Preferred citation style for this presentation

LTA – FCL Steering committee – Meeting 5

Land Transport Authority
Singapore

May 2013
I. MATSim Decision Support System: making MATSim accessible to practice

II. New bus services and MRT lines: Evaluation with MATSim

III. Improvements, calibration and validation of MATSim

IV. Detection of urban activities beyond home/work using Cepas data

V. Outlook
MATSim Decision Support System (MDSS)

Making MATSim accessible to practice

Alex Erath, Pieter Fourie, Michael van Eggermond
MATSim and practical transport planning

**Advantages**

Full temporal dynamics
- Bunching phenomena
- Overcrowding of individual vehicles
- Time-dependent demand management

Agent-based paradigm
- Individuals
- Parcel or building (or unit) as base unit
- Interdependency of trips and activities, e.g. tour based mode choice

**Challenges**

How to deal with the wealth of data?
- Who?
- With how much time?
- What skills?
- New questions?
Analyzing MATSim scenarios: current situation I

- Displaying the network and vehicles in the application.
- Highlight one or more transit lines.
- Displaying the complete day plan of a single agent.
- Analyze different aspects, e.g., the number of passengers waiting at a transit stop.
Analyzing MATSim scenarios: current situation II
Stakeholders for MATSim Decision Support System

Transport planners
• Effects of new bus services/network
• Impact of travel demand management schemes

Urban planners:
• Temporal patterns of buildings and neighbourhood
• Flow between public transport stops to surrounding buildings

Policy-makers
• Costs and benefits of infrastructure measures?
• Who and where are the winners and losers?

Public transport operators
• Who profitable will a new line be?

Service industry
• Which customers are in catchment areas, separated by mode?
Requirements for MATSim Decision Support System

**Functional:**

Appraisal
- Cost-benefit
- Winners and losers

Scope
- Journeys
- Stages
- Activities

Temporal analysis
- Full temporal resolution for filtering and aggregation

**Technical:**

Database
- Open source with open interface
- Spatial queries
- Flexible permission setting

Front-end
- Business analytics software for customisable and interactive analysis
- GIS
General Framework
MDSS for Singapore
Interactive analysis of MATSim demand (based on HITS 2008)
II  New bus services and MRT lines

Evaluation with MATSim and MDSS

Ljun Sun, Sergio Ordonez, Pieter Fourie, Artem Chakirov, Alex Erath, Michael van Eggermond
Supply

Base scenario
Schedule GTFS 2011
Vehicles information according to www.sgwiki.com

Test scenarios:

a) Adding later introduced services
   1. Bus line 860
   2. Circle line Stage 4, 5 and extension to Marina Bay

b) Amendment of existing bus line 51
   1. Split at Blk 79 Ganges Road
   2. Short cut at Alexandra Road
Experimental setup

Initial demand

MATSim

DSS

Baseline scenario

Simulation → Scoring → Analysis

Replanning, e.g. new route

Baseline

Simulation → Scoring → Analysis

Replanning, e.g. new route

Test scenarios

Cepas data:
• 1 journey = 1 MATSim plan
Cepas data

Transactions recorded on Tuesday, 22\textsuperscript{nd} April 2011
Assumption of uniform arrival rate between two scheduled services
Journey starts and ends at reported public transport stops

**Accounted demand reactions**
- New routes (including transfers)
- Walk to other stops

**Not accounted demand reactions**
- Mode switch (except for walk)
- Time of day
- Location of start/end stop
- Induced demand
Stochastic nature of travel times

Speed between stops

\[ v \sim N(\mu, \sigma) \]
\[ \mu = f\left(\frac{f}{c}, v_f, tl, m, l \ldots \right) \]
\[ \sigma = f\left(\frac{f}{c}, v_f, tl, m, \ldots \right) \]

Dwell time

\[ d \sim N(\mu, \sigma) \]
\[ \mu = f(b, a, p, t) \]
\[ \sigma = f(\mu) \]

Trip speed

\[ v \sim N(\mu, \sigma) \]
\[ \mu = f\left(\frac{f}{c}, v_f, tl, m, b, a, p, t, \ldots \right) \]
\[ \sigma = f\left(\frac{f}{c}, v_f, tl, m, \mu_d \right) \]
Calibration of simulation (I)

