A Mesoscopic DTA Multi-Modal Aimsun Model for the GTA

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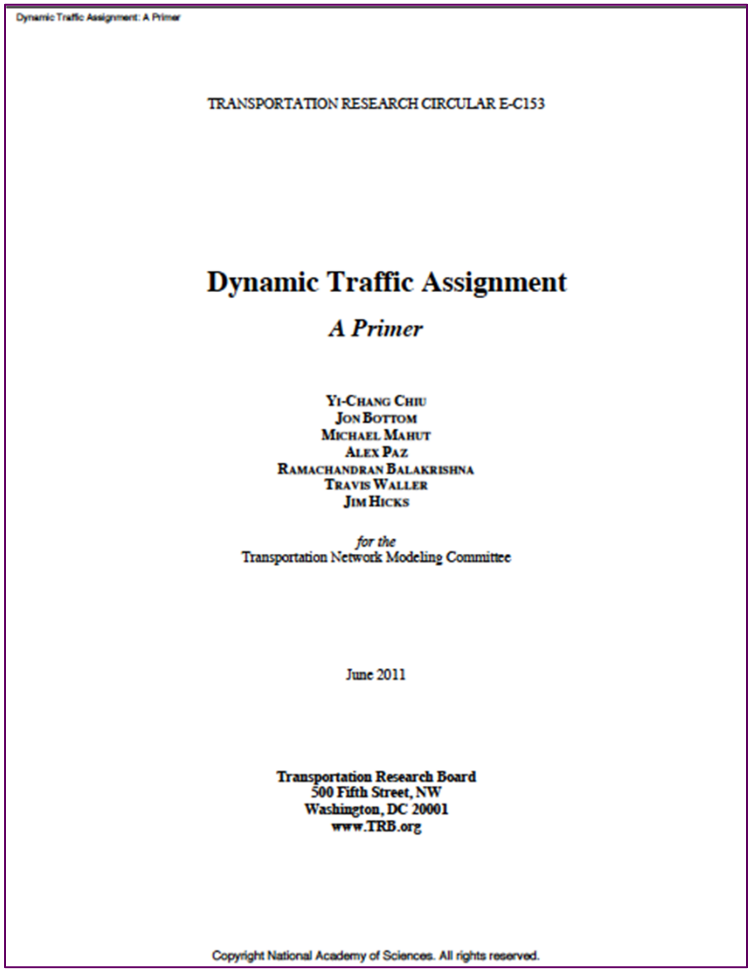
Outline

- The case for Dynamic Traffic Assignment
- The UofT Aimsun GTA DTA model



Dynamic Traffic Assignment: A Primer

TRANSPORTATION RESEARCH CIRCULAR E-C153

Dynamic Traffic Assignment

A Primer

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Why do we need dynamic system representation and modelling?

- We need accurate representation of **cost of travel**:
  - in transportation planning
  - in traffic engineering /operations

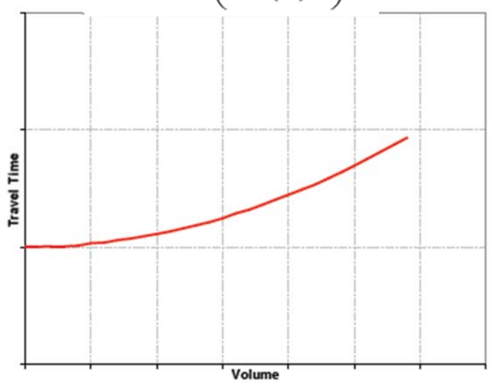
- Static Network Analysis and Models:
  - variables of interest that are time-invariant
  - the concept of user equilibrium traffic assignment
  - may or may not directly correlate with physical measures describing congestion (e.g. flow density ..)

- Dynamic Network Analysis and Models:
  - more detailed representation of the interaction between travel choices, traffic flows, and time and cost measures in not only spatially but also temporally coherent manner.
  - Dynamic Traffic Assignment combines time-dependent route choice (assignment) concepts and traffic flow theory

Modelling Congestion:
Static vs. Dynamic Models

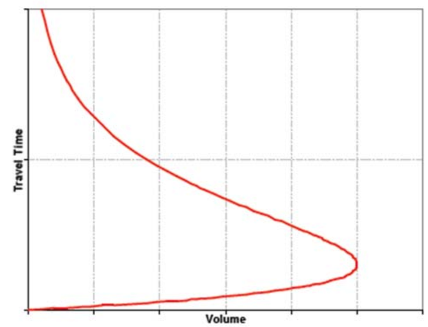
- Typical VDF (BRP)

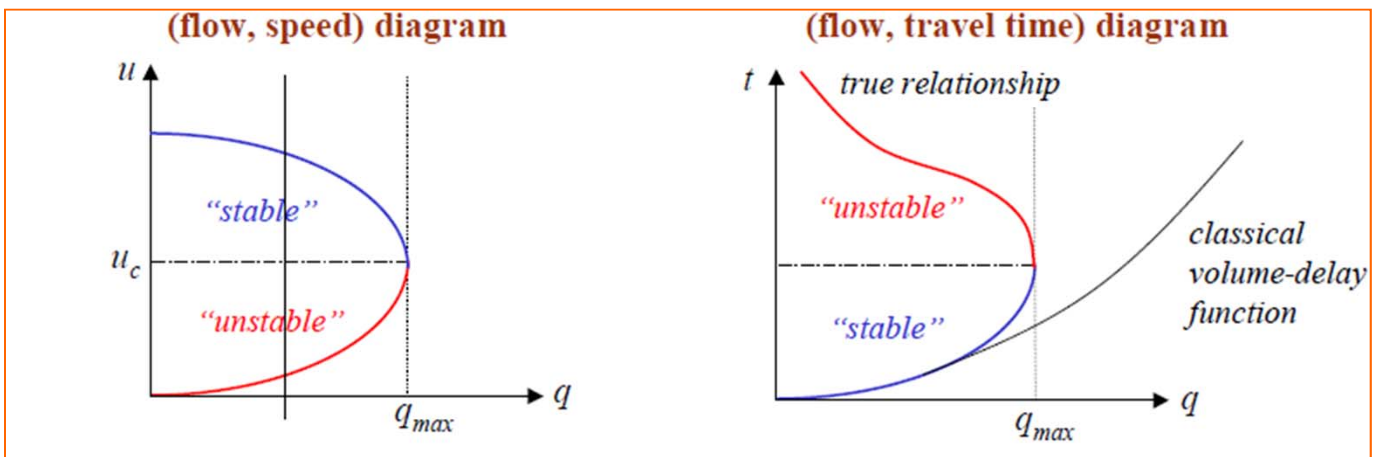
$$t(v) = t_o \cdot \left(1 + \left(\frac{v}{c}\right)^{\alpha}\right)$$



- Simple Traffic Model

$$u(k) = u_f \cdot \left(1 - \frac{k}{k_j}\right) \qquad q = u \cdot k \qquad t(u) = \frac{t_0 \cdot u_f}{u}$$





Drawbacks and Limitations of Static Models

- Conceptual Drawbacks
  - Allow V/C >1, has no intuitive meaning, does not correspond to reality or real measurements
  - Restricted to FIFO
  - Cannot model traffic moving in different lanes
  - Inflow = Outflow, i.e.
    - Single value of link flow
    - Steady state representation only
    - Cannot capture temporal congestion spread and spill-back
- Application Limitations: cannot do
  - Signal synchronization
  - HOV and HOT Lanes
  - Evacuation, congestion pricing optimization
  - ITS applications, ATMS, ATIS, RM, Adaptive Control

