Nexus

Data-Driven Simulation Platform for the Planning & Management of Multi-Modal Transit Networks

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Outline

- Introduction
- Overview of Nexus
- Demo
- Case Studies
- Ongoing Developments

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Introduction

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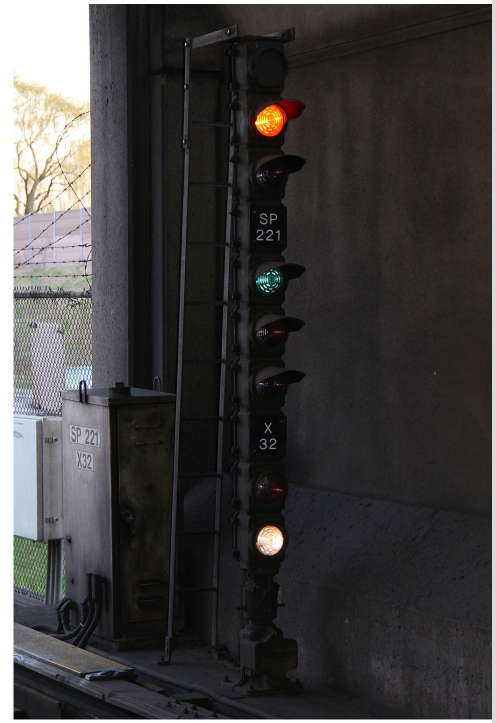
What is Nexus?

- Nexus is a
  - Software platform combining big data, simulation and other models/analytics to support transit planning and management
  - Research program to develop the Nexus building blocks and various analytics for specific applications

What can Nexus do?

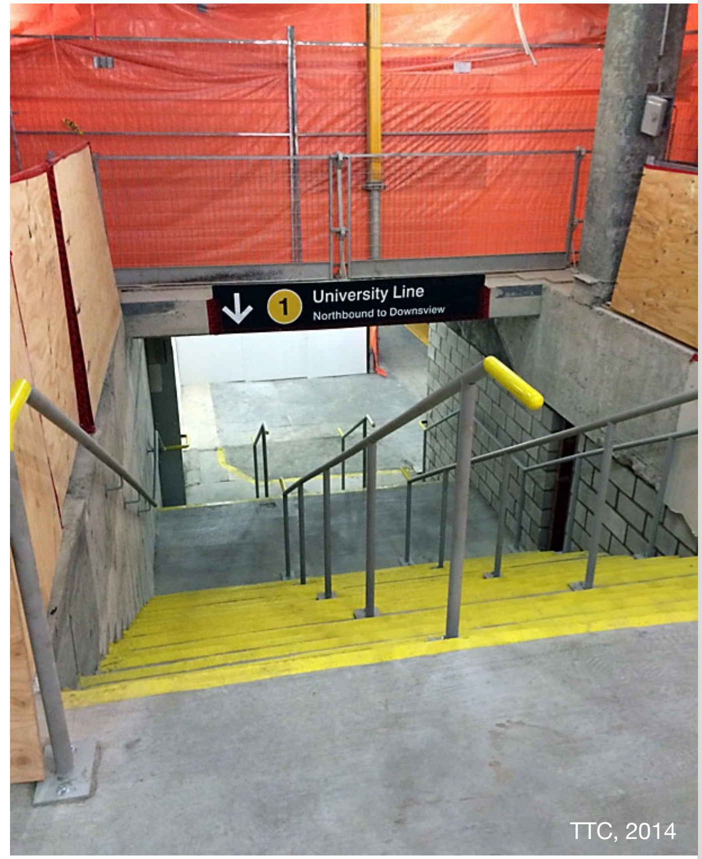
- Nexus aims at allowing the user to
  - Quickly build or update a transit network model based on GTFS and other big transit data (important for short range planning, scheduling and management)
  - Simulate operations and demand
    - of all transit modes: rail, bus, streetcar and pedestrian
    - at various spatial levels: rail platform, transit hub, route, corridor, network
    - at different resolution levels: microscopic, mesoscopic, hybrid
  - Represent system and user behaviours under normal conditions or scenarios of service disruption and emergencies

Capacity/Performance Analysis



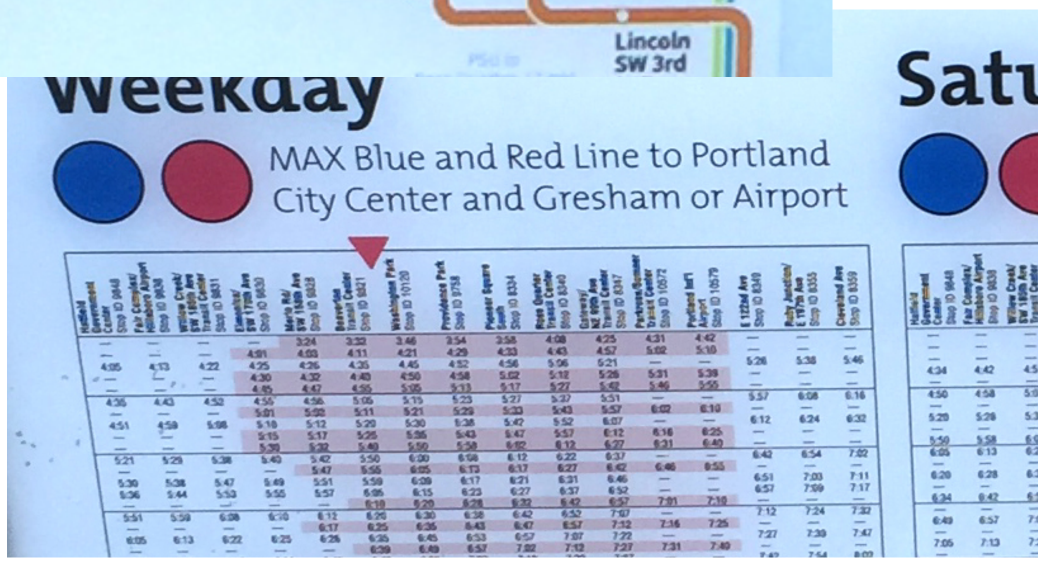
- Capacity analysis of YUS under ATC and other operational improvements

Capacity and Expansion Studies

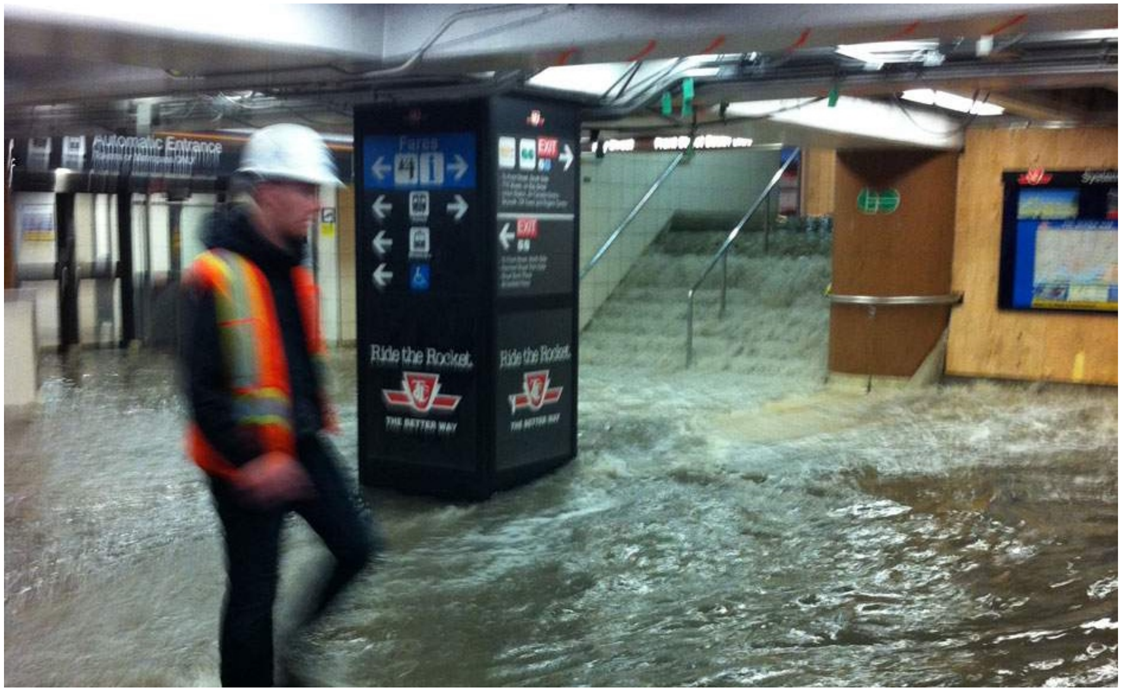


- Impact is traditionally tested in isolation – Nexus will offer the ability to test within a high-fidelity, calibrated network

Integrated Route Planning & Scheduling



Network Resilience & Response



- Current analysis is performed using simplified network models, and can only handle complete removals of network segments
- Nexus will allow for a broader range of examination, including testing of transient disruptions and accounting for passenger behaviour

