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An extended transit assignment model in MATSim: A case study of Hong Kong

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Hong Kong public transport – in a nutshell

Hong Kong public transport – in numbers

- In 2016, 12 million passenger trips per day, 90% usage rate[1]
- ~5 million trips per day in MTR, ~4 million trips in franchised bus[1]
- **577** franchised bus routes by end December 2017 [2]
- **350** minibus route [2]
- 11 heavy rail lines and 93 stations [1] [3]
- A light rail network comprises of 12 routes serving 68 stops [1] [3]

[1] MTR Service performance (https://www.legco.gov.hk/research-publications/english/1718issh07-mtr-train-service-performance-20171220-e.pdf)
[2] Hong Kong : The Facts – Transport (https://www.gov.hk/en/about/abouthk/factsheets/docs/transport.pdf)
[3] MTR Investor's information (http://www.mtr.com.hk/en/corporate/investor/investor_faq.html)

Characteristics

- Non-linear, non-zonal fare structure
- Transfer discount (e.g. Bus – tram interchange)
- Overcrowded transit network → platform congestion
- High usage → a lot of transit assignment
- Congested road network → high variability

Existing transit routers

- Default transit router
  - Super slow, as numerous transfer links are created
  - Fare is not considered
  - Platform congestion omitted.
- Event-based public transport router (EVPTR)
  - Slow convergence in our scenario
  - Non-linear fare is not considered
- Route-based public transit routing (RAPTOR)
  - Did not passed the test when we implemented the extended model

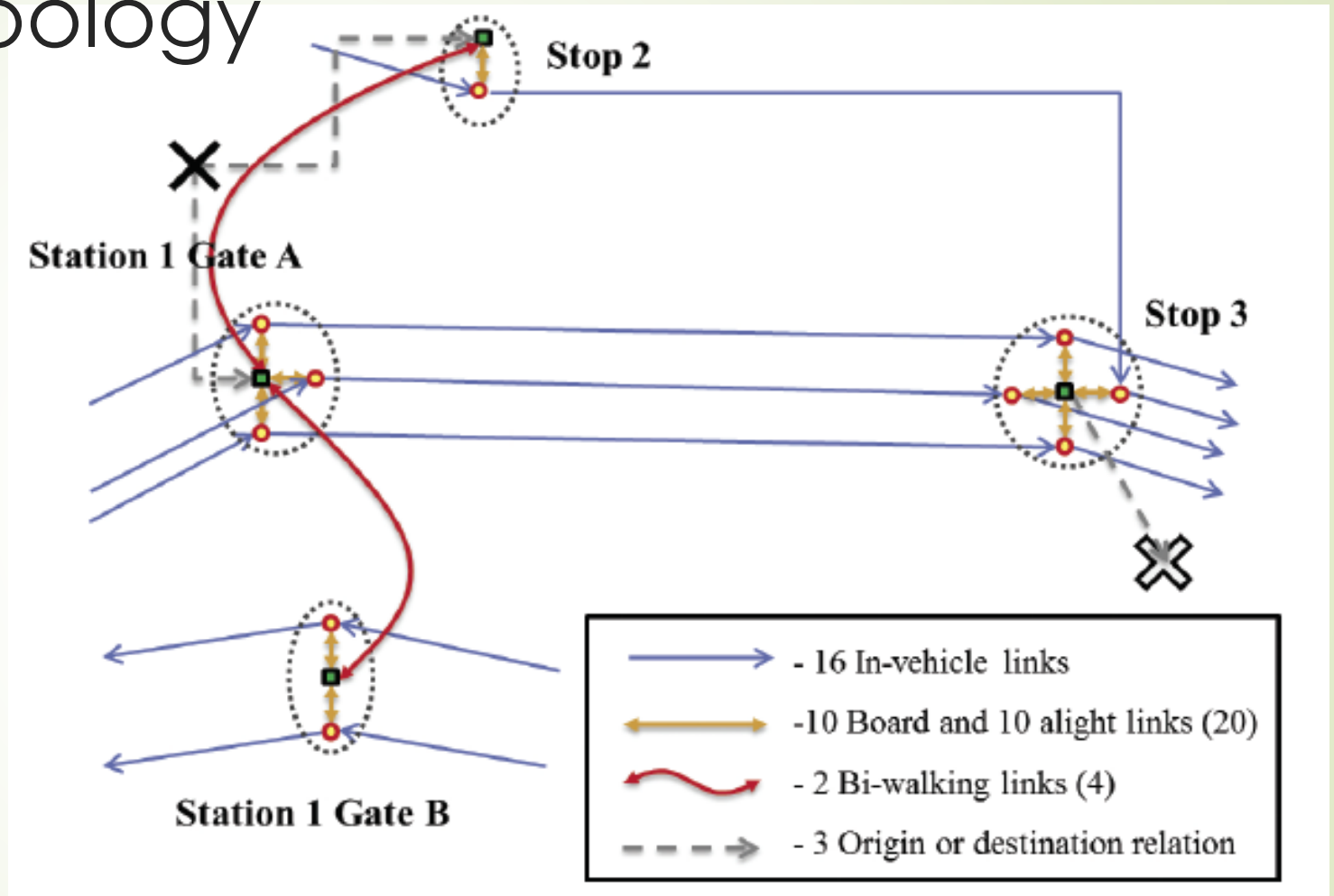
Network structure and cost calculation

What is the network topology to perform Dijkstra?

How is the cost be defined?

Network topology

- Same network topology as EBPTR
- Different link cost calculation
- Implicitly included 'occurrence' concept



Ordóñez Medina, S. A. New Dynamic Events-Based Public Transport Router. In *The Multi-Agent Transport Simulation MATSim* (A. Horni and K. Nagel, eds.), Ubiquity Press, pp. 123–132.

