Preferred citation style for this presentation

Erath A.L., A. Chakirov, M. van Eggermond, P. Fourie, S. Ordóñez, L. Sun, K.W. Axhausen (2013) Presentation for LTA steering committee, Future Cities Laboratory, May 2013

LTA – FCL Steering committee – Meeting 5

Land Transport Authority
Singapore

May 2013

(FCL) FUTURE CITIES LABORATORY 未来城市实验室

(SEC) SINGAPORE-ETH CENTRE 新加坡－ETH研究中心

Content

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

I

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

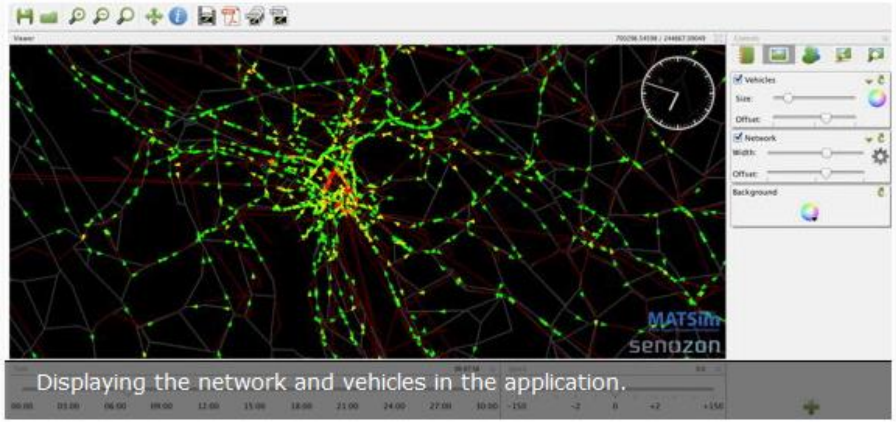
- Individuals
- Parcel or building (or unit) as base unit
- Interdependency of trips and activities, e.g. tour based mode choice

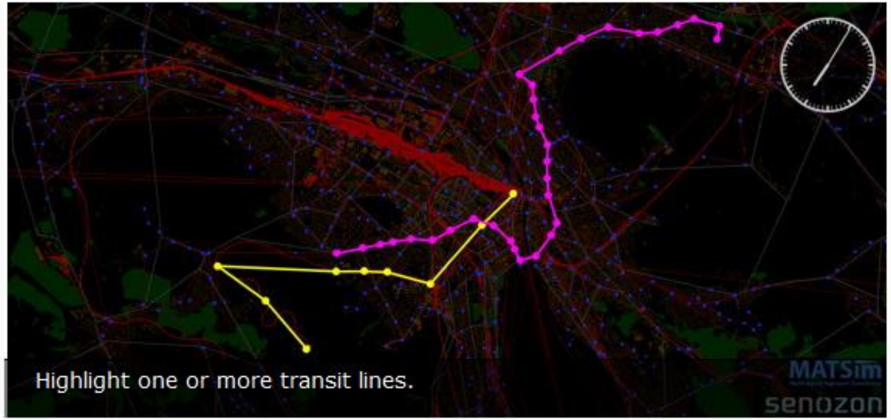
Challenges

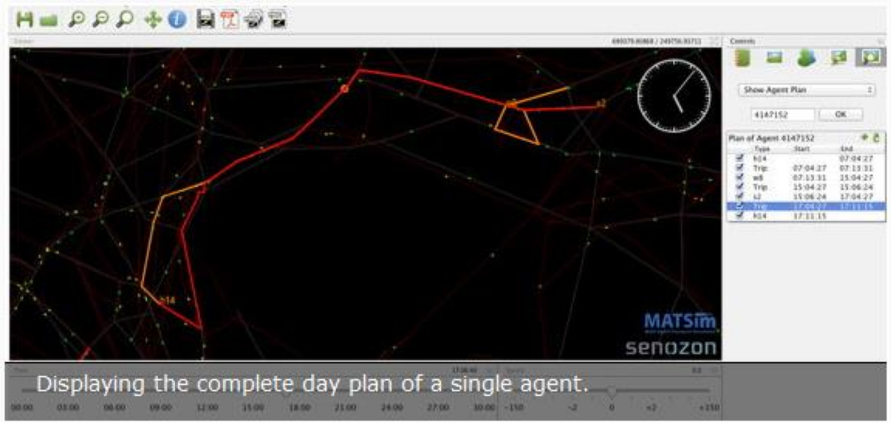
How to deal with the wealth of data?

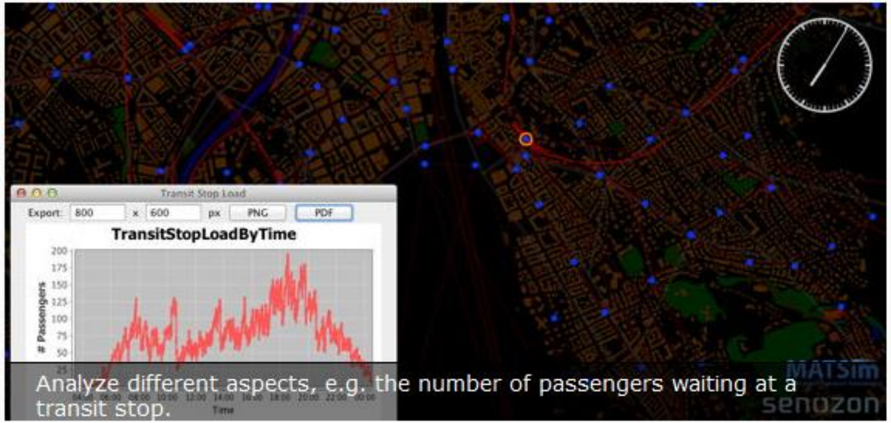
- Who?
- With how much time?
- What skills?
- New questions?

Analyising MATSim scenarios: current situation I

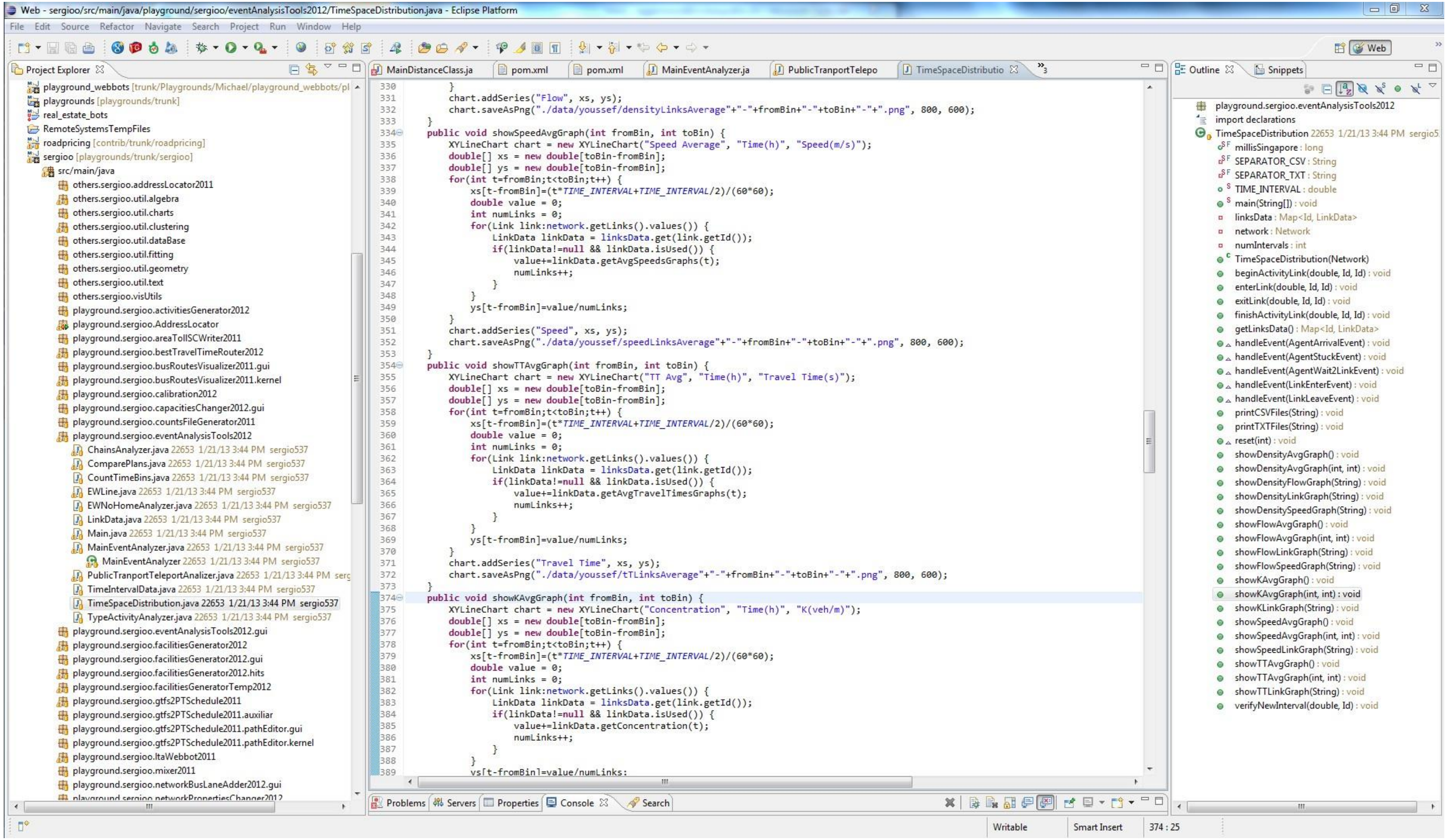








Analyising MATSim scenarios: current situation II



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 a 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:

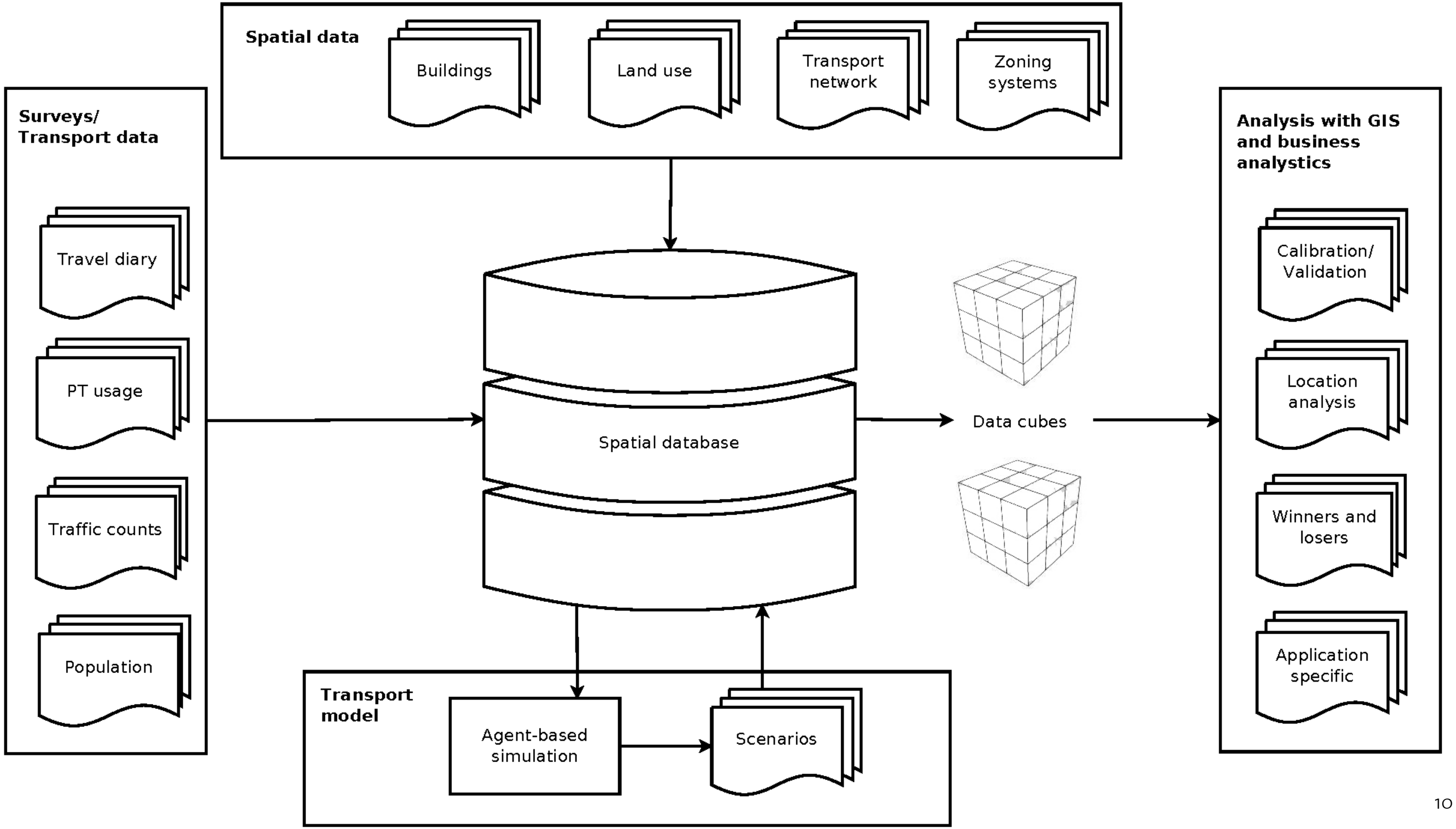
Database

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

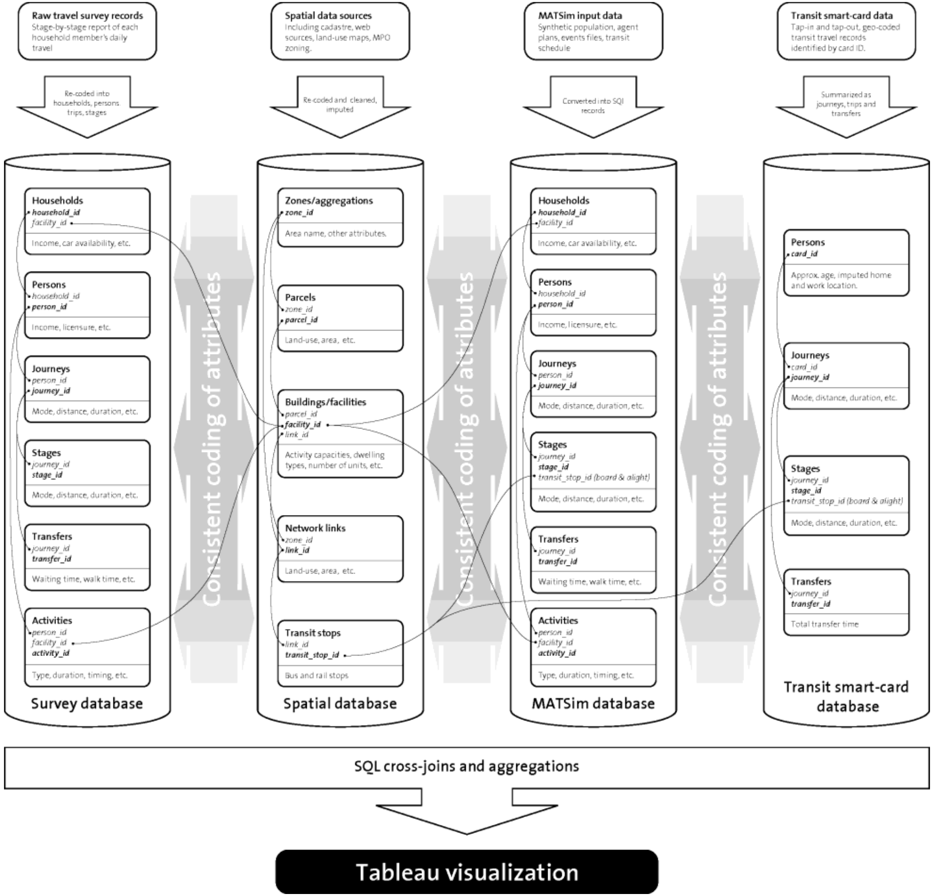
Front-end

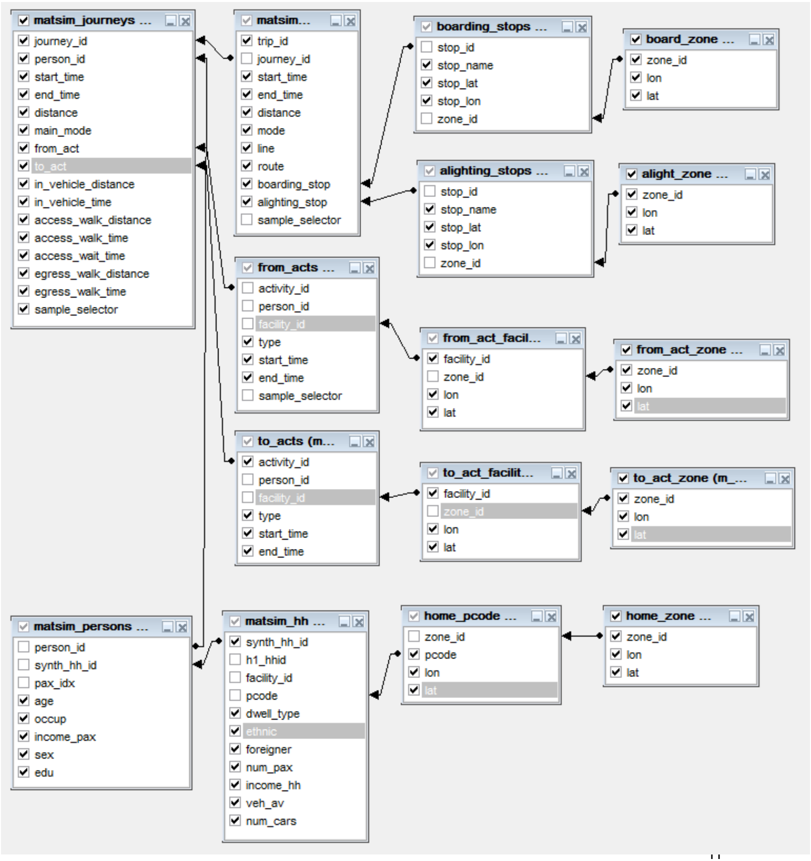
- Business analytics software for customisable and interactive analysis
- GIS