Overview of Nexus

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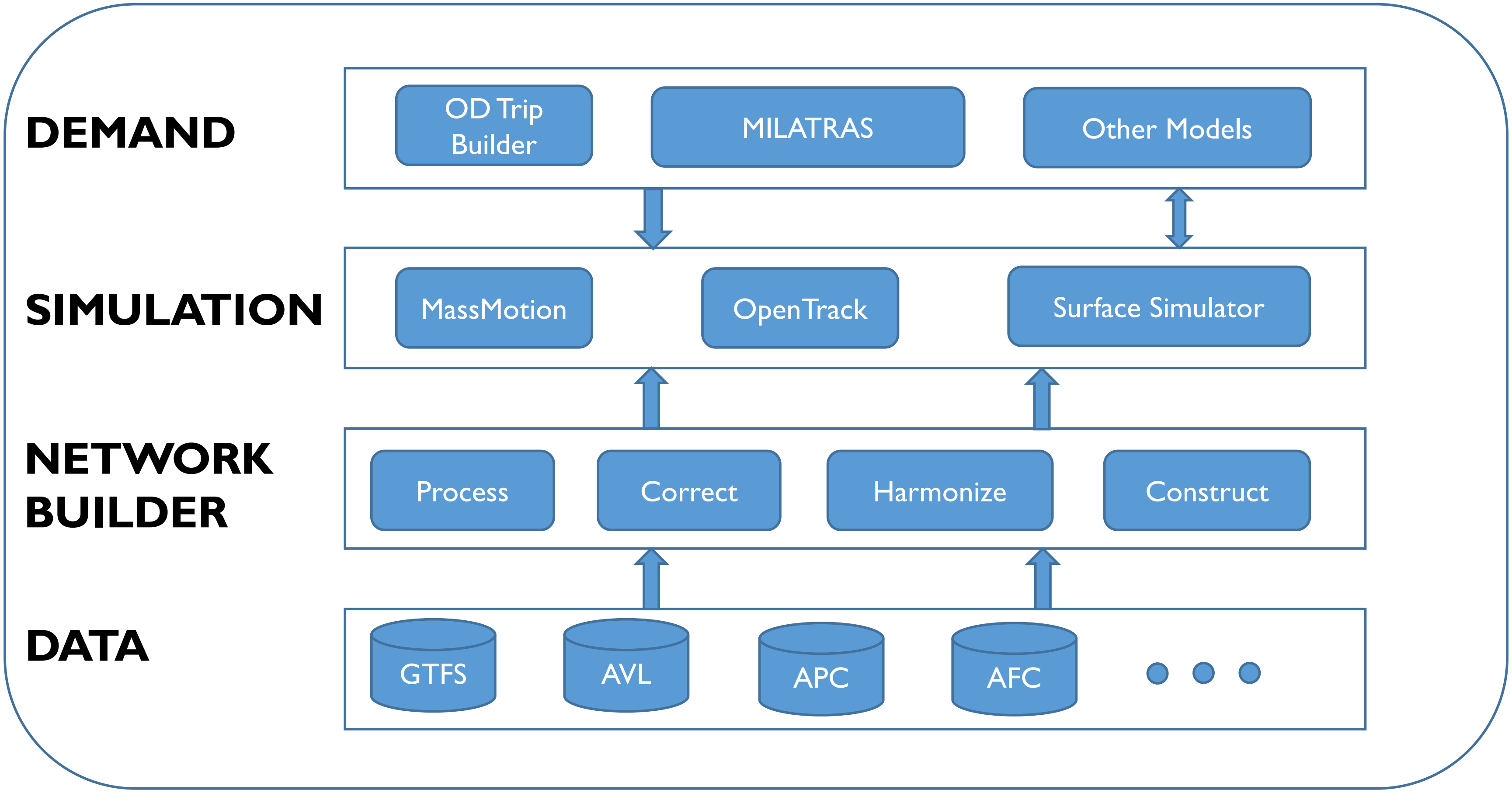
Nexus Framework



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Description of Nexus

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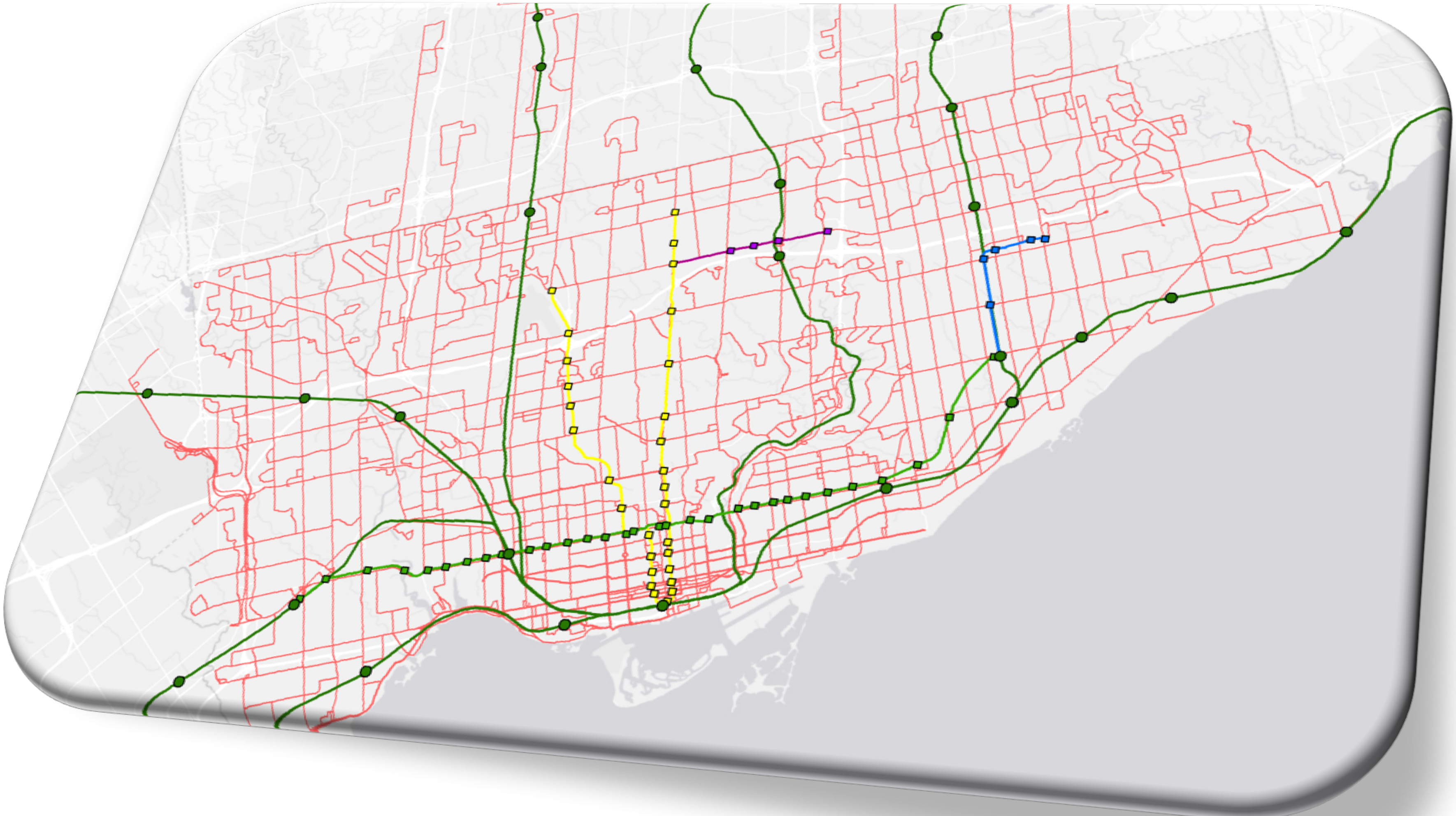
Description of Nexus



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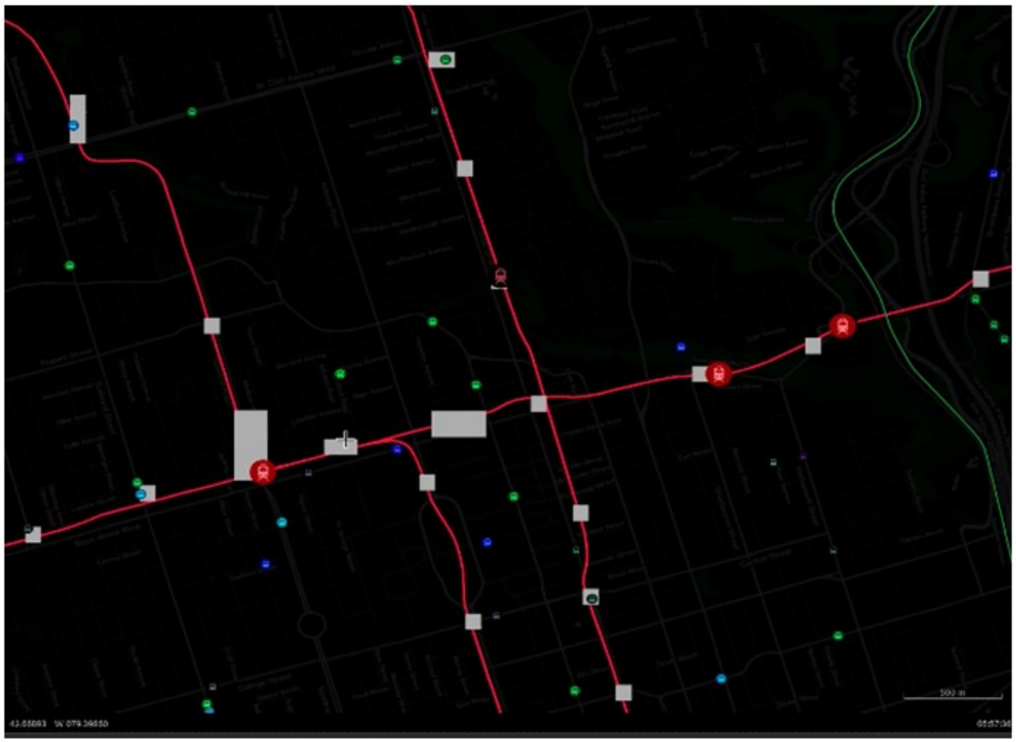
Nexus Main Features

Live network-view dashboard visualizing key network service performance.