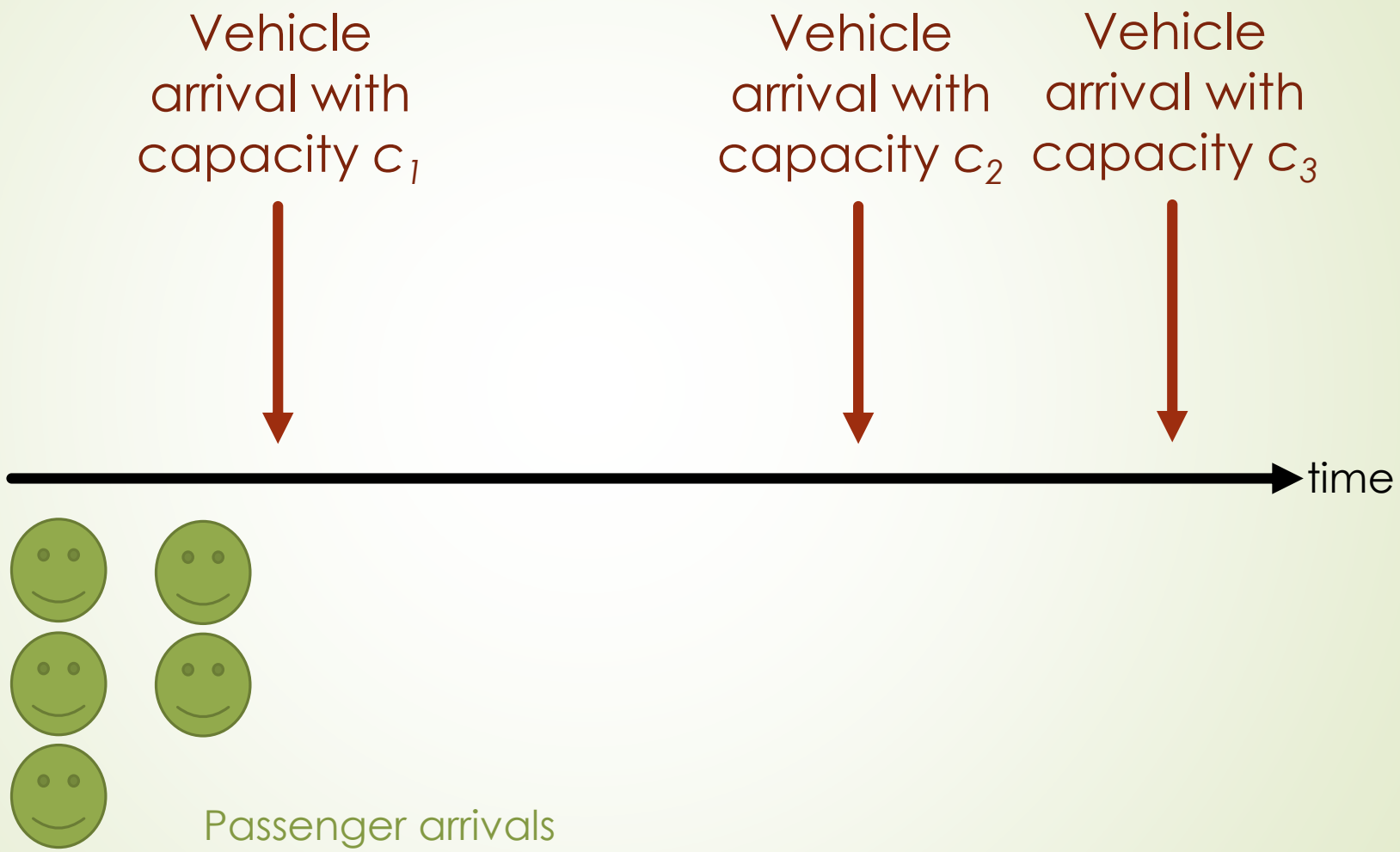
Costs

Mobsim

- Exact arrival time, standing and seats available, as well as queues for every stop are stored.

Replanning

- Then, the **vehicle at departure** anticipated to take is identified
- Travel cost and waiting cost are calculated based on the past performance of that departure.
- The fare disutility is added on top of it.


Vehicle arrival with capacity c_1
Vehicle arrival with capacity c_2
Vehicle arrival with capacity c_3
time
Passenger arrivals

Fare handler

How we handle the fare?

Fare difference

- In the boarding link, the minimum fare (i.e. One stop for bus) is added to the disutility.
  - The boarding stop/station is stored
- In the travel link, the fare difference of travel one stop is calculated.
  - For example, if the fare from stop A to stop B is $2, and from stop A to stop C is $3, then for a passenger who've aboard in stop A, the fare difference from stop B to stop C is $1.