General Framework

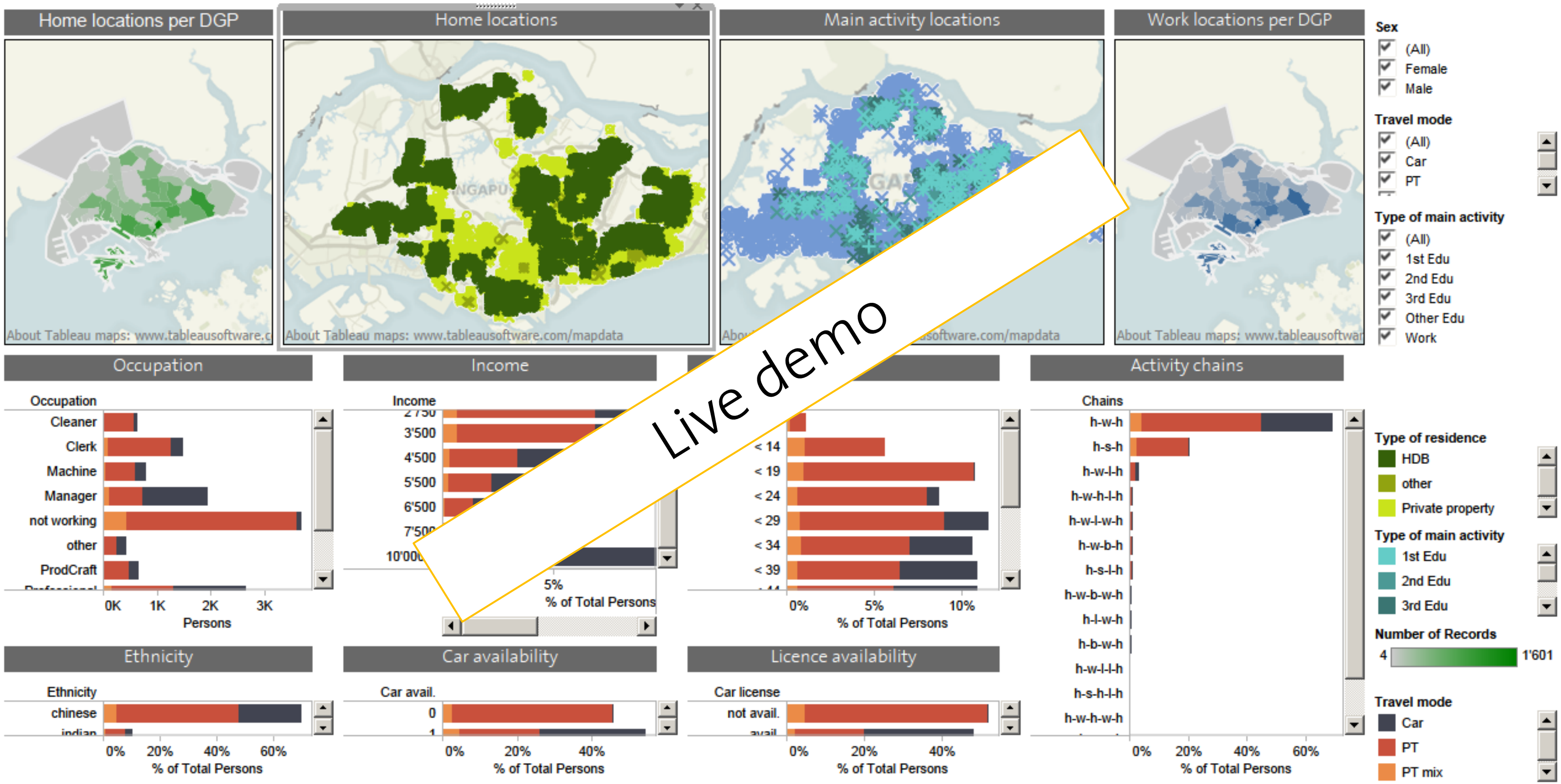


MDSS for Singapore





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

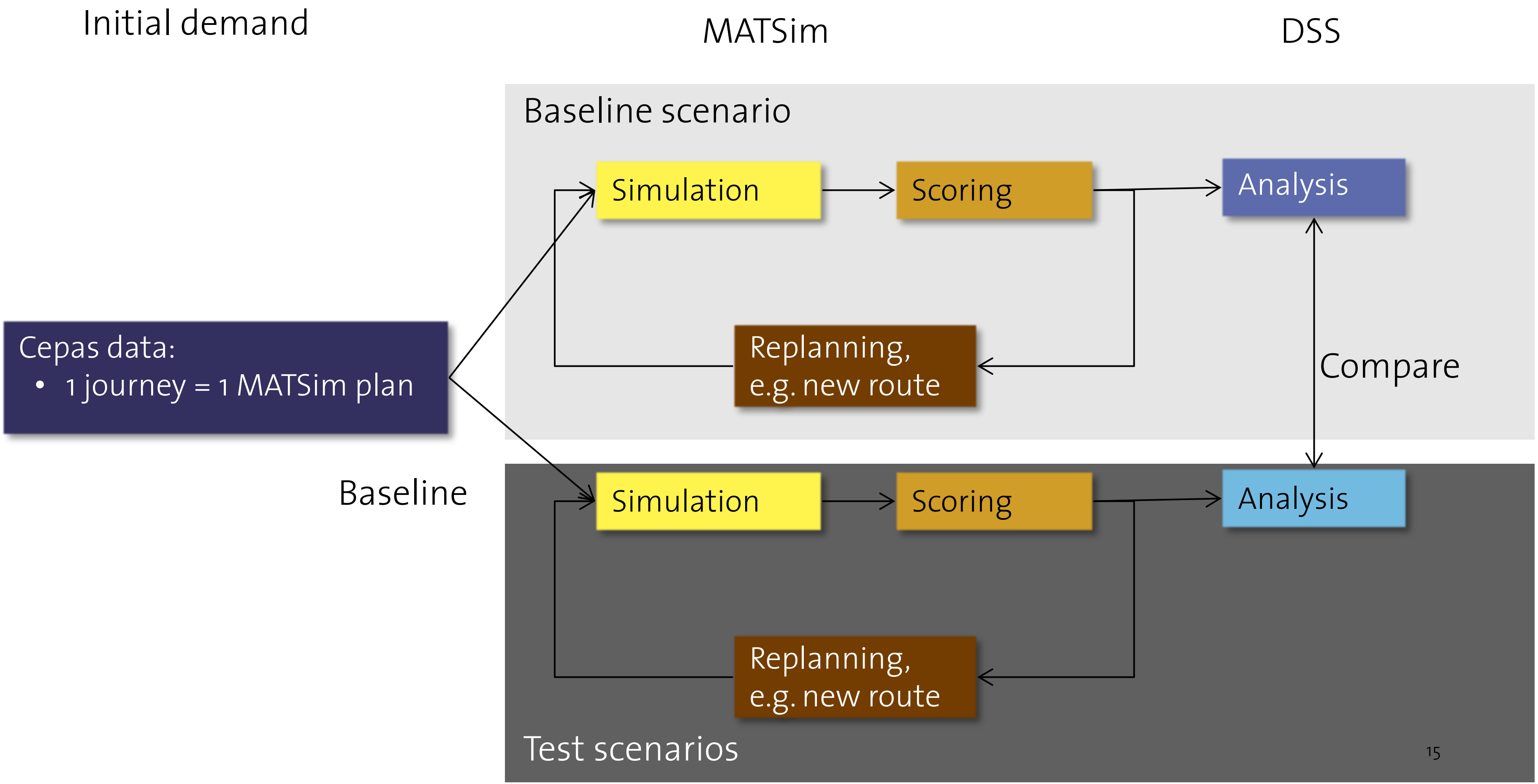
Vehicles information according to www.sgwiki.com

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



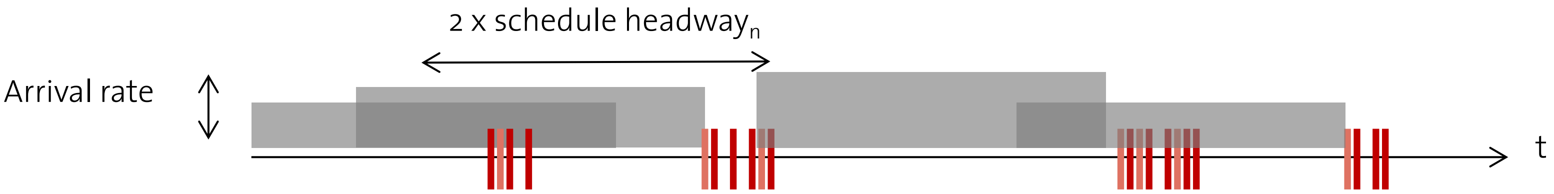
Demand

Cepas data

Transactions recorded on Tuesday, 22nd April 2011

Assumption of uniform arrival rate between two scheduled services

Journey starts and ends at reported public transport stops



Boarding, alighting at stop x, bus line y

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

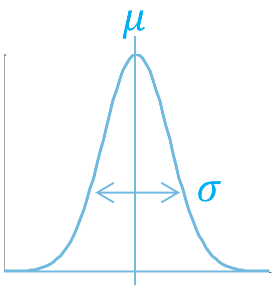
Simulation parameters

Speed between stops

$v \sim N(\mu, \sigma)$

$\mu = f(\frac{f}{c}, v_f, tl, m, l \ldots)$

$\sigma = f(\frac{f}{c}, v_f, tl, m, \ldots)$

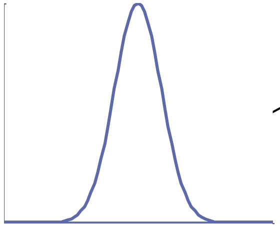


Dwell time

$d \sim N(\mu, \sigma)$

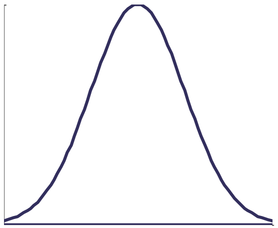
$\mu = f(b, a, p, t)$

$\sigma = f(\mu)$



Observation from Cepas

Trip speed

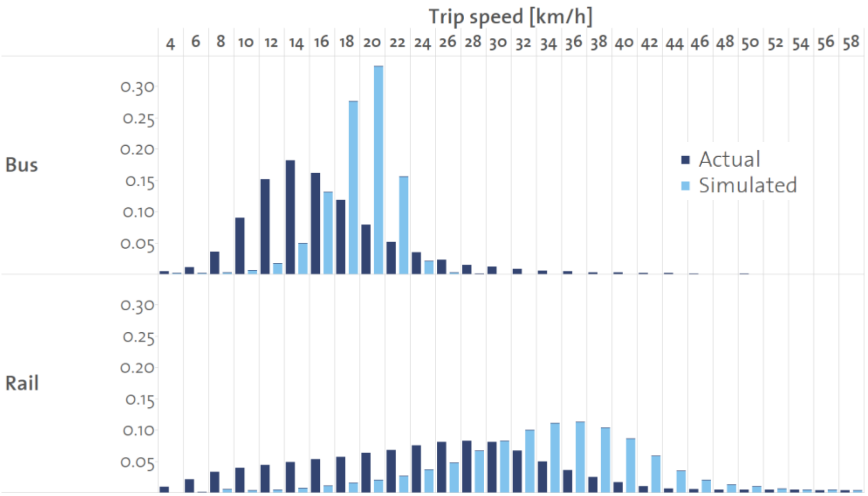


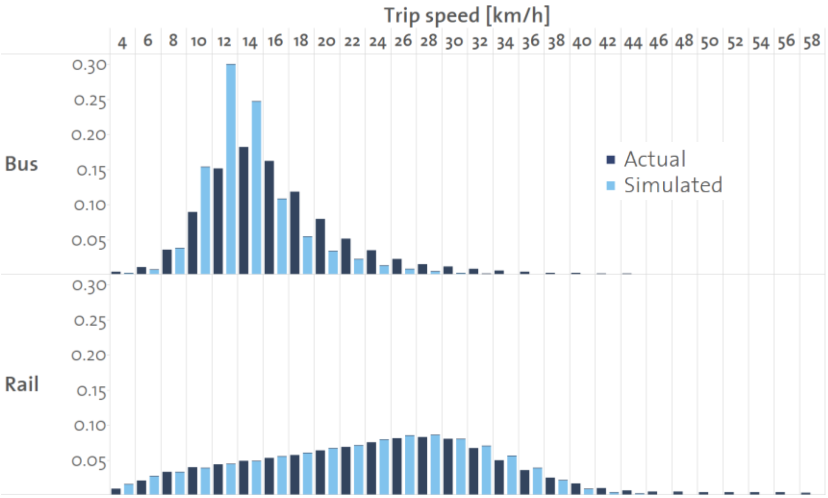
$v \sim N(\mu, \sigma)$

$\mu = f(\frac{f}{c}, v_f, tl, m, b, a, p, t, \ldots)$

$\sigma = f(\frac{f}{c}, v_f, tl, m, \mu_d)$

Calibration of simulation (I)





Starting values

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

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

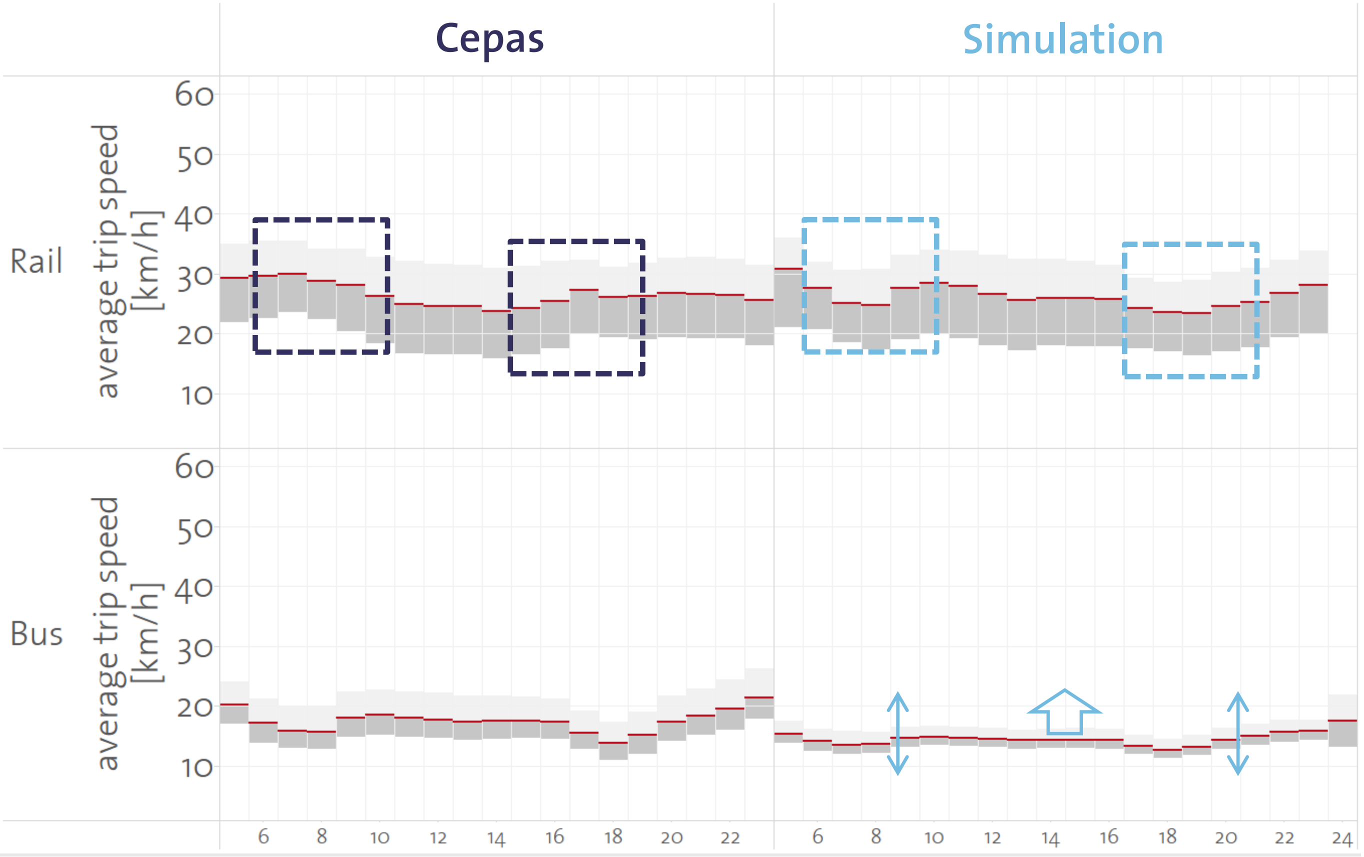
Dozens of calibration runs →

Calibrated values

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

Bus stops: parallel boarding
Rail: access and waiting time **included**

Experimental setup: calibration of simulation (II),trip speed over time of day



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

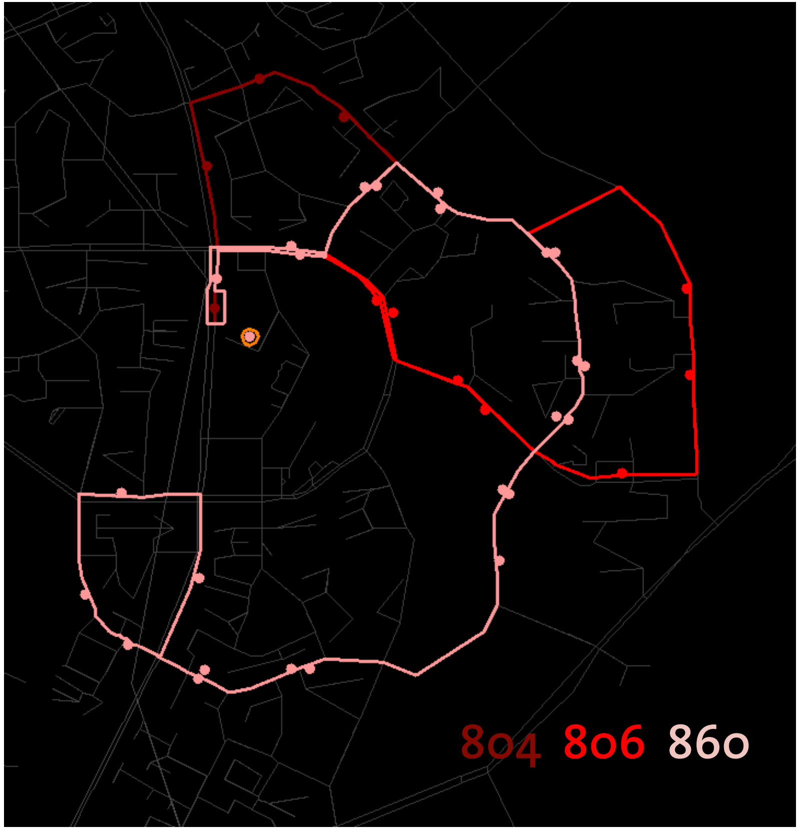
On foot (access/egress)