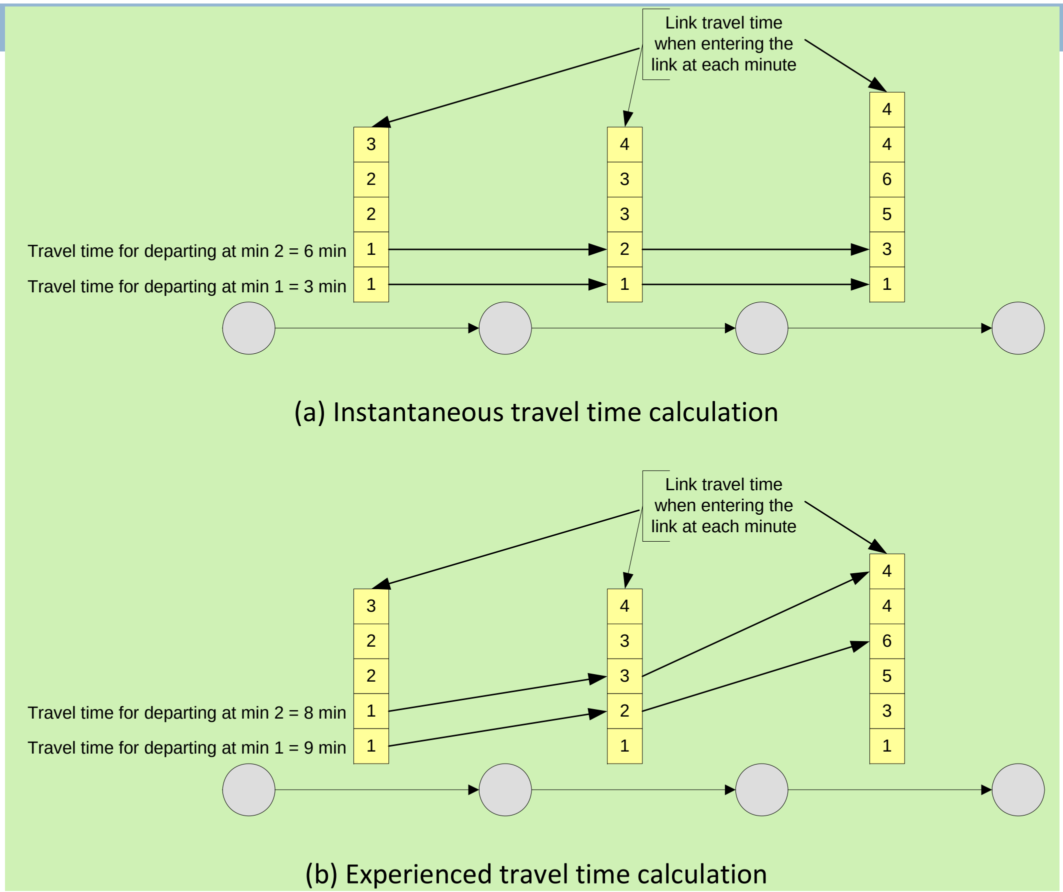
Now: What is Dynamic Traffic Assignment (DTA)?

- In a network with many OD zones and a time period of interest, for ***each OD pair and departure time***, all used routes have equal and lowest ***experienced travel time (generalized cost)***.

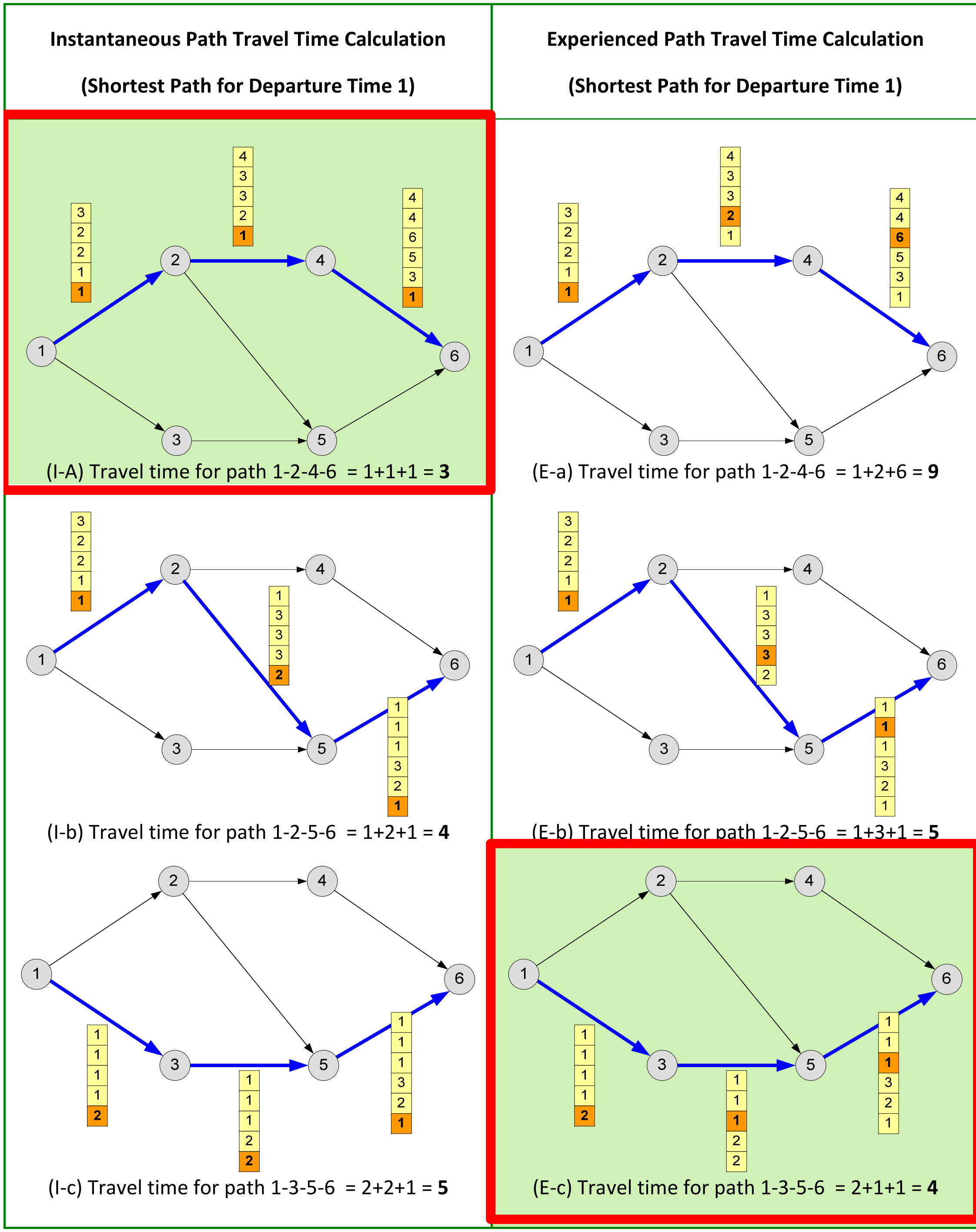
Compared with Static Traffic Assignment below:

- In a network with many OD zones, for ***each OD pair***, all used routes have equal and lowest ***travel time (generalized cost)***.

