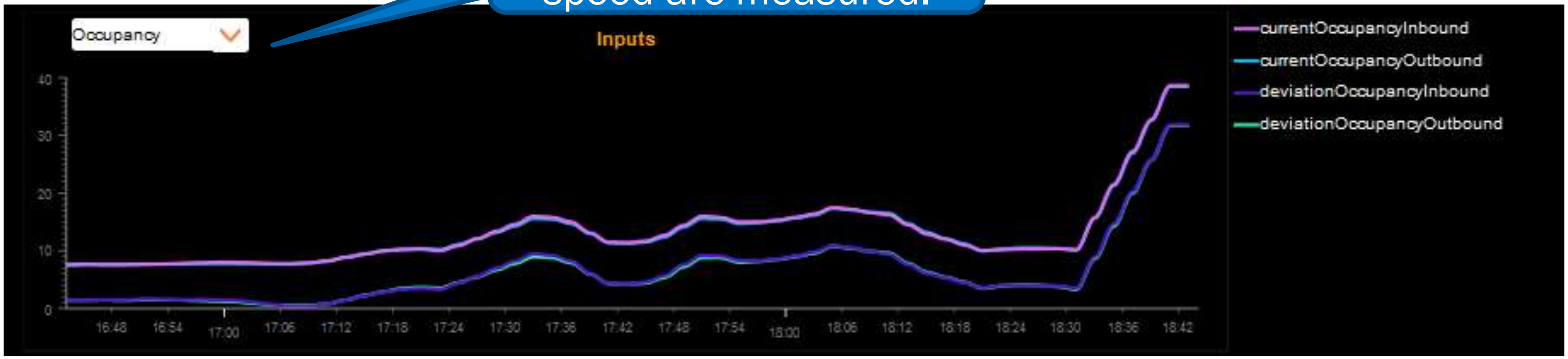
Establishing Baseline Traffic Conditions



- Volumes, occupancies, and speeds are kept for a configurable historical window (set to 12 weeks) representing baseline conditions
- Current conditions are compared to the baseline to identify non-recurrent congestion

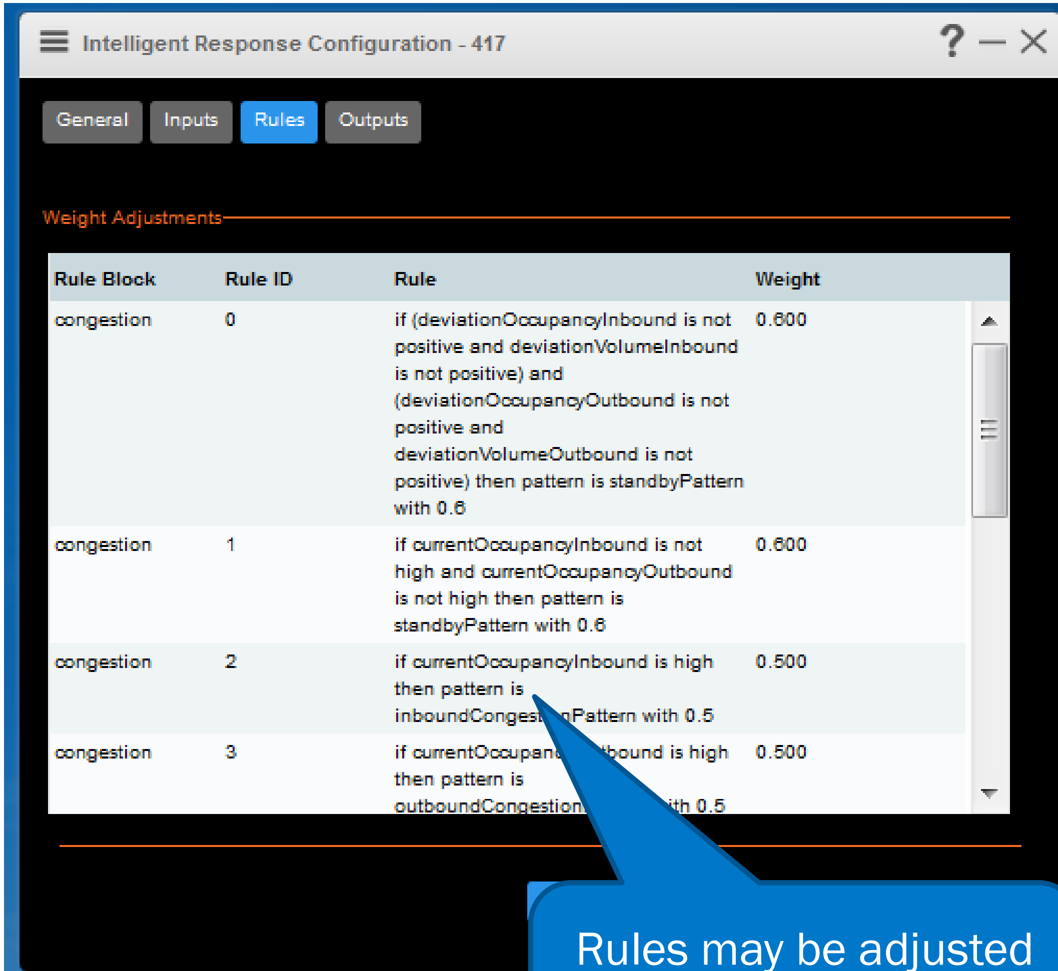
Measuring Inputs

Volume, occupancy and speed are measured.