MILATRAS

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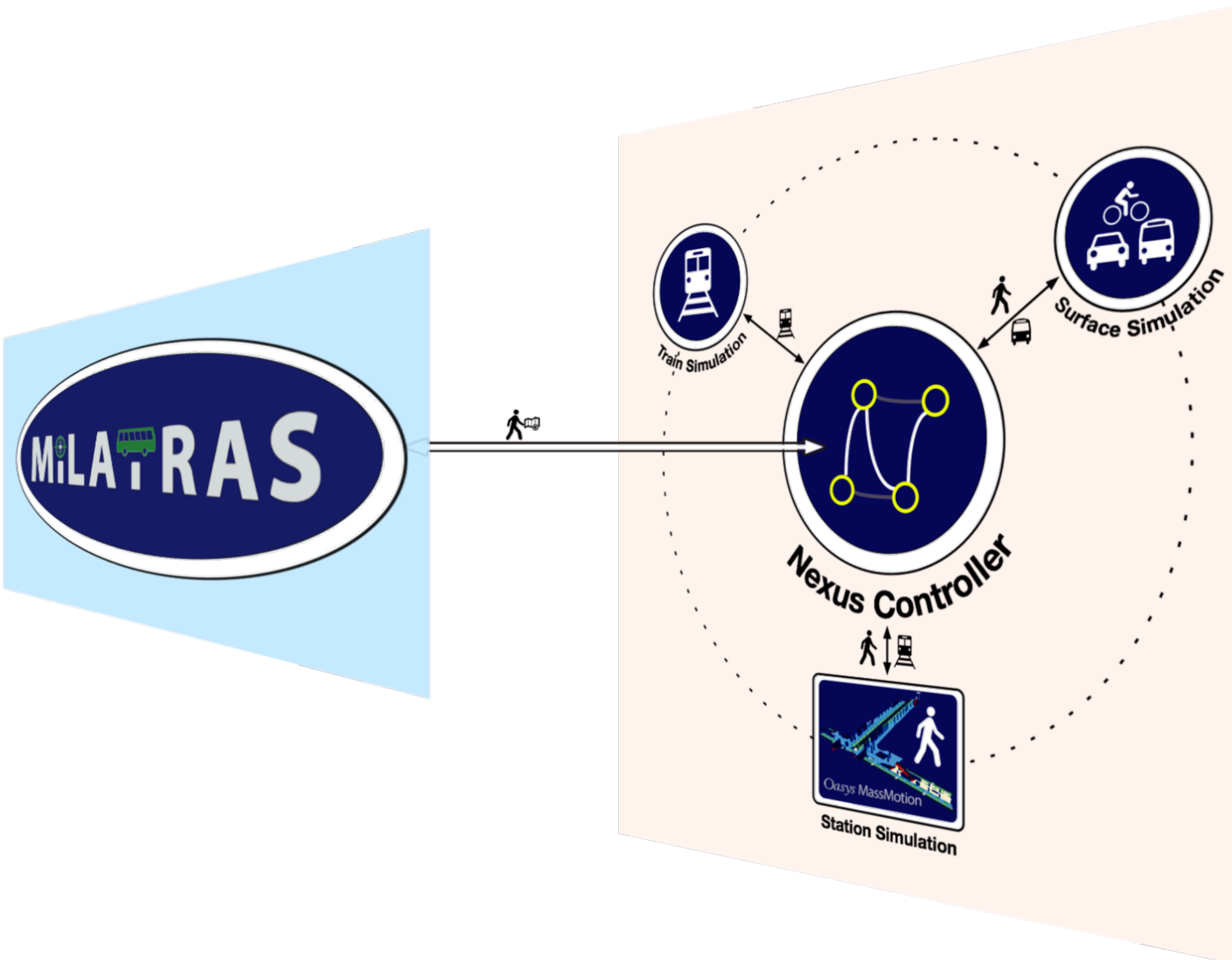
MILATRAS

- Multi-agent learning based transit assignment
- Models departure time, stop and path choices simultaneously using the Markovian Decision Process and Reinforcement Learning-based techniques
- Cognitive model to represent the learning process of users as they choose stop, path, departure time
- Agents learn from prior experience, update trip choices with each iteration
- Allows for re-routing midway based on new information

The *Nexus* Platform



Demo

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Nexus Building Blocks: Recent Research Projects

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Recent Research Projects

- Data-driven surface transit simulator
- Models of user behaviour under transit service disruption
- Agency decision-making during/after disruptions
- Models of crowd dynamics

Data-Driven Mesoscopic Surface Transit Simulator

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Background

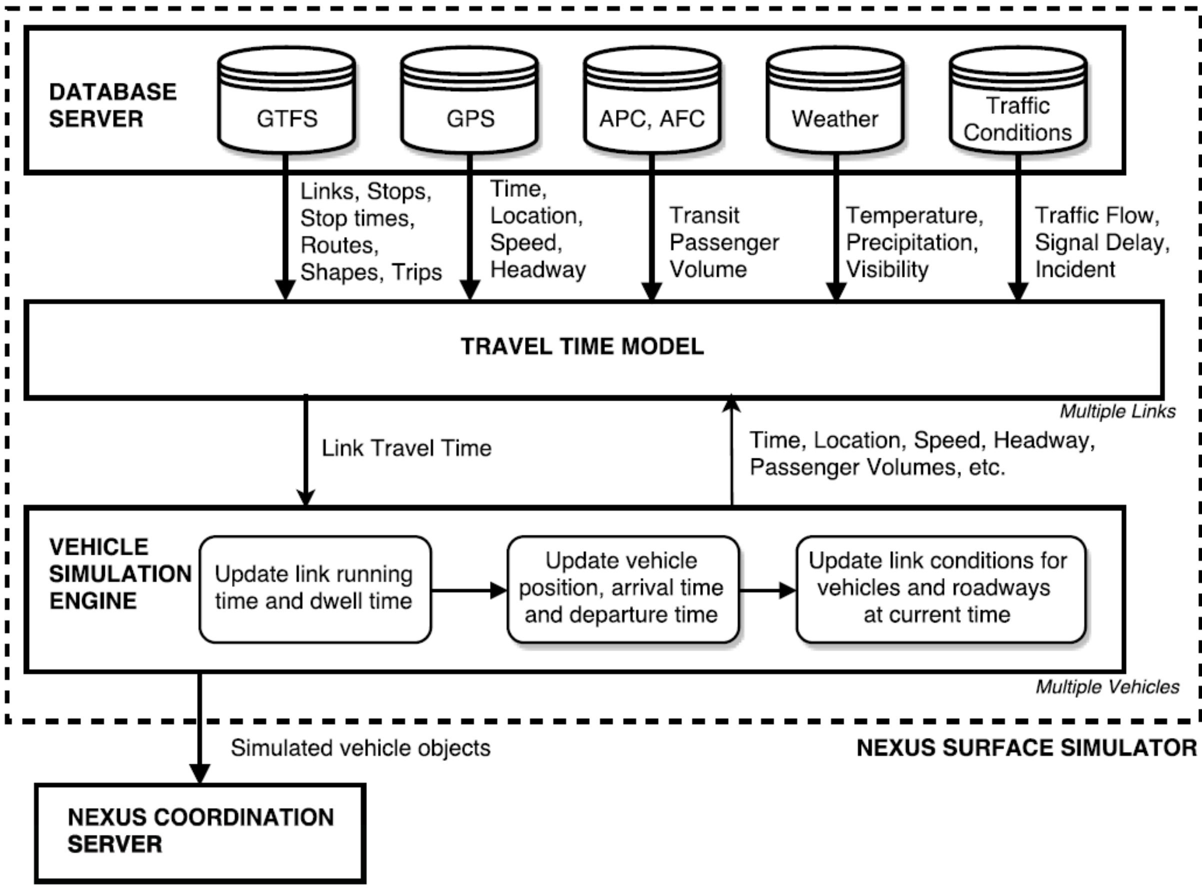
- Main goal: Represent accurately bus and streetcar on-route travel patterns and arrival/departure patterns at subway stations

- Existing microsimulation methods impose high computational requirements for network-wide simulation

- Instead, travel time models constructed using open data and machine learning algorithms

- TTC surface network used as a case study

Framework



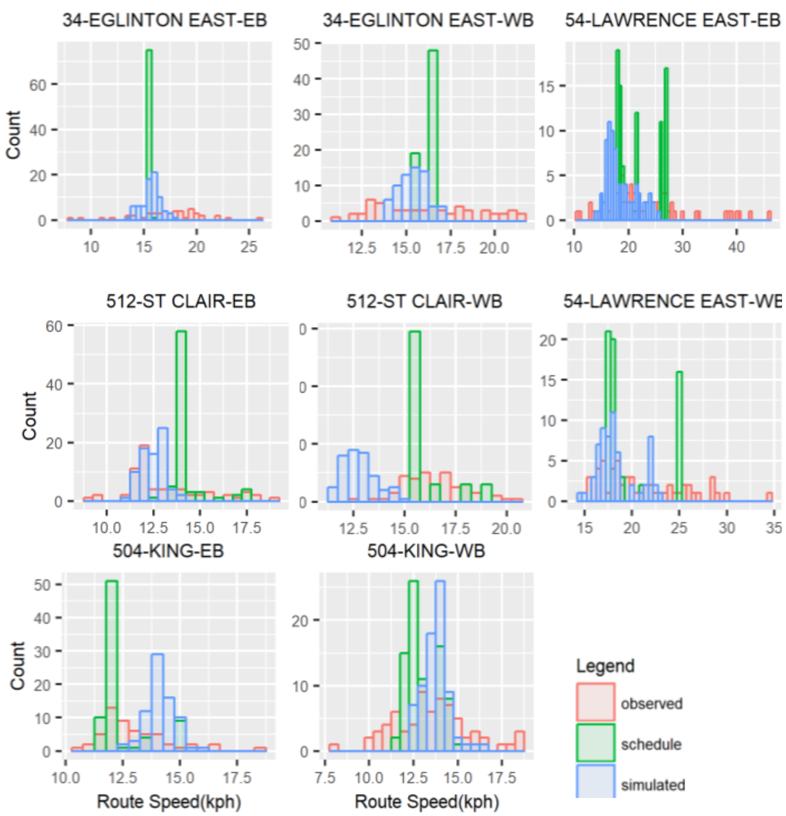
DATABASE SERVER
GTFS
GPS
APC, AFC
Weather
Traffic Conditions
Links, Stops, Stop times, Routes, Shapes, Trips
Time, Location, Speed, Headway
Transit Passenger Volume
Temperature, Precipitation, Visibility
Traffic Flow, Signal Delay, Incident
TRAVEL TIME MODEL
Multiple Links
Link Travel Time
Time, Location, Speed, Headway, Passenger Volumes, etc.
VEHICLE SIMULATION ENGINE
Update link running time and dwell time
Update vehicle position, arrival time and departure time
Update link conditions for vehicles and roadways at current time
Multiple Vehicles
Simulated vehicle objects
NEXUS SURFACE SIMULATOR
NEXUS COORDINATION SERVER