Experienced vs Instantaneous Travel Time

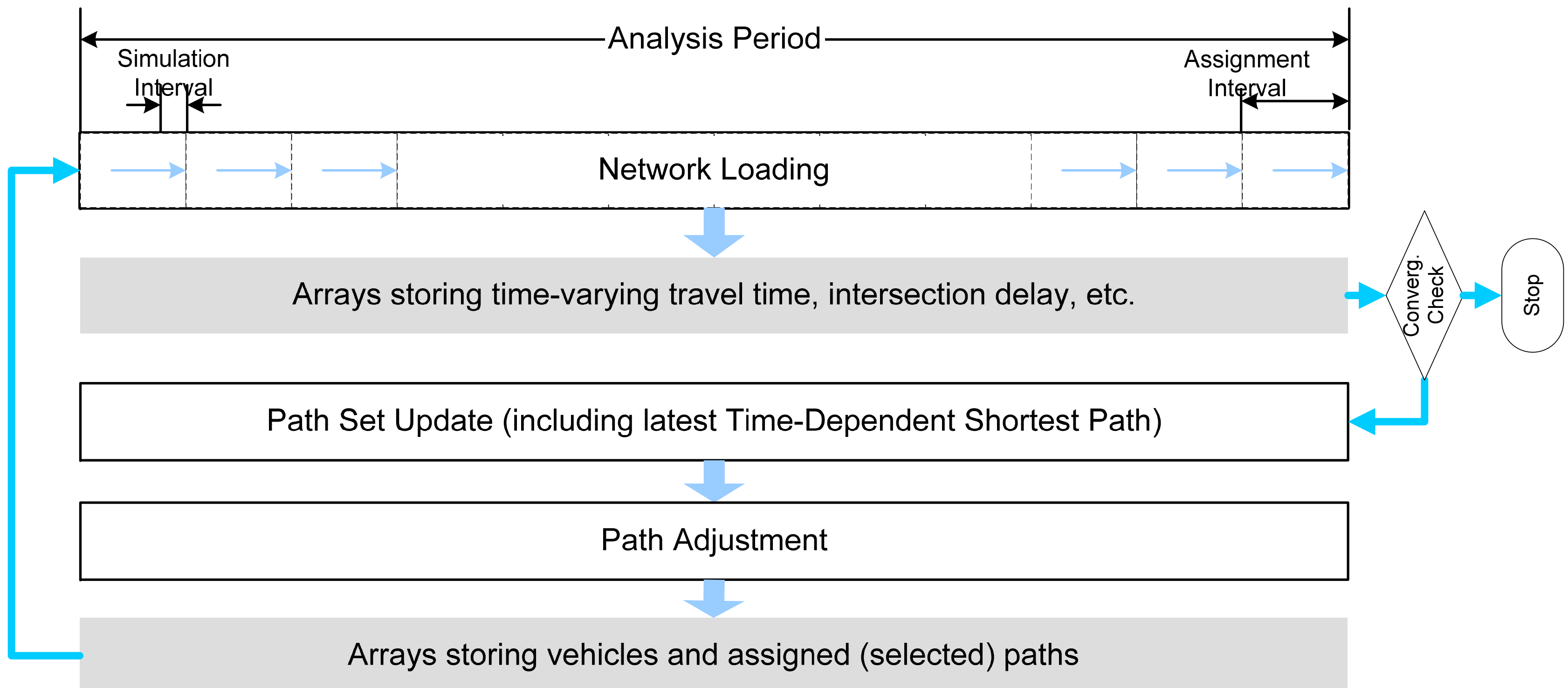


- Note how the modelling period is sliced into assignment intervals
- Experienced travel time is much different from instantaneous and can only be realized after the fact of going through the trip



- Different shortest paths obtained by instantaneous travel time and experienced travel time approaches (departure time 1)

Simulation DUE/DTA Algorithmic Structure

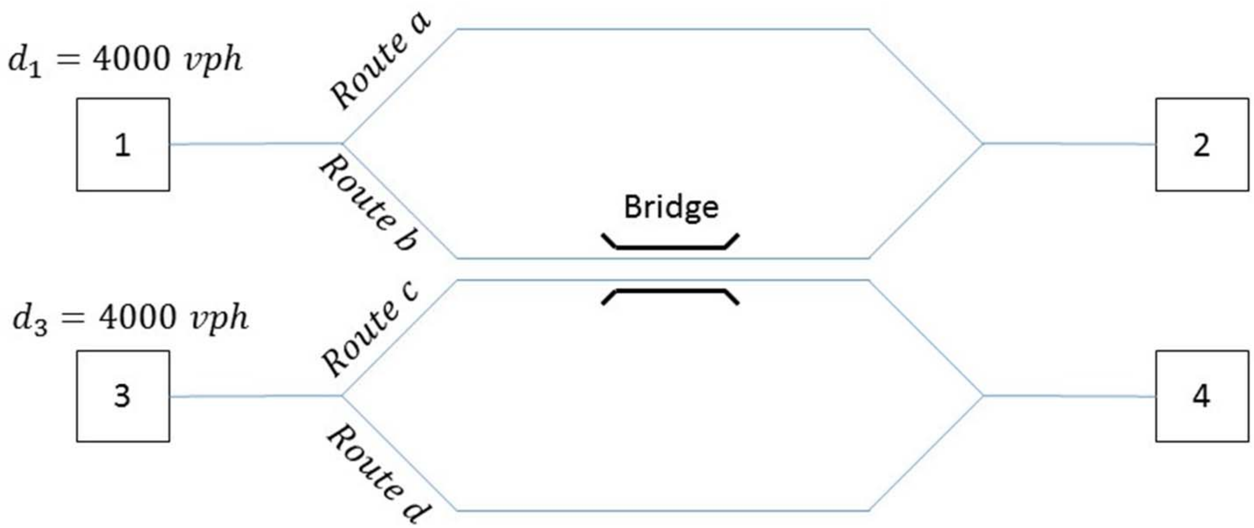


What to use iterative DTA for:

- Operational planning (or planning for operations) aimed at making planning decisions that are likely to induce a **spatio-temporal** (temporal, spatial or both) pattern shift of traffic among different roadway facilities at a corridor or network wide level.

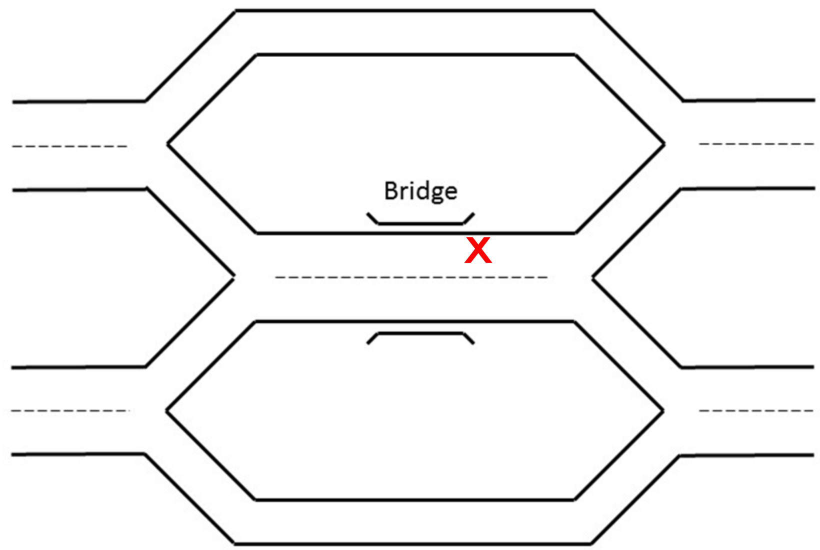
Illustration: Static vs. Dynamic Modelling

- Illustrative Example: consider
  - 2 identical O-D pairs with 4000 vph demand
  - 4 identical routes, each with capacity of 2000 vph
  - Routes b and c pass through a bridge with capacity of 4000 vph



Static vs. Dynamic Modelling

- If the capacity of the bridge is or drops to 2000 vph, evaluate the performance of both static and dynamic modelling during the transient and at steady state?



Static vs. Dynamic Modelling

At steady state	Static	Dynamic
Before capacity drop	All routes carry 2000 vph	All routes carry 2000
After capacity drop	• Some traffic shifts to outer routes • On the bridge flows are greater than capacity • Just before the bridge, flows are less than capacity which implies abnormally high speeds	• Precise amount of traffic shifts to outer routes • On bridge, flows cannot exceed capacity • Congestion spills back to the origins affecting all upstream links

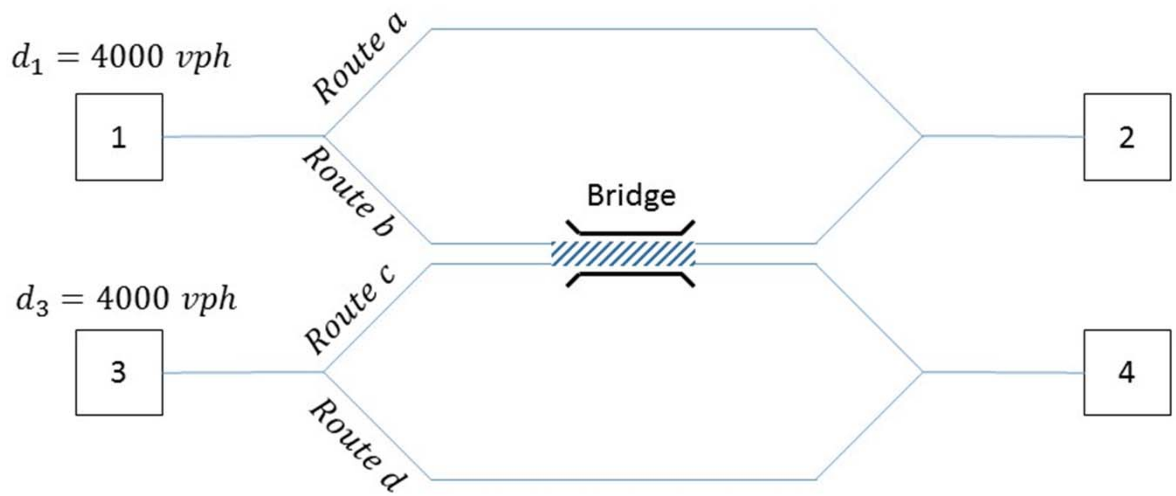
Static vs. Dynamic Modelling

	Static	Dynamic
Steady state traffic flows at the bridge	✘ Flows greater than capacity on all routes (v/c >1)	✓ Flows limited to the capacity
Steady state traffic flows upstream of bridge	✘ Flows less than capacity and high speeds	✓ Congestion spills back upstream from the bridge
Transient state	✘ Cannot be modelled	✓ Properly captures gradual congestion spreading on inner routes (time variant travel costs) ✓ Can be modelled in both one-shot and iterative