A* algorithm

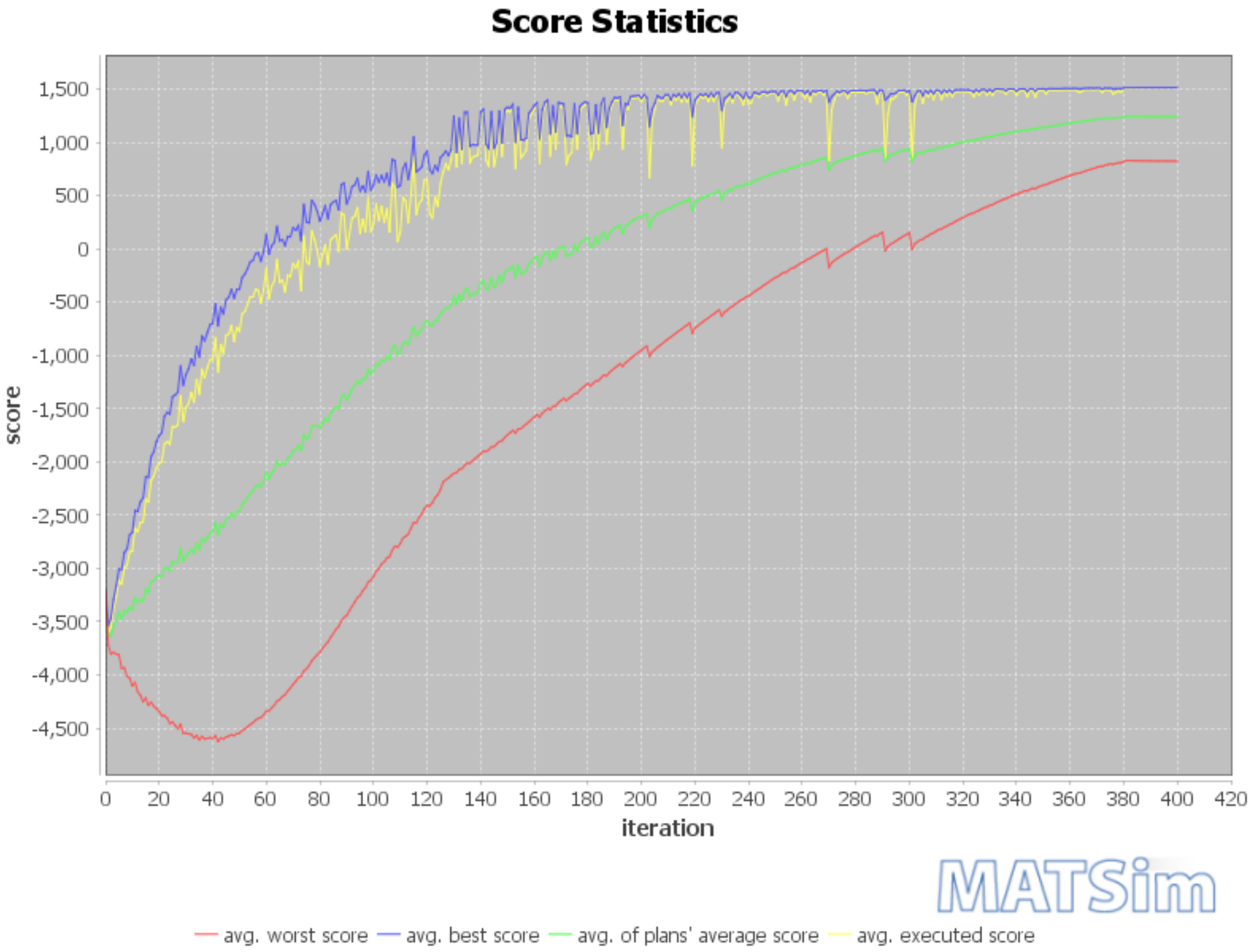
A heuristic to increase the speed

Performance

- Scenario :
  - 1.33 millions population, 2.72 millions trips, 2.41 millions transit trips
  - Transit network : 88258 links
    - 14248 travel links
    - 14849 waiting links + 14849 alight
    - 44312 transfer links
  - Strategy: 1.5% time mutation, 1% re-route, and 0.5% change trip mode
  - Intel Xeon CPU E5-2690 v3 @ 2.60GHz, 128Gb ram. 23/24 thread were used for replanning
- Result:
  - EVPTR: About 550s per iterations for replanning
  - Extended model With A*: About 200s per iterations for replanning **(↓63%)**

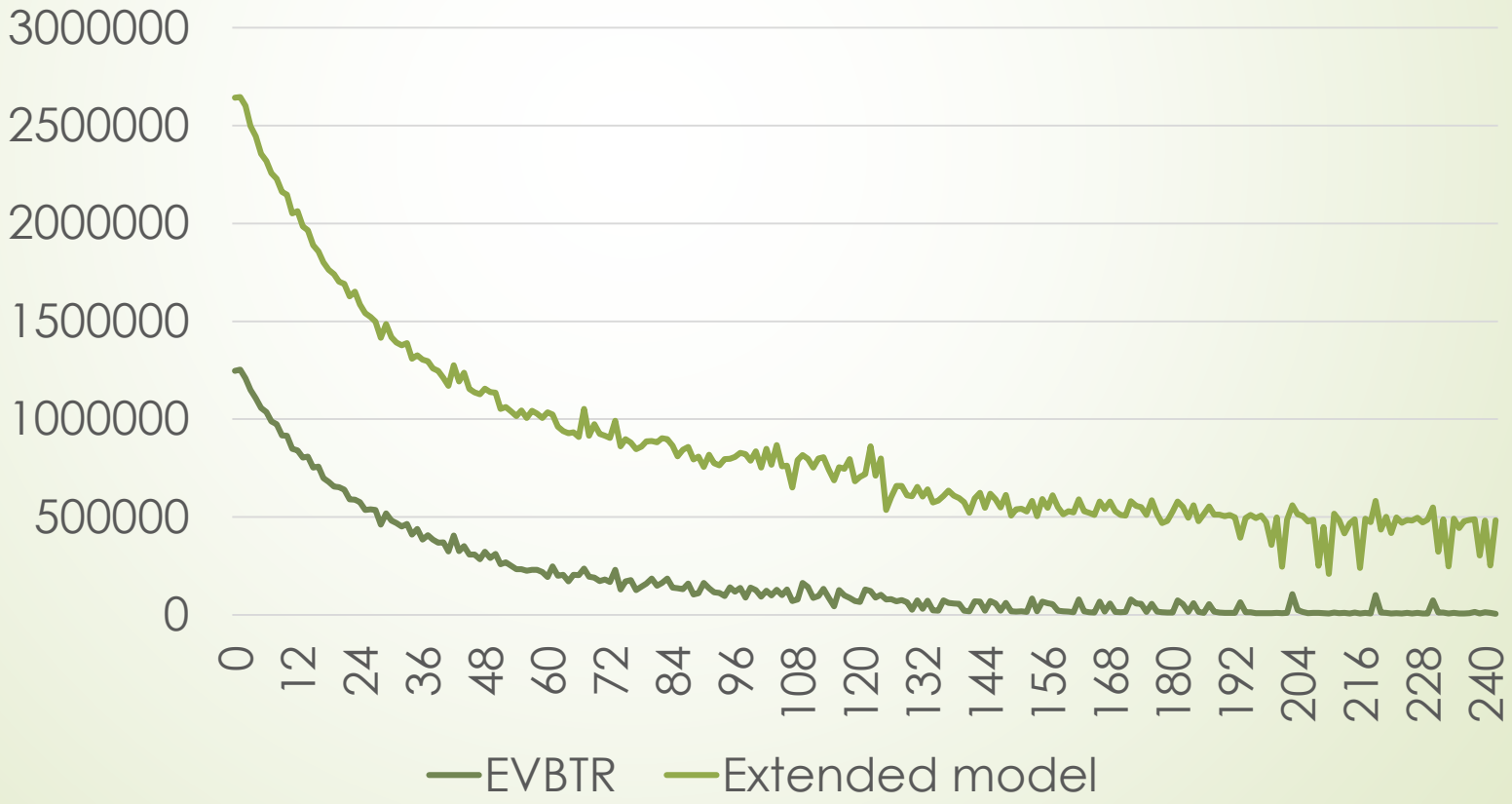
Example - Hong Kong Island

About to converge in 250 iterations.



