Preferred citation style for this presentation

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Modelling for Walkability

Understanding pedestrians' preferences in Singapore

Alex Erath, Michael van Eggermond, Sergio Ordóñez, Kay Axhausen

14th International Conference on travel behavior research
23rd July 2015

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

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

Motivation

Walking is the most basic and prevalent form of transport (in cities).

Long legacy of elaborate planning tools and design guidelines for roads and public transport.

But most cities are just starting to plan for walkability.

Existing research highlights distance as dominant attribute.

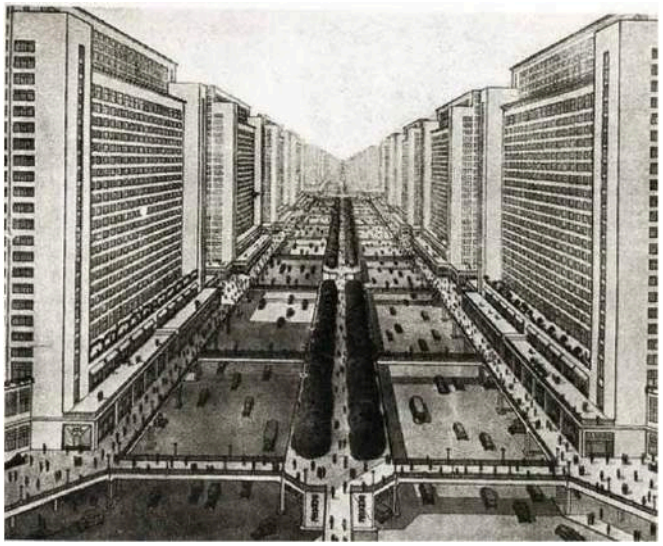
Singapore context

Focus has been on creating an efficient, ***modern*** transport system.

Very effective (technocratic) civil service.

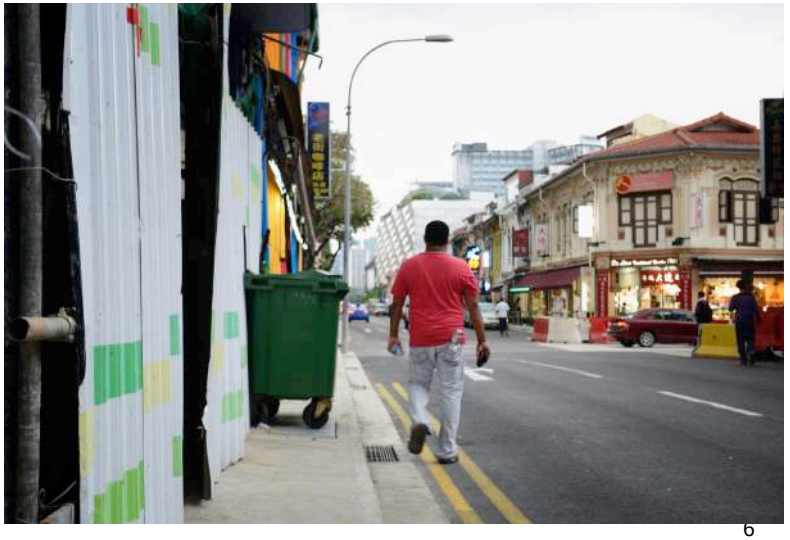
Walking and cycling are now big topics in Singapore's Masterplan.

What can be measured counts more.



Situations pedestrians face in Singapore

Situations pedestrians face in Singapore



Full video available at https://vimeo.com/106792004

Addressed research questions

Surveying the **physical environment**

- What to measure?
- How to quantify?
- How do we measure it?