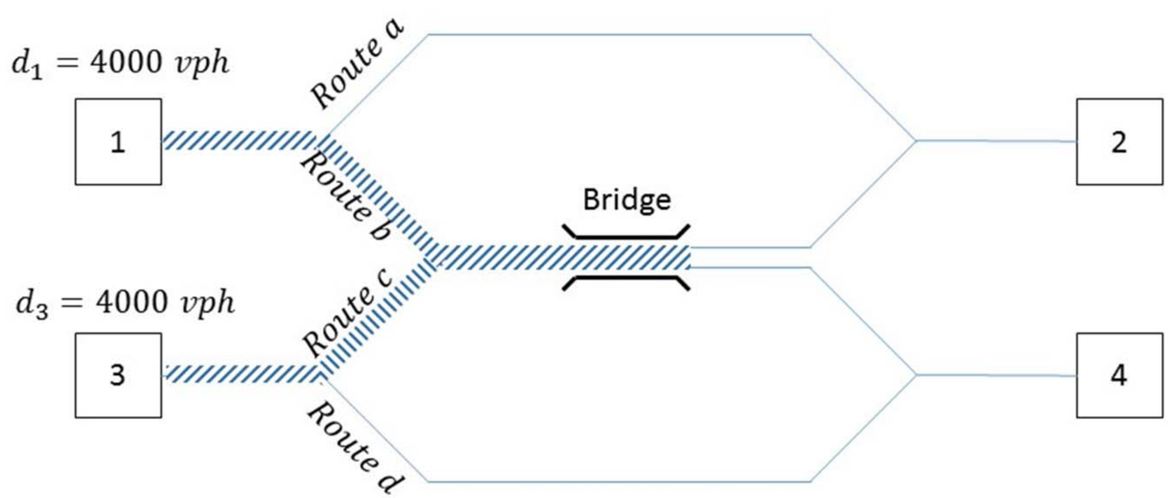
Static vs. Dynamic Modelling

- Transient state after capacity drop: Conges

Static:



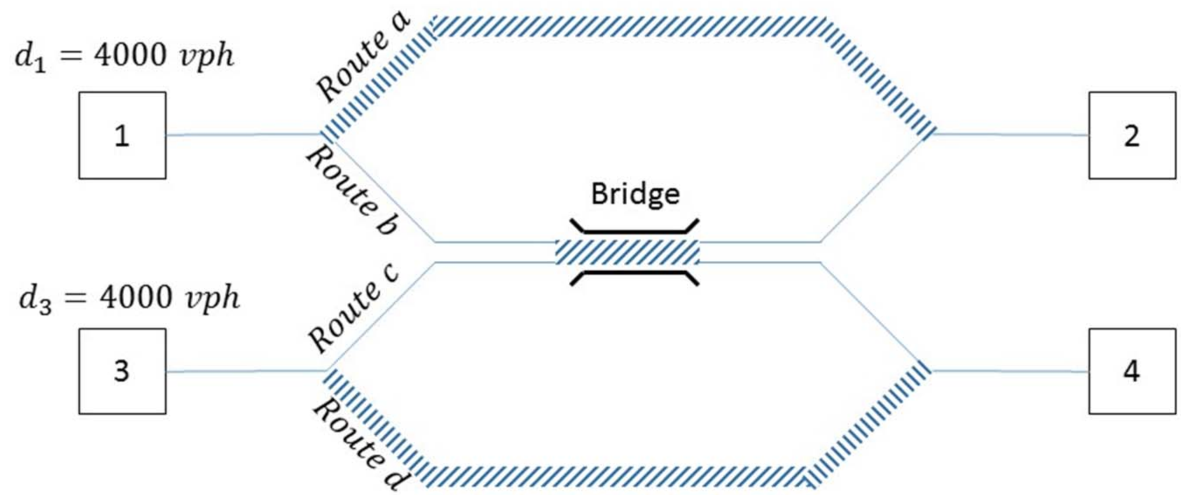
Dynamic:



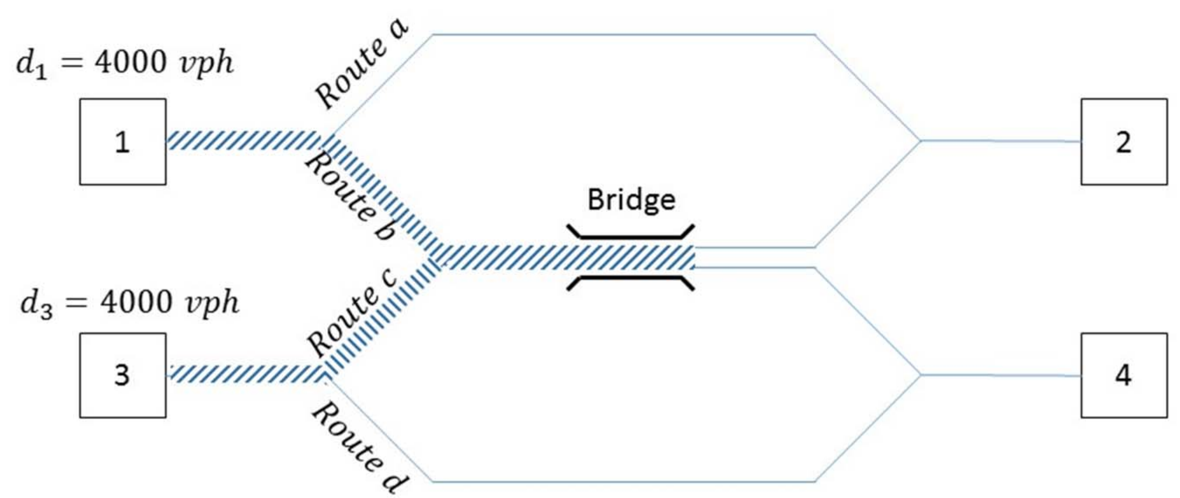
Static vs. Dynamic Modelling

- Steady state after capacity drop: Congestion

Static:



Dynamic:



Policy implications

- If the purpose of the analysis is to identify the bridge for expansion (typical planning), both approaches would somewhat do, despite the misrepresentation of static.

- If the purpose of the analysis is to adjust the spatio temporal patterns of traffic (changes in departure time, route choice etc.), which is typical in over congested networks, only dynamic models should be used, static cannot do and can be misleading or even wrong (tolling the outer routes for instance).