- Walking speed: 4km/h
- Value of walking time: 16.92 SGD/h

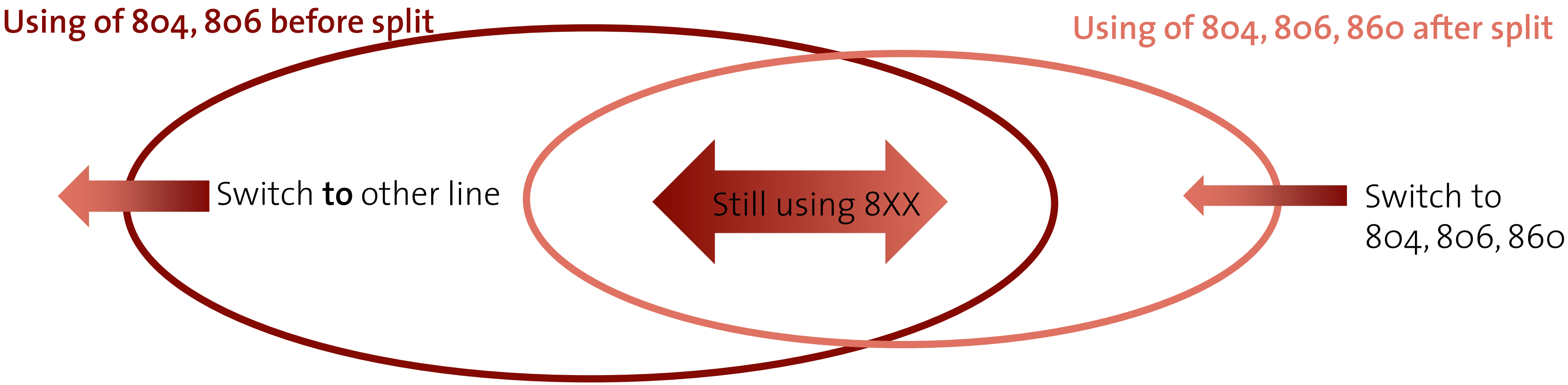
In future scenarios:

- Value of a seat/crowdedness
- Preference for bus (anecdotal evidence)
- Agent specific preference

Adding bus line 860



Analysis of winners and losers: concept



How many?

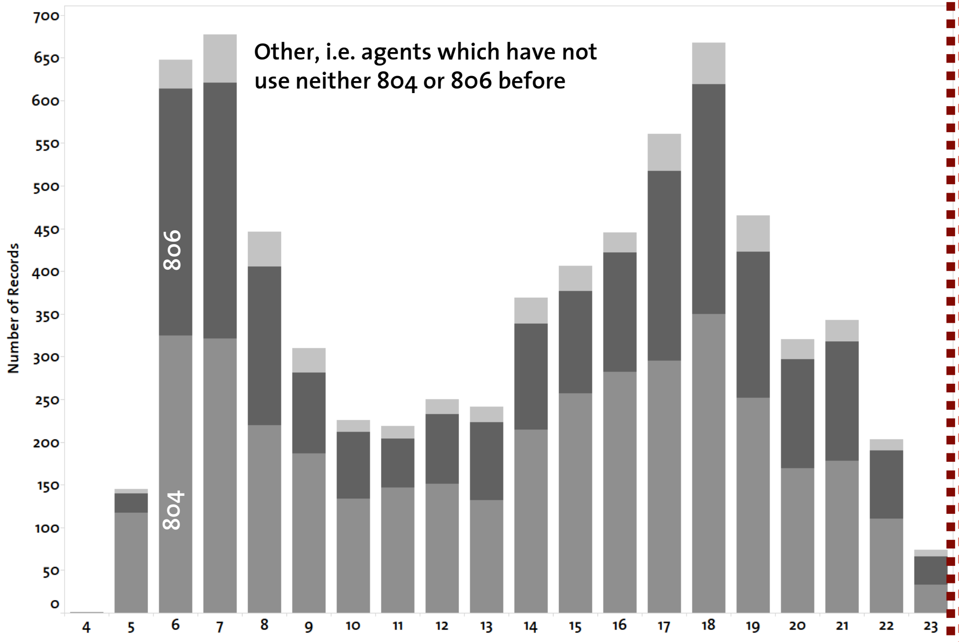
Using 804, 806, 860 as part of journey

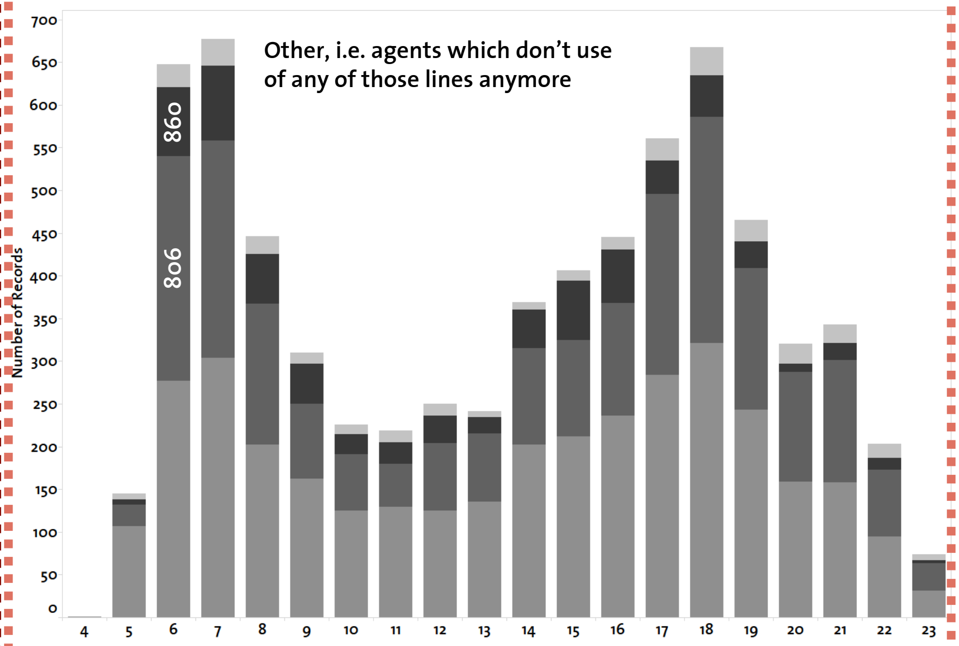
Gains and losses?

a) Travel time
b) Waiting time
c) Transfers

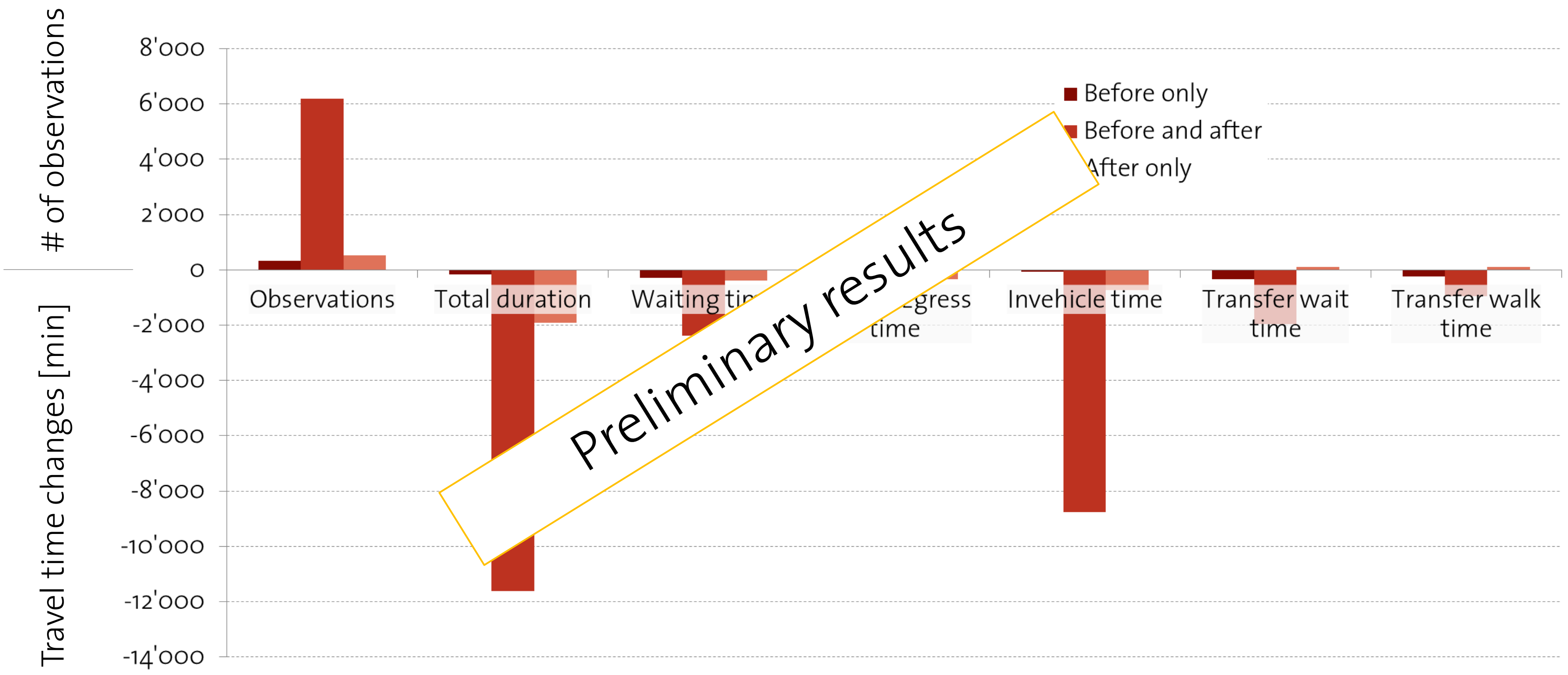
Where?

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

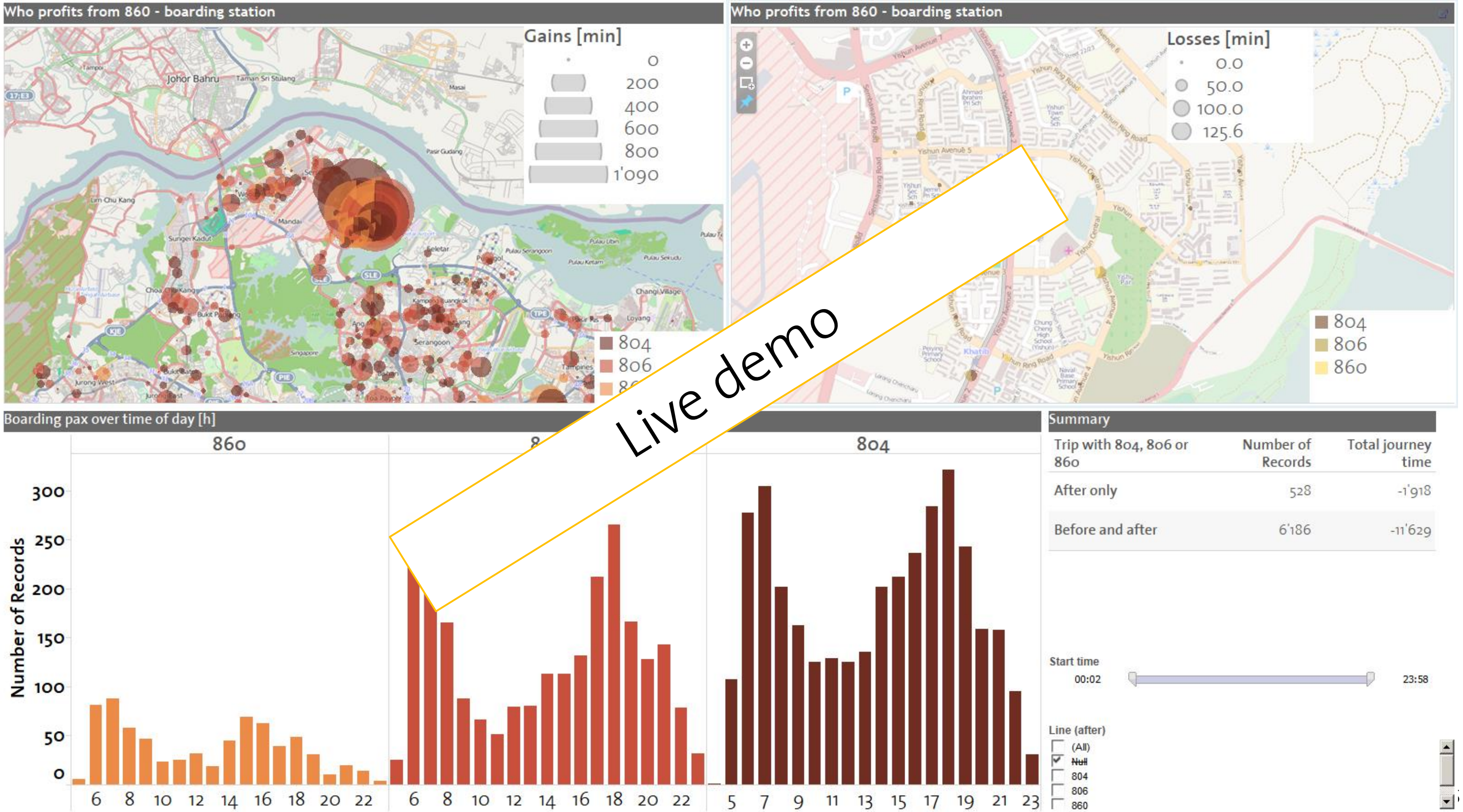




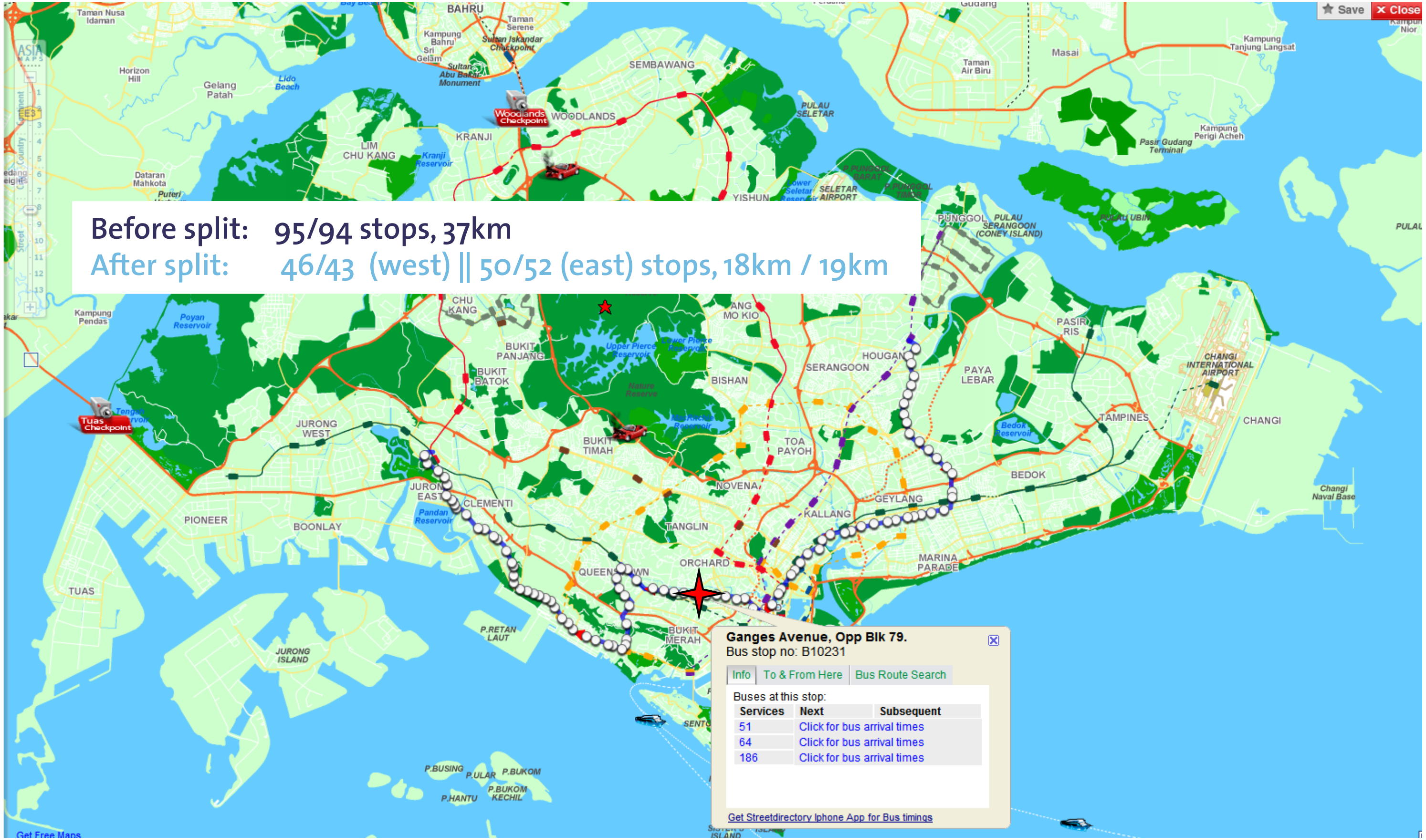
Changes in travel time for 860, 804 and 806 users