Methods

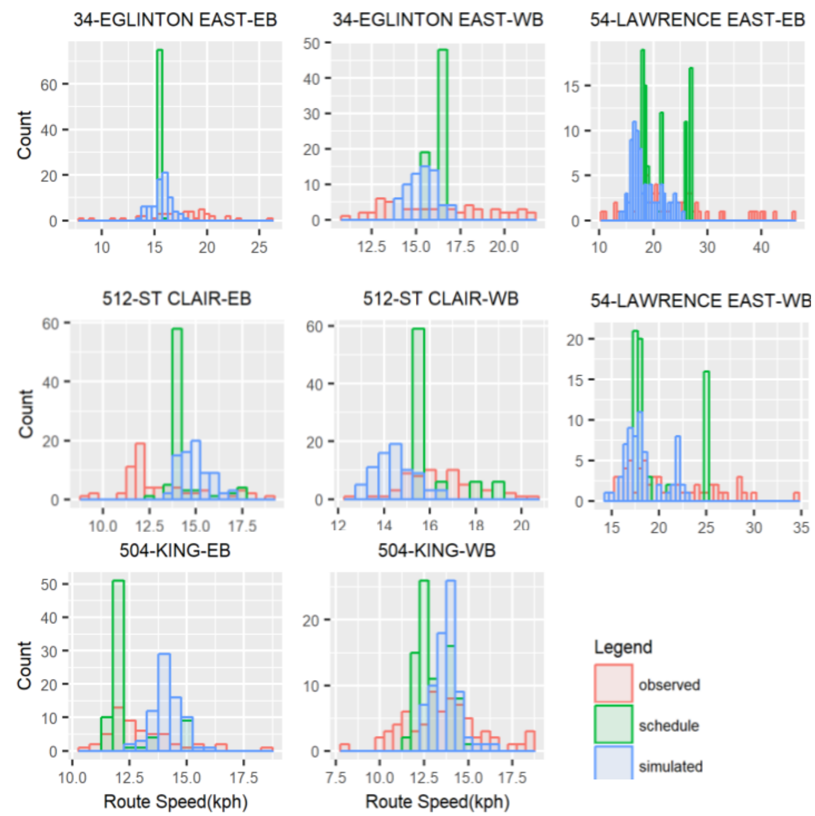
- Segment Travel Time Models
  - Multiple Linear Regression (MLR)
  - Support Vector Machine (SVM)
  - Linear Mixed Effect Model (LME)
  - Regression Tree (RT)
  - Random Forest (RF)

Model Validations – Route Speeds

Random forest



Linear Mixed Effect



Findings

- Data-driven transit simulation model
  - replicated instances of vehicle bunching, distribution of dwell times, and stochastic patterns of delays and headways

- Validation results suggests the need to incorporate:
  - Effect of traffic congestion
  - Signal delays
  - Vehicle short-turns

Disruption Behaviour

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Agency Response During Disruptions

- Survey of Canadian and international transit agencies with rail systems

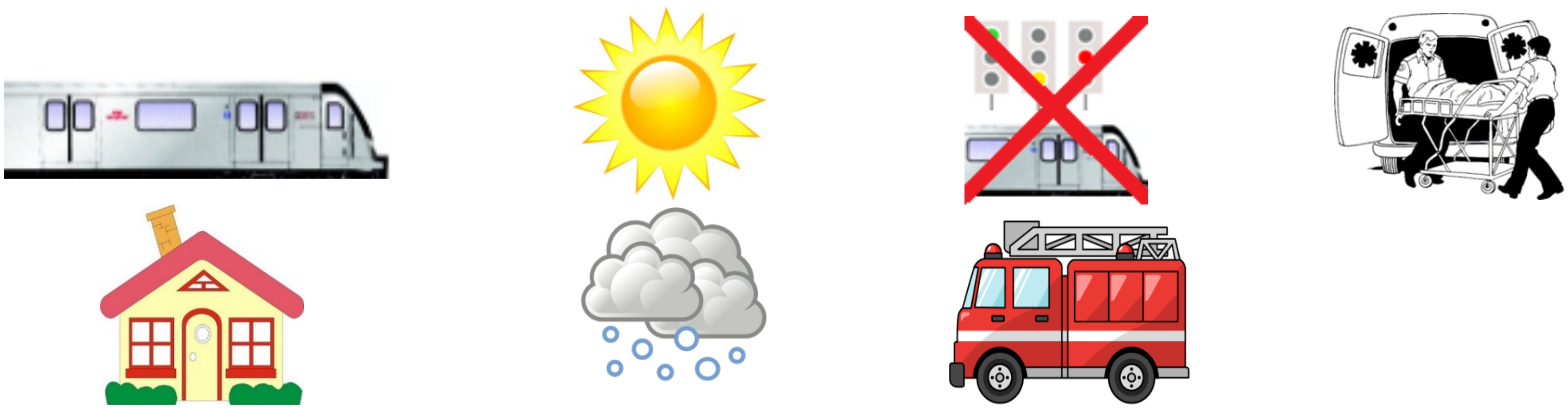
- Focus: process followed by agencies from disruption detection to response

- Goal: provide understanding to allow for better modelling of decisions made during response

User Behaviour During Disruptions

- Goal

  Understand the mode choice of passengers when faced with different types of rapid transit disruptions



Survey Scope

- Riders of TTC rapid transit system
- Peak period school and work trips
- Immediate actions: pre-trip and en-route
- Seven available mode options
- Revealed Preference: last experience
- Stated Preference: hypothetical scenarios

You are **on your way** to your destination and the weather is **not comfortable** outside with rain, snow or extreme temperature. You are approaching *Spadina Station* and you have just found out that there is a "**Medical Emergency**" at *St George Station*, causing the subway service to be suspended between *Spadina Station* and *Union Station. You have the following mode options shown in the table with the associated attributes.* ***Please choose your most preferred option to get to your destination from Spadina Station given the situation.***

	Taxi	Other TTC Routes	Shuttle	Walk	Wait	Cancel Trip
Length of Delay (minutes)			No Information Provided		50-60	
Cost (CAD)	$6.7	$0	$0	$0	$0	$0
Number of Transfers		0	2		1	0
Access Time (minutes)		0	0		0	1
In-vehicle Travel Time (minutes)	6	1	15		7	23
Transfer Time (minutes)		0	9		4	6
Egress Walking Time (minutes)		13	2		2	0
Total Travel Time (minutes)	6	14	At least 27	17	64-74	30
Total Travel Distance (KM)				1		
Choice	○	○	○	○	○	○

In the future, how likely are you to get to your destination using your selected choice above if you encounter this scenario in real life?

-- select an option --

Findings

- Econometric models developed, including one combining the RP/SP results
- Significant variables: Travel time, cost, frequency of subway trip, trip purpose, subway delay, shuttle bus delay, weather, age, income
- Importance of getting across info on alternative options clear

Pedestrian Modelling Approaches

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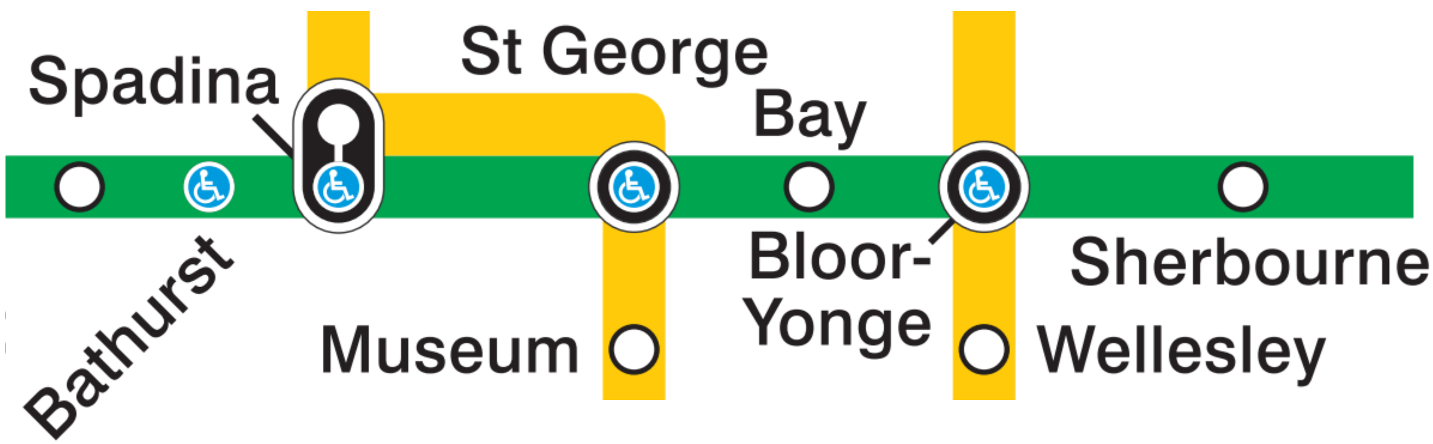
Context & Motivation

- Currently, MassMotion is the simulator of choice for accurate station models – very demanding in terms of data, computer resources, and time
- Practical solution is to use a simplified station simulator for smaller and less complex facilities when simulating the full network



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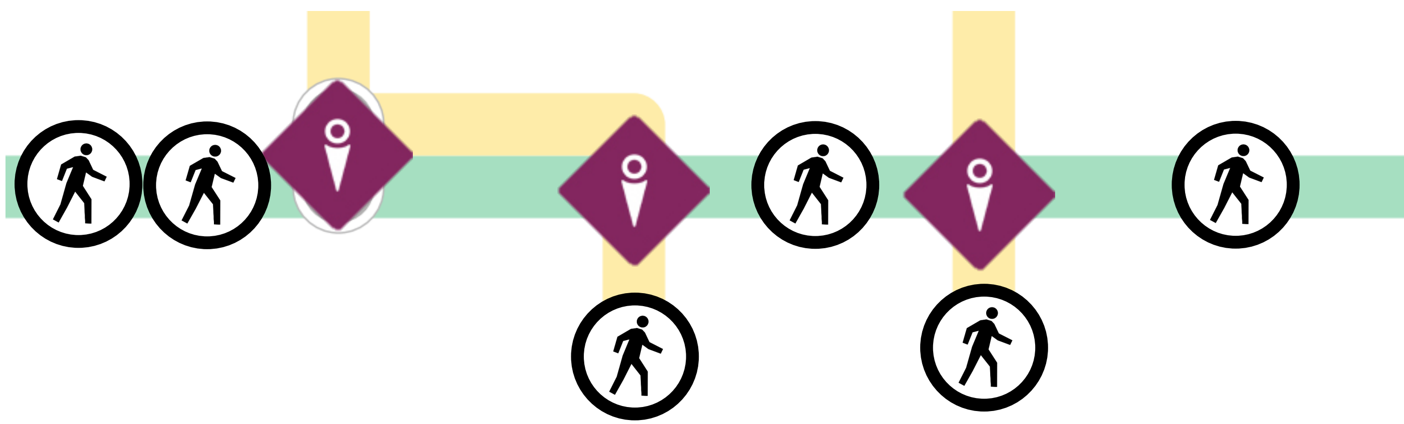