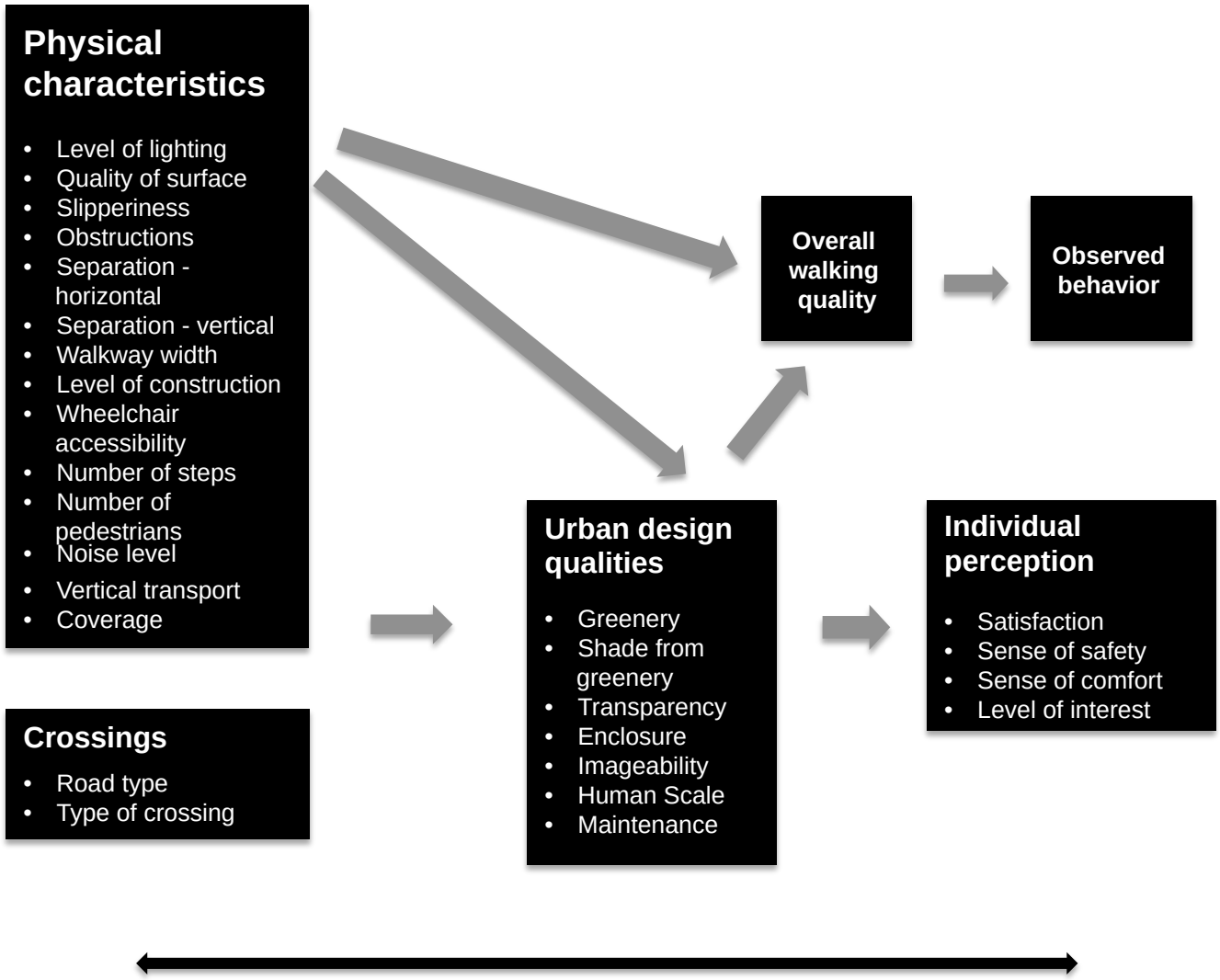
Surveying and modelling **behavior**

- Based on revealed preference
- Based on stated preference

Developing a software tool for planners

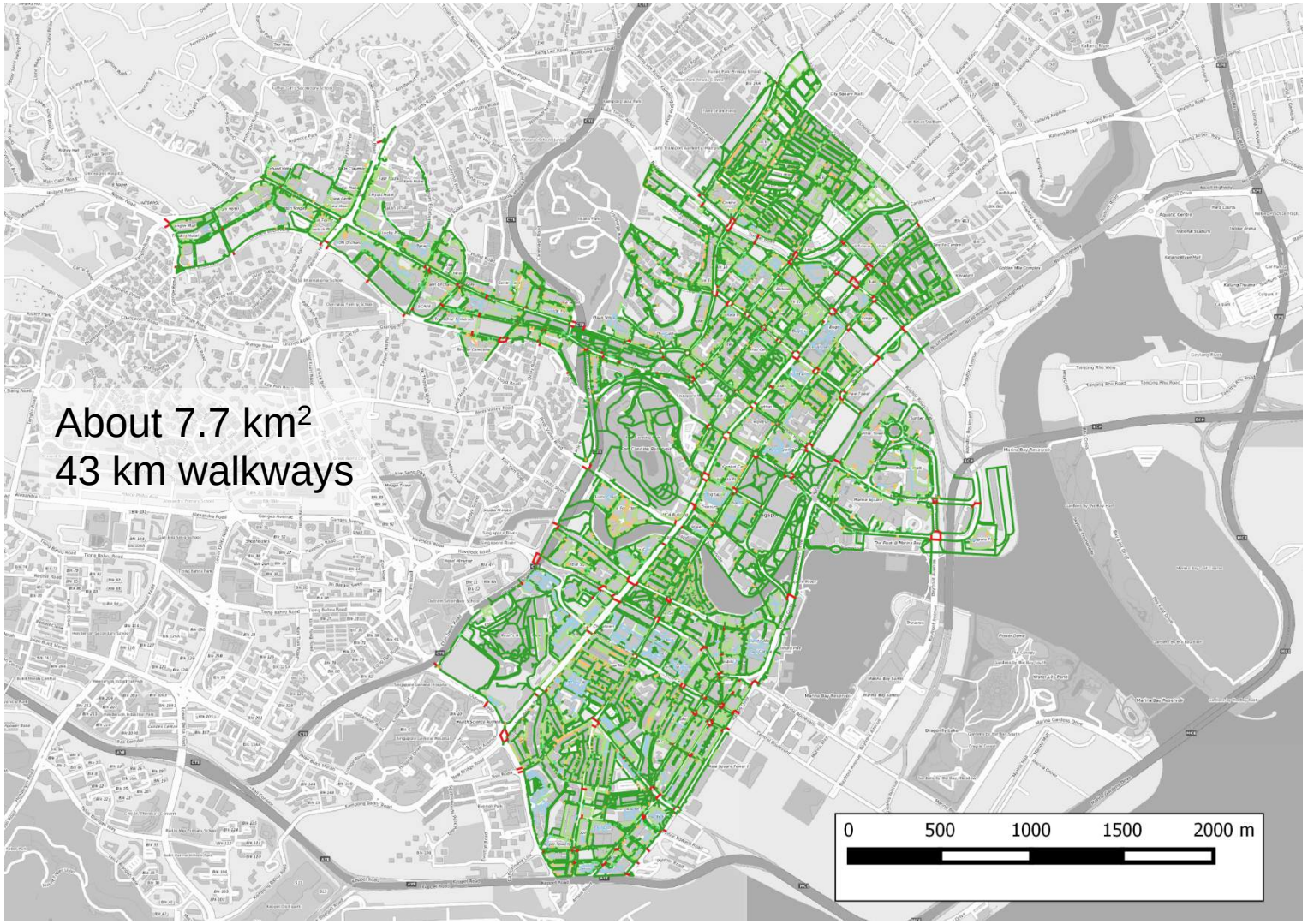
- For planners to assess infrastructure and policy measures
- A new ArcGIS add-in