Example – Hong Kong Island (cont.)

- We compared the ratio of pt users stucked in first 240 iterations.



Example – comparison between transfer discount

- There are two interchange discount between a bus company (KMB), with tram and a minibus company respectively, within certain timeframe.
- The difference before and after the accounting of discount is shown below.
- The effectiveness was demonstrated.

	Without discount	With discount
Bus/minibus interchange	1268	1583 **(+25%)**
Bus/tram interchange	2007	3913 **(+95%)**

MATSim – Hong Kong

Team members

- Prof. Hong K. LO
- Dr. Wei HUANG
- Ashraf Uz Zaman PATWARY
- Yue HUAI
- Enoch LEE

Hong Kong scenario – in numbers

- Road network
  - Nodes: 8005
  - Links: 16568
- Population: 7.4 million
  - many of them have only one trips
  - the total number of legs is about 12 million

Outline

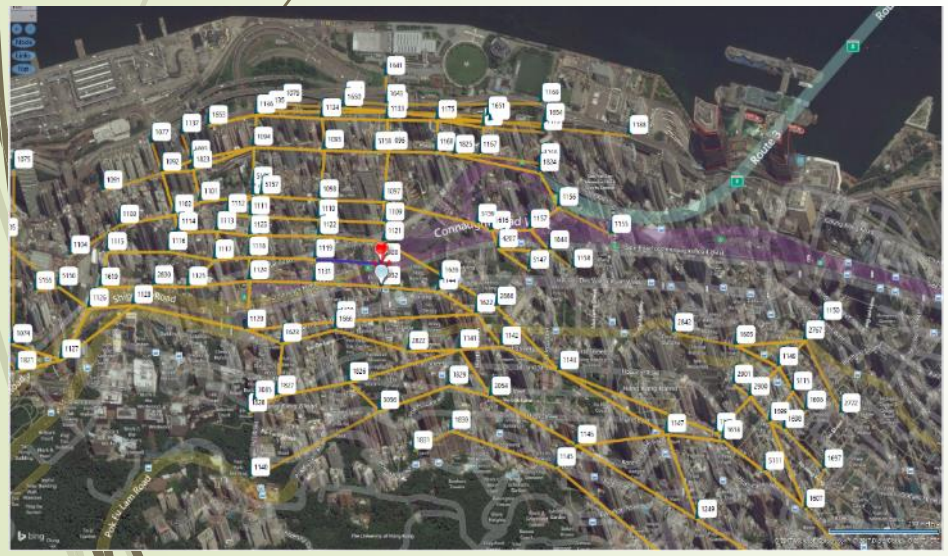
- Input
  - Road network
  - Public Transportation
  - Population
- Development on top of MATSim
  - Calibration by meta-model
  - Emission model
  - Extended Transit assignment model
- Challenges
  - On Python analysis
  - Runtime
  - Calibration and validation