Case Studies

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Union Station Rail Corridor

- Increased train frequency can affect platform density, which in turn can result in train delays
- Whether complex infrastructure at rail hubs can support demand growth and system expansion can be difficult to evaluate
- Comprehensive capacity analysis of a complex station area is necessary to identify bottlenecks and maximum throughput

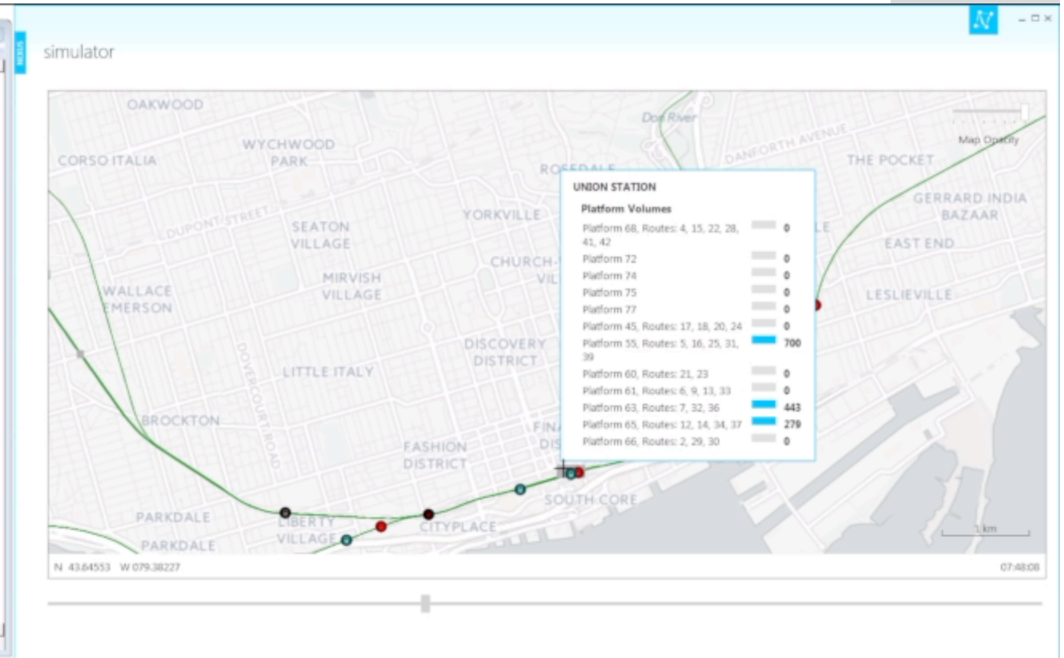
Union Station Rail Corridor

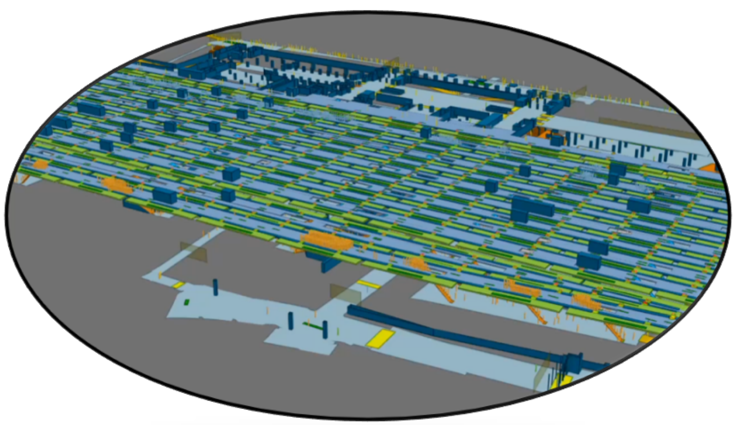
- OpenTrack was used to model the complex track configuration and signal layout at Union GO Station

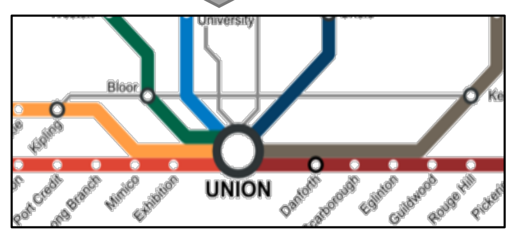
- MassMotion was used to model Union Station (developed by Arup); separate model developed for alighting behaviour at the terminal

- Nexus allowed these two models to interact in real-time to examine interplay during dwell

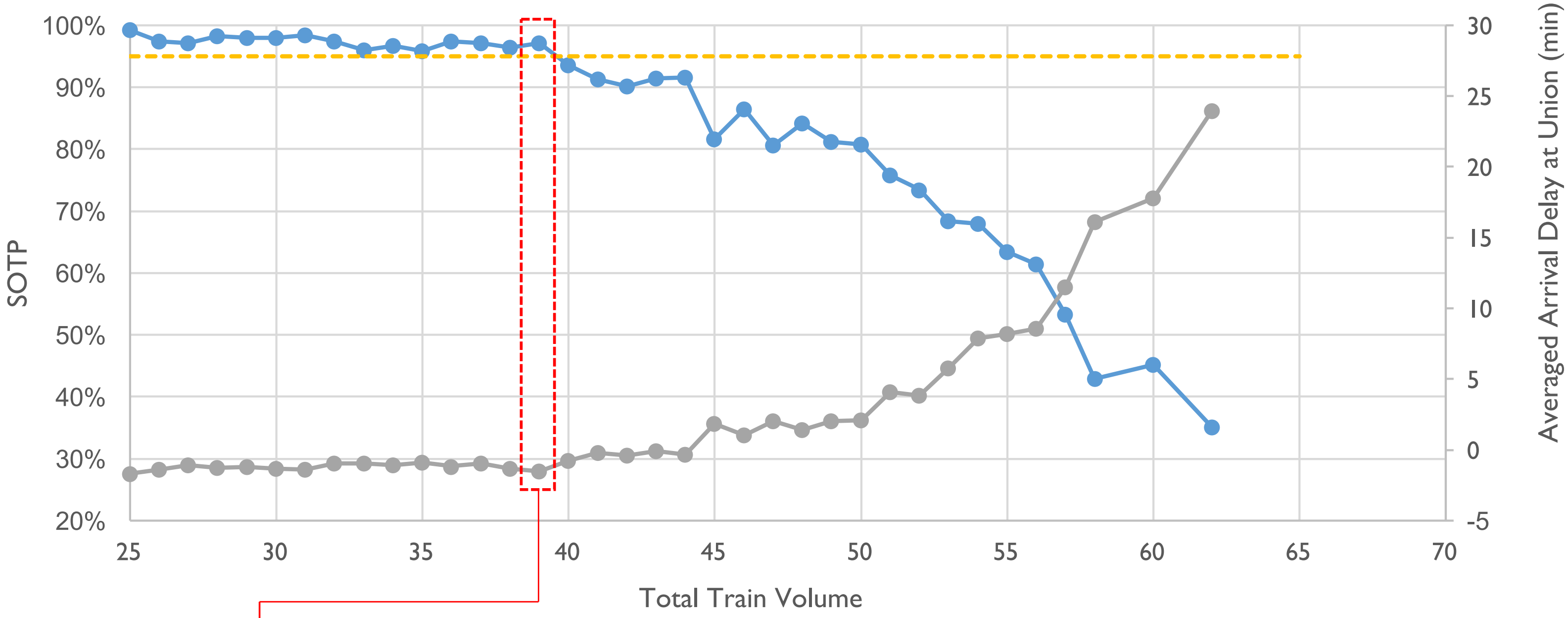
USRC Case Study







Trackside Train Capacity

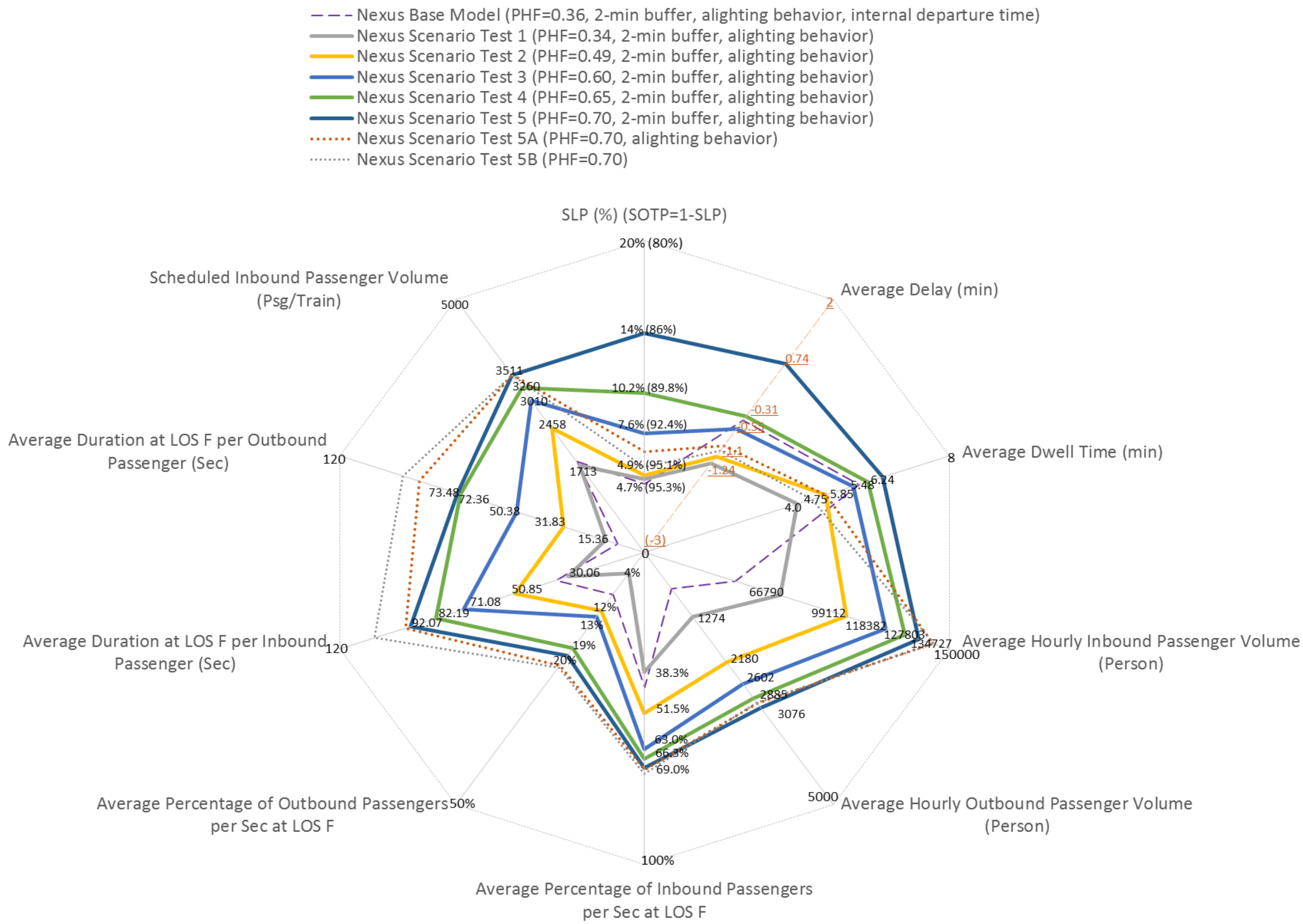


Method	Total # of Trains	LSW	LSW_E	LSE	LSE_E	KI	MI	BA	RH	ST
OpenTrack	39	4	5	4	4	4	5	4	4	5