Measurement framework

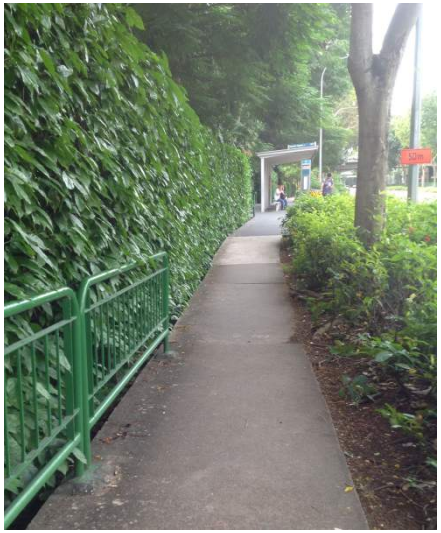


Ewing, Reid and Susan Handy (2009). 'Measuring the Unmeasurable: Urban Design Qualities Related to Walkability', Journal of Urban Design 14(1): 65–84.

Extent of the pedestrian network

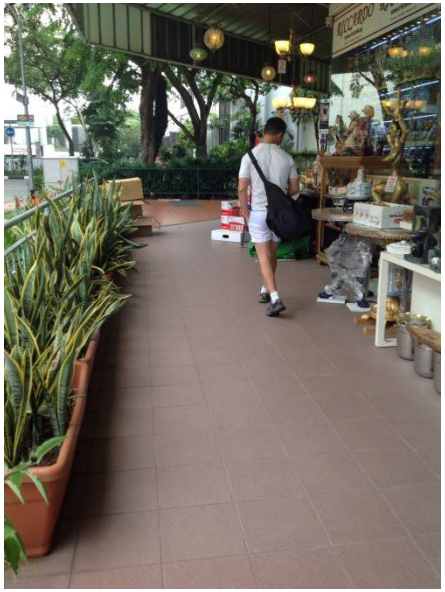


Beach road



Width open walkway	1-2m
Width covered walkway	n.a.
Separation horizontal	1-3m
Separation vertical	medium high hedge
Noise level	69db
Noise source	Mainly from street
Maintenance	5/5 – no rubbish in sight
Slipperiness	No, no tendency to slipperiness
Greenery	5/5 – lush greenery
Shade from greenery	4/5 - clearly shaded
Obstructions	0 – no obstructions in sight
Construction	0%
Imageability	1 feature
Human scale	1 feature
Enclosure	4/5
Transparency	0/100
Level of lighting	2/5 – small amount
Number of persons	5
Wheelchair	fully accessible
Date	6. July 2014

Sultan Gate



Width open walkway	2 – 3 m
Width covered walkway	1 – 2m
Separation horizontal	1-3m
Separation vertical	grass
Noise level	60db
Noise source	Mainly from street
Maintenance	4/5 – a little rubbish in sight
Slipperiness	No, no tendency to slipperiness
Greenery	3/5 – some greenery
Shade from greenery	1/5 - no shade from greenery
Obstructions	0 – no obstructions in sight
Construction	0%
Imageability	2 features
Human scale	13 features
Enclosure	4/5
Transparency	40/100
Level of lighting	2/5 – small amount
Number of persons	4
Wheelchair	fully accessible
Date	8. July 2014

How people walk in Singapore

… and how they experience it.

Some basic facts

Data collection period		March / April 2015
Number of valid tracks:		1077
Average walking distance:		259 m
Median walking distance:		210 m
Lower quartile:		143 m
Upper quartile:		305 m
Max:		2059 m
Average walking duration		3.96 min
Median walking duration		3.23 min
Average walking speed		4.51 km/h
Median walking speed	3.98 km/h	