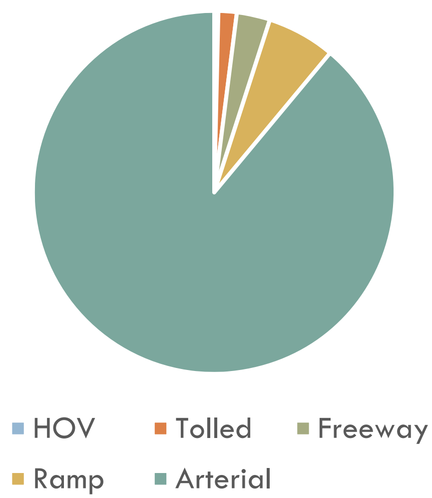
Mesoscopic DTA Multi-modal Model for the GTA

- Mesoscopic model covers most of the GTA, focusing on freeways, major arterials, and arterials carrying TTC vehicles
- Dynamic traffic assignment captures how congestion evolves over time
- Multi-modal model includes driving, transit (GO, TTC, parts of MiWay), and park-and-ride
- The model simulates AM peak trips

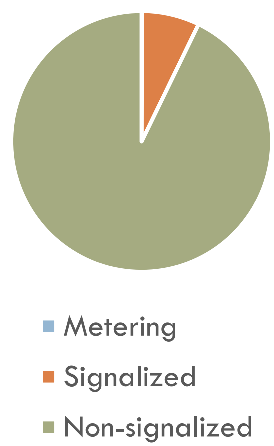
Model Development

29,422 Links

26,769 Km



12,986 Nodes



Model Development

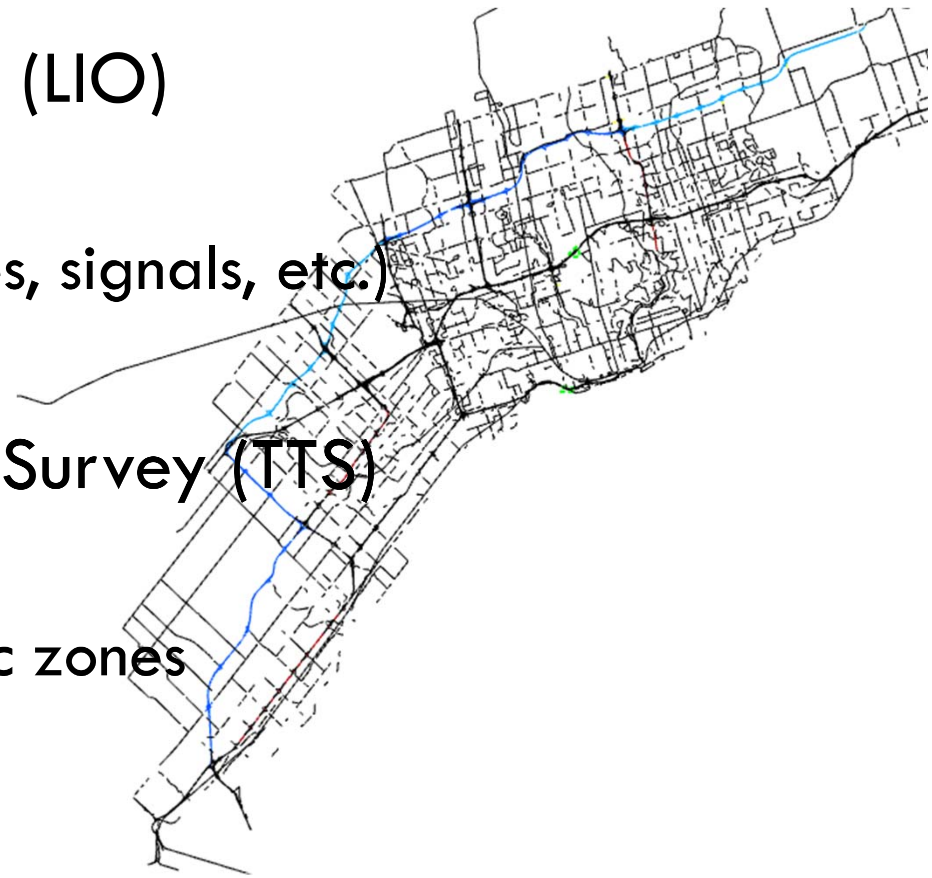
Travel Demand
1497 Traffic Zones

During AM Peak
436,000 Hourly Trips
36 Million records

Origin Zones \ Destination Zones	1	2	…	1497
1	0	2300	…	9847
2	9984	2208	…	0
⋮	⋮	⋮	⋱	⋮
1497	6788	9188	…	398

Model Development

- Land Information Ontario (LIO)
  - GIS database (links, nodes, signals, etc.)
- Transportation Tomorrow Survey (TTS)
  - Travel demand and traffic zones



Model Development

- The GIS model
  - Auxiliary lanes
  - Speed limits
  - Traffic signals
- Travel demand data
  - Flip-flopping data trend
  - Background demand
  - Intra-zonal demand

Model Development: Travel Demand

- The GIS model
  - Auxiliary lanes
  - Speed limits
  - Traffic signals
- Travel demand data
  - Flip-flopping behavior
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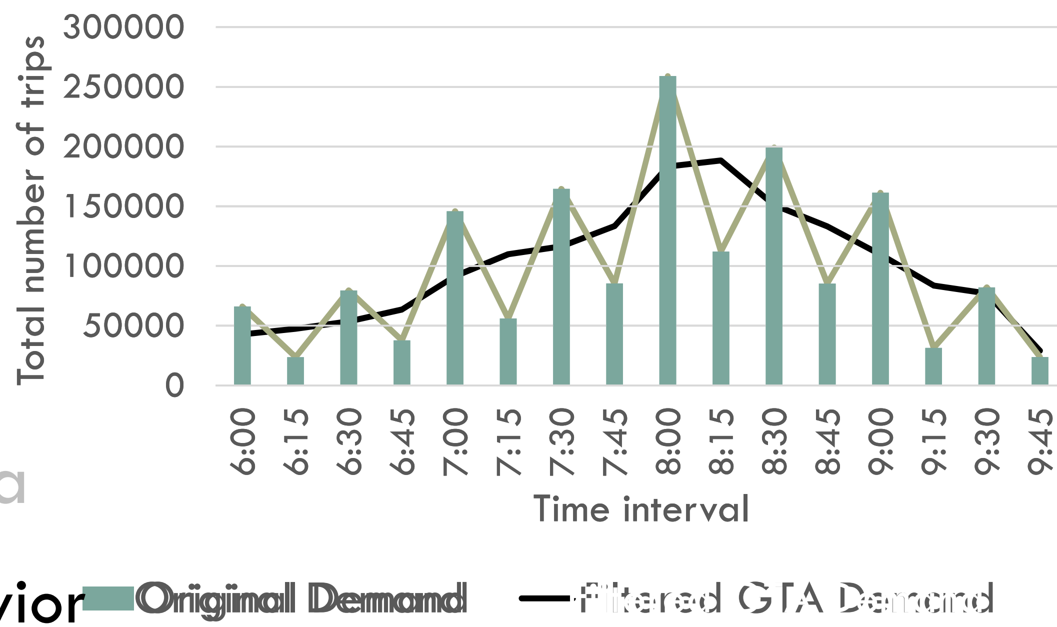
  - Intra-zonal demand



Model Development: Travel Demand

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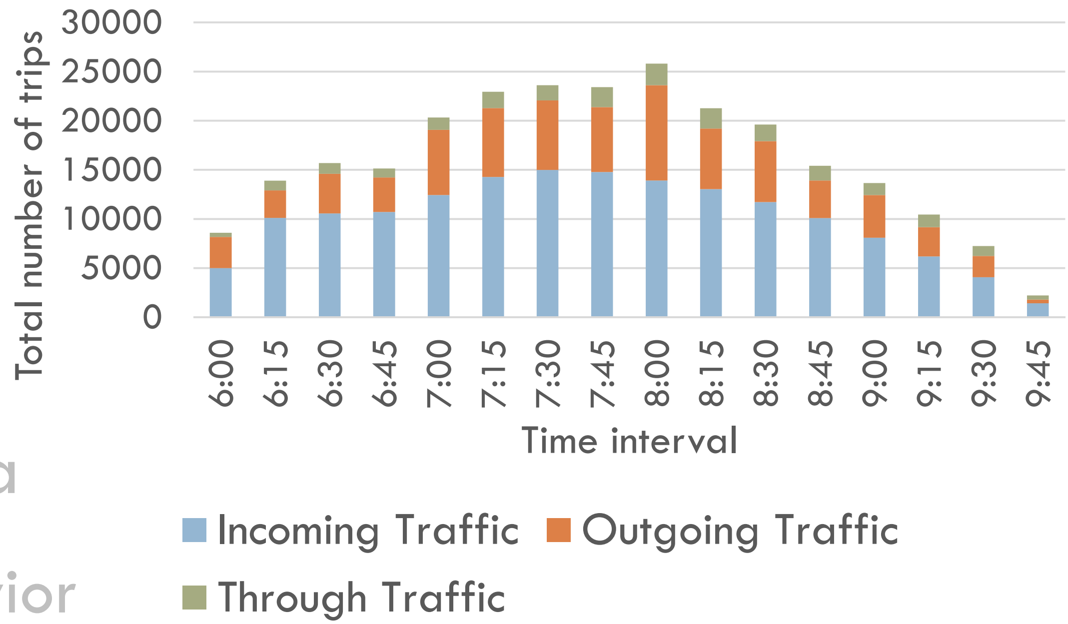