LSW: Lakeshore West Line
LSW_E: Lakeshore West Express
LSE: Lakeshore East Line
LSE_E: Lakeshore East Express

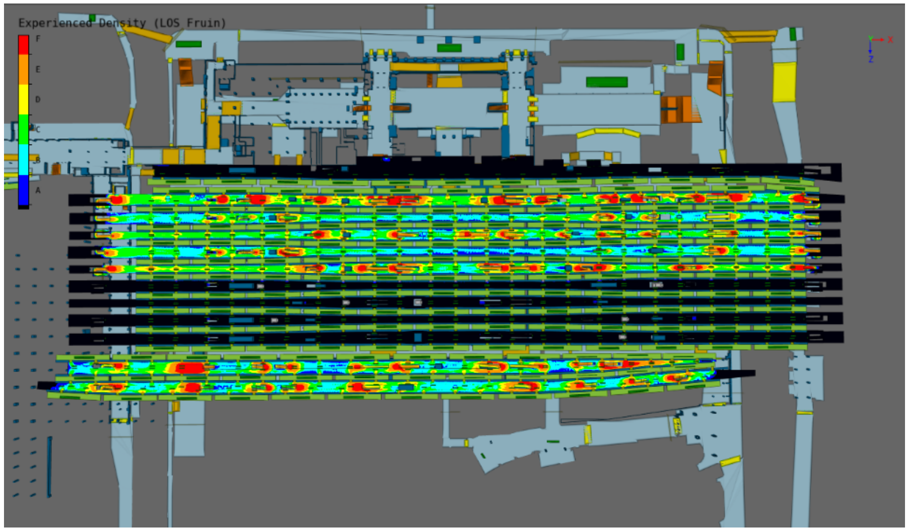
KI: Kitchener Line
MI: Milton Line
BA: Barrie Line
RH: Richmond Hill Line
ST: Stouffville Line

Scenario Tests Results

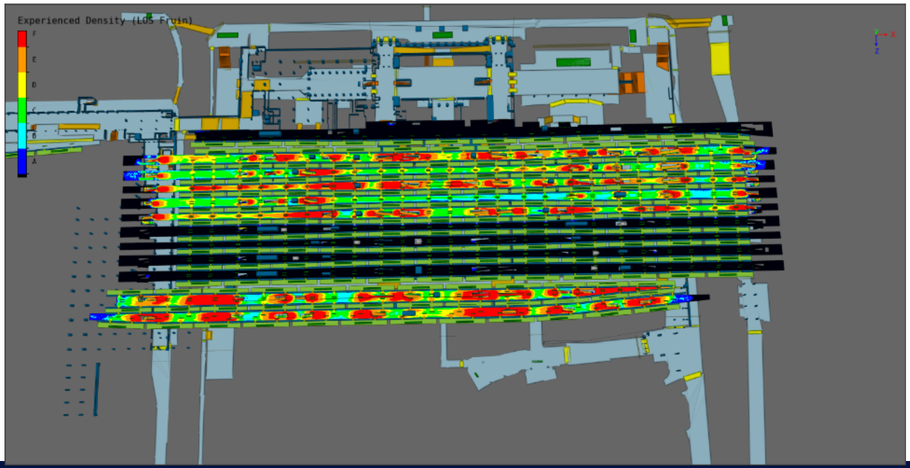


Scenario Tests Results

Base Model



Scenario 5



Downtown Relief Line Case Study

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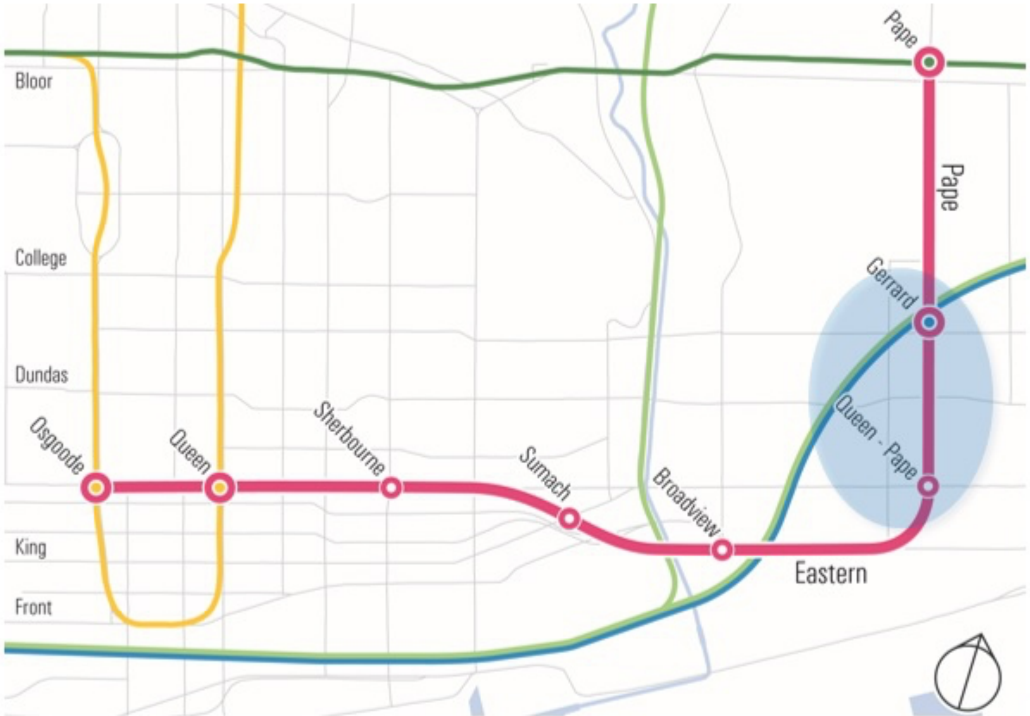
Objective

- Transit planning showcase of Nexus platform
- Show impact of DRL on transit user flow, line and station capacity