- Each intersection and assesses its own measured traffic conditions and their deviation from the historical norm
- Large positive deviations between the current volume and occupancy and the historical baseline indicate non-recurrent congestion
- If non-recurrent congestion is identified, actual volumes and occupancies are then used to determine the pattern to run
- Groups of intersections will respond in unison to the extent that they share stations (allows for flexible grouping)

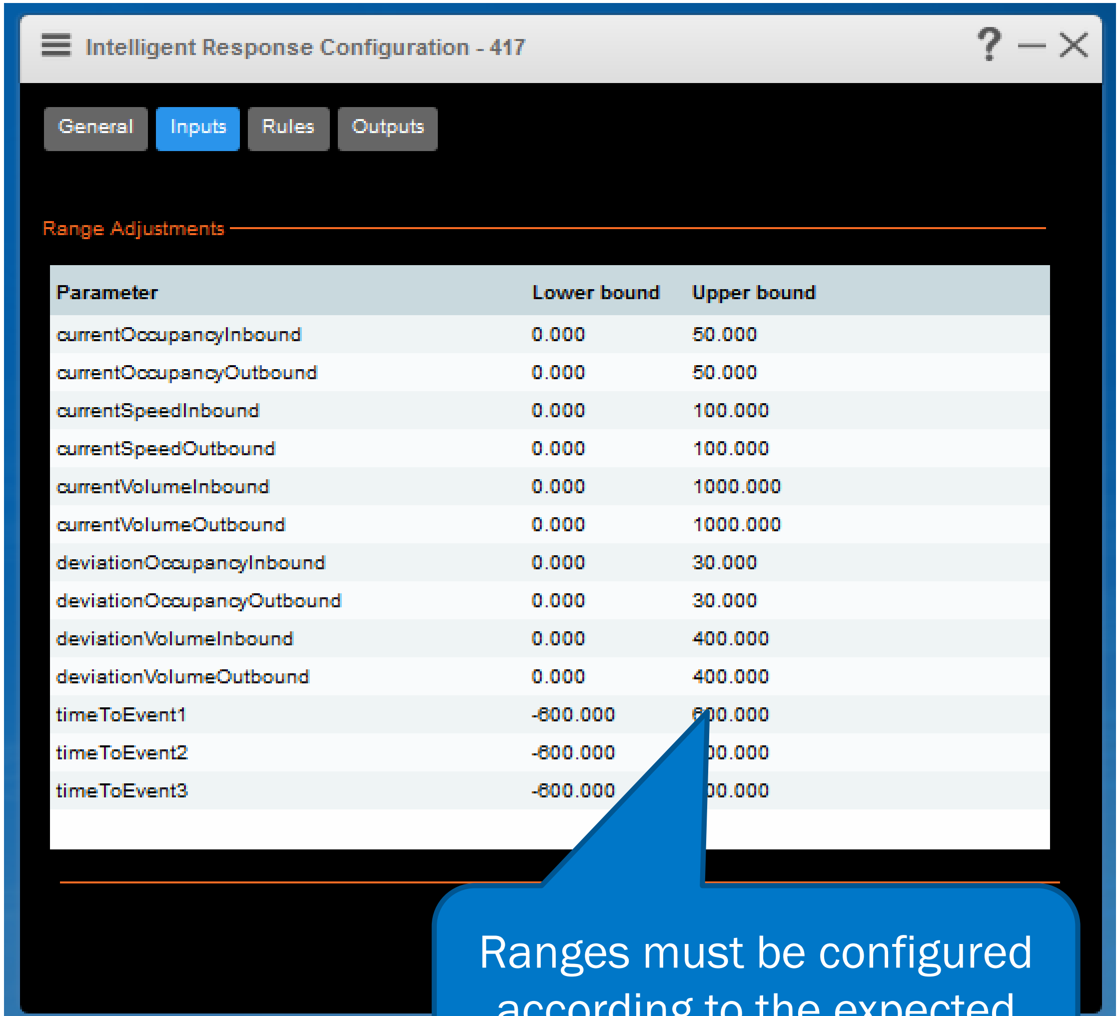
Response Plan Generation Using Expert Rules



Rules may be adjusted to suit agency objectives.

- Capture the relevant traffic engineering knowledge
- First rule maintains the local TOD pattern if there is no positive deviation from the historical norm
- Second rule maintains local TOD pattern if neither volume nor occupancy indicate congestion
- Remaining rules select the pattern according to the conditions