Model Development: Travel Demand

- The GIS model
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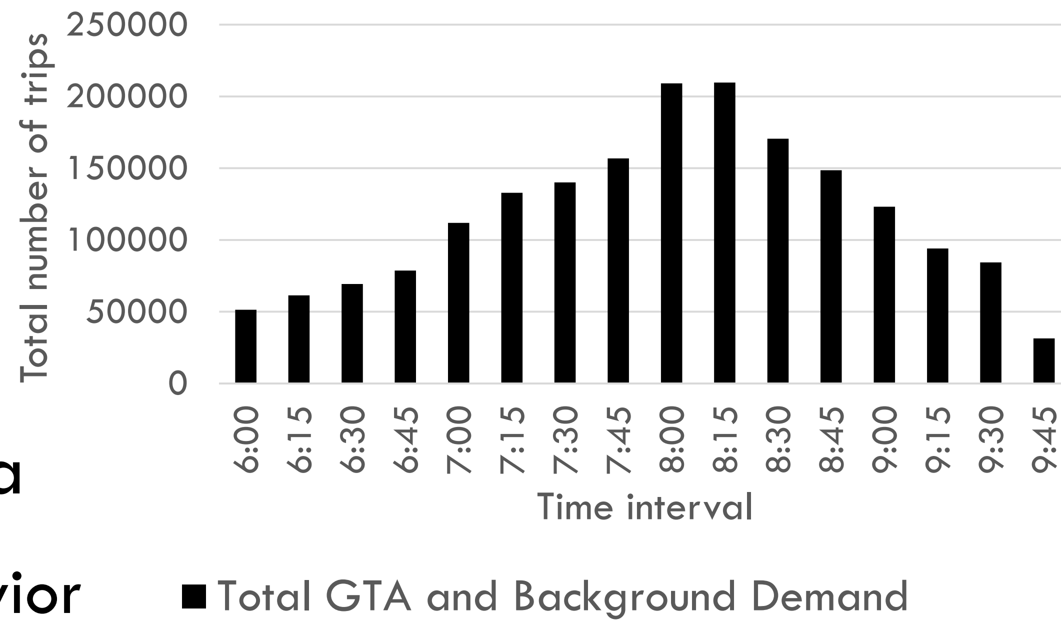


- Travel demand data
  - Flip-flopping behavior
  - Background demand
  - Intra-zonal demand

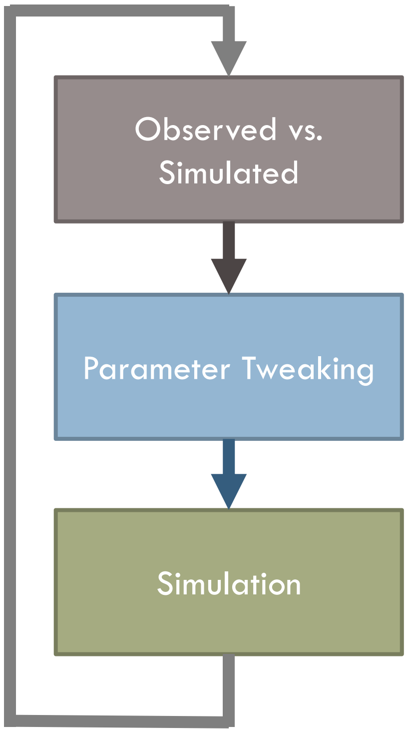
DTA Setup

- Mesoscopic DUE
- Iterative (30 iterations)
- Experienced travel times
- Road attractiveness:
- Jam density:
- Fixed reaction time:

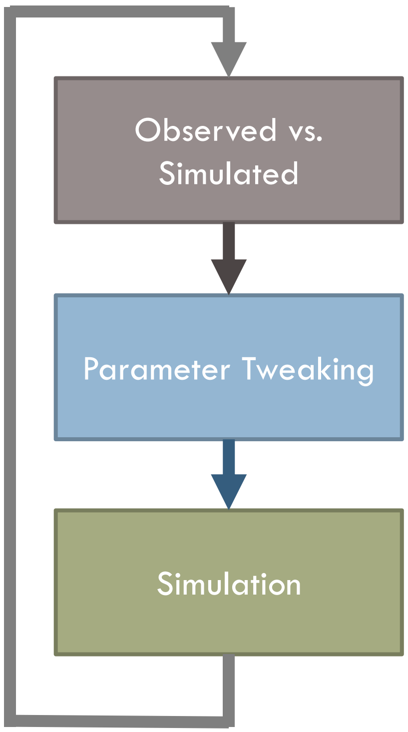
DTA Outputs

- Flow, speed, density, queue length, travel time, …
- Network-wide statistics
- Sections, nodes, traffic signals, turns, …
- Vehicle trajectories

Model Calibration

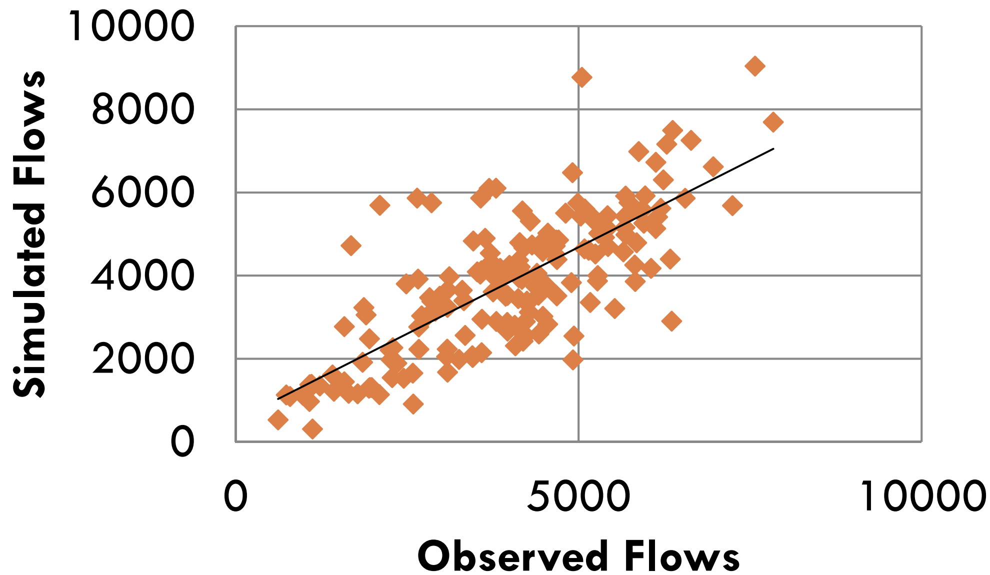


Calibration: Observed vs Simulated



- Loop detectors
- Google maps

- 176 loop detectors / updated every 20 sec



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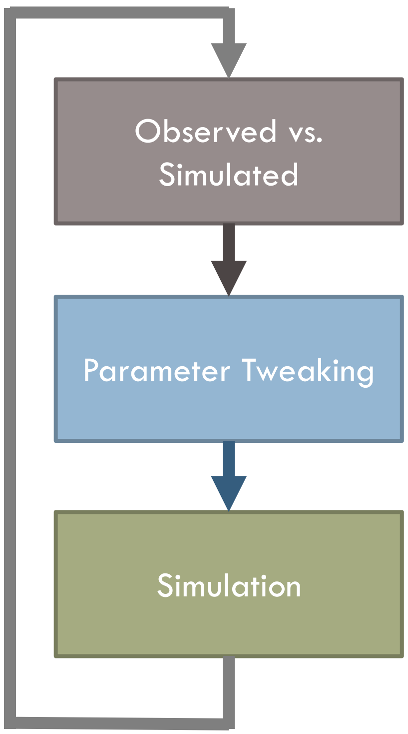