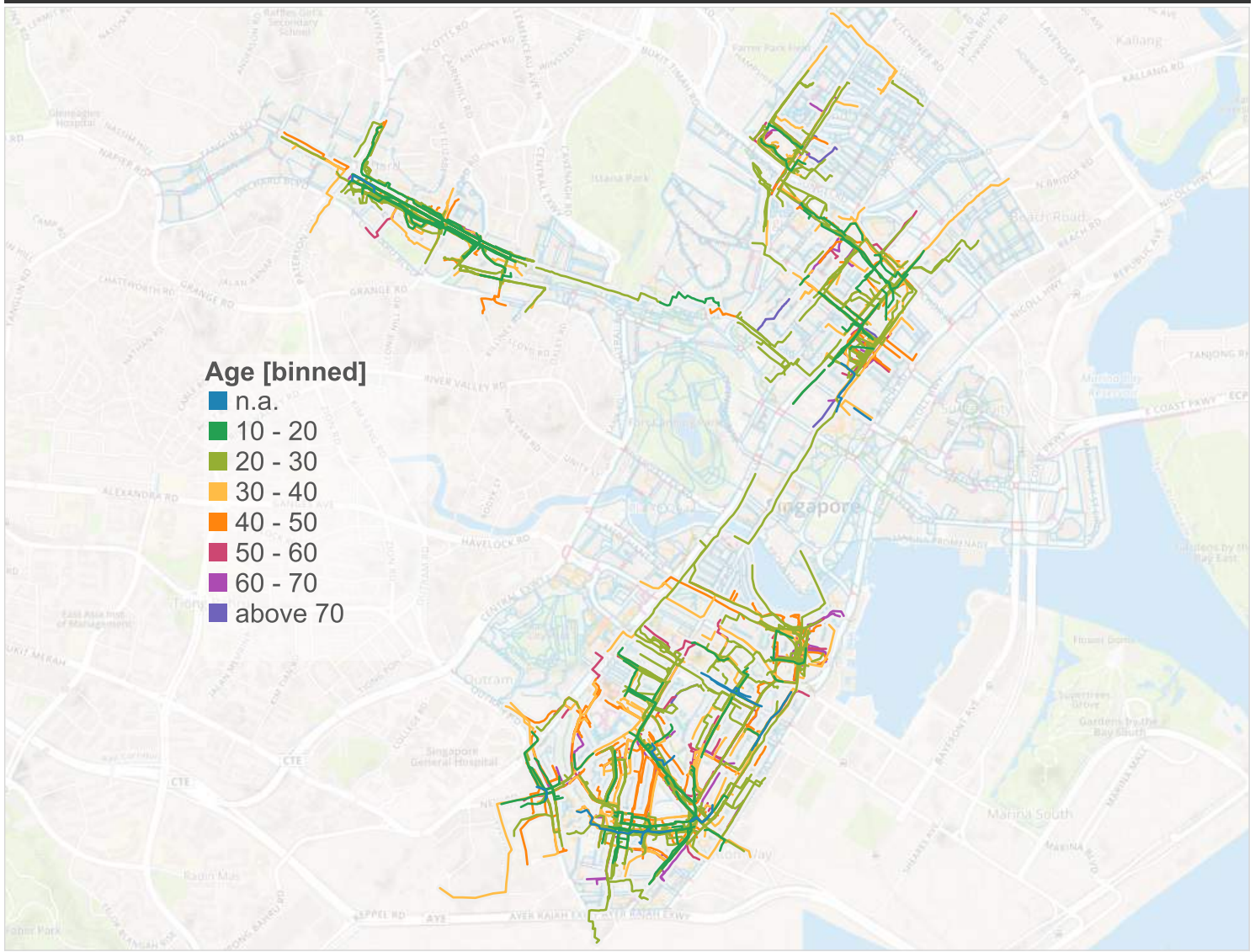
Comparison of average walking distance in other cities:

Calgary, city centre (1986):	330m
Portland, city centre / whole city (2014):	790m / 446m
San Jose / Portland, MRT stops (2012)	832m

Seneviratne, P. N. and J. F. Morrall (1985). 'Analysis of Factors Affecting the Choice of Route of Pedestrians', Transportation Planning and Technology 10(2): 147–159.
Dill, Jennifer (2015). *Where Do People Prefer to Walk?*, Active Living Research Conference, San Diego.
Agrawal, Asha Weinstein, Marc Schlossberg and Katja Irvin (2008). 'How Far, by Which Route and Why? A Spatial Analysis of Pedestrian Preference', *Journal of Urban Design* 13(1): 81–98.

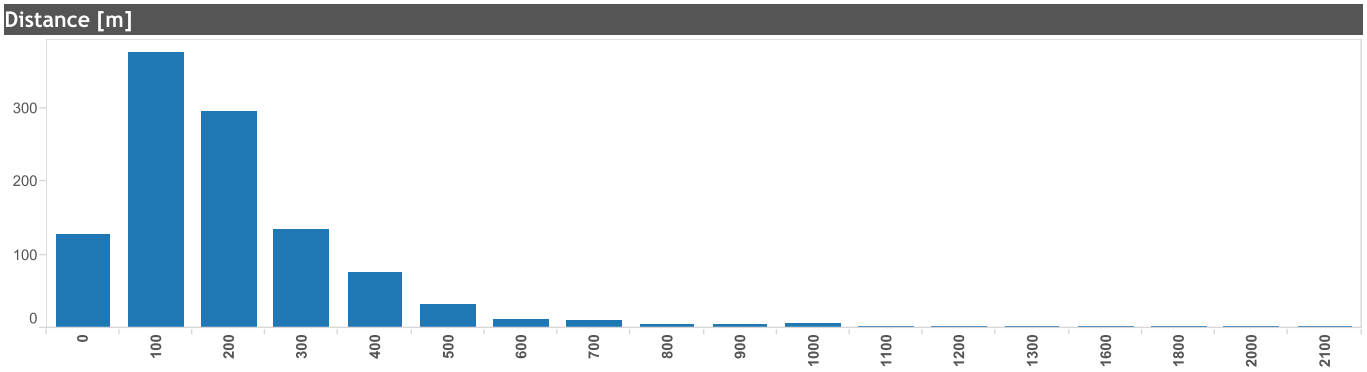
Who walks where?