Starting values

- $v_{bus,\text{trunk}} = 26 \text{ km/h}$
- $v_{bus,\text{exp}} = 50 \text{ km/h}$
- $\sigma_{bus}(v) = 0.2 \cdot v_{bus}$
- $v_{\text{train}} = 72 \text{ km/h}$
- $\sigma_{\text{train}}(v) = 0$

Bus stops: sequential operations
Rail: access and waiting time not included in MATSim

Calibrated values

- $v_{bus,\text{trunk}} = 22 \frac{\text{km}}{h} \pm f(h)$
- $v_{bus,\text{exp}} = 50 \text{ km/h}$
- $v_{bus,\text{art}} = 40 \text{ km/h}$
- $\sigma_{bus}(v) = 1.1 \cdot \sigma_{\text{bus,cepas},h}$
- $v_{\text{train}} = 72 \text{ km/h}$
- $\sigma_{\text{train}}(v) = 0$

Dozens of calibration runs

Bus stops: parallel boarding
Rail: access and waiting time included
Experimental setup: calibration of simulation (II), trip speed over time of day

![Graph showing average trip speed for Rail and Bus over time of day for Cepas and Simulation.]
Behavioral parameters

Public transport
- Value of in-vehicle time: 8 SGD/h
- Value for waiting (start and transfer): 12.89 SGD/h
- Additional penalty for transfer: 0.65 SGD = 5 min in-vehicle time

On foot (access/egress)
- Walking speed: 4km/h
- Value of walking time: 16.92 SGD/h

In future scenarios:
- Value of a seat/crowdedness
- Preference for bus (anecdotal evidence)
- Agent specific preference
Adding bus line 860

Newly added bus line 860: 26 stops; 10km
Analysis of winners and losers: concept

Using of 804, 806 before split

Using of 804, 806, 860 after split

Switch to other line

Still using 8XX

Switch to 804, 806, 860

How many?
Using 804, 806, 860 as part of journey

Gains and losses?
  a) Travel time
  b) Waiting time
  c) Transfers

Where?
Ridership over time of day for 804, 806 and 860: before and after

Other, i.e. agents which have not use neither 804 or 806 before

Other, i.e. agents which don’t use of any of those lines anymore
Changes in travel time for 860, 804 and 806 users

Preliminary results
Winners and losers of 860: interactive analysis of effects in Tableau
Amendment of Bus 51: split at Ganges Avenue, Opp Blk 79

Before split: 95/94 stops, 37km
After split: 46/43 (west) || 50/52 (east) stops, 18km / 19km
Detection of cutting point: based on waiting time

\[
\min \gamma = \gamma_1 + \gamma_2 + \theta \times \gamma_3
\]

\[
\gamma_1 = \frac{\sum_{i=1}^{m-1} E \cdot w_i \cdot \sum_{j=1}^{M} B_{i,j}}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}
\]

\[
\gamma_2 = \frac{\sum_{i=m}^{M} E \cdot w_i \cdot \sum_{j=1}^{M} B_{i,j}}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}
\]

\[
\gamma_3 = \frac{\sum_{i=1}^{m-1} \sum_{j=m+1}^{M} B_{i,j}}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}
\]

Optimal split point: stop 52 Ganges Avenue
Detection of cutting point: based on demand

\[
\min \gamma = \gamma_1 + \gamma_2 + \theta \times \gamma_3
\]

\[
\gamma_1 = \sum_{i=1}^{m-1} \left( E \sum_{j=1}^{M} w_j \cdot B_{i,j} \right) / \sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}
\]

\[
\gamma_2 = \sum_{i=m}^{M-1} \left( E \sum_{j=1}^{M} w_j \cdot B_{i,j} \right) / \sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}
\]

\[
\gamma_3 = \sum_{i=1}^{m-1} \left( T_{\text{hold}} \sum_{j=m+1}^{M} B_{i,j} \right) / \sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}
\]

Optimal split point: Stop 52 Ganges Avenue
Bus 51 Jurong to Hougang, 5-8pm, before line split simulated in MATSim vs Cepas

Simulated in MATSim

Observed in Cepas

Hougang
Bugis
Blk 79
Alexandra
Jurong E

5pm 6pm 7pm 8pm

Occupancy

30 60 90

0
Improved reliability

Simulated in MATSim before line split

Simulated in MATSim after line split
Changes in travel time for 51 split, BUT......