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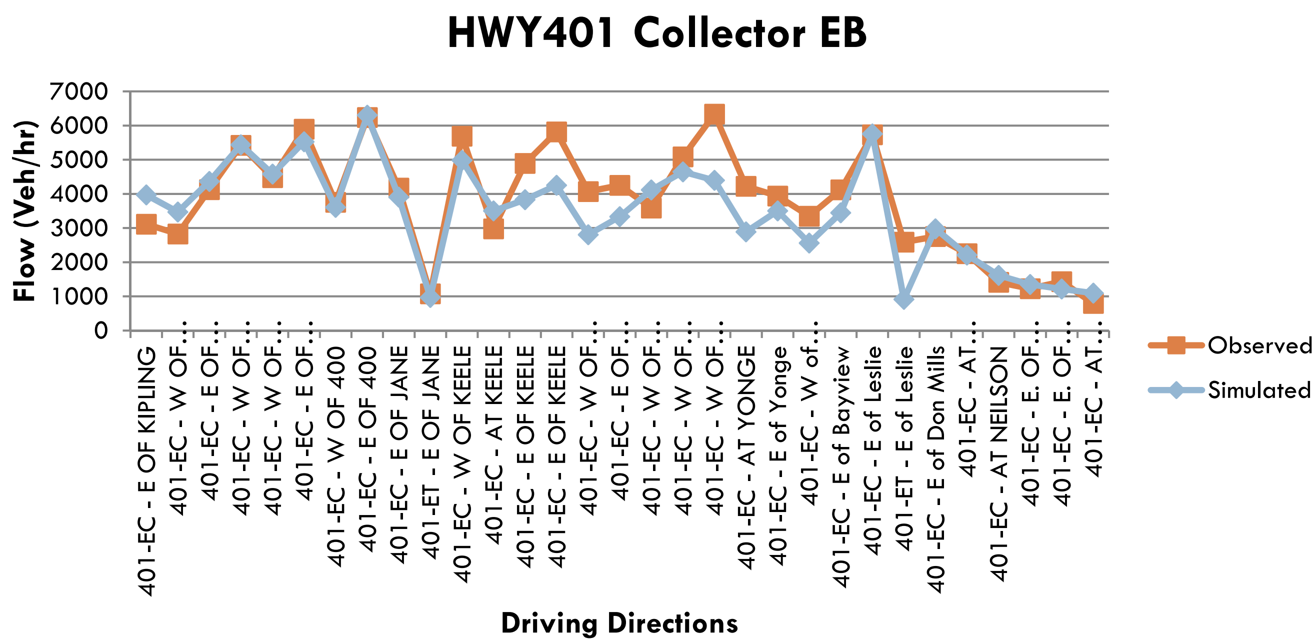
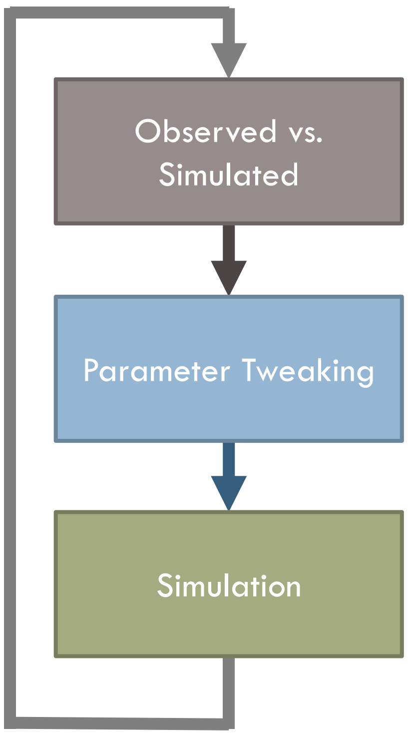


Calibration: Parameter Tweaking



- Loop detectors
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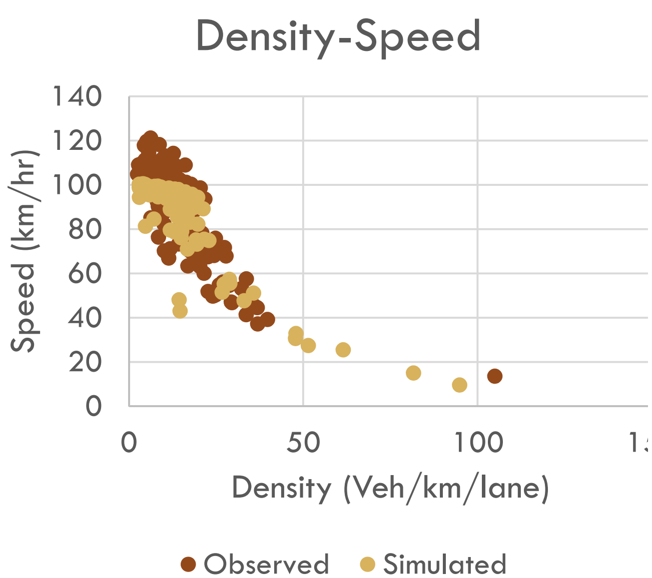
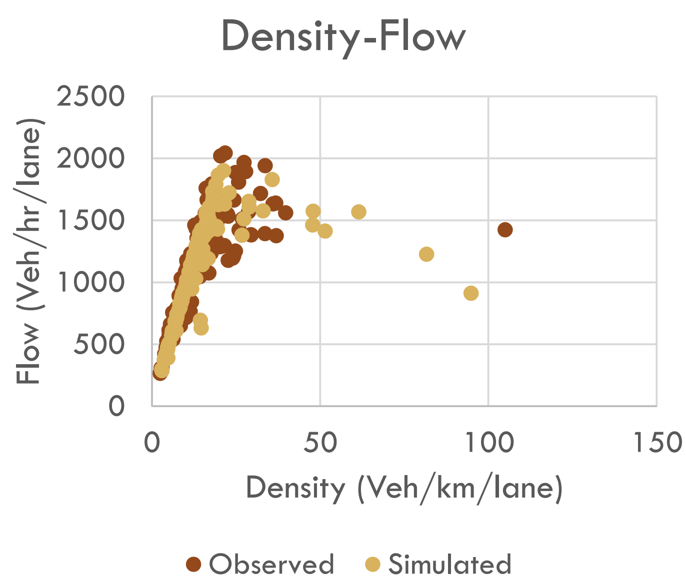
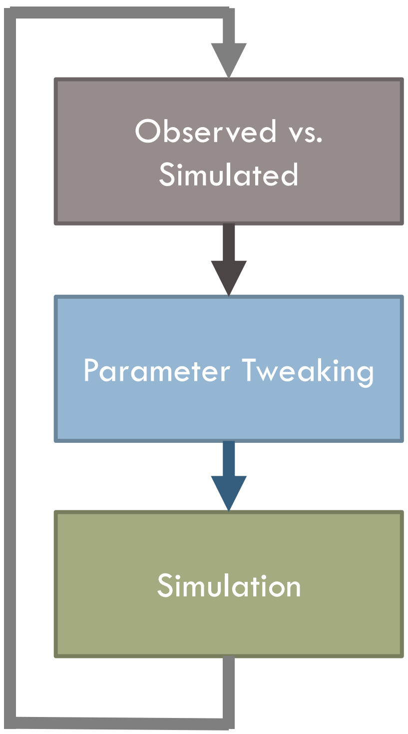
- Traffic flow model parameters

- Jam density, look ahead distance, merging distance, …





Calibration : Demand Tweaking

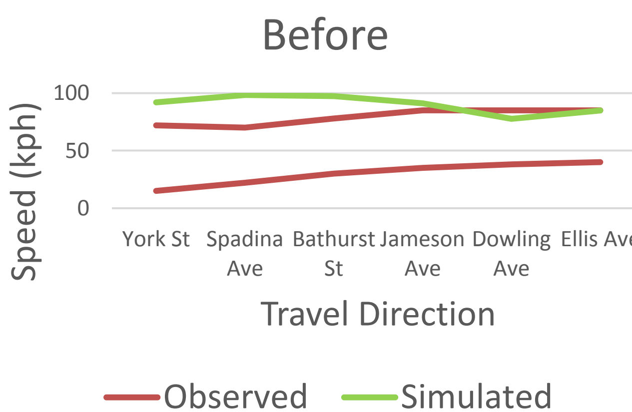


- Loop detectors
- Google maps

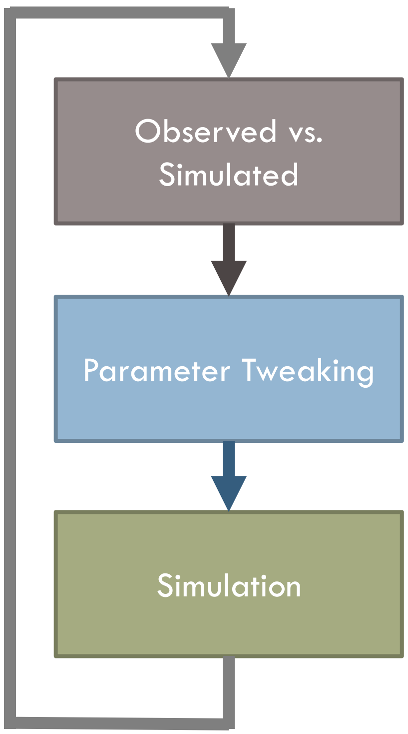
- 176 loop detectors / updated every 20 sec