Expert Rule Inputs

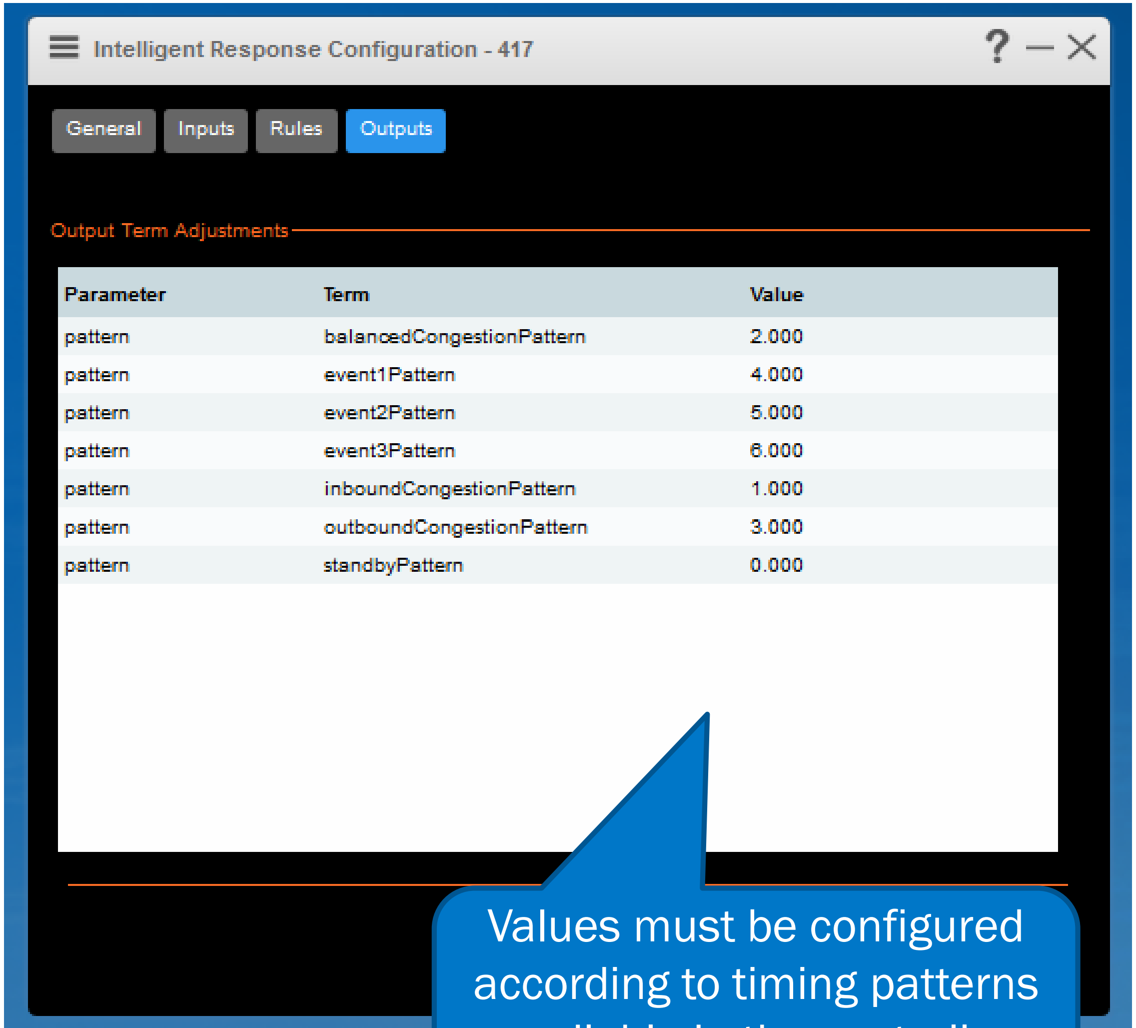


Parameter	Lower bound	Upper bound
currentOccupancyInbound	0.000	50.000
currentOccupancyOutbound	0.000	50.000
currentSpeedInbound	0.000	100.000
currentSpeedOutbound	0.000	100.000
currentVolumeInbound	0.000	1000.000
currentVolumeOutbound	0.000	1000.000
deviationOccupancyInbound	0.000	30.000
deviationOccupancyOutbound	0.000	30.000
deviationVolumeInbound	0.000	400.000
deviationVolumeOutbound	0.000	400.000
timeToEvent1	-600.000	600.000
timeToEvent2	-600.000	[illegible]00.000
timeToEvent3	-600.000	[illegible]00.000

Ranges must be configured according to the expected range of measurements.

- Ranges are used to convert numeric measurements (in % or vph) to degrees of membership in a class (positive, high, etc.)
- This form is required to be able to evaluate the rules

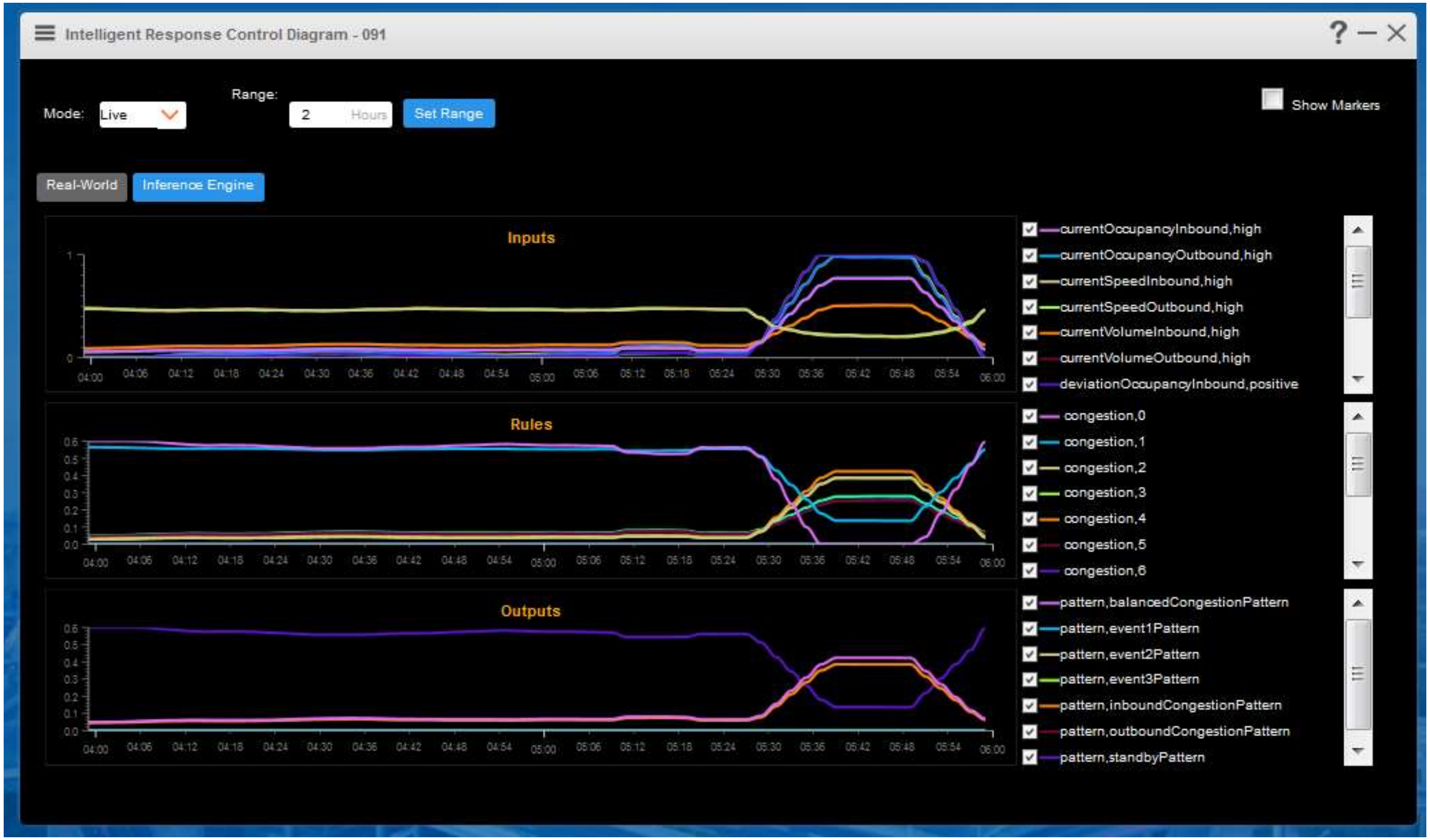
Expert Rule Outputs



Values must be configured according to timing patterns available in the controller unit.