Preliminary results
...... to few iterations -> line switcher are still searching for better routes
Using MDSS for validation of MATSim demand and calibration of simulation

Towards a more accurate MATSim Singapore model

Pieter Fourie, Alex Erath, Michael van Eggermond
Public transport: trip distance distribution - MATSim vs Cepas vs HITS
Public transport: trip distribution: MATSim vs Cepas
IV Understand the City from Building Scale to Regional Scale

Detection of urban activities beyond home/work using Cepas data

Chen Zhong, Xianfeng Huang, Stefan Müller Arisona
“Space Shapes the transportation as much as transportation shapes the space.” (Rodrigue et al. 2009).

**Motivation:** better understand urban space, dynamics, especially, interaction between human and built environment

**Data:** transportation data

**Question:** Reality =? Plan: function and spatial structure
1. Infer individual travel purpose
2. How individuals’ activities re-shape the city
3. how to find the city centers
1. Infer travel purposes and building functions

Data:

- EZLink data
- Household Interview Travel Survey (HITS) data:
Method – Patterns of travel behaviors (statistic data from HITS)

- Starting time
- Walking time
- Travel frequency
- Age distribution
- Time use
- Activities Vs. Places

(Also referred to other literature)
Using Bayesian classifier to find the most possible purpose, with HITS data as the prior probability.

Arrive at 7:30 am  Stay 6 hours  5 times per week  Using student card

Giving a prior information and trip information, the probability of a travel purpose can be calculated:

$$P((a_d,a_t,a_f|c) = \prod_{h=1}^{n} P(a_i | c)$$

Shopping

Studying
Method – Bayesian probabilistic model + spatial analysis

Table A. Original trip

<table>
<thead>
<tr>
<th>Trip Id</th>
<th>P type</th>
<th>stop Id</th>
<th>Arr time</th>
<th>Stavtime</th>
<th>freq</th>
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<tbody>
<tr>
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<td>3</td>
<td>28499</td>
<td>7.679773</td>
<td>10.37633</td>
<td>6</td>
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<tr>
<td>2000**********00</td>
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<td>21069</td>
<td>6.528593</td>
<td>11.38393</td>
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<td>21.39484</td>
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<td>1.157689</td>
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<td>21759</td>
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<td>11.93996</td>
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Table B. Prior probability

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<th>freq</th>
<th>education</th>
<th>shopping</th>
<th>working</th>
<th>homing</th>
<th>eating</th>
<th>social-visiting</th>
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<tr>
<td>1</td>
<td>0.031165</td>
<td>0.714492</td>
<td>0.152148</td>
<td>0.139172</td>
<td>0.614155</td>
<td>0.586769</td>
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<tr>
<td>2</td>
<td>0.020701</td>
<td>0.135544</td>
<td>0.03715</td>
<td>0.035877</td>
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<tr>
<td>3</td>
<td>0.036624</td>
<td>0.102379</td>
<td>0.047331</td>
<td>0.053844</td>
<td>0.086758</td>
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<td>4</td>
<td>0.047998</td>
<td>0.010094</td>
<td>0.031697</td>
<td>0.031878</td>
<td>0.034247</td>
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<td>5</td>
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<td>0.025234</td>
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<td>6</td>
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<td>7</td>
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Table C. Summed posterior probability