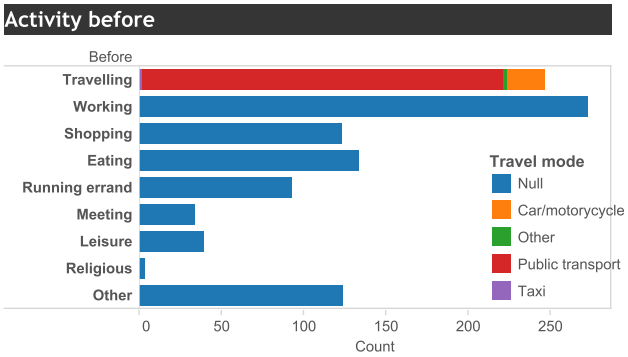
Pedestrian tracks

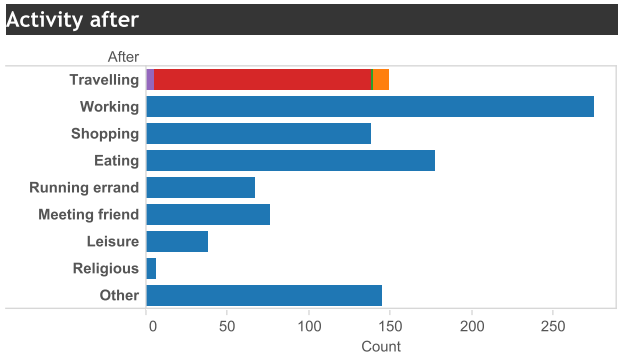


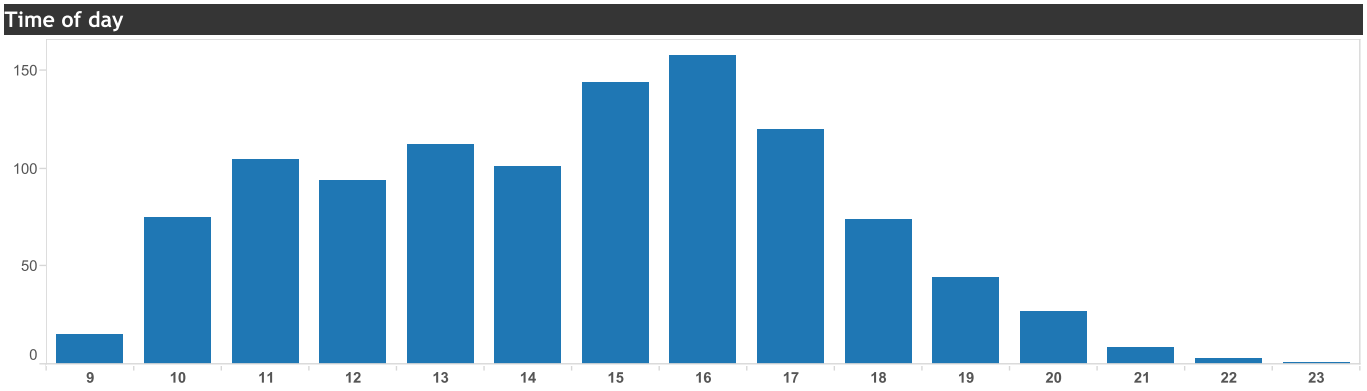
Interactive graph available at:
https://public.tableau.com/profile/alexerath#!/vizhome/Directorsmeeting/Sampling1024

How long, why, when?