- Values are used to convert rule outcomes (e.g., outboundCongestionPattern) into pattern numbers to be applied at the intersection

Explainable Decisions

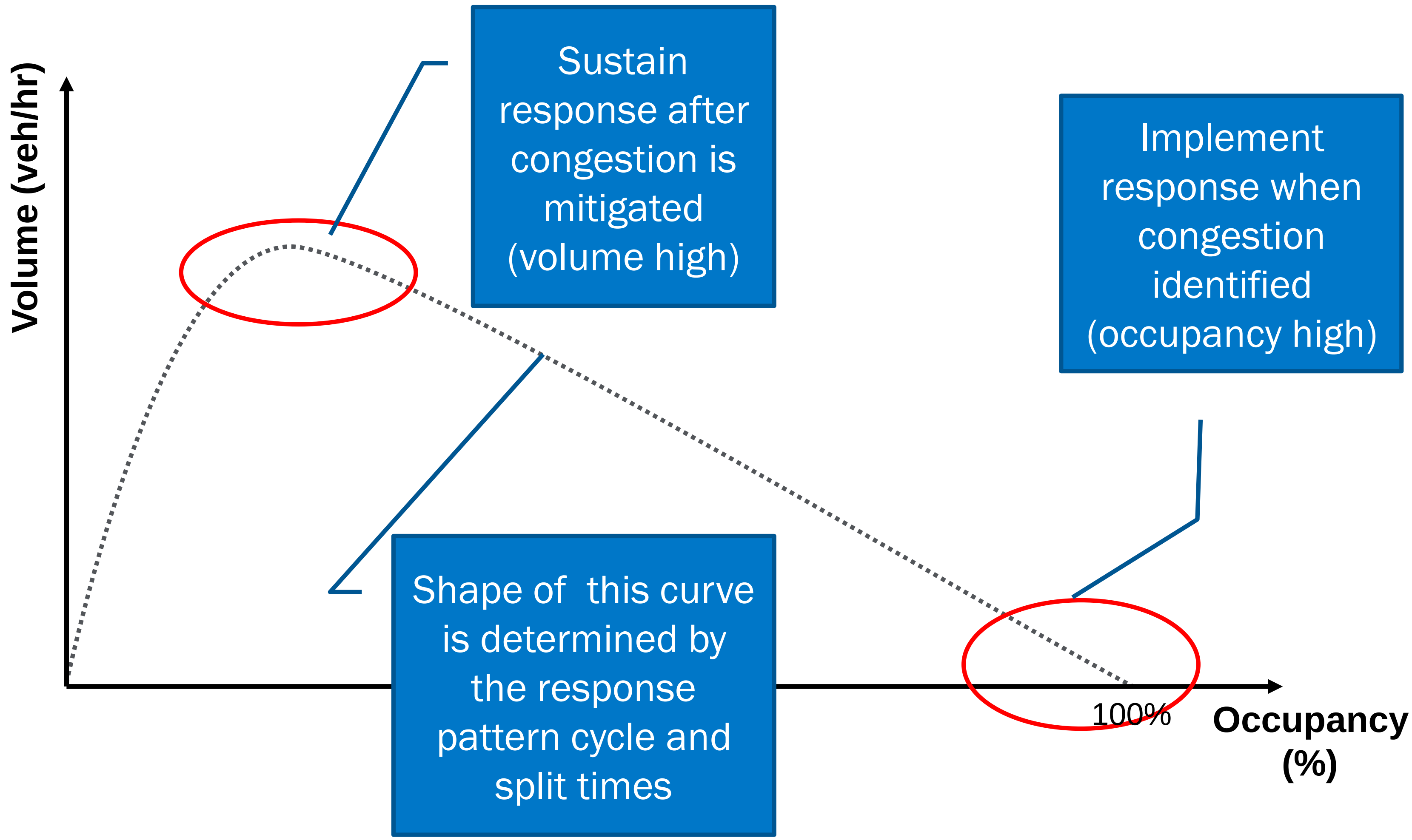


- A complete history of all responsive pattern decisions is maintained, along with the corresponding input and rule activations that went into each decision