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

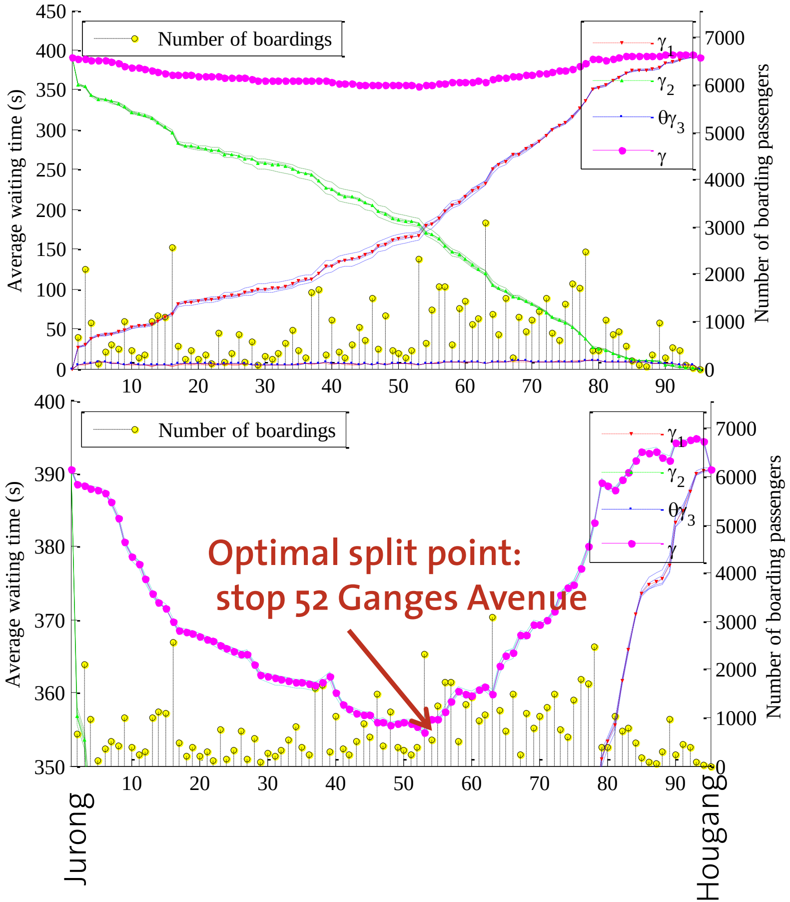
Detection of cutting point: based on waiting time

$$\min \gamma = \gamma_1 + \gamma_2 + \theta \times \gamma_3$$

$$\gamma_1 = \frac{\sum_{i=1}^{m-1} \left(E\ \ w_i \cdot \sum_{j=i}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$

$$\gamma_3 = \frac{\sum_{i=1}^{m-1} \left(\overline{T_{hold}} \cdot \sum_{j=m+1}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$

$$\gamma_2 = \frac{\sum_{i=m}^{M} \left(E\ \ w_i \cdot \sum_{j=i}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$



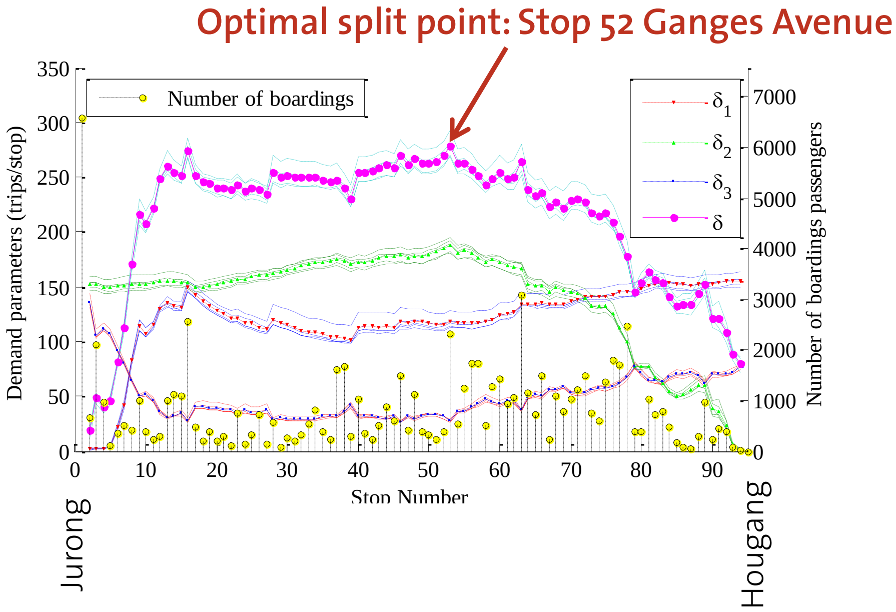
Detection of cutting point: based on demand

$$\min \gamma = \gamma_1 + \gamma_2 + \theta \times \gamma_3$$

$$\gamma_1 = \frac{\sum_{i=1}^{m-1} \left(E\ w_i \cdot \sum_{j=i}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$

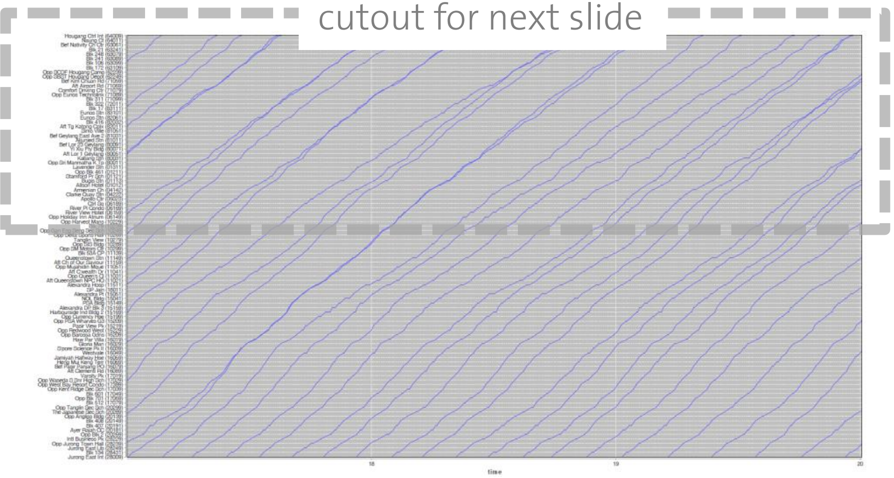
$$\gamma_3 = \frac{\sum_{i=1}^{m-1} \left(\overline{T_{hold}} \cdot \sum_{j=m+1}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$

$$\gamma_2 = \frac{\sum_{i=m}^{M} \left(E\ w_i \cdot \sum_{j=i}^{M} B_{i,j} \right)}{\sum_{i=1}^{M-1} \sum_{j=1}^{M} B_{i,j}}$$



Bus 51 Jurong to Hougang, 5-8pm, before line split simulated in MATSim vs Cepas

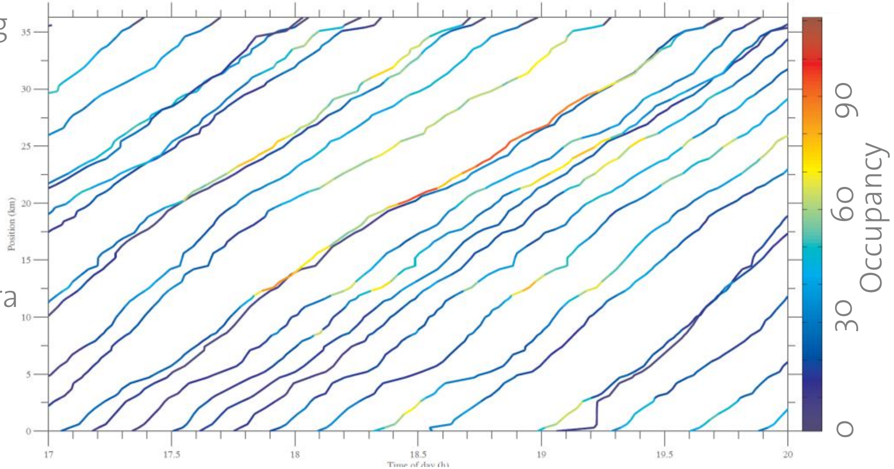
Simulated in MATSim



5pm 6pm 7pm 8pm

Observed in Cepas

Hougang
Bugis
Blk 79
Alexandra
Jurong E

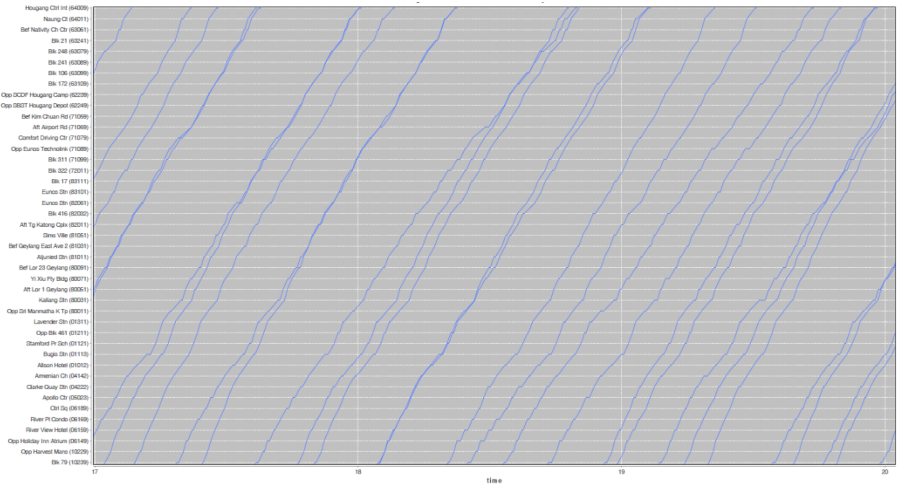


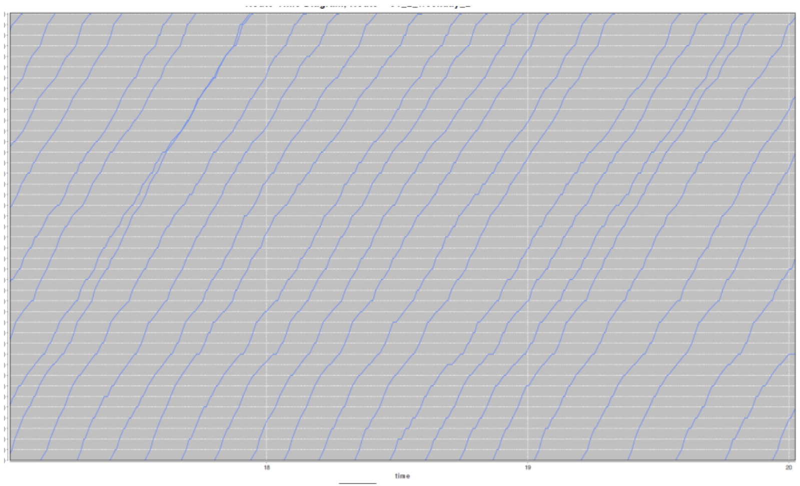
5pm 6pm 7pm 8pm

Improved reliability

Simulated in MATSim before line split

Simulated in MATSim after line split





Hougang

Eunos

Geylang

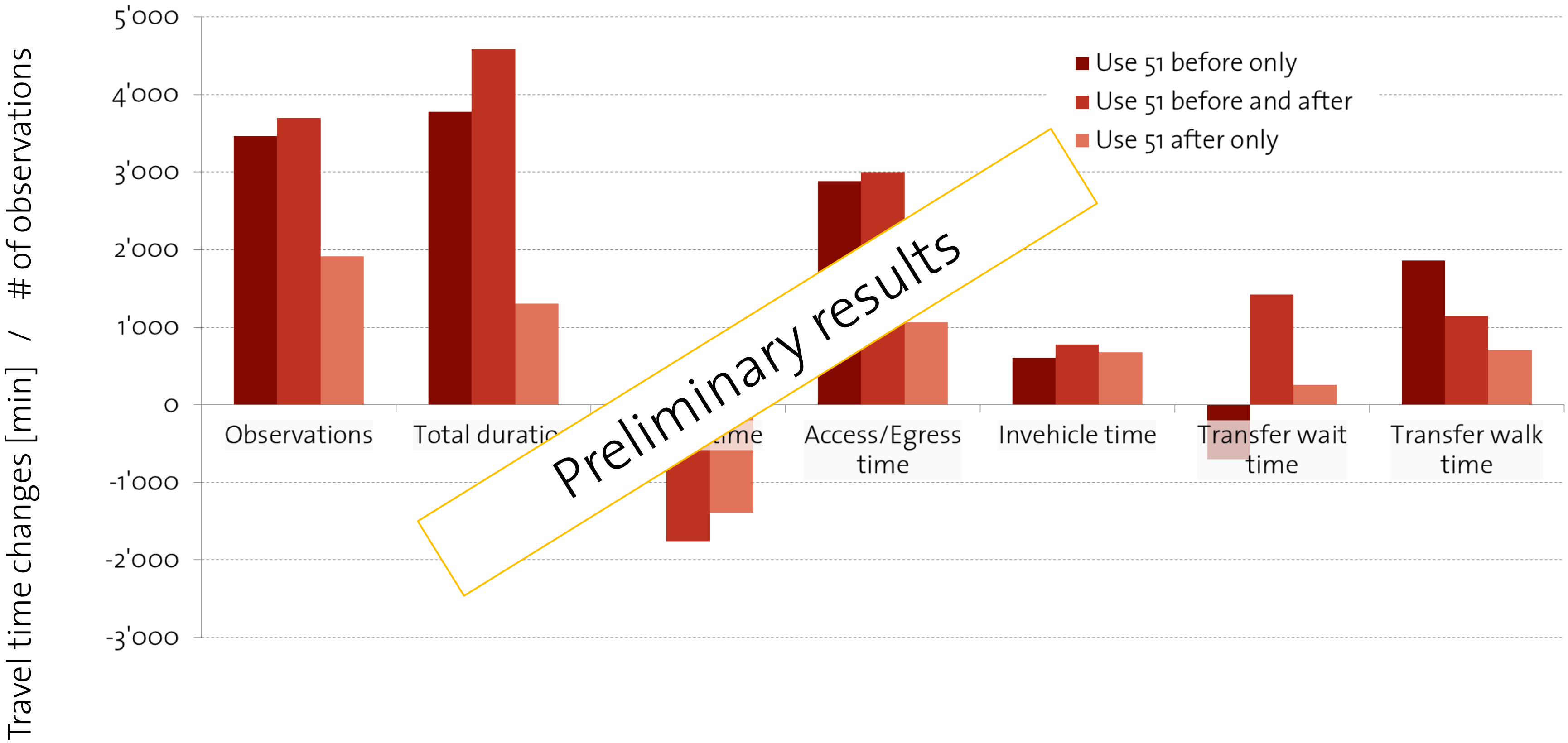
Bugis

Blk 79

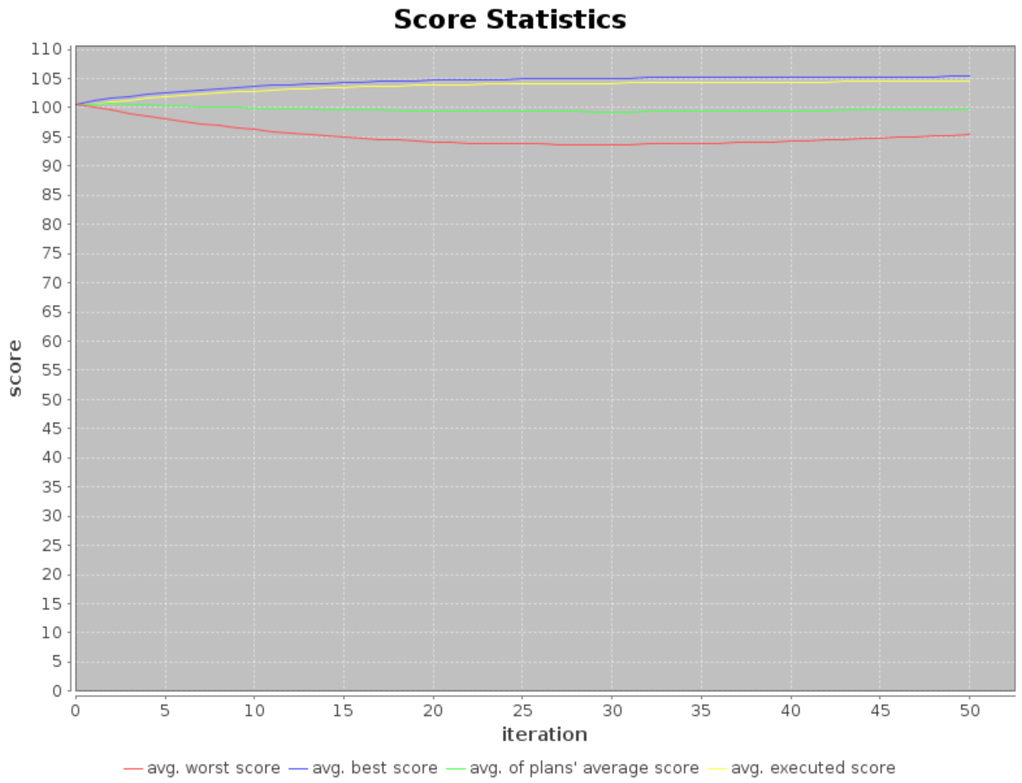
5pm 6pm 7pm 8pm

5pm 6pm 7pm 8pm

Changes in travel time for 51 split, BUT…….