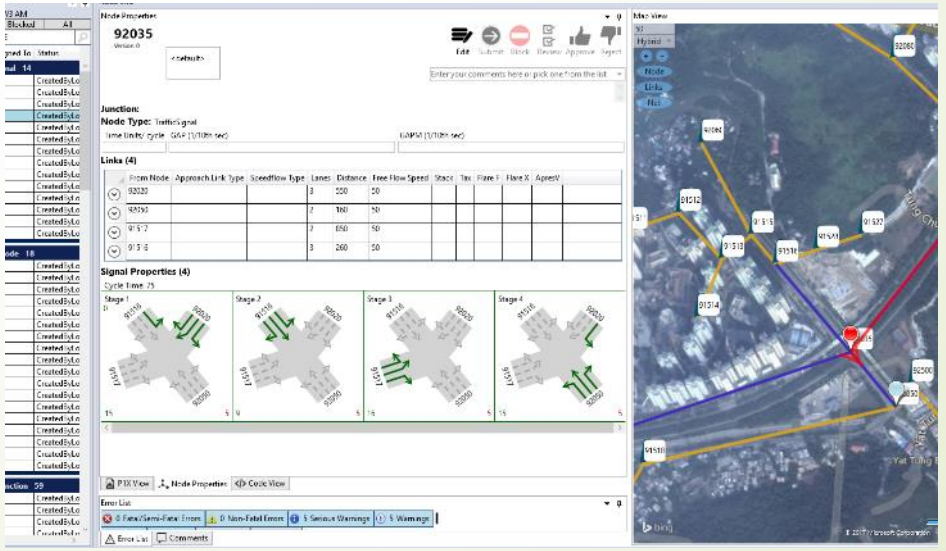
Google Satellite Map of Hong Kong

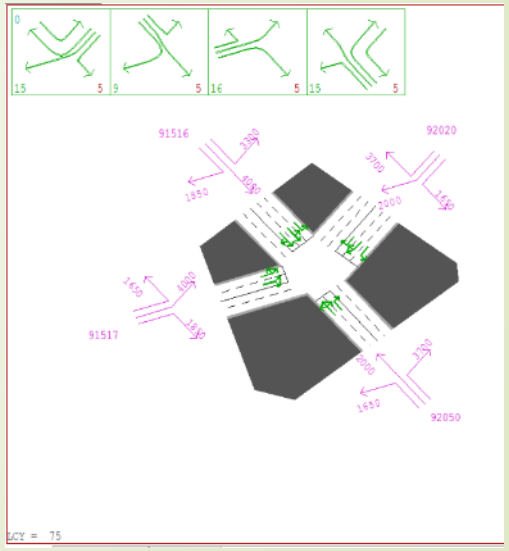
MATSim network in Hong Kong

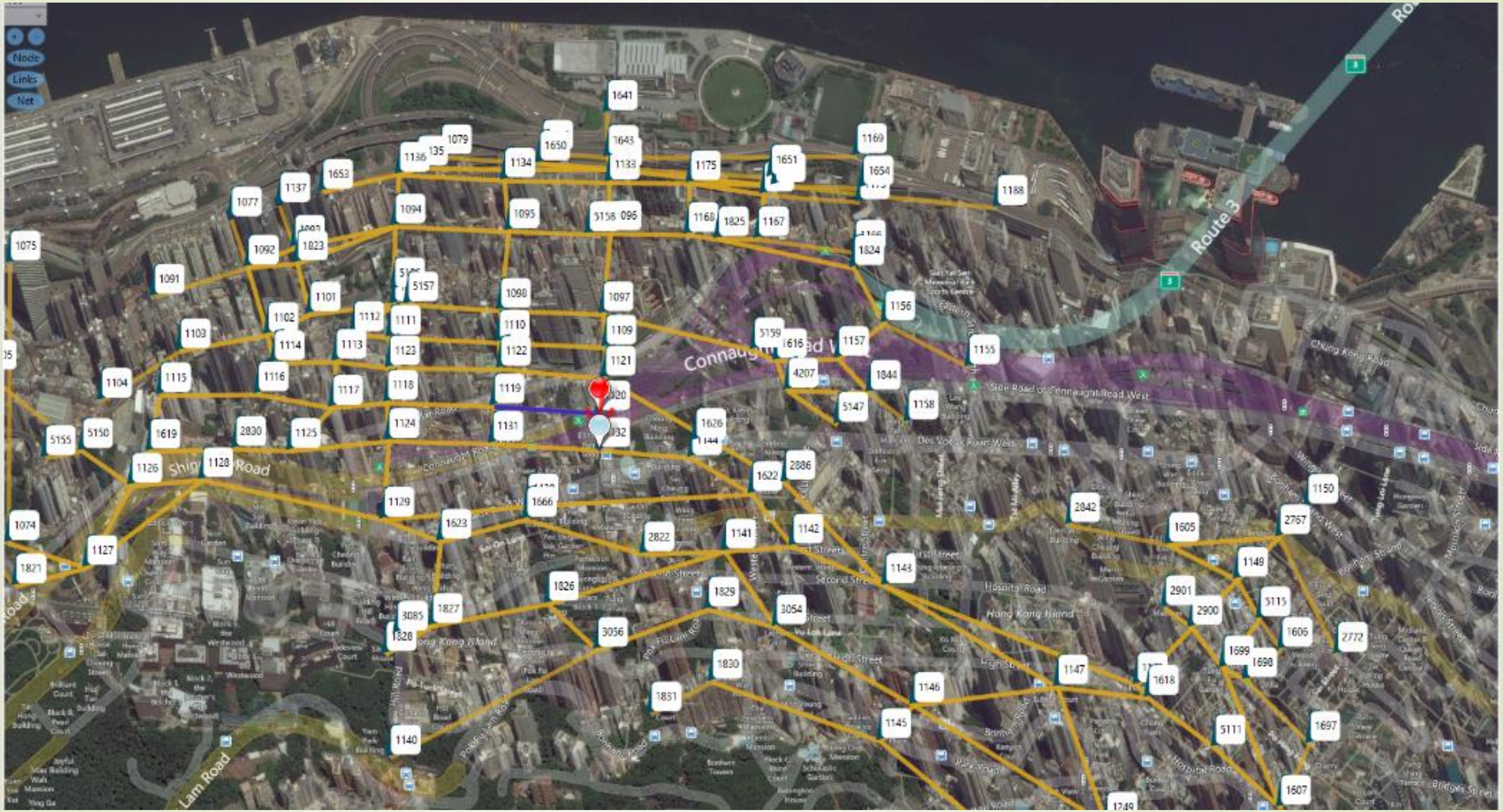
Input – Road network

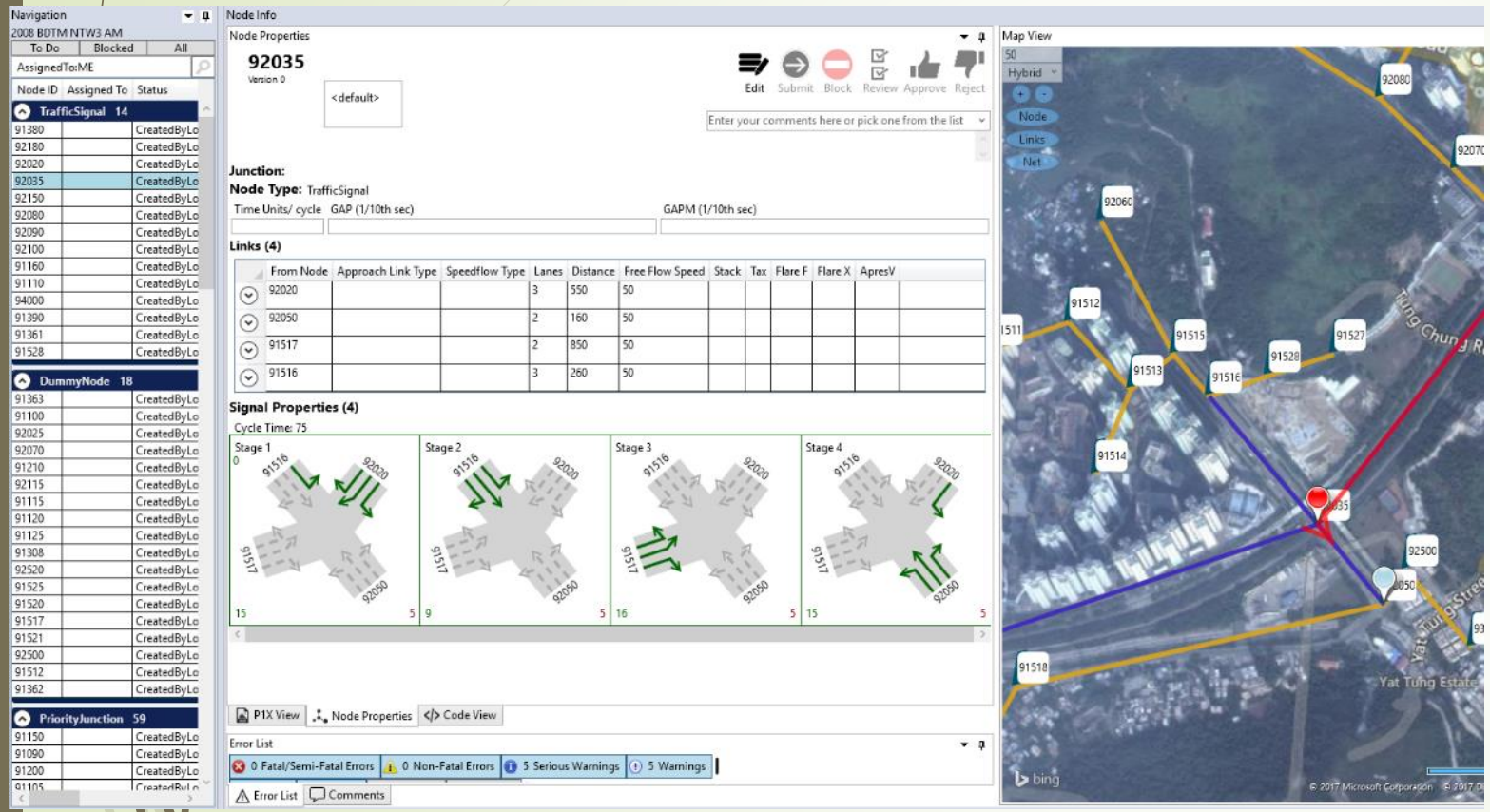
- Road network : Saturn (2008)
  - Traffic Network (10 zones), including HK island (3 zones), Kowloon Peninsula (2 zones) and New Territories (5 zones)
  - Updated links and nodes in 2017 (priority junction, traffic signal, roundabout, etc)