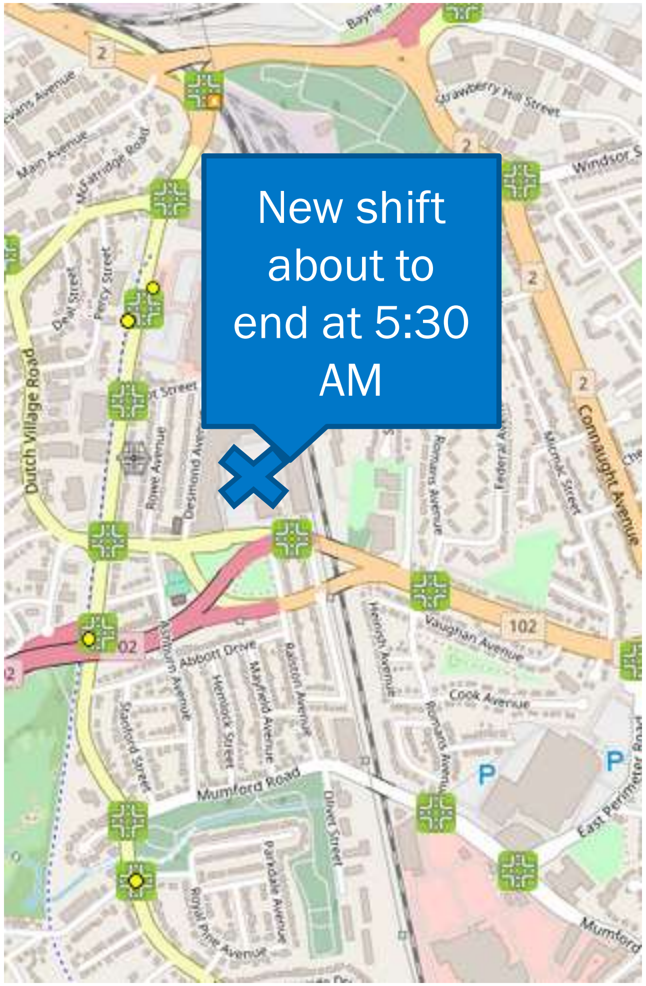
Stability and Feedback Control

- Basic stability is achieved through smoothing of sensor data, applying a persistence threshold before activating a pattern, and enforcing a minimum activation time once a pattern is activated
- If effective, activating a responsive pattern will reduce congestion in the applicable control area
- This reduction in congestion could feed back into the system through the sensors and cause the pattern to be removed too early only to be reactivated again once congestion returns
- This problem is addressed in our rule base by responding to both high volumes and high occupancies