……. to few iterations -> line switcher are still searching for better routes

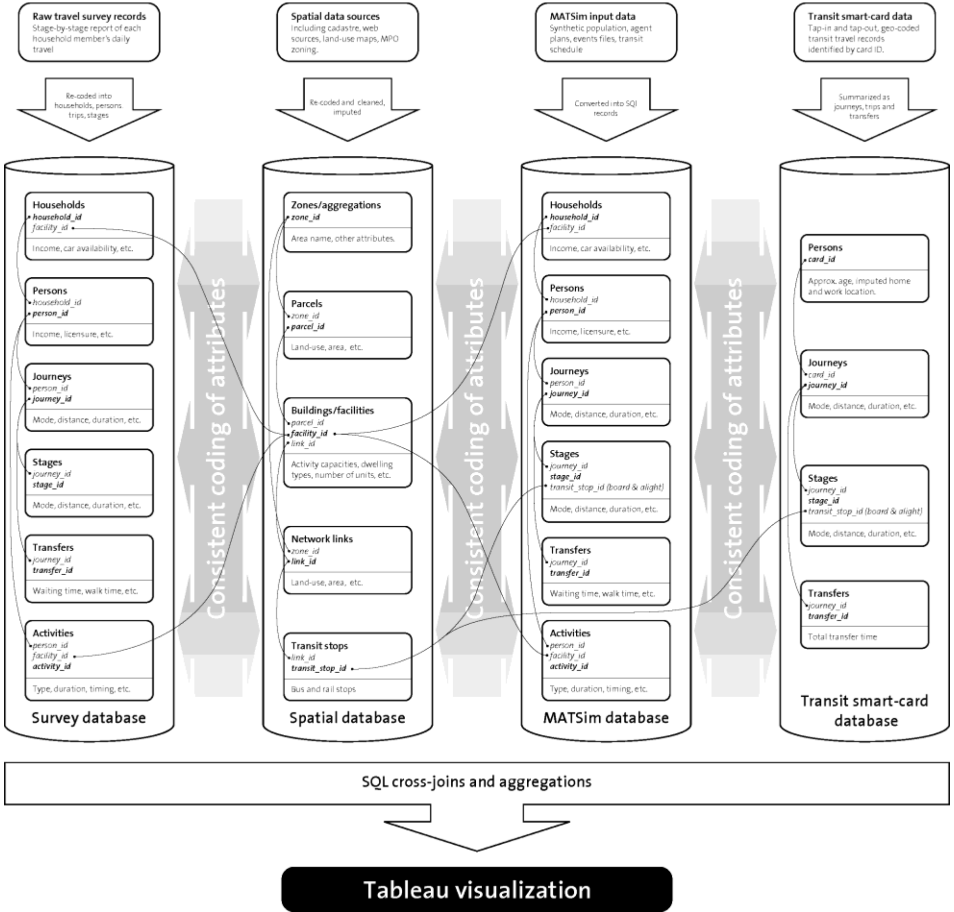


III Using MDSS for validation of MATSim demand and calibration of simulation

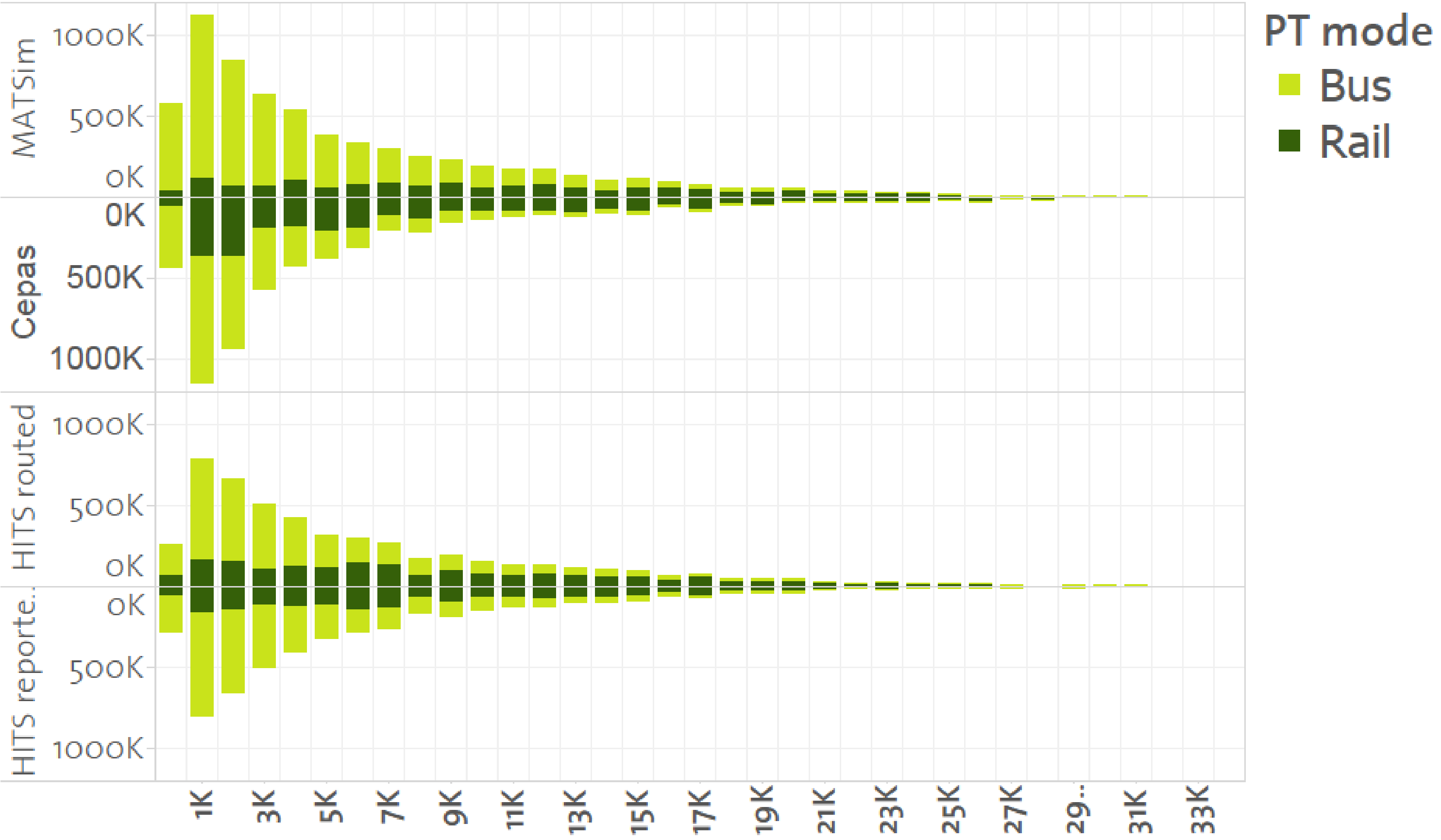
Towards a more accurate MATSim Singapore model

Pieter Fourie, Alex Erath, Michael van Eggermond

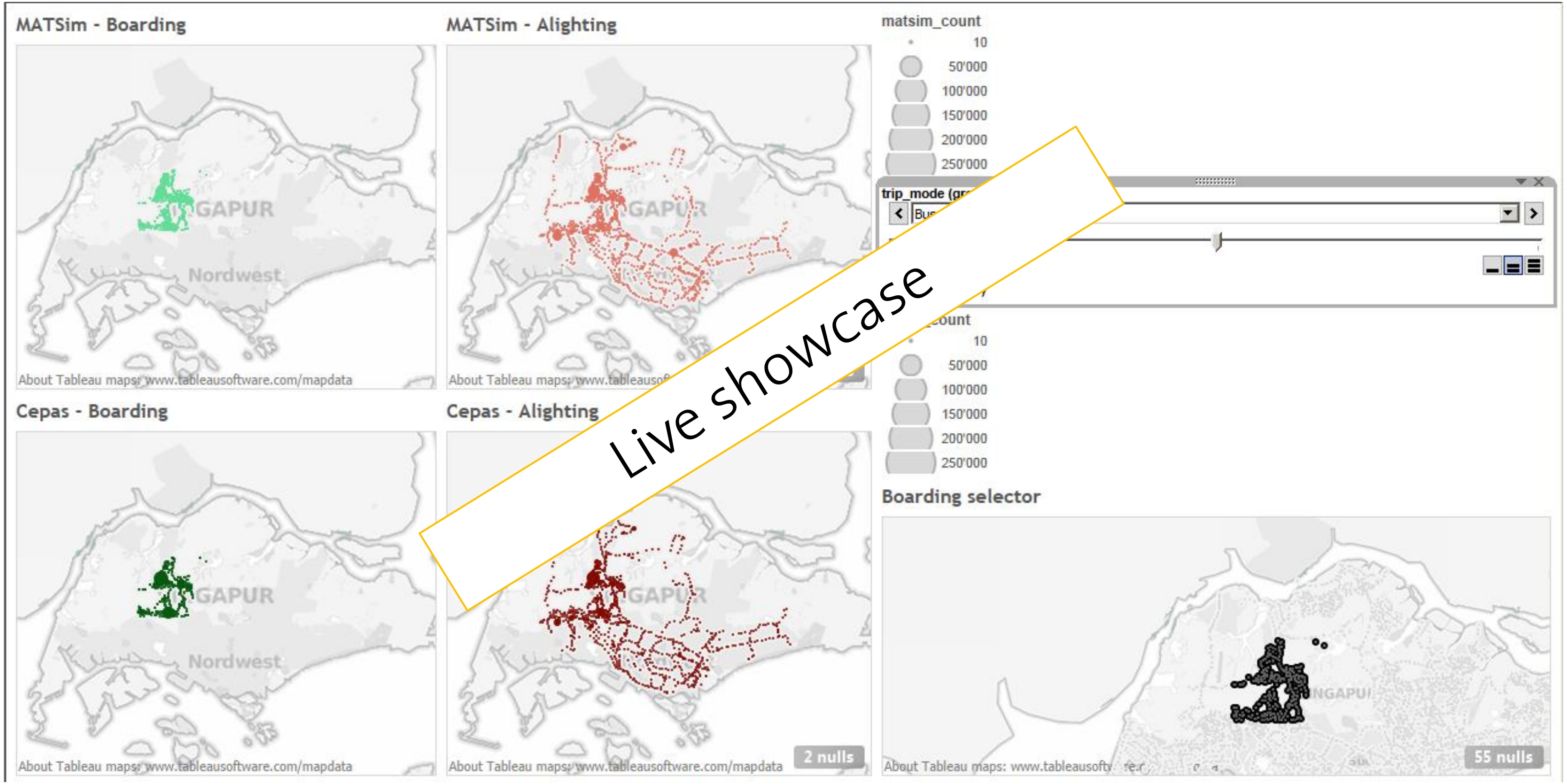
MDSS for calibration



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

Background

“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

Our work

For what?

1. Infer individual travel purpose
2. How individuals' activities re-shape the city
3. how to find the city centers

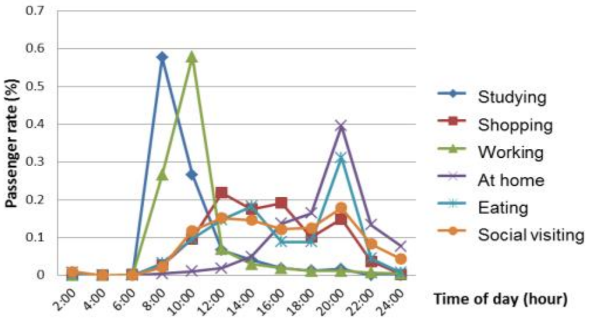
1. Infer travel purposes and building functions

Data:

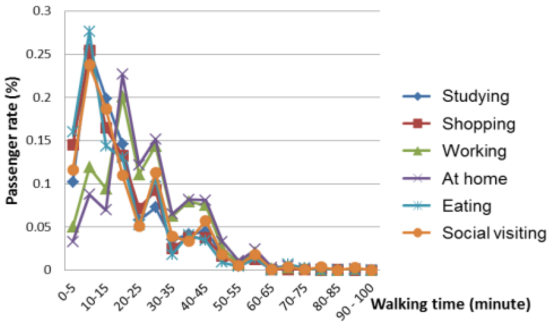
- EZLink data
- Household Interview Travel Survey (HITS) data:

For what?

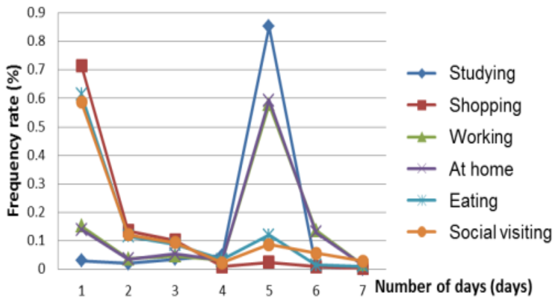
Method – Patterns of travel behaviors (statistic data from HITS)



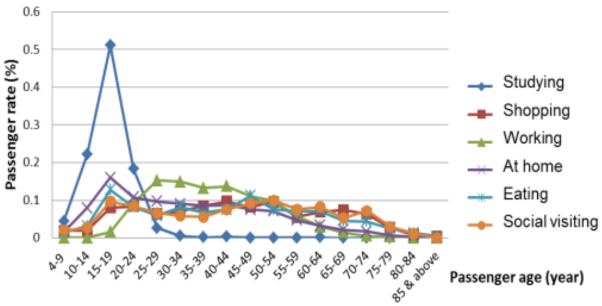
Starting time



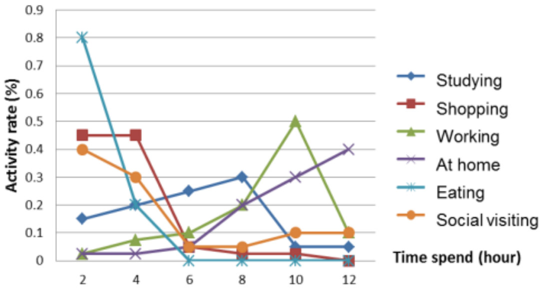
Walking time



Travel frequency

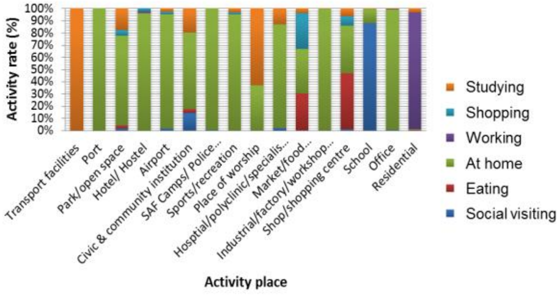


Age distribution



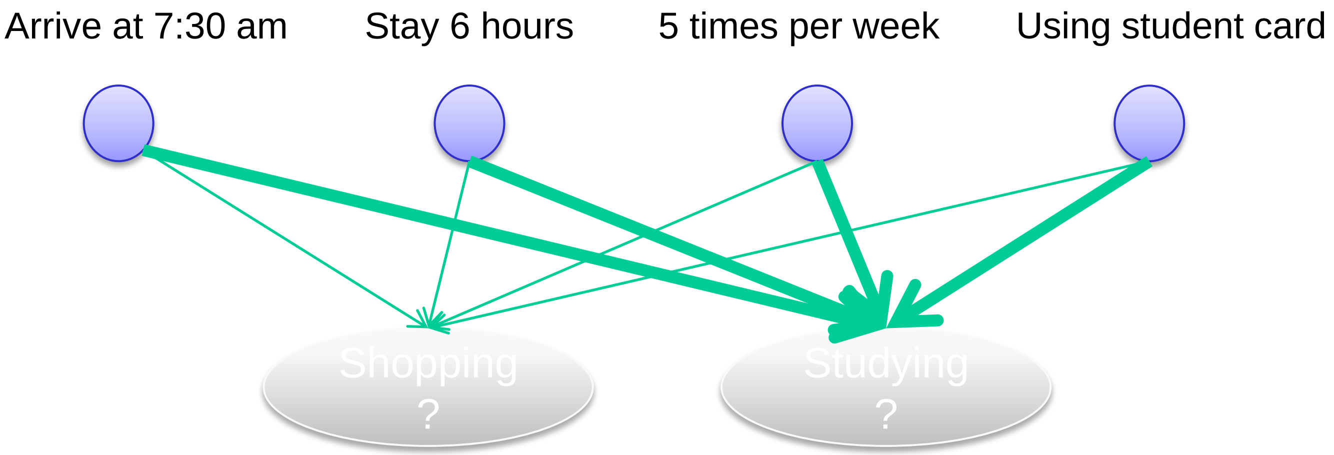
Time use

(also referred to other literature)



Activities Vs. Places

Using Bayesian classifier to find the most possible purpose, with HITS data as the prior probability.



