Nexus

Large-Scale Simulation Platform for Capacity Analysis and Emergency Planning of Multi-Modal Transit Networks

Siva Srikukenthiran
Amer Shalaby

December 2, 2016
Overview

• Motivation
• Description of Nexus
• Potential Applications
• Nexus Research Projects
• Prototype Examples
Growing Congestion

- Demand outpacing capacity expansion
- Recurring service disruptions
Transit Incidents

2013 TTC Subway Delays

TOTAL HOURS OF DELAY: 498 Hrs
Profile of Subway Delays

- Delays in subway network concentrated during rush hour, majority less than 20min in length
Agency Response

• Network capacity building (strategic)

• Operational Improvements

• Disruption management strategies
Motivation for *Nexus*

- Large-scale regional models generally use aggregate or high-level techniques

- Simulation is difficult to do for large regions

- Complexity of rail systems and passenger behaviour generally ignored

- Tools do not exist for understanding transient events like short-term disruptions
Motivation for Nexus

• Need for a high-fidelity multimodal transit network modelling system with capability to:
  
  • Represent the dynamic behaviour of transit lines and stations
  
  • Predict passenger travel behaviour under normal and irregular conditions
  
  • Scenario analysis of disruptions, response strategies, and longer range planning
Designing Nexus

- Stations
- Surface Transit
- Rail Transit
Designing Nexus
In-simulation manipulation of transit service (of particular importance in being able to test response strategies to disruptions)
Potential Applications
Capacity Analysis

- Capacity analysis of train lines under ATC and other operational improvements, while including impact/effect of stations

- Impact of new lines and service on key transit hubs
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
Policy and Planning Evaluations

- Nexus aims to offer the ability to examine the behavioural response of users at both the network and local level to policy and network changes
Nexus Research Projects

- Set of graduate research projects to better model behaviour of all transit actors
  - Agency decision-making during/after disruptions
  - Models of user behaviour under disrupted conditions using a joint RP-SP survey
  - Surface transit simulator based on GPS data
  - Basic research into models of crowd dynamics
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: providing understanding to allow for better modelling of decisions made during response
User Behaviour During Disruptions

• Goal

Understand the mode choice of passengers when facing 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
- 7 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.**

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

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?

---

**UNIVERSITY OF TORONTO**
**FACULTY OF APPLIED SCIENCE & ENGINEERING**
Transportation Research Institute
Nexus Surface Simulator

• Main goal: Produce accurate arrival/departure patterns at subway stations

• Existing methods of modelling public transit impose high computational requirements

• Instead, travel time models constructed using open data and machine learning algorithms
Nexus Surface Simulator Framework
Nexus Station Simulator

- Currently, MassMotion is the simulator of choice for accurate station models – very demanding in terms of data, computer resources, and time
- Ideal solution is to use a simplified station simulator for smaller and less complex facilities
Nexus Station Simulator

- Currently, MassMotion is the simulator of choice for accurate station models – very demanding in terms of data, computer resources, and time
- Ideal solution is to use a simplified station simulator for smaller and less complex facilities
Understanding Performance of Crowd Dynamics Models

• Some performance/accuracy trade-offs are acceptable

• Several types of crowd dynamics models exist

• Little research done to compare their performance and accuracy
Crowd Model Evaluation Framework

Simulation Models
- Fruin Queueing
- Fluid Flow

Test Scenarios
- Cellular Automata
- Social Forces (MassMotion)

Metrics / KPIs
- Gradient Steps
GTA Prototype Examples
Yonge/Bloor Station
GTHA Case Study
GTHA Case Study
Example: USRC Model
Questions?