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<th>stop Id</th>
<th>e</th>
<th>s</th>
<th>w</th>
<th>h</th>
<th>c</th>
<th>v</th>
<th>max</th>
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<tr>
<td>284**</td>
<td>0.2797</td>
<td>0.1981</td>
<td>0.1510</td>
<td>0.2696</td>
<td>0.2131</td>
<td>0.1595</td>
<td>e</td>
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<tr>
<td>283**</td>
<td>0.2994</td>
<td>0.2258</td>
<td>0.2053</td>
<td>0.2008</td>
<td>0.2351</td>
<td>0.1794</td>
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<tr>
<td>282**</td>
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<td>0.3281</td>
<td>0.4008</td>
<td>0.2659</td>
<td>0.2863</td>
<td>0.2379</td>
<td>w</td>
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<tr>
<td>280**</td>
<td>0.0234</td>
<td>0.2247</td>
<td>0.0534</td>
<td>0.3877</td>
<td>0.2286</td>
<td>0.1960</td>
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<tr>
<td>284**</td>
<td>0.0942</td>
<td>0.4955</td>
<td>0.3436</td>
<td>0.1241</td>
<td>0.4320</td>
<td>0.3625</td>
<td>s</td>
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<tr>
<td>280**</td>
<td>0.1566</td>
<td>0.1926</td>
<td>0.2368</td>
<td>0.2461</td>
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<td>280**</td>
<td>0.0769</td>
<td>0.2611</td>
<td>0.1089</td>
<td>0.3817</td>
<td>0.3136</td>
<td>0.2182</td>
<td>h</td>
</tr>
</tbody>
</table>
Objective: travel behavior $\rightarrow$ activity type (travel purpose) and building functions.
Result – Probability distribution of certain activities in Jurong East area.
Result – Assigning function to building

Building functions in Jurong East area (left) and Rochor area (right).
2. Detect spatial structure of centers and their spatial impacts

Question: How collective activities shape the urban space?
Data: Household Interview Travel Survey (HITS) Data
HITS data provide many information → How to find real center?

Entropy map of activity types using travel survey 2008
How to identify a “center” in city?

Many people go there

⇒ *Density*

Many types of function(activities)

⇒ *Entropy*
Method – Centrality index

The joint probability dense function of two independent events is the convolution

\[ C_{xy} = P_D(x, y) \otimes P_E(x, y) \]
Detected centers in 2004 (top) and 2008 (bottom)

(Copied from course material – theory is urban design)
3. Identify spatial structure of borders using historical transportation data

How the people’s activities re-shape the region?
Data: EZLink Data
Complex networks (bus stop/MRT statin as the nodes)
**Method** – Spatial analysis + **complex network** analysis

<table>
<thead>
<tr>
<th>Label</th>
<th>Degree</th>
<th>Weighted Degree</th>
<th>Modularity Class</th>
<th>Clustering Coefficient</th>
<th>Closeness Centrality</th>
<th>Betweenness Centrality</th>
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<td>1012</td>
<td>533</td>
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<table>
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<th>2011_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2010_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;E&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;E&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>MRT: 4514 BUS:107</td>
<td>MRT: 4531 BUS:108</td>
<td>93</td>
<td>93</td>
<td>4131</td>
<td>4139</td>
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<table>
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<th>Number of edges</th>
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<th>2008_MRT&lt;sub&gt;E&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;E&lt;/sub&gt;</th>
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</table>

<table>
<thead>
<tr>
<th>Avg. path length</th>
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<th>2010_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;E&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;E&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>2.177 (di)</td>
<td>2.004 (indi)</td>
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<table>
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<th>Avg. clustering centrality</th>
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<th>2010_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;E&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;E&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>0.250 (di) 0.392 (indi)</td>
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<td>0.9216</td>
<td>0.562047</td>
<td>0.533689</td>
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<table>
<thead>
<tr>
<th>Avg. Eigenvector centrality</th>
<th>2011_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2010_MRT&amp;BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_MRT&lt;sub&gt;E&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;D&lt;/sub&gt;</th>
<th>2008_BUS&lt;sub&gt;E&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.115567 (di) 0.141721 (indi)</td>
<td>0.1030 (di) 0.131633 (indi)</td>
<td>0.103</td>
<td>0.103</td>
<td>0.0104</td>
<td>0.0102</td>
<td></td>
</tr>
</tbody>
</table>
Result – Complex networks parameters – **Closeness**

Closeness distribution of bus stops & MRT stations

Interpolated closeness distribution
Result – Complex networks analysis – **Community** (spatial) structure of borders

Communities of complex networks re-project to map

Concept plan 1991
Conclusion and Future Work

Integrated methods to infer urban activities and to detect spatial structures from transportation data.

In the further, we want to further understand the dynamic urban space in terms of changing travel behavior, spatial impacts of urban developments, which could contribute to the future transportation plan.
The need for more (historical) data

To compare the travel behaviors before and after the operation of new MRT line.
To find the cause and sequence of changing.