Achieving Feedback Control using Volume and Occupancy

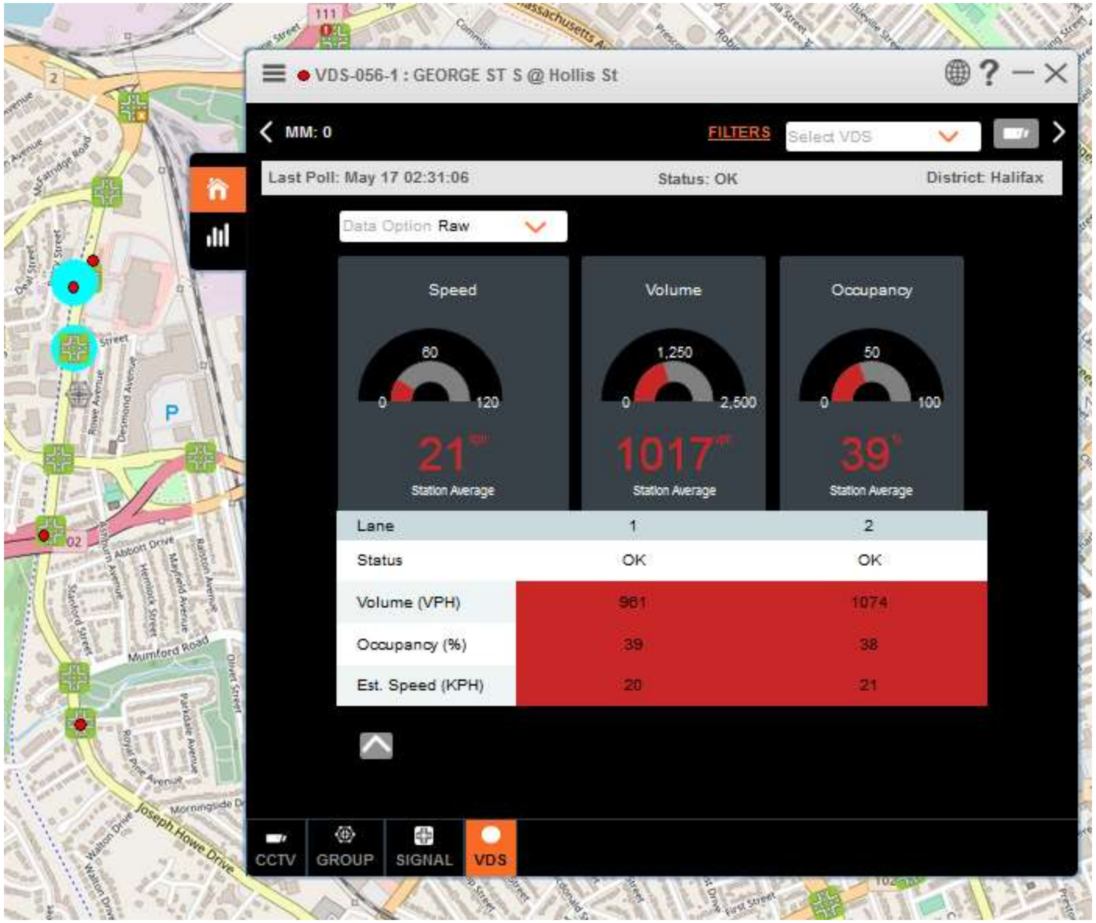


Case Study



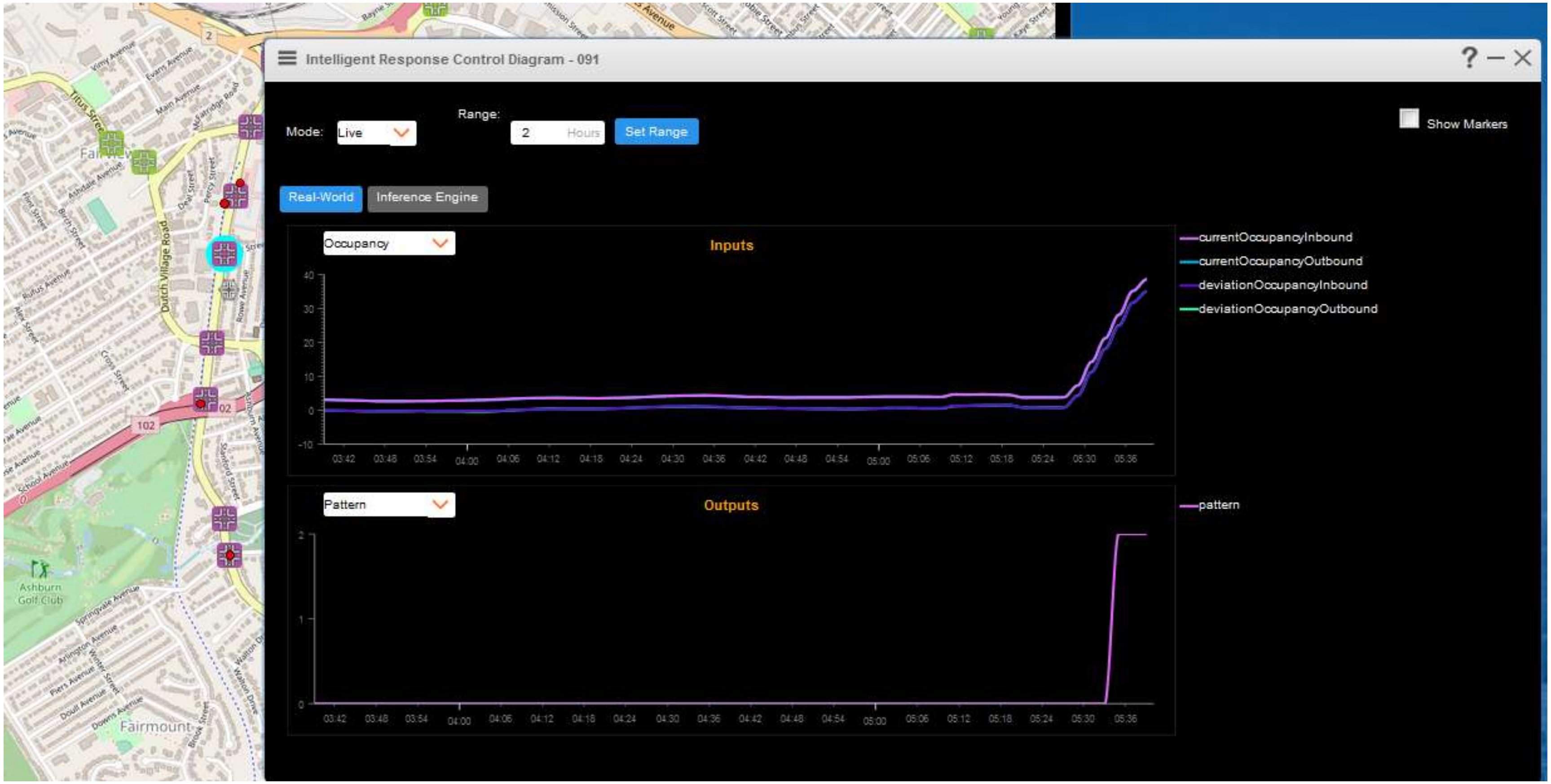
- A nearby successful business east of the control area adds a new shift resulting in a short-term heavy demand on Joseph Howe Drive in both directions when the shift ends in the early morning
- Initially, intersections are running free with sensors detecting no congestion

Start of Congestion



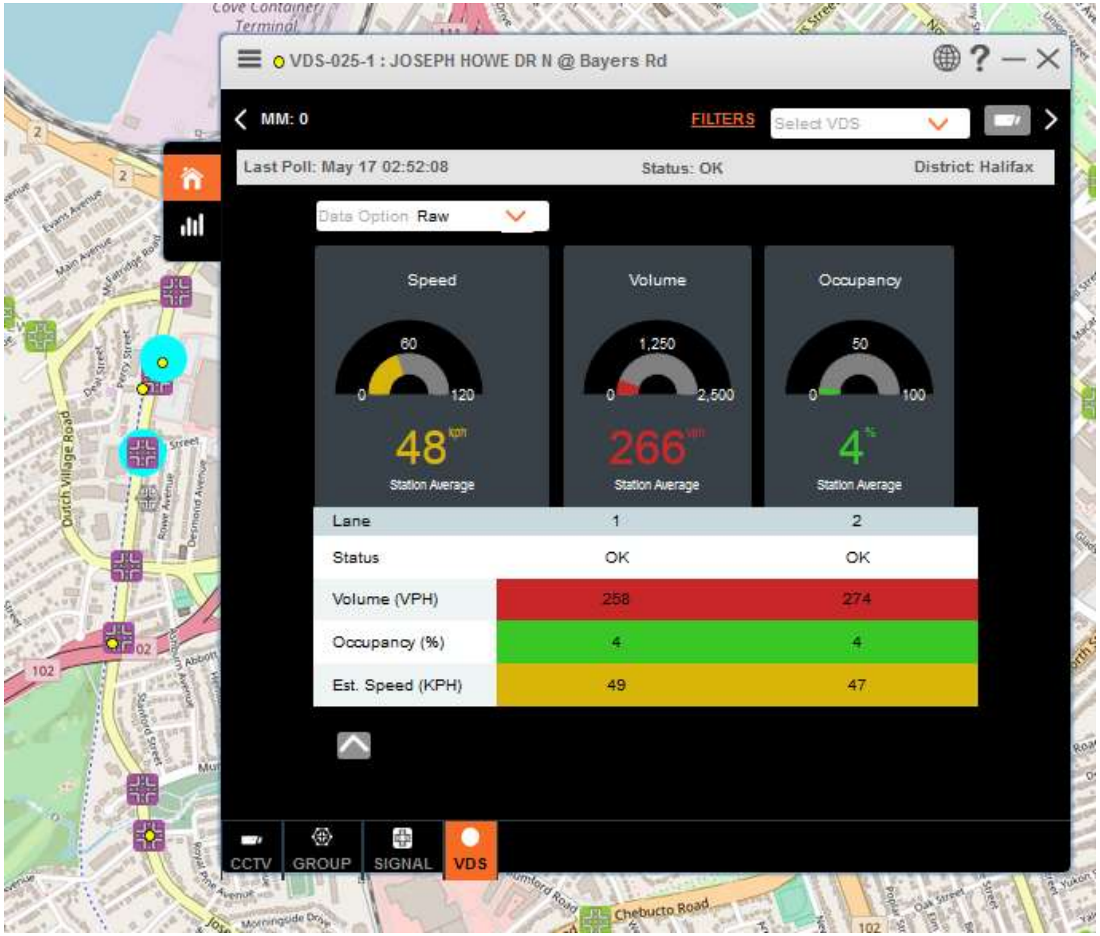
- Within a short time, congestion begins to build at the sensors within the control area