- Traffic flow model parameters
- Demand tables

- Jam density, look ahead distance, merging distance, …
- OD pairs travelling over specific corridors



Calibration: Miscellaneous



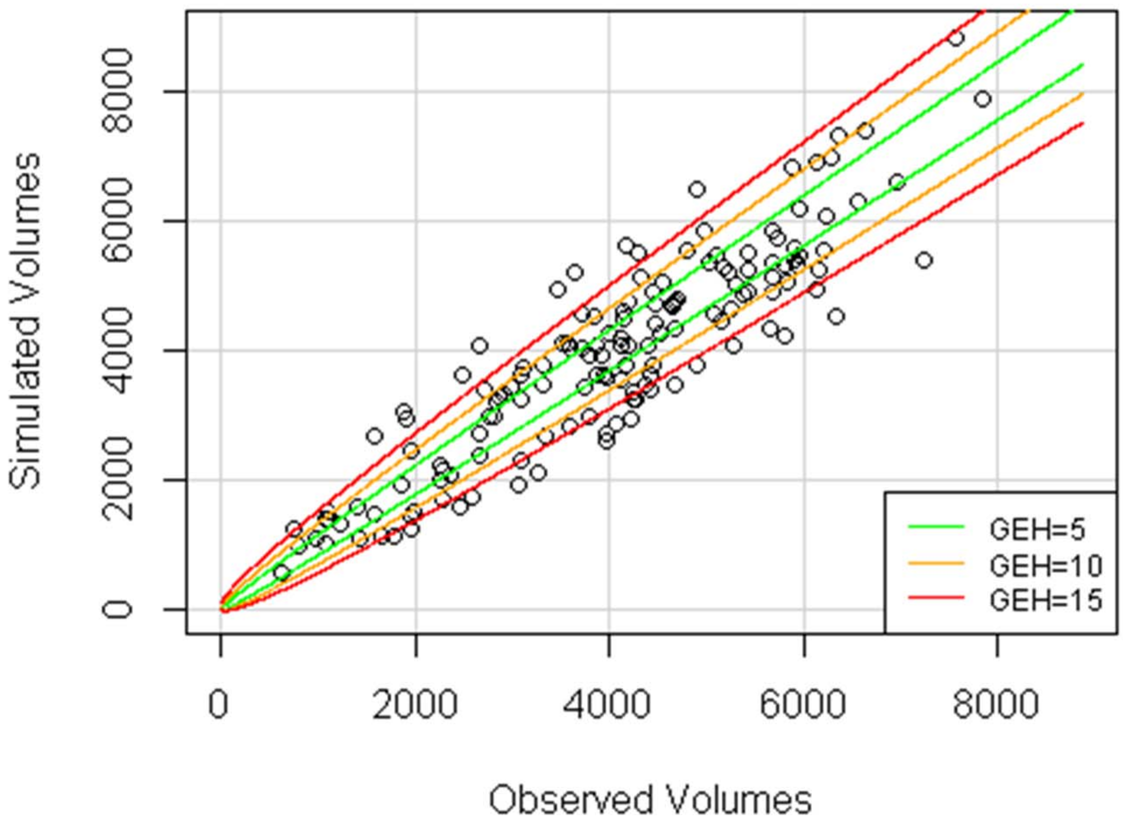
- Loop detectors
- Camera feeds
- Google maps

- 35 million daily readings / updated every 20 sec

- Traffic flow model parameters
- Demand tables
- Network geometry-related parameters

- Jam density, look ahead distance, merging distance, …
- OD pairs travelling over specific corridors
- Signal timing, number of lanes, …

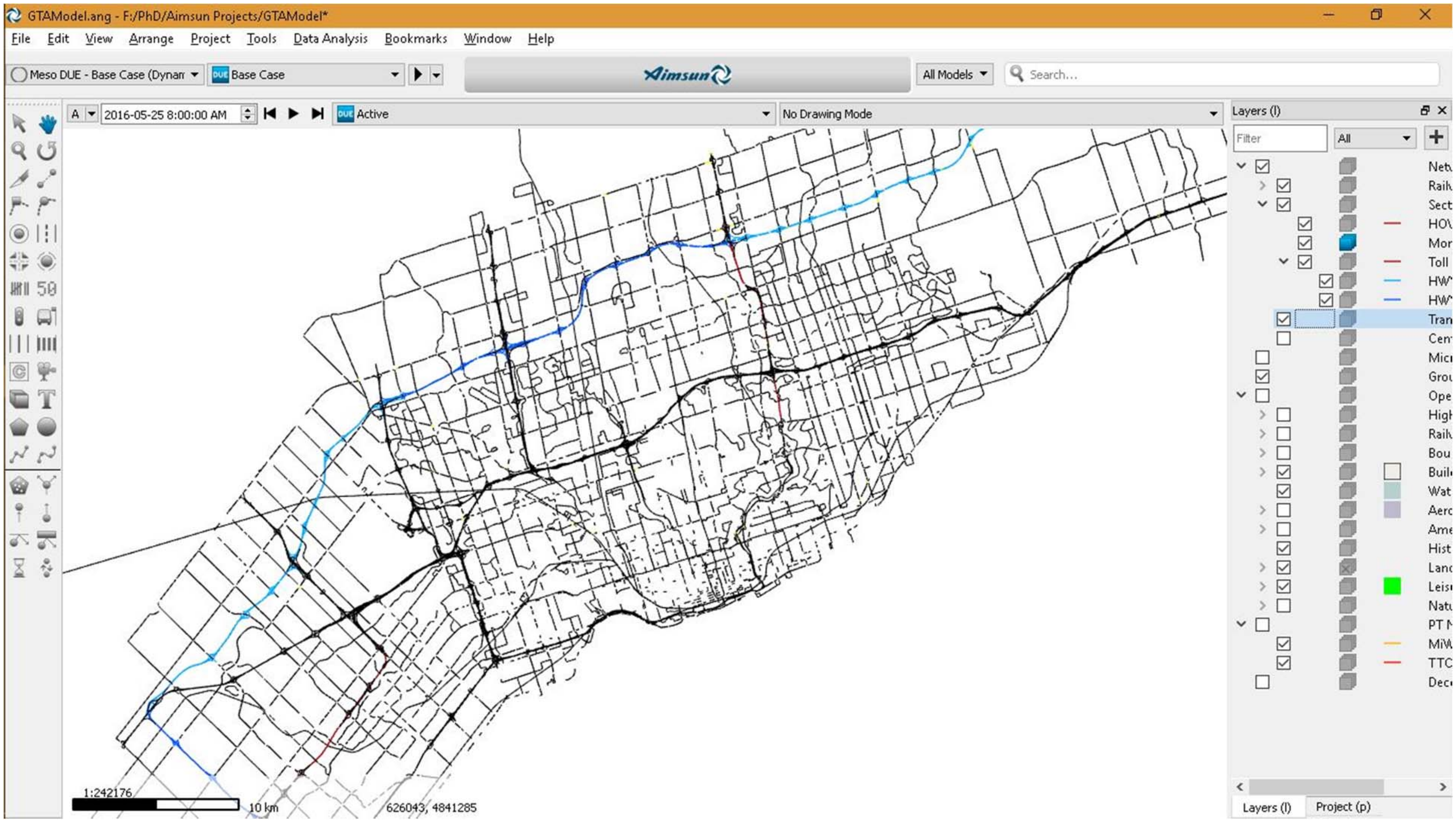
Calibration: GEH



Ongoing Work

- Transit layers
- Joint departure time and mode choice model
- Concurrent optimization of dynamic congestion pricing and variable transit fares

Demo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