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

$$P((a_a, a_t, a_d, a_f) \mid c) = \prod_{h=1}^{m} P(a_i \mid c)$$

Method – Bayesian probabilistic model + spatial analysis

Table A. Original trip

Trip_id	P_type	stop_Id	Arr_time	Staytime	freq
2000**********00	3	28499	7.679773	10.37634	6
2000**********00	3	21069	6.528593	11.38391	2
2000**********00	1	21639	0.263213	21.39484	2
2000**********00	1	21639	18.18231	1.157685	2
2000**********00	2	21759	6.885319	11.93996	2
2000**********00	2	21651	16.61348	1.188741	1
2000**********00	3	21149	7.874	9.666556	3
2000**********00	2	21759	6.883111	11.01522	3
2000**********00	2	21759	6.86131	12.8448	1

Check prior probability of travelling purpose

Table B. Prior probability

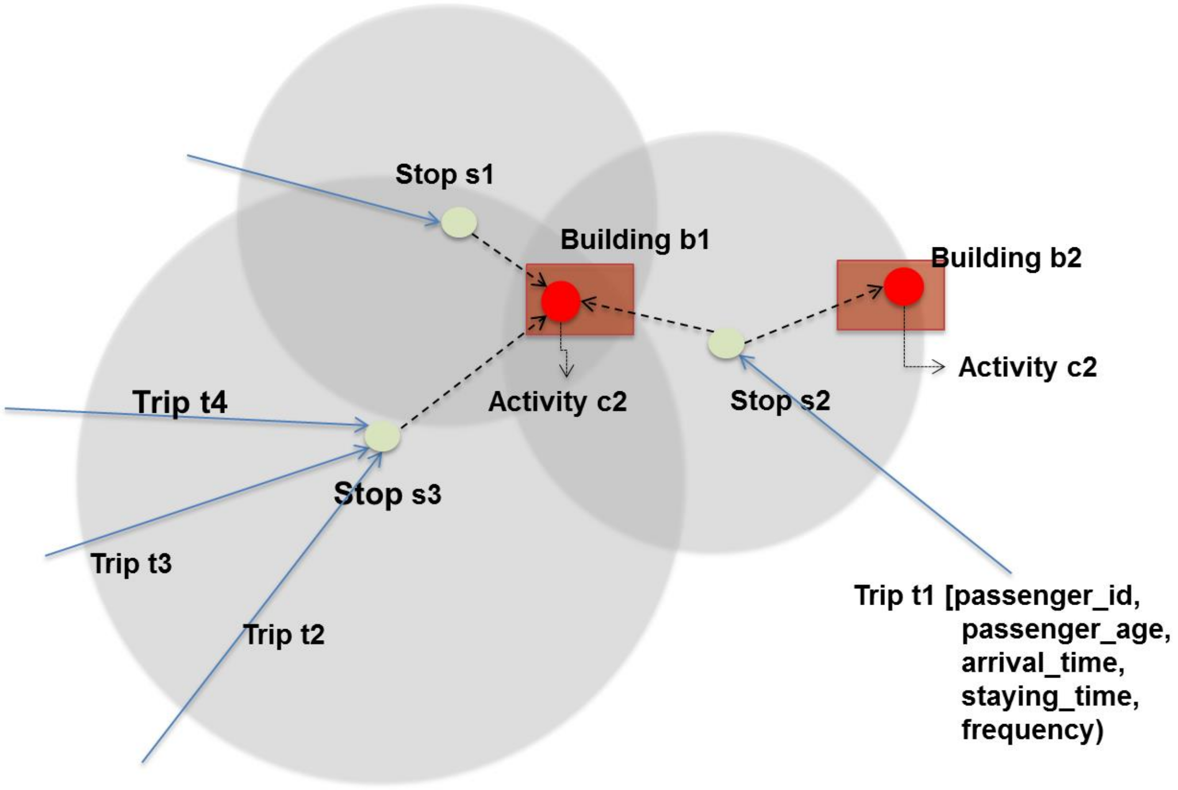
freq	education	shopping	working	homing	eating	social-visiting
1	0.031165	0.714492	0.152148	0.139172	0.614155	0.586769
2	0.020701	0.135544	0.03715	0.035877	0.116438	0.121764
3	0.036624	0.102379	0.047331	0.053844	0.086758	0.09396
4	0.047998	0.010094	0.031697	0.031878	0.034247	0.023969
5	0.852366	0.025234	0.577914	0.593016	0.121005	0.087248
6	0.009327	0.009373	0.136406	0.130273	0.015982	0.056568
7	0.00182	0.002884	0.017353	0.015939	0.011416	0.029722

Posterior probability of travel purpose

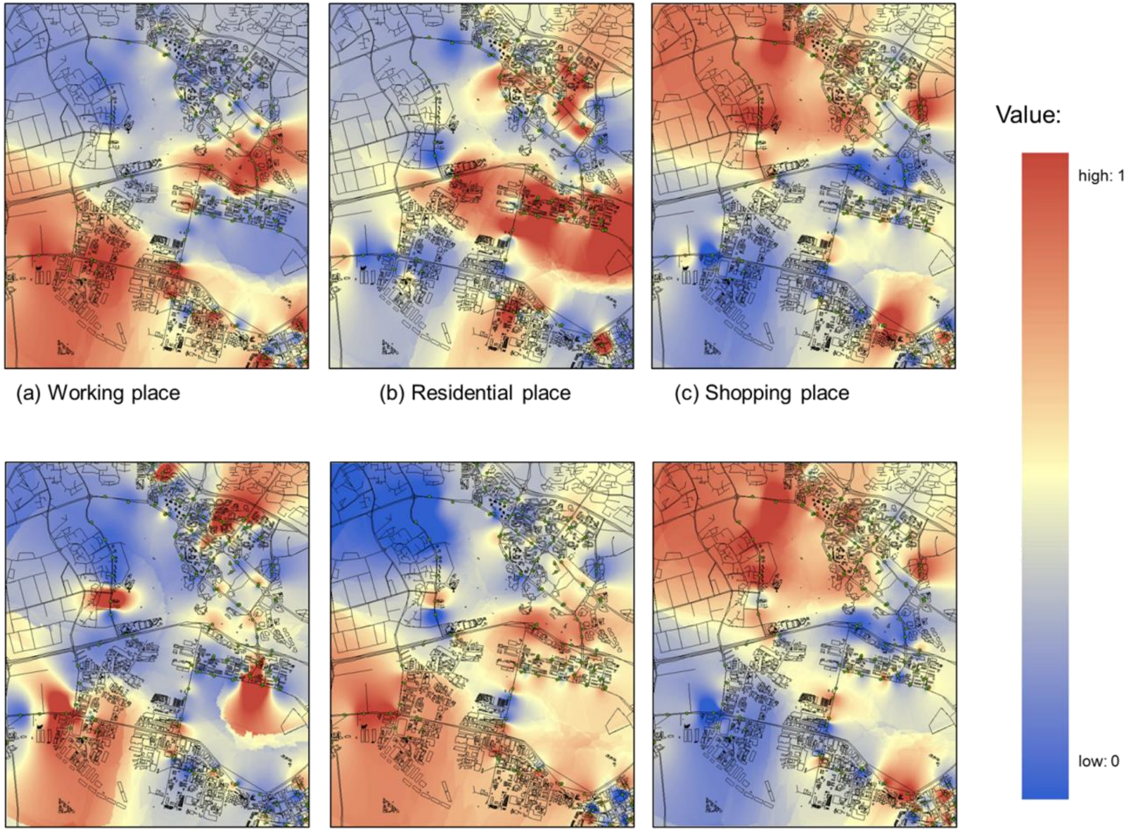
Table C. Summed posterior probability

stop_id	e	s	w	h	c	v	max
284**	**0.2797**	0.1981	0.1510	0.2696	0.2131	0.1595	**e**
283**	**0.2994**	0.2258	0.2053	0.2008	0.2351	0.1794	**e**
282**	0.0506	0.3281	0.4008	0.2659	0.2863	0.2379	**w**
280**	0.0234	0.2247	0.0534	0.3877	0.2286	0.1960	**h**
284**	0.0942	0.4955	0.3436	0.1241	0.4320	0.3625	**s**
280**	0.1566	0.1926	0.2368	0.2461	0.1760	0.1582	**h**
280**	0.0769	0.2611	0.1089	0.3817	0.3136	0.2182	**h**

Objective: travel behavior → activity type (travel purpose) and b



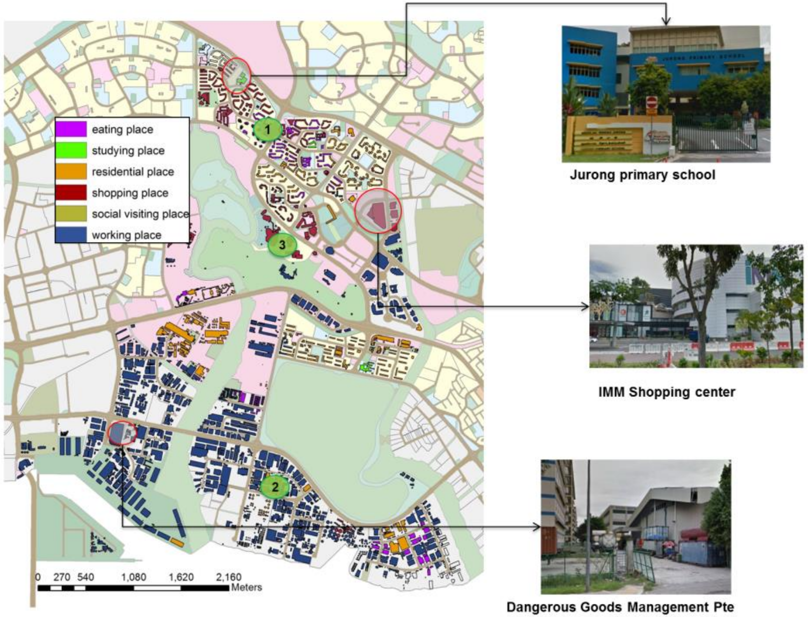
Result – Probability distribution of certain activities in Jurong Eas

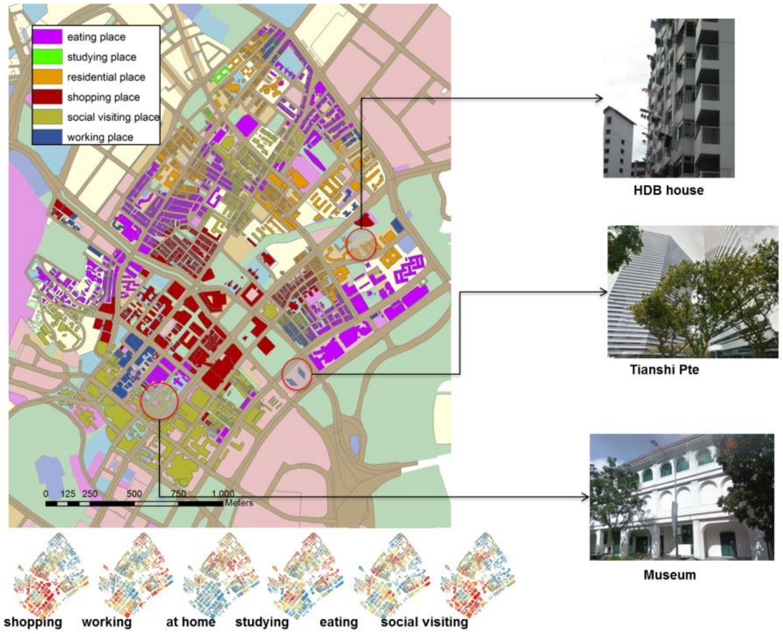


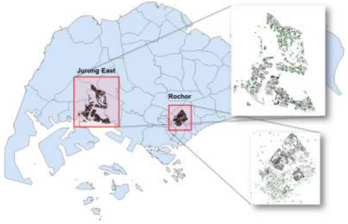
(a) Working place (b) Residential place (c) Shopping place

(d) Studying place (e) Eating place (f) Social visiting place

Result – Assigning function to building







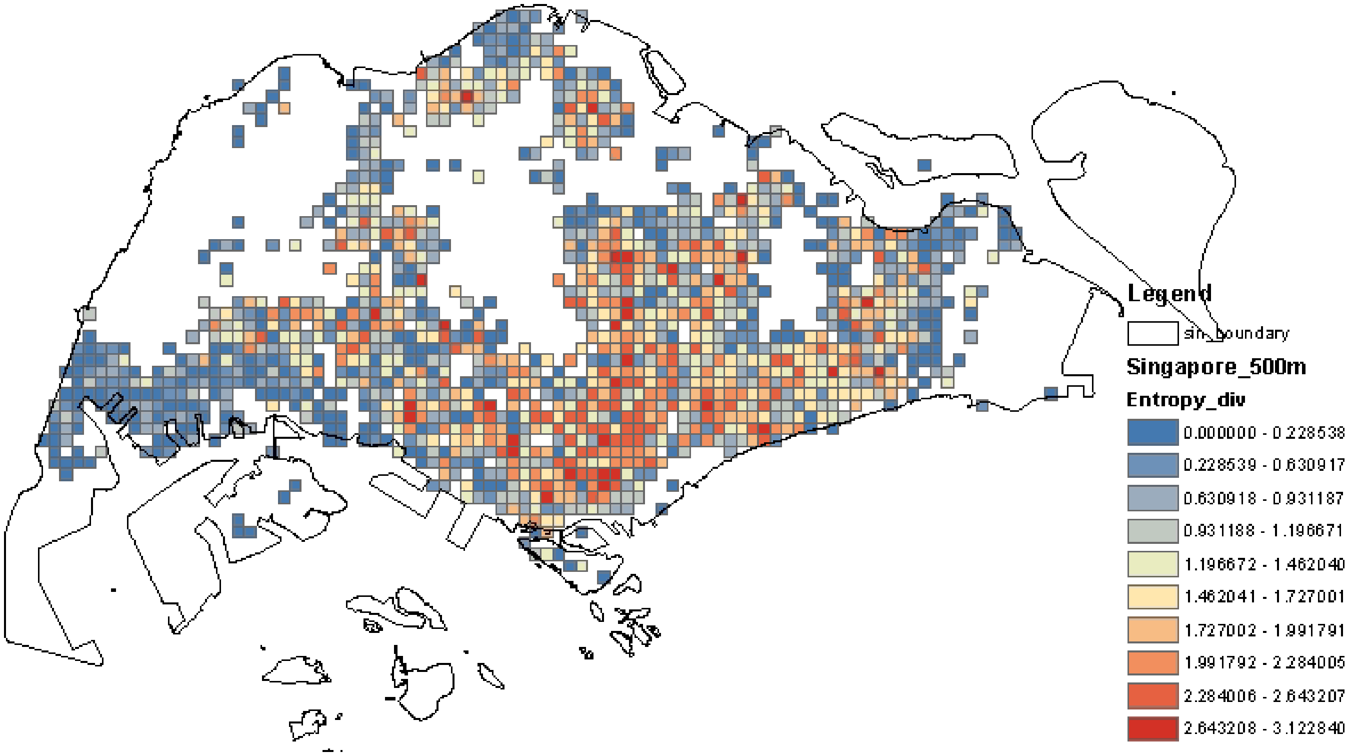
Building functions in Jurong East area (left) and Rochor area (right).

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?

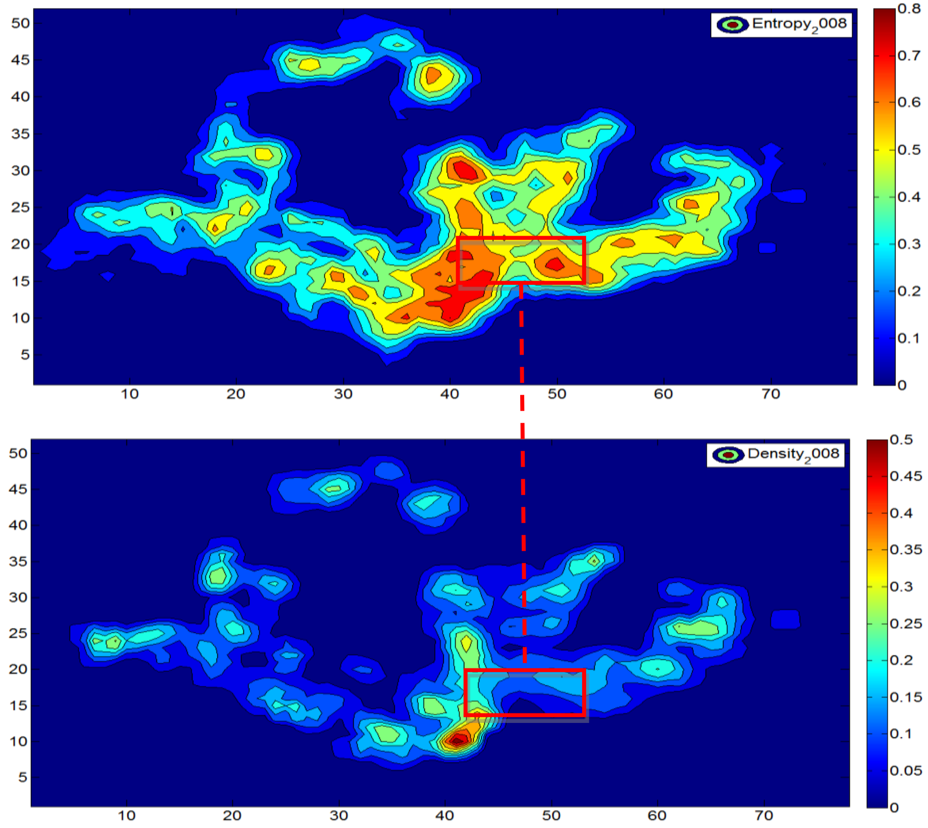
Many people go there

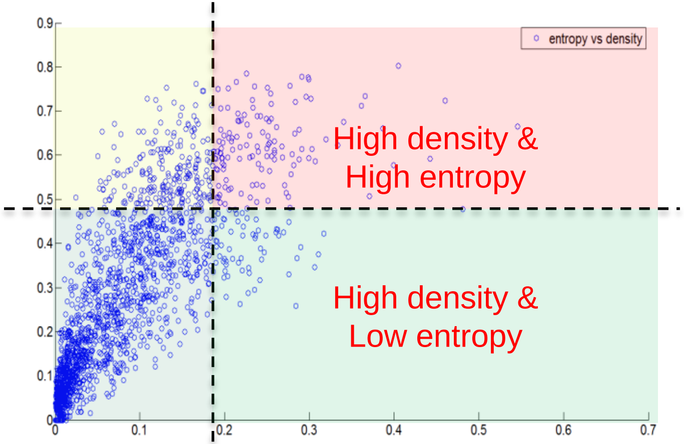
➔ **Density**

Many types of function(activities)