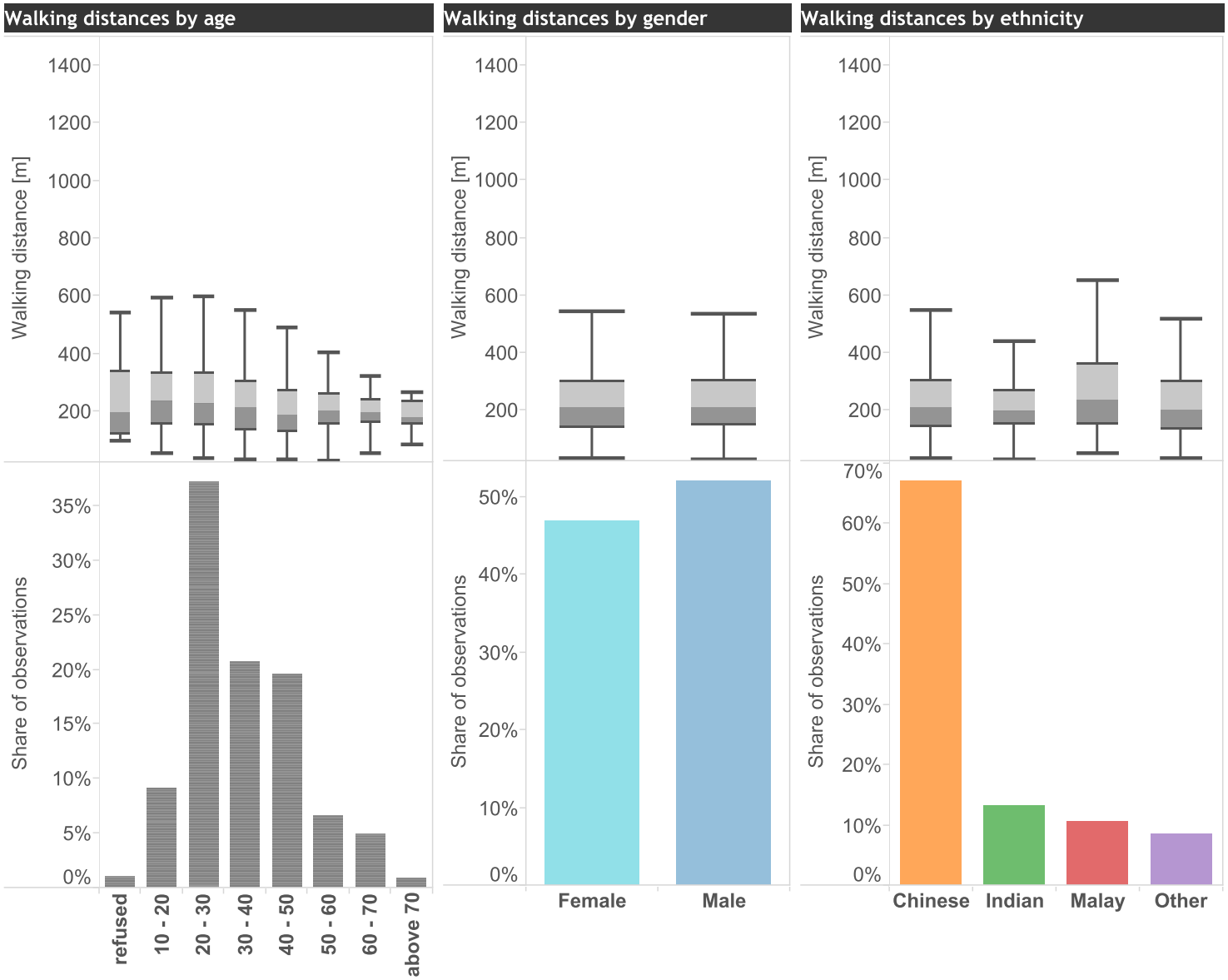




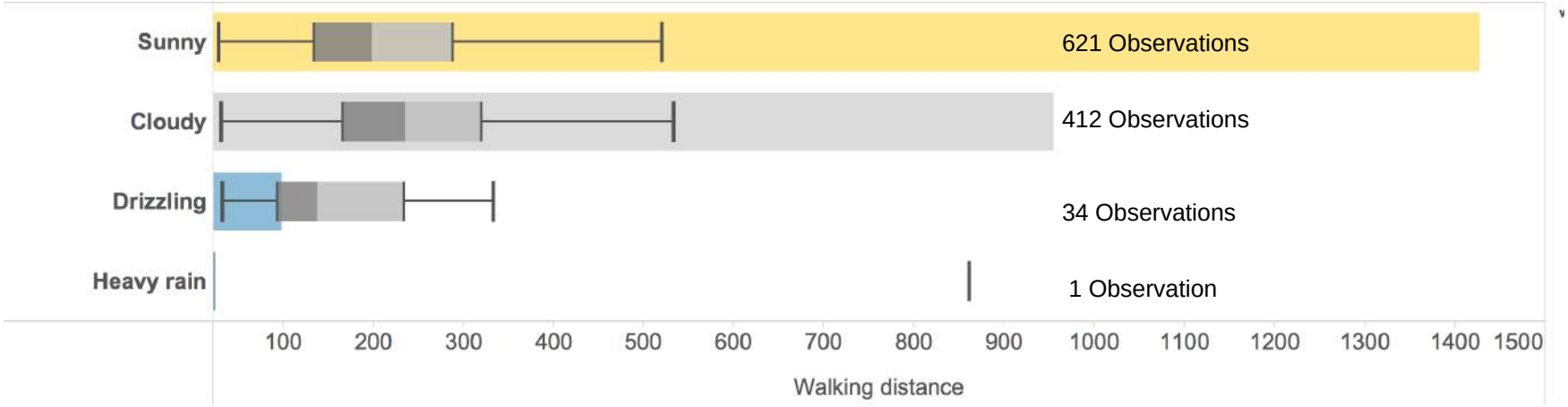




Sampling and walking distance by demography



Walking distance by weather

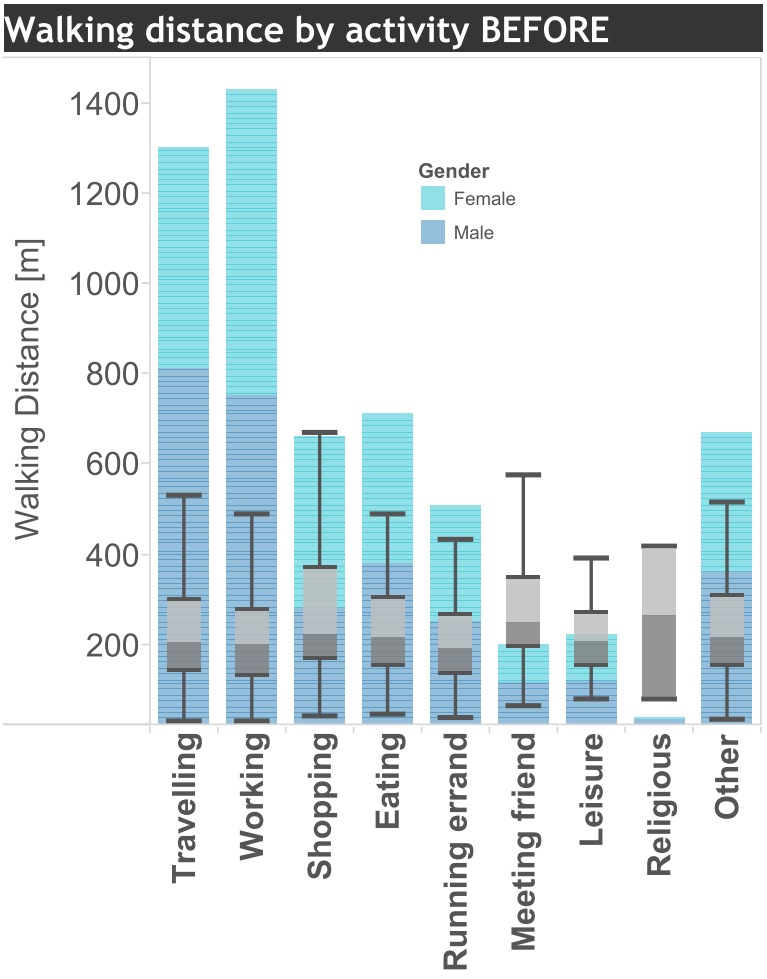