Start of Response



- Within 5 minutes, an appropriate response pattern is activated at all intersections

End of Congestion



- After 20 minutes, congestion begins to subside at the sensors within the control area

End of Response

- Within 5 minutes, all intersections are once again running free

Some Current and Planned Deployments

- Region of Halifax – One control area (7 intersections) currently in operation with more detectorized areas in the process of "learning" traffic conditions. Halifax and Parsons are currently reviewing Halifax' operational experience with the system for a future presentation (stay tuned).
- City of Mississauga – Two adjacent control areas (7 and 6 intersections) with detector installation currently in progress.
- Macau (China) – Two crossing control areas (7 and 3 intersections) with detector technology evaluation and selection currently underway

Takeaways

- “Intelligent Response” self-calibrates by continuously re-learning baseline traffic conditions as they evolve over time
- The system uses simulated reasoning (AI) to select signal timing patterns in response to non-recurrent congestion
- The form of AI used results in decisions that are fully explainable and auditable
- By using both volume and occupancy to identify congestion, the system manages feedback in a stable manner
- The system can respond by activating a new pattern or by extending the existing TOD pattern in response to conditions
- System is currently in operation at several control areas in the Region of Halifax, with new deployments underway in the City of Mississauga and in Macau (China).

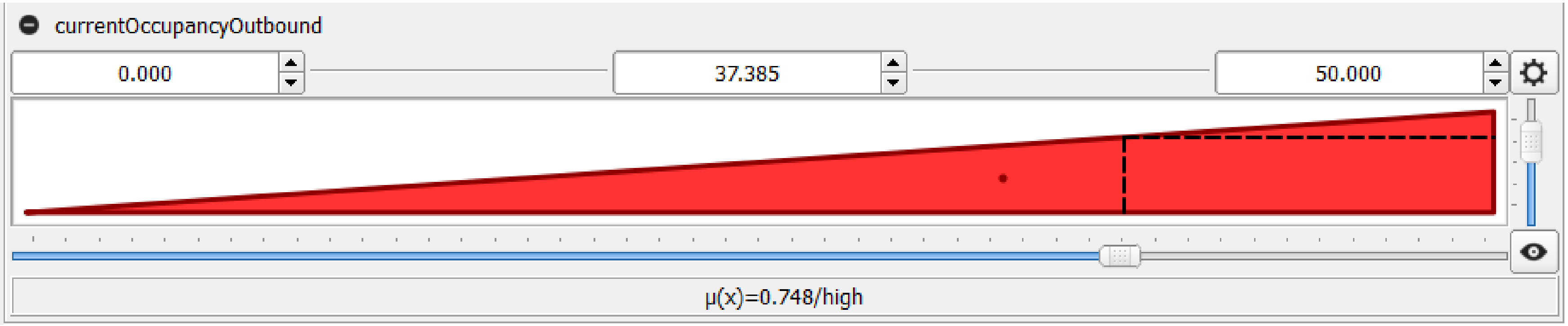
Acknowledgements