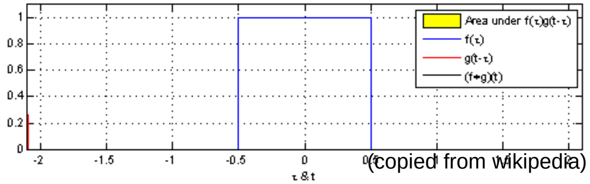
➔ **Entropy**

Method – Centrality index





Convolution

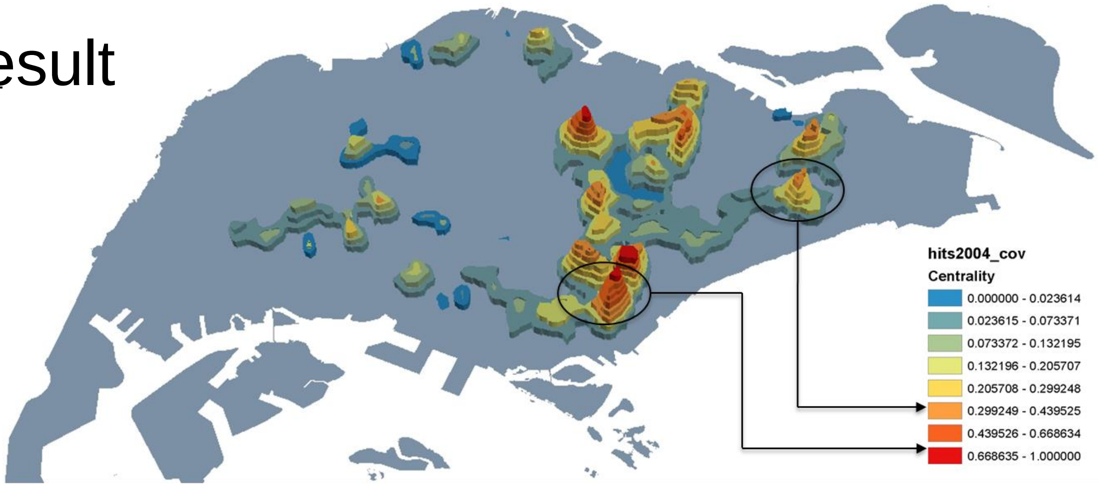


(copied from wikipedia)

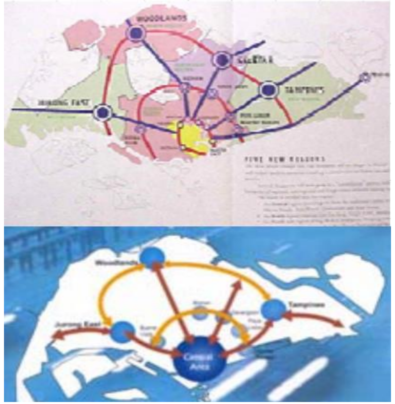
The joint probability dense function of two independent events is the convolution

$$C_{xy} = P_D(x,y) \otimes P_E(x,y)$$

Result



Detected centers
in 2004 (top)
and 2008 (bottom)

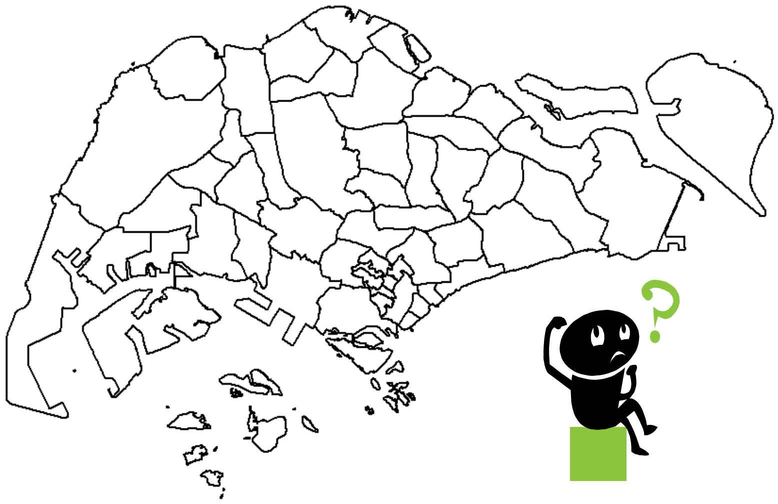


(Copied from course material
– theory is urban design)

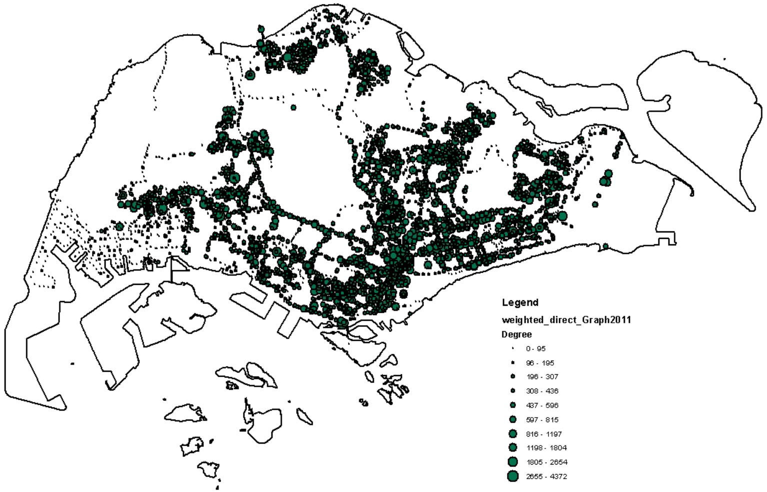
3. Identify spatial structure of borders using historical transportation data

How the people's **activities re-shape** the region?

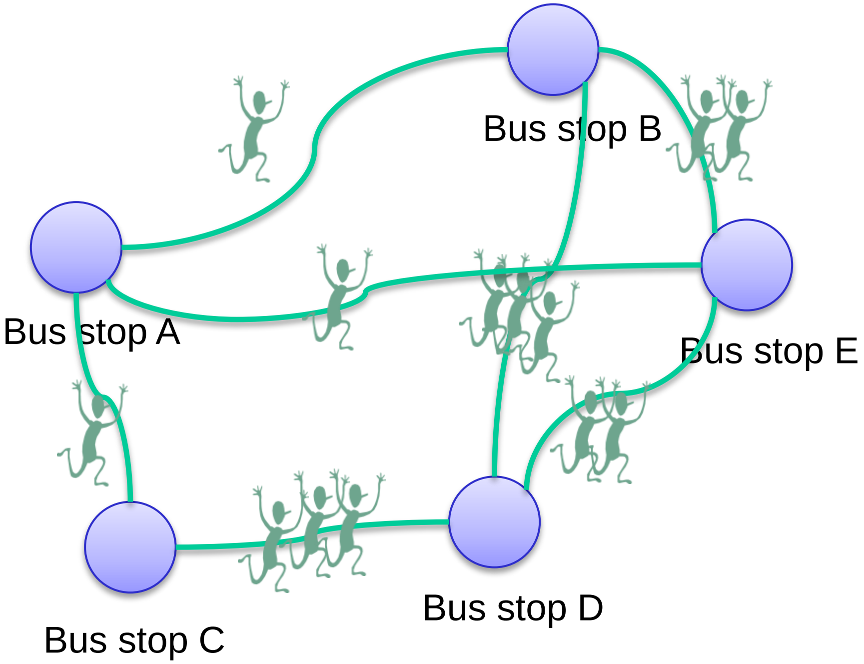
Data: EZLink Data



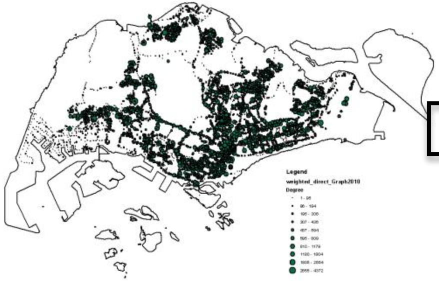
Complex networks (bus stop/MRT statin as the nodes)

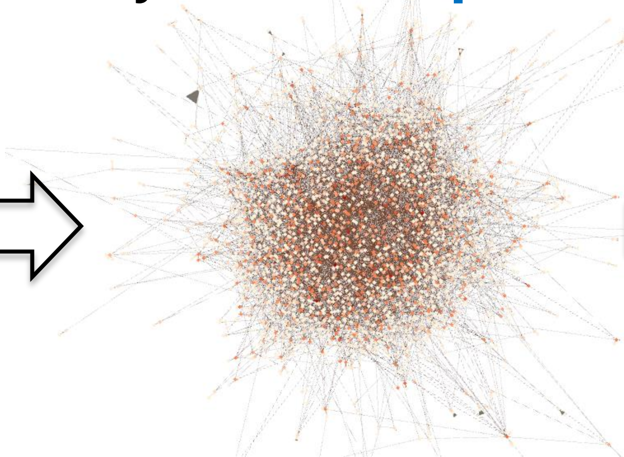


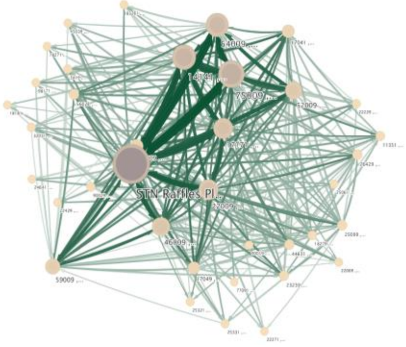
Smart card data 2011



Method – Spatial analysis + complex network analysis





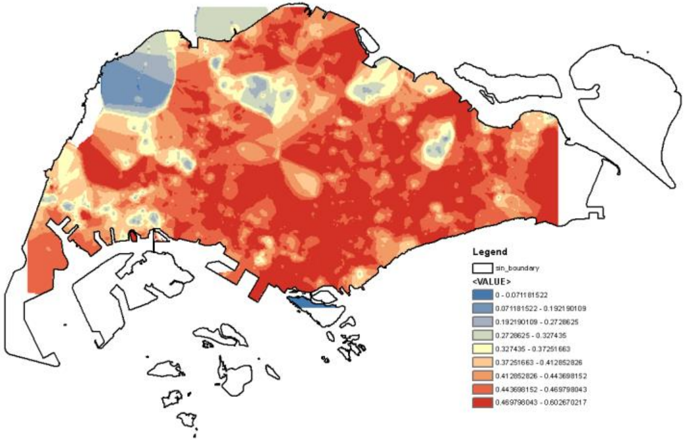


Label	Degree	Weighted_Degree	Modularity_Class	Clustering_Coefficient	Closeness_Centrality	Betweenness_Centrality
1012	533	2418	1	0.168256	0.488631	1.73E-04
1013	382	1654	1	0.180353	0.493501	8.17E-05
1019	355	1301	1	0.199139	0.47837	4.26E-05

	2011_MRT&BUS$_D$	2010_MRT&BUS$_D$	2008_MRT$_D$	2008_MRT$_E$	2008_BUS$_D$	2008_BUS$_E$
Number of nodes	MRT: 4514 BUS:107	MRT: 4531 BUS:108	93	93	4131	4139
Number of edges	702803	621731	3843	3733	213103	108109
Avg. path length	2.177 (di)	2.004 (indi)	1.101	1.127	2.5403	2.5762
Avg. clustering centrality	Diameter	0.250 (di) 0.392 (indi)	0.9341	0.9216	0.562047	0.533689
Avg. Elgenvector centrality	0.115567 (di) 0.141721 (indi)	0.1030 (di) 0.131633 (indi)	0.103	0.103	0.0104	0.0102

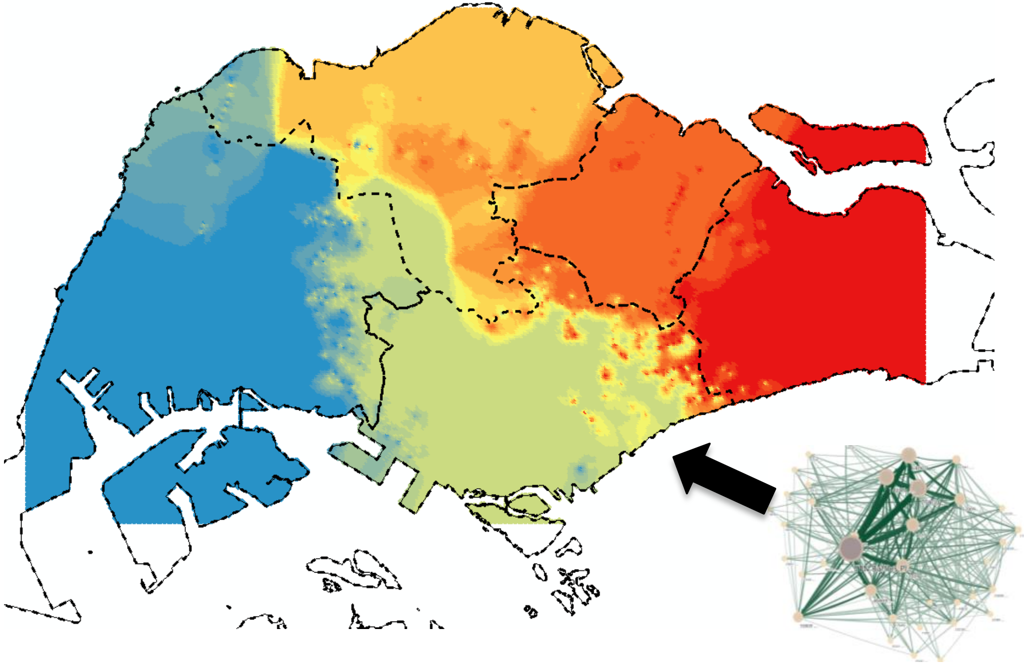
Result – Complex networks parameters – **Closeness**

Closeness distribution of bus stops & MRT stations

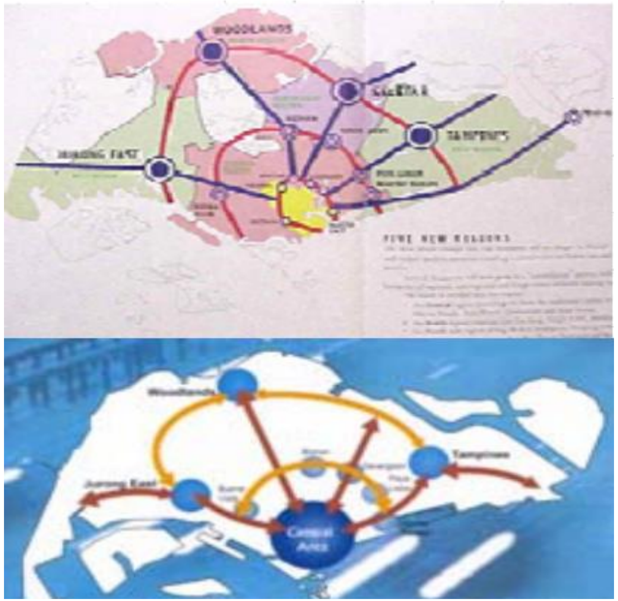


Interpolated closeness distribution

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

PhD projects I - IV

Optimisation of mobility pricing

- Distance based vs point/zone based
- Impact on PT
- Heterogeneous willingess 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

$$P_i = \sum_{j=1}^{n} O_j \exp\left(-\lambda t_{ij}\right)$$

P_i	Potential number of activities accessible to building *i*
O_j	Opportunities in building *j*
λ	Distance decay factor
t_{ij}	Travel time from *i* to *j*