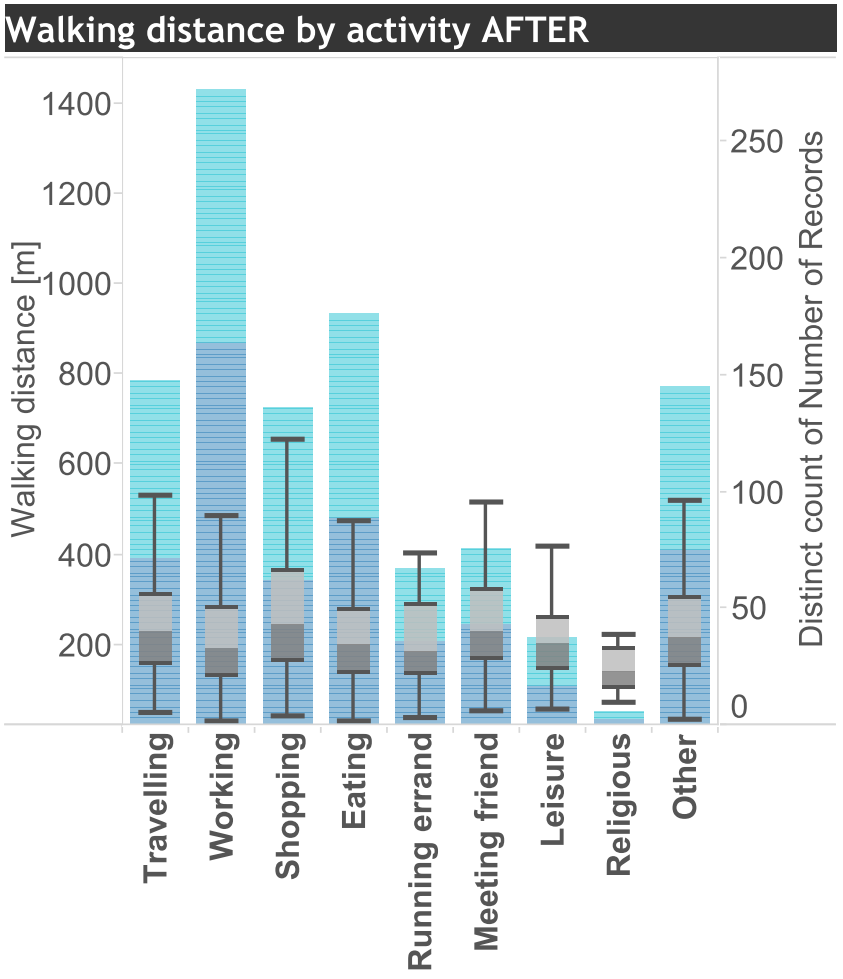
Compared to sunny conditions, people walk:

- Cloudy: +37 meters
- Drizzling: -98 meters

We have too few observation of walks in heavy rain condition to draw a valid conclusion.