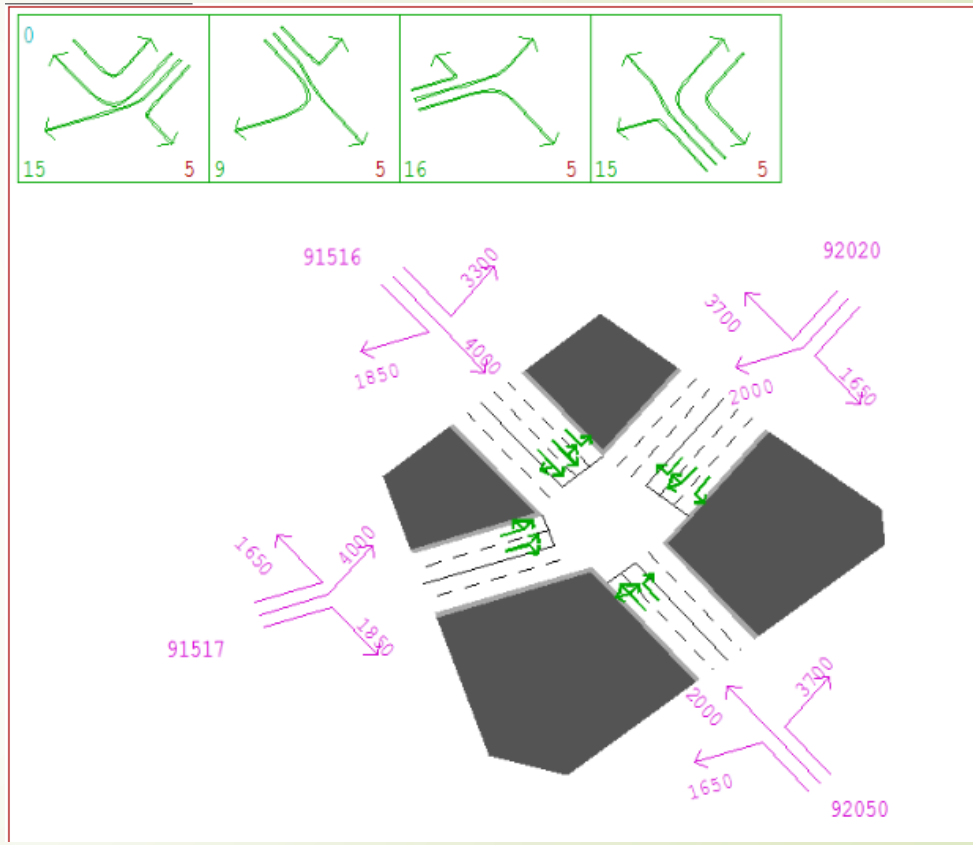




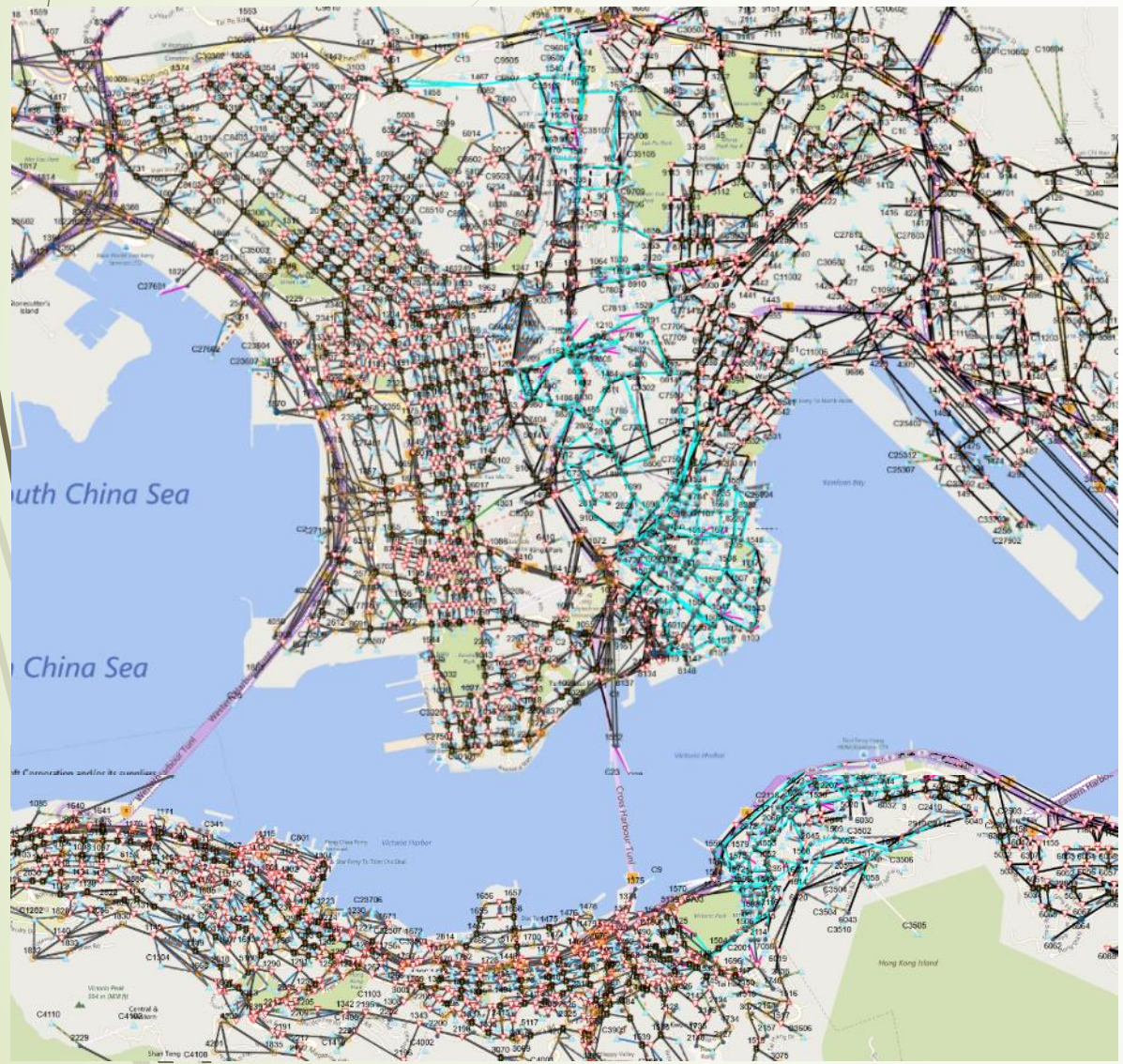



Node
Links
Net
Route 3
Connaught Road West
Hong Kong Island
Hospital Road
Lam Road