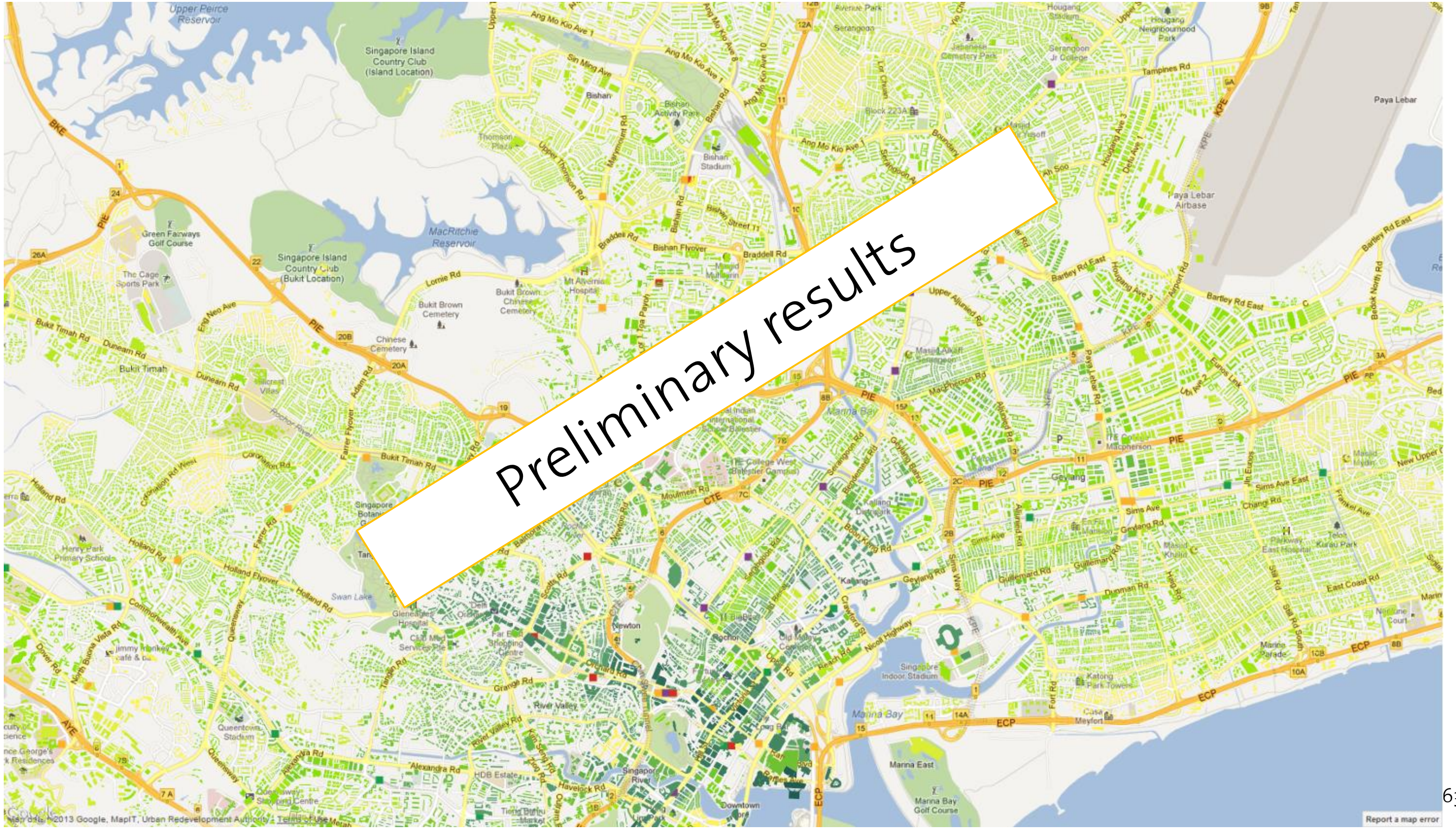
Methodology

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

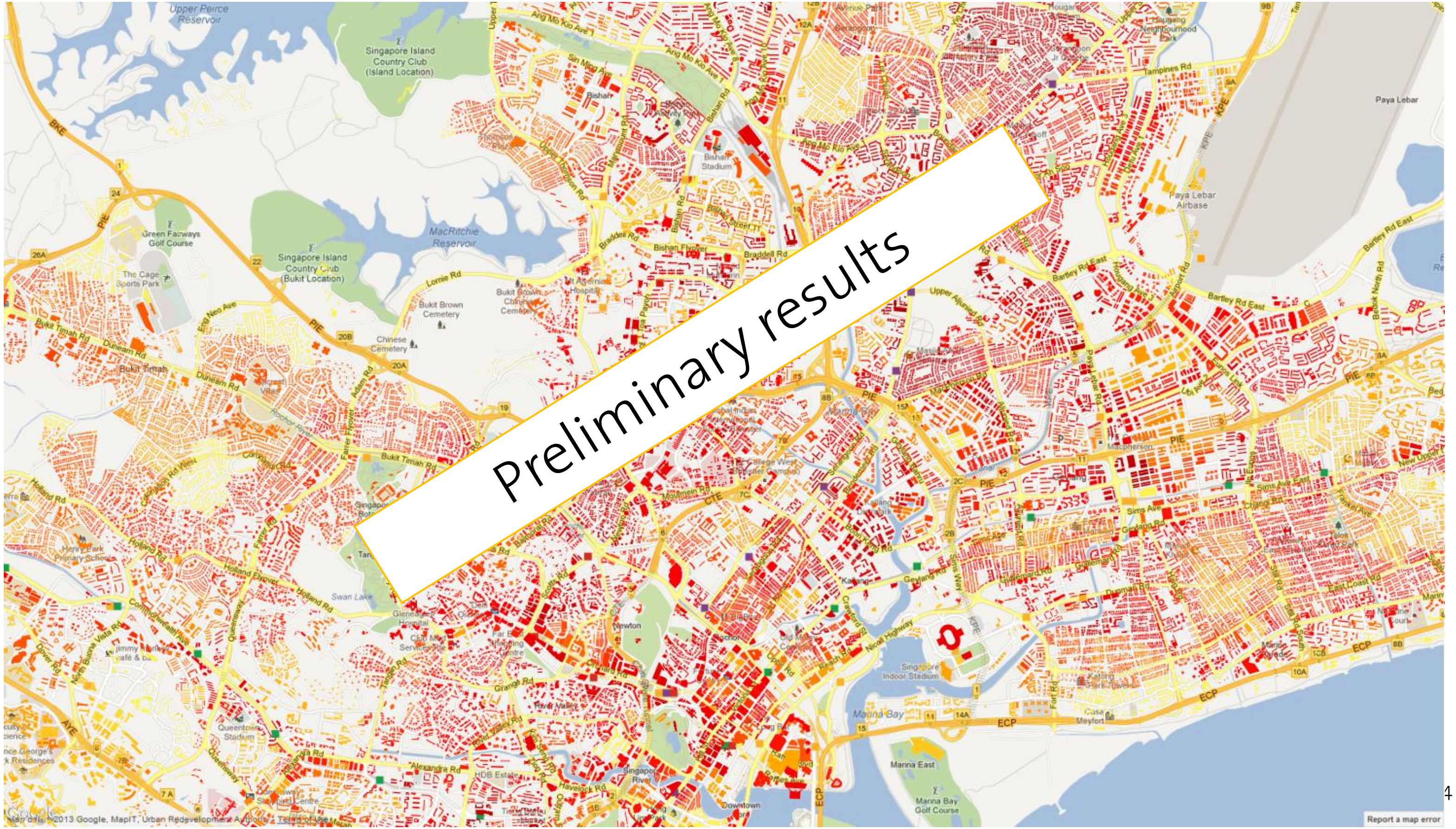
To-do

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:
27. - 28. June 2013
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

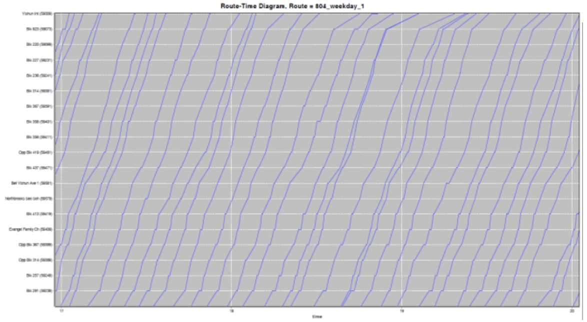
SITCE:
7. - 10. October 2013
MATSim as tool for public transport planning

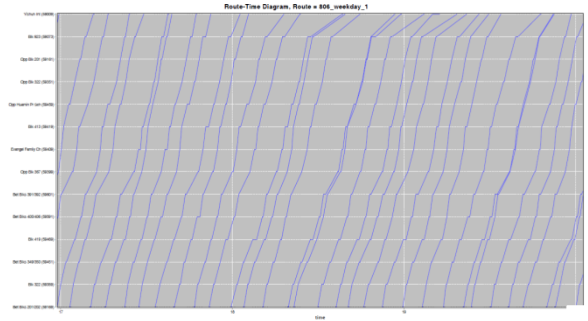
Appendix

Adding bus line 86o

before

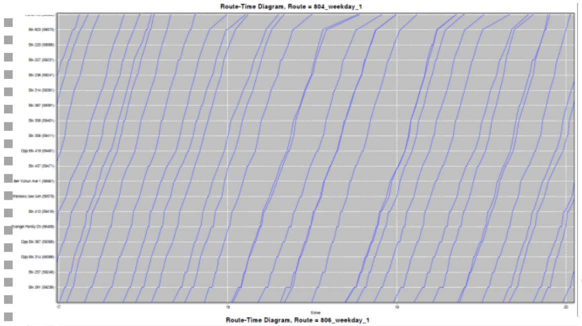
8o4

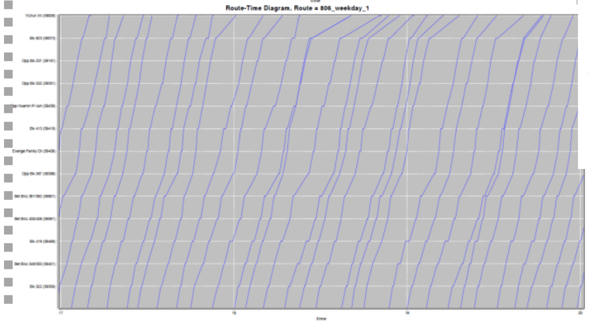




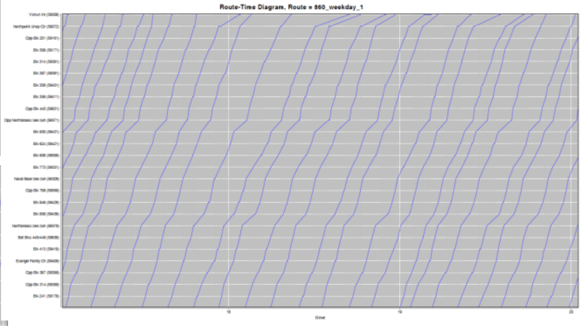
8o6

after





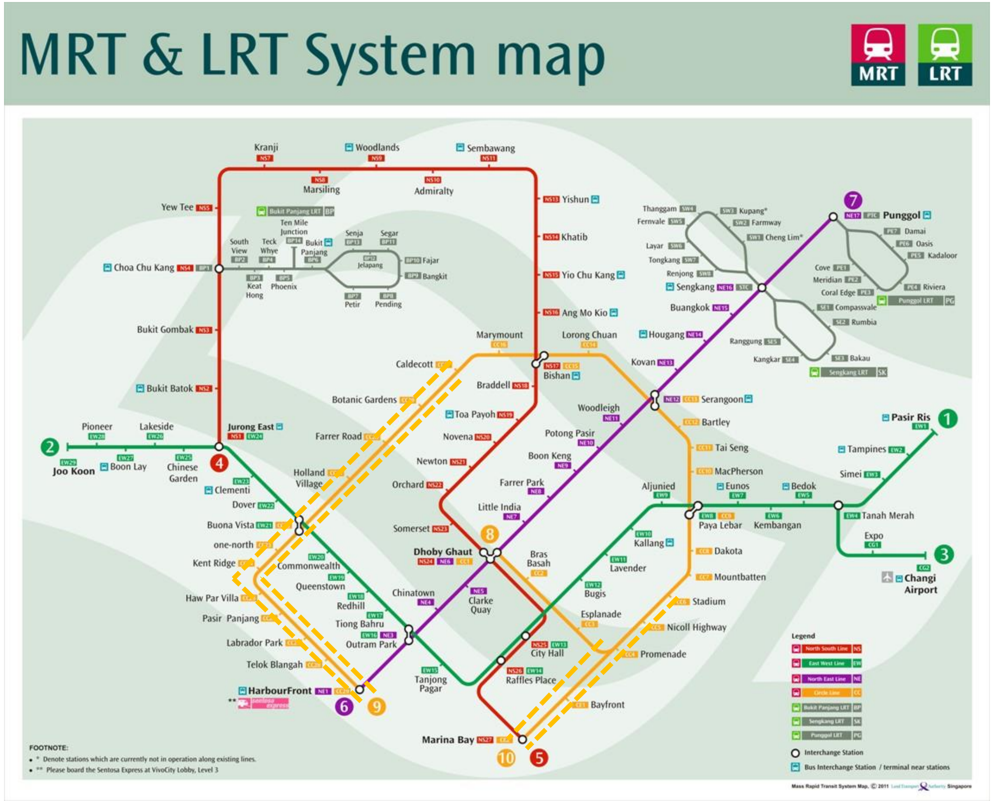
86o



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

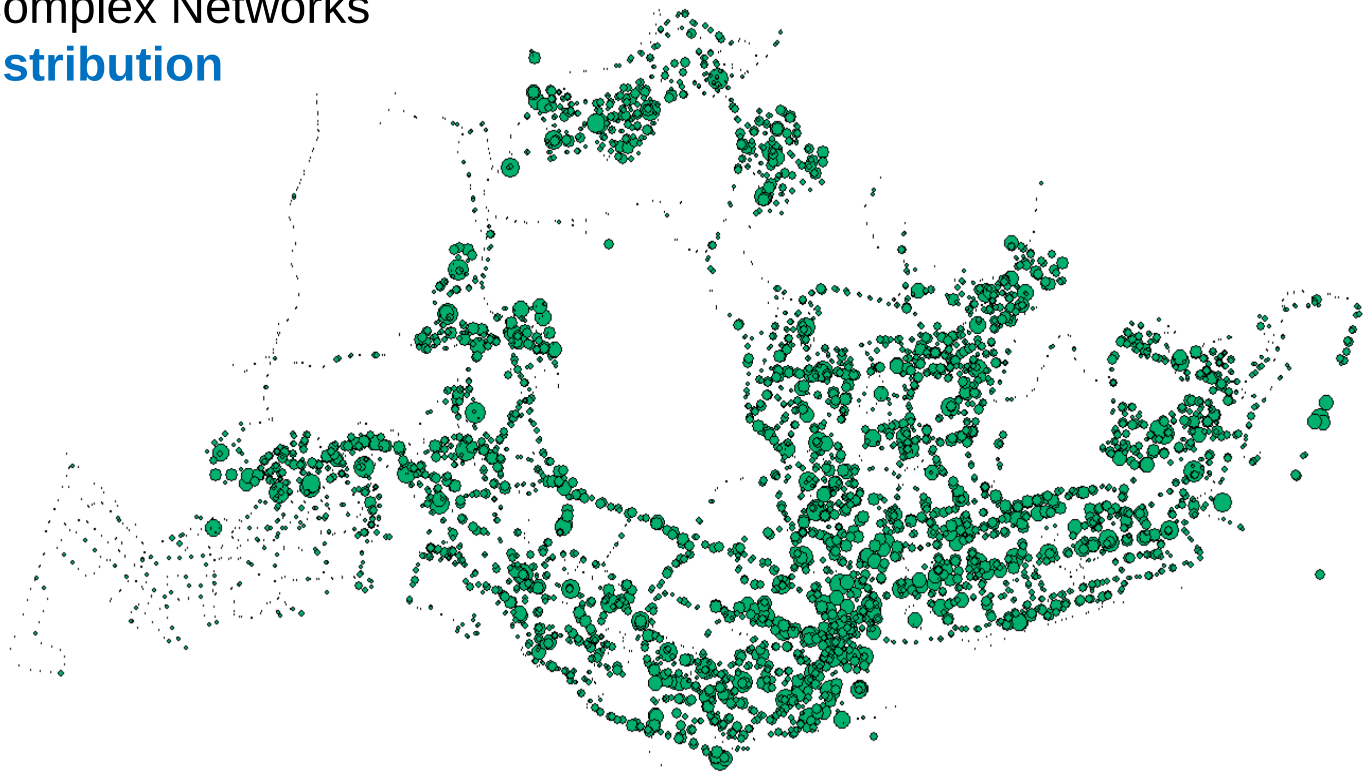


Thanks

Appendix I:

Result – Complex Networks

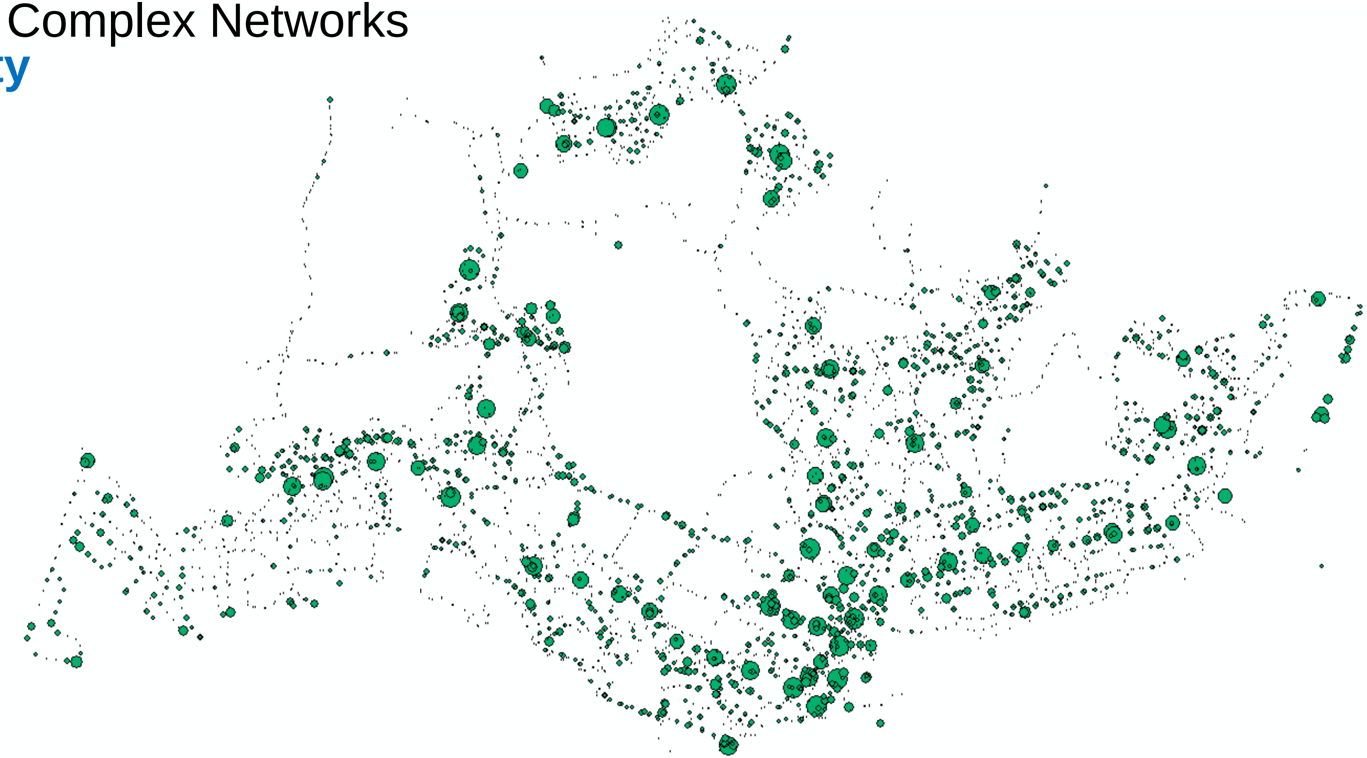
Degree Distribution



Degree distribution of the bus stops & MRT stations

Appendix II:

Result – Complex Networks
Authority



Authority values of bust stops & MRT stations