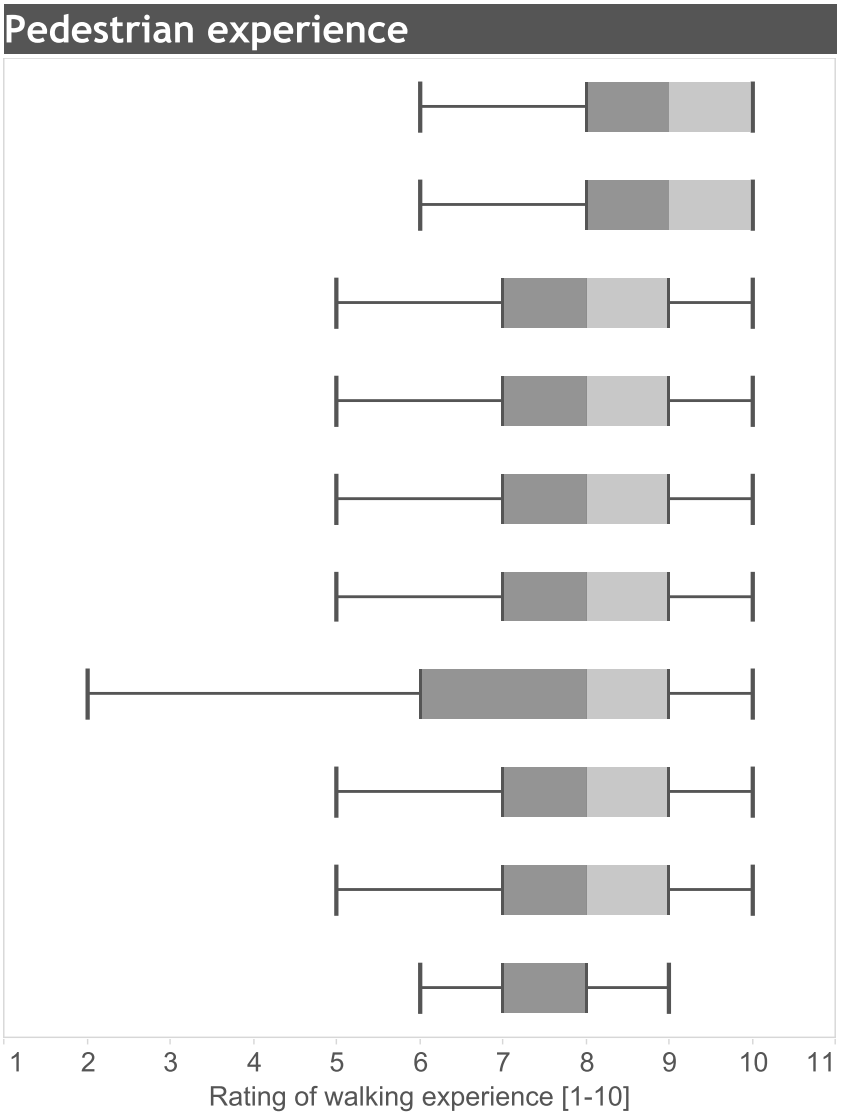
Walking distance by activity before and after

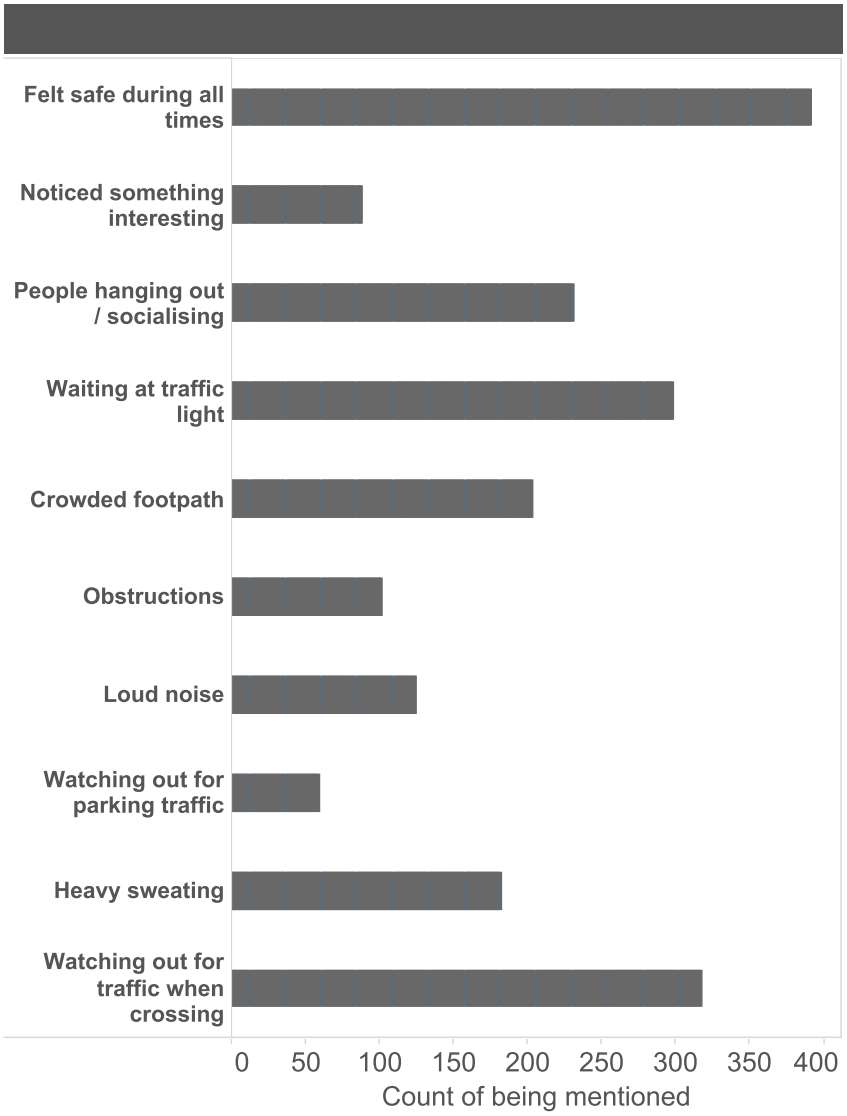