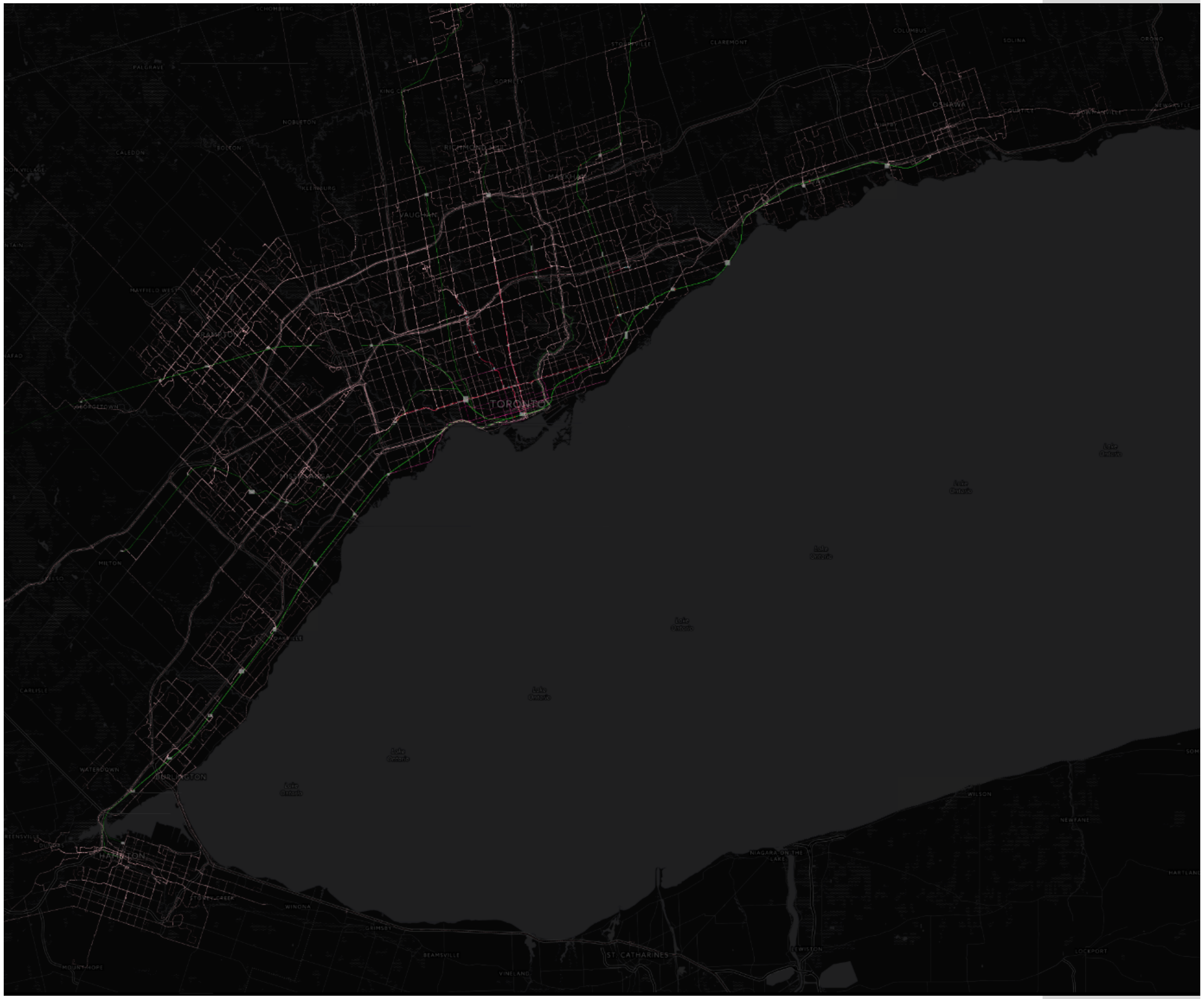
Scope



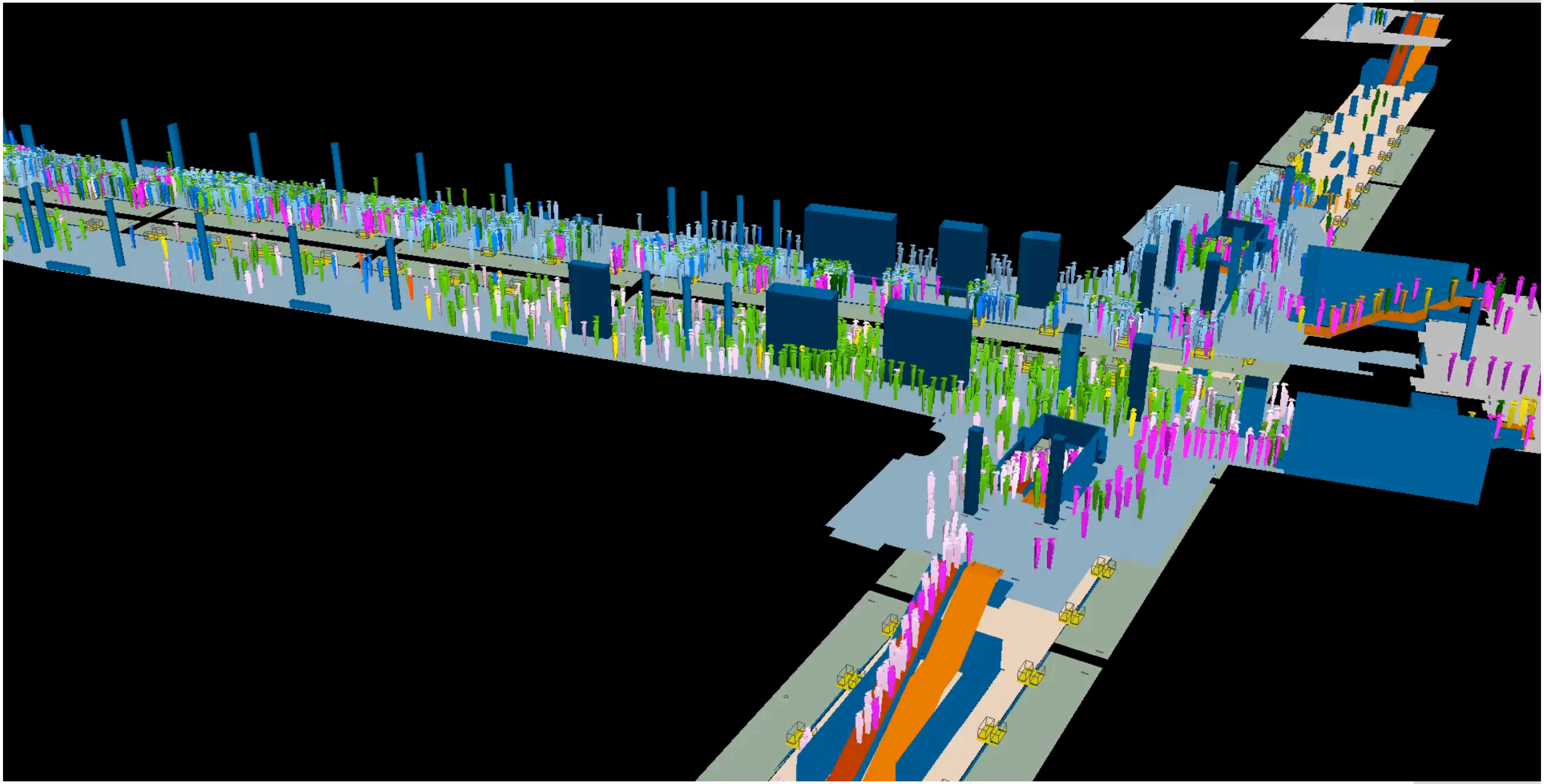
- Detailed model of inner area of DRL zone
  - MassMotion models of most stations
  - OpenTrack model of USRC section and subway lines
- Lower level of detail for rest of GTHA Network

Scope

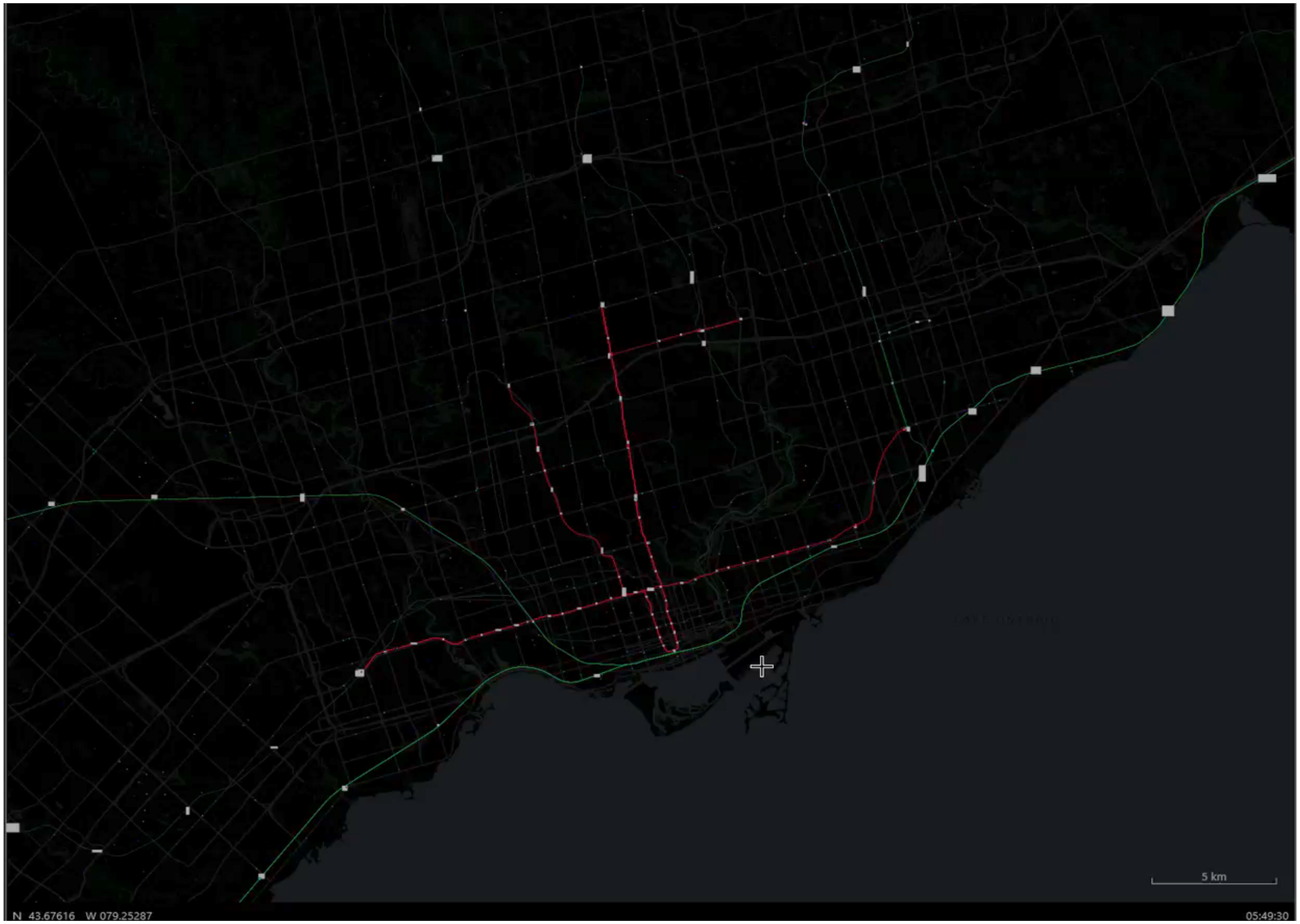
- Greater Toronto Area
- 13 transit agencies
- OpenTrack models of GO and TTC Subway
- Detailed MassMotion models of Union Station and 10 subway stations
- GTFS based surface transit model
- Schedule-based route choice model