- Taso Koutroulakis, P. Eng., PTOE, Manager, Traffic Management, Halifax

Thank You

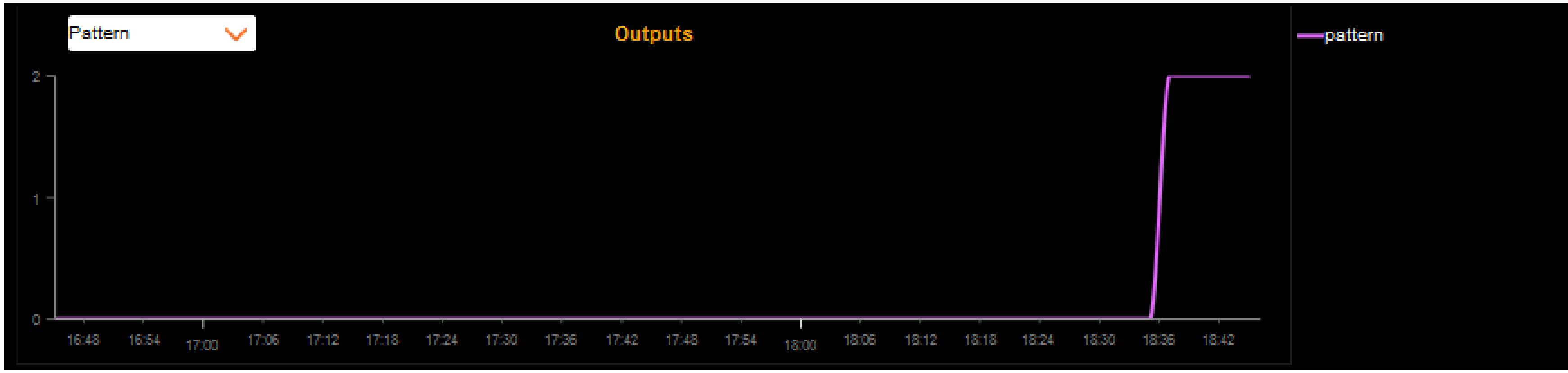
- Closing Remarks
- Questions

Input Ranges

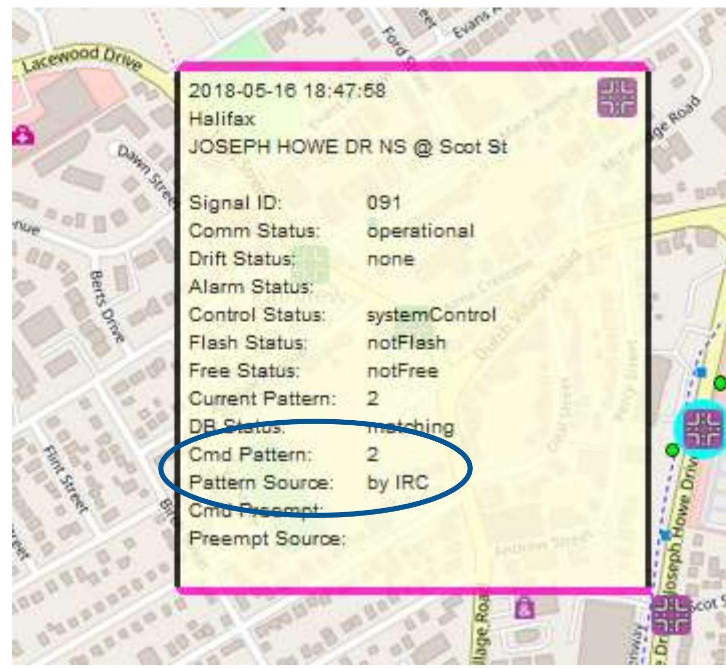


- The response to the numeric input varies within the specified range
- In this example, we have tuned "currentOccupancyOutbound is high" to affect no response (0.0) at or below an occupancy of zero, and a maximum response (1.0) at or above an occupancy of 50%
- All of the input ranges can be likewise tuned so that the system is responsive to each measurement in the proper range

Control Outputs



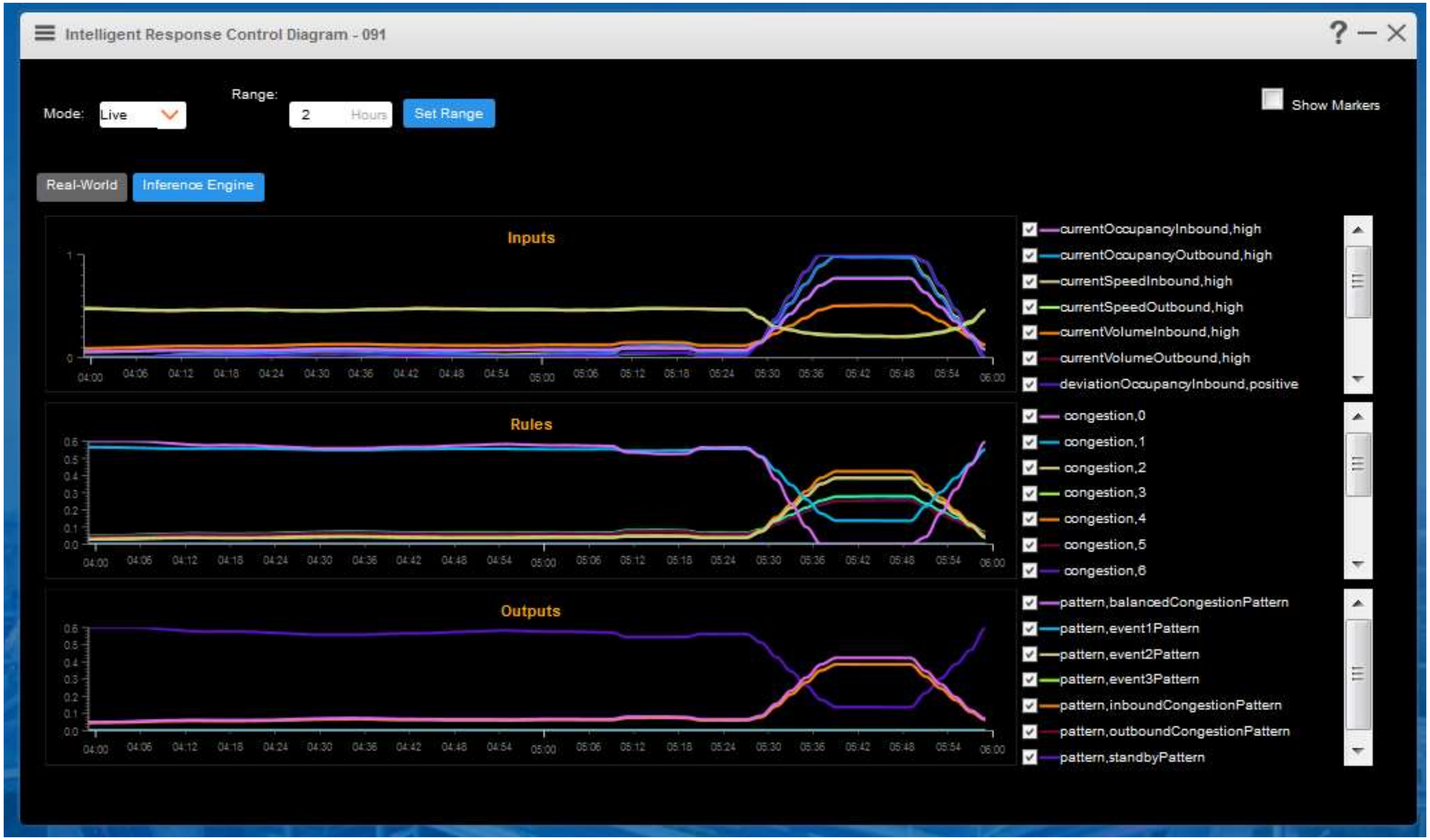
- The selected pattern number is applied to the controller unit once the persistence and minimum activation time constraints have been met



Sidebar – Kinds of Artificial Intelligence

	Symbolic	Statistical
Focus:	Reasoning	Pattern recognition
Knowledge Representation:	Expert-defined model (rule base, simulation, etc.)	Learned coefficients within a mathematical process
Knowledge Definition:	Manual calibration	Automated learning from a large data set
Explainable Outcomes:	Yes	No
Pitfalls:	Inappropriate level of detail in model, poor calibration	Insufficient training data, overfitting
Techniques:	Expert systems, fuzzy logic, inference, dynamic programming, hill climbing	Regression, Markov Chain, Neural Networks ("deep learning")
Computations:	Low - Moderate	Moderate - Very High
Applications:	diagnostics, decision support, translation, knowledge discovery, control systems	image recognition, speech recognition, traffic prediction, autonomous vehicles

Auditing



- At any time in the future, we can return to the response and review the reasoning behind the pattern activation