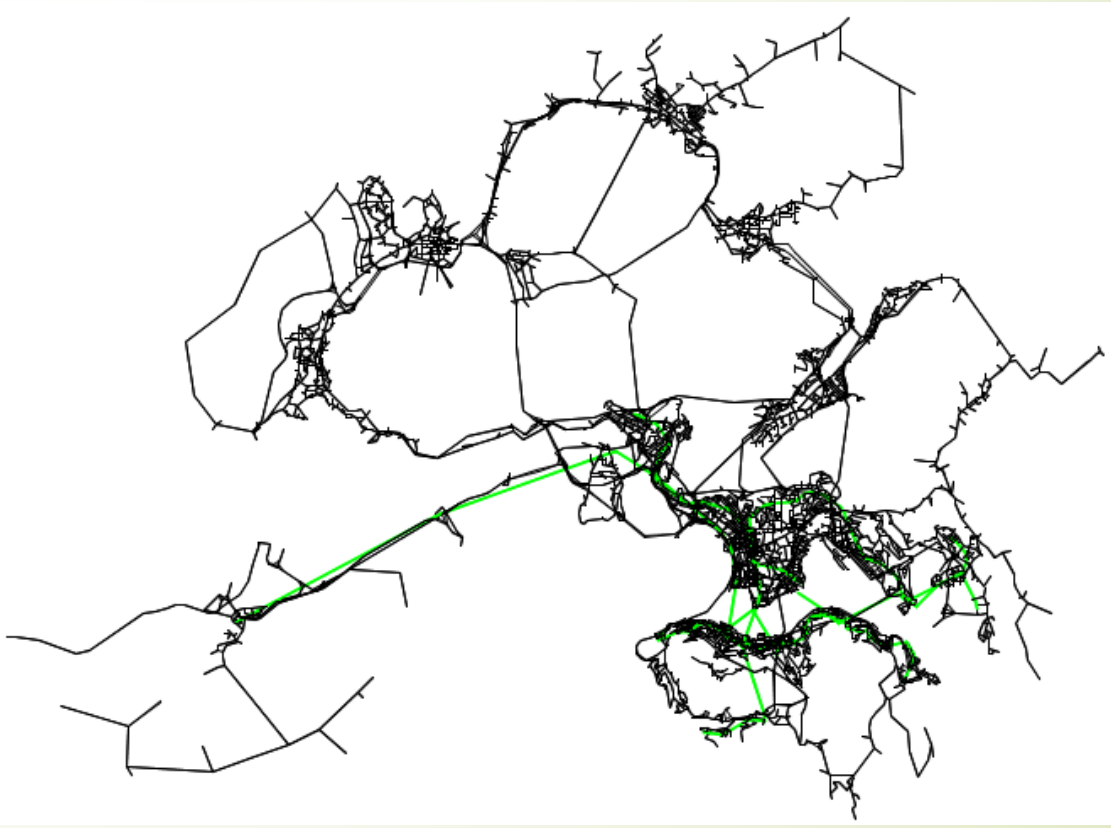

Navigation
2008 BDTM NTW3 AM
To Do
Blocked
All
AssignedTo:ME
Node ID
Assigned To
Status
TrafficSignal 14
91380
92180
92020
92035
92150
92080
92090
92100
91160
91110
94000
91390
91361
91528
DummyNode 18
91363
91100
92025
92070
91210
92115
91115
91120
91125
91308
92520
91525
91520
91517
91521
92500
91512
91362
PriorityJunction 59
91150
91090
91200
Node Info
Node Properties
92035
Version 0
<default>
Edit
Submit
Block
Review
Approve
Reject
Enter your comments here or pick one from the list
Junction:
Node Type: TrafficSignal
Time Units/ cycle
GAP (1/10th sec)
GAPM (1/10th sec)
Links (4)
From Node
Approach Link Type
Speedflow Type
Lanes
Distance
Free Flow Speed
Stack
Tax
Flare F
Flare X
ApresV
92020
92050
91517
91516
Signal Properties (4)
Cycle Time: 75
Stage 1
Stage 2
Stage 3
Stage 4
P1X View
Node Properties
Code View
Error List
0 Fatal/Semi-Fatal Errors
0 Non-Fatal Errors
5 Serious Warnings
5 Warnings
Error List
Comments
Map View
Hybrid
Node
Links
Net
92080
92060
91512
91515
91527
91513
91516
91528
91514
92500
91518
Yat Tung Estate
bing


15
5
9
5
16
5
15
5
91516
92020
3300
3700
4000
1850
2000
1650
1650
4000
91517
1850
2000
3300
1650
92050

Input – Road network



- Road network : Saturn (2008)
  - Combined 10 districts and input into MATSim



Input - Transit information

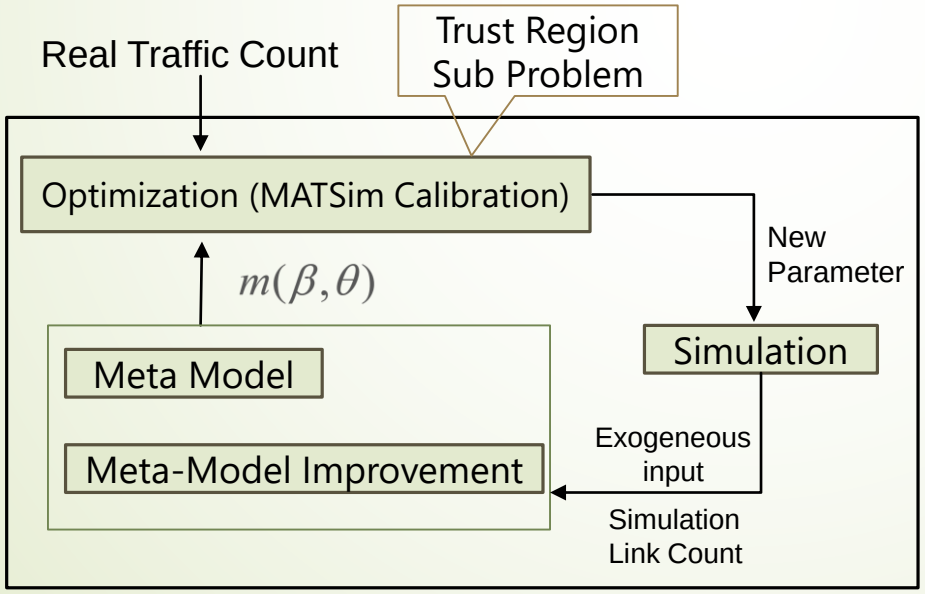
- Source :
  - Government open data
  - Operators websites
- Data in head
  - Headway
  - Stop sequences and stop coordinates(In WGS 84 /HKG1980 coordinate)
- Methodology
  - Custom converter that used the idea of pt2matsim package. (Identify links and paths by choose the shortest length among possible links between stops)

Input - Population

- Traffic Characteristic Survey was conducted on 2011 (TCS 2011)
  - 5% sample
  - Stated their mechanized trip in the day
- Goods vehicle Travel Characteristics Survey (GVTCS 2011)
  - Stated the vehicle type and trips in a day
- They are directly adapted, times the trip expansion factor given in the survey by the engineers of government

Development - Calibrating MATSim

- Calibration will be done using observed link flow.
- An analytical model is used as part of the Meta-Model for providing some structural information about the objective function.



Methodology: Meta-Model

Meta Model = Analytical Traffic Model + Generic Polynomial

More Formally,

$$m_{l,t,k}(\theta,\alpha,\beta,\kappa) = \alpha_{l,t,k}\lambda_{l,t}(\theta,\kappa) + \beta_o + \sum_{j=1}^{d}\beta_{l,t,k,j+1}\theta_j$$

Analytical Model Desired Property:

- Incorporates all parameters to be calibrated.
- Fast multimodal traffic Assignment.
- Dynamic to some extant.

Air pollution model for Hong Kong

- The Environmental Protection Department of Hong Kong government have introduced a **emission factor** (EMFAC) for Hong Kong average.
- Given link average speed and vehicle type, EMFAC provides emission factor per meter of road.
- A module is developed for it to approximate the emission as of simulation result.

Future development

- **Accurate** link flows of different vehicle types with respect to time.
- Disruption scenario analysis, planned (e.g. Road blockage of Marathon) and unplanned (e.g. Traffic incidents)
- Meteorological impact on transport

Challenges

- Python analysis
  - A large computer is needed even to unzip the xml file.
- Runtime problem and machine issues
  - 4 days for a simulation for only parts of Hong Kong
  - A 728Gb ram server is purchased for a scenario of complete Hong Kong
- Calibration and validation
  - It takes a lot of time as every iteration of our calibration method is a run of MATSim
  - Not validated yet

Acknowledgement

- This work is part of Personalised Real-Time Air Quality Informatics System for Exposure – Hong Kong (PRAISE-HK), sponsored by the HSBC 150th Anniversary Project, and Charity Programme
- Team from MATSim users who created and maintained the platform.