Yonge/Bloor Station



GTHA Case Study



Ongoing Efforts

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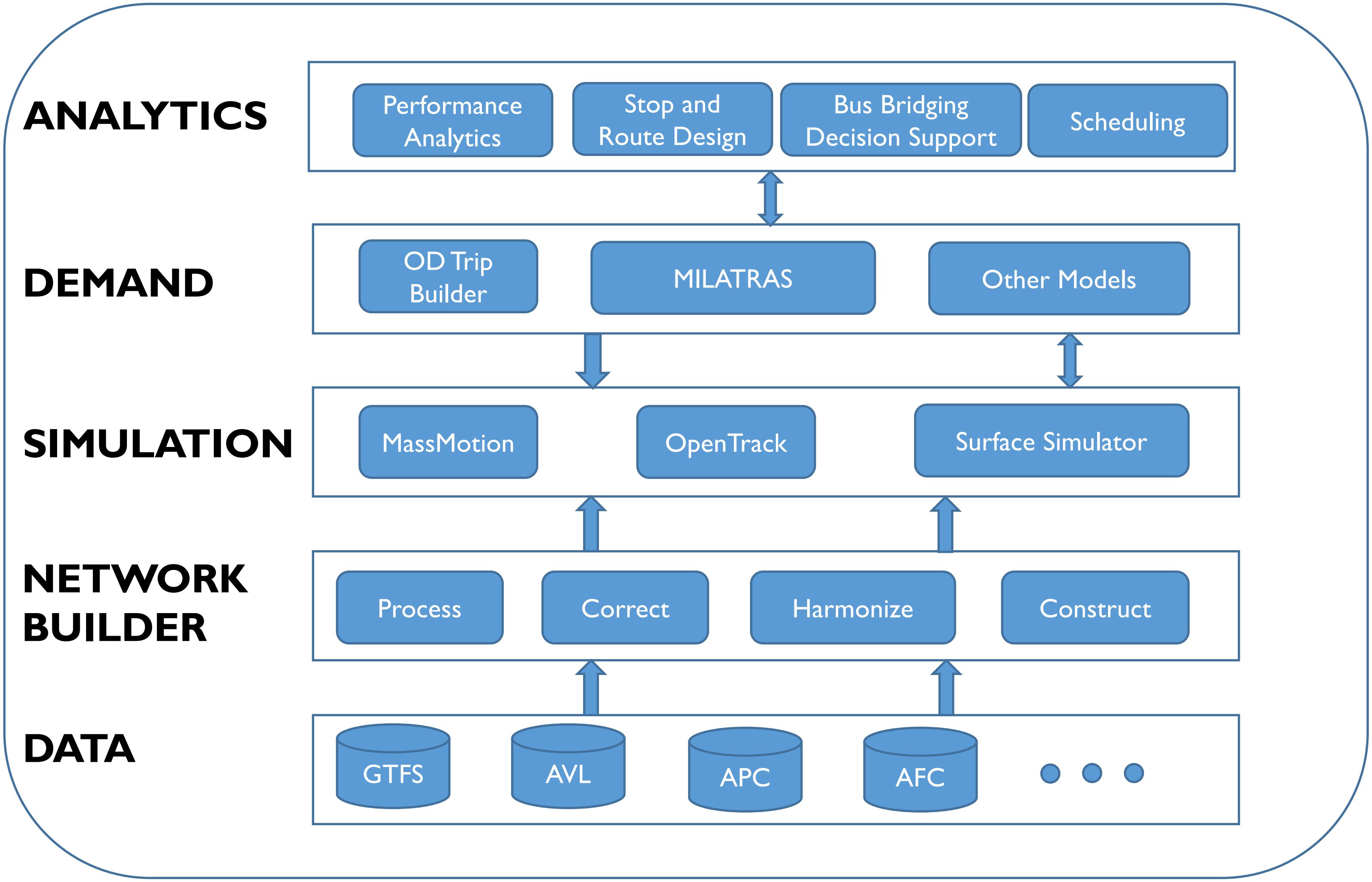

ANALYTICS
Performance Analytics
Stop and Route Design
Bus Bridging Decision Support
Scheduling
DEMAND
OD Trip Builder
MILATRAS
Other Models
SIMULATION
MassMotion
OpenTrack
Surface Simulator
NETWORK BUILDER
Process
Correct
Harmonize
Construct
DATA
GTFS
AVL
APC
AFC

Stop & Service Pattern Optimization

- Assessment of changes to an existing route is usually made based on a set of metrics that do not comprehensively evaluate their impact

- Impact assessment tends to disregard implications for timetables and vehicle schedules

Stop & Service Pattern Optimization

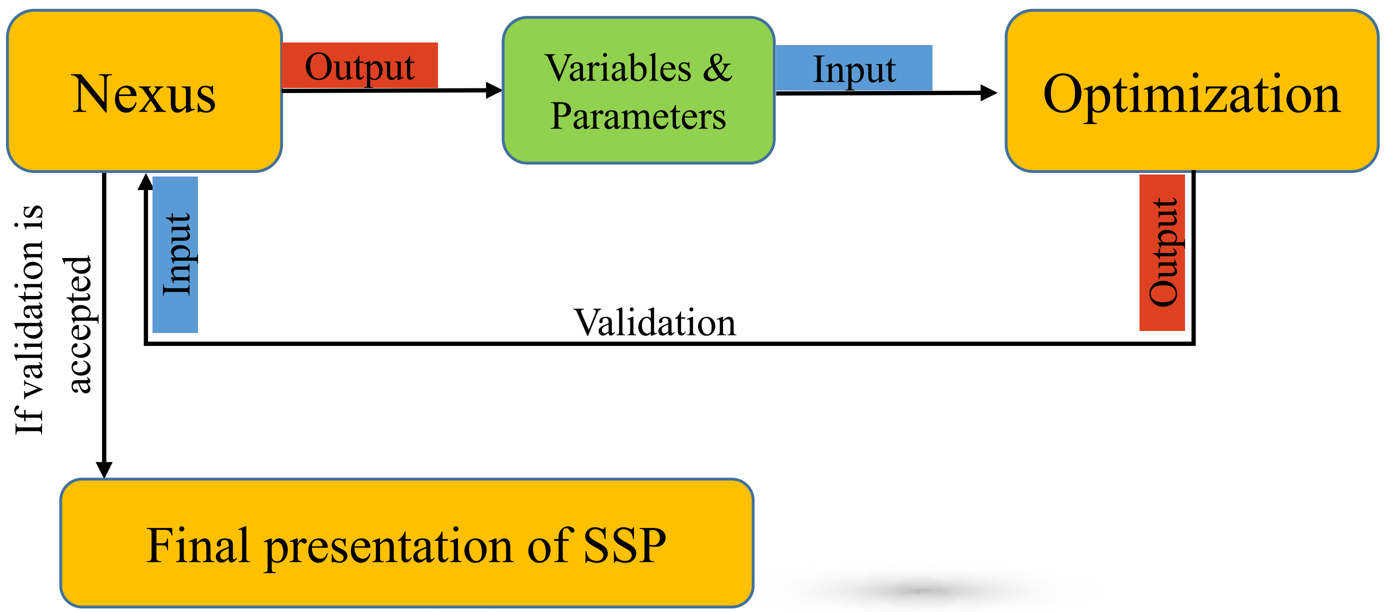
- Goal: Develop a model that can be used in service planning to achieve efficient selection of stop and service patterns (route branches)

- Aims at reducing both passenger travel time and improving system performance

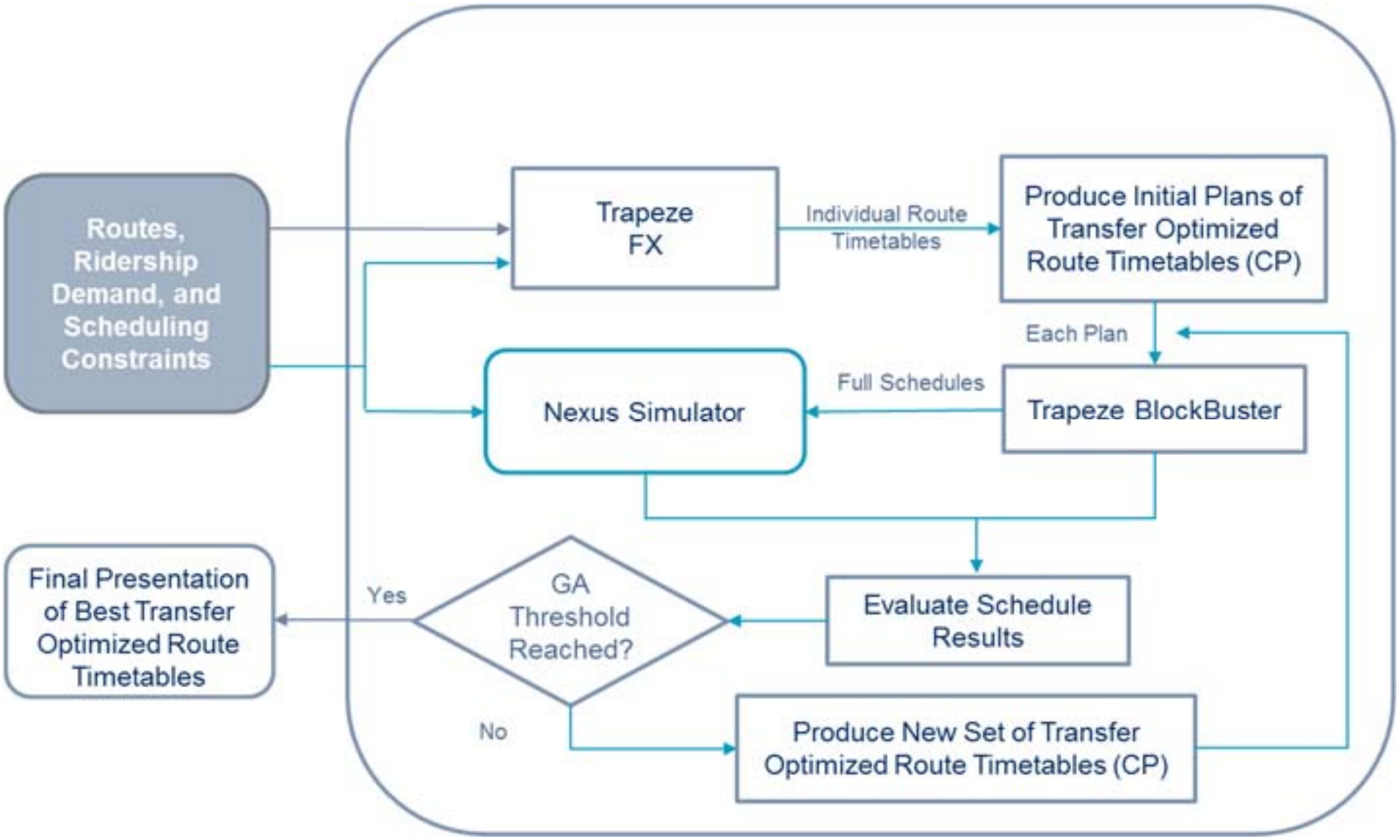
- Can result in savings of the required # of vehicles

Stop & Service Pattern Optimization

- Nexus used for network-wide simulation of public transit vehicle and transit user movements
- Allows dynamic modification to service and automation in a cloud environment



Transfer Optimization



Bus Bridging Module

- Motivation: Large # of agencies (including TTC) pull buses from existing routes to serve as shuttles in response to rail service disruptions

- Number of buses based on expected delay, affected stations and time period

- For the TTC, buses are dispatched equally from each of the seven divisions, no clear criteria

Bus Bridging Module

- Goal: Enhance transit resiliency by expediting return of service to normal after disruptions

- Focused on assisting practice of bus bridging with a tool to help decide how to deploy shuttle buses, using Nexus to calculate and evaluate

- Two phases:
  - Tool to calculate total user delay
  - Optimize bus bridging assignment

Questions?

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