Could provide reference information for LTA to optimize/adjust the transportation system.
V  Outlook
Optimisation of mobility pricing

- Distance based vs point/zone based
- Impact on PT
- Heterogeneous willingness to pay
- Relevance of time adaptation

Coordination within household:

- 12% of pick up and drop off activities (HITS 08)
- How drives the car and with whom, when and where
- Behavioral modeling with HITS data
- Implementation in MATSim

Weekly model

- Planning horizon of 1 week
- Which activity on that day
- Regularity of travel
- SMART MIT HITS 2012 survey as data basis?

Bus optimisation

- Determinants of link travel time (in between stops)
- Guidelines for network design and operation improvements
- Evaluation of proposed measures
PhD projects V & VI

Location-fine decision models
• Building fine accessibility
• Impact of accessibility on land and real estate value
• Where do people in Singapore move, when and why?

Social network and mobility:
• Geography of social networks in Singapore
• Impact of transport infrastructure
• Mobility biographies
**Accessibility computation**

**Measure currently used**

\[
P_i = \sum_{j=1}^{n} O_j \exp(-\lambda t_{ij})
\]

- \(P_i\): Potential number of activities accessible to building \(i\)
- \(O_j\): Opportunities in building \(j\)
- \(\lambda\): Distance decay factor
- \(t_{ij}\): Travel time from \(i\) to \(j\)

**Methodology**

1. Calculate shortest travel time by transit between all transit stops in MATSim per time interval
2. Select 5 transit stops within 500m closest to building \(i\) and \(j\) (euclidean)
3. Select shortest travel time between the 25 stops

**To-do**

1. Evaluate distance decay factor and formula
2. Evaluate transit stop selection
3. Use generalized costs including walking time to bus stop
4. Incorporate pedestrian network for ‘true’ pedestrian costs
First results: object fine, Hansen style accessibility to WORKPLACES with pt
First results: object fine, Hansen style accessibility to RESIDENTIAL UNITS with pt
MSc project + side projects

Hedonic regression of commercial, office and industrial real estate
- Accessibility
- Transport infrastructure and real estate value

Calibration and validation of MATSim
- Travel speed and congestion
- Mode, route, time and location choice
- Test data
  - Circle line extension
  - Peak spreading travel for free

Traffic light meta model
- Simplified, demand sensitive model for traffic lights in MATSim

Proposal: Cooler Calmer Singapore (NRF)
- Impact of electrified Singapore
- MATSim Singapore as key data source

Proposal: bus network optimisation for NUS
- MATSim NUS Campus (incl surroundings)
- Evaluation of new bus network and mobility concepts

Proposal: Walkability (URA)
- How to nudge people to walk more?
- Quantifying pedestrian behaviour
- Evaluation of pedestrian environments
What would we do with new/more data

4 weeks of Cepas

Statistical model explaining mean and variability of travel time between stops
- Time of day
- Influence of traffic light (and flows)
- Availability of bus lane
- Overlapping bus lines
- Number of bus lines serving a stop (and flows)

Even more accurate simulation of public transport in MATSim

Weekly dynamics
- Long term regularity of demand (and encounter networks)
  - Locations
  - Trip times
- Stability of route choice

HITS 2012

Coordination within household
- Who drives, with whom, when where
- Behavioral model

Service: Generating trip information for non-chosen modes
- Mode choice revealed preference

Long term development of car ownership
- Merging with HITS 2004, 2008

SMART Mobility Survey
- Weekly model
- Location choice models
Next big events in Singapore/Asia

Urban Sustainability R&D Congress:
   Object fine accessibility

FCL Midterm review:
   6. - 7. September 2013
   Special session on Mobility and Transport

EASTS 2013:
   9. - 12. September 2013
   MDSS | Generating pedestrian networks for accessibility computation

SITCE:
   7. - 10. October 2013
   MATSim as tool for public transport planning
Appendix
Adding bus line 860

before

804

806

after

860
Amendment of Bus 51: shortcut at Alexandra Road

Before shortcut:
95 stops, 37 km,

After short cut:
-5 stops, -2.2km
Adding Circle Line stage 4, 5 and extension
Thanks
Appendix I:

Result – Complex Networks

Degree Distribution

Degree distribution of the bus stops & MRT stations
Appendix II:

Result – Complex Networks

Authority

Authority values of bust stops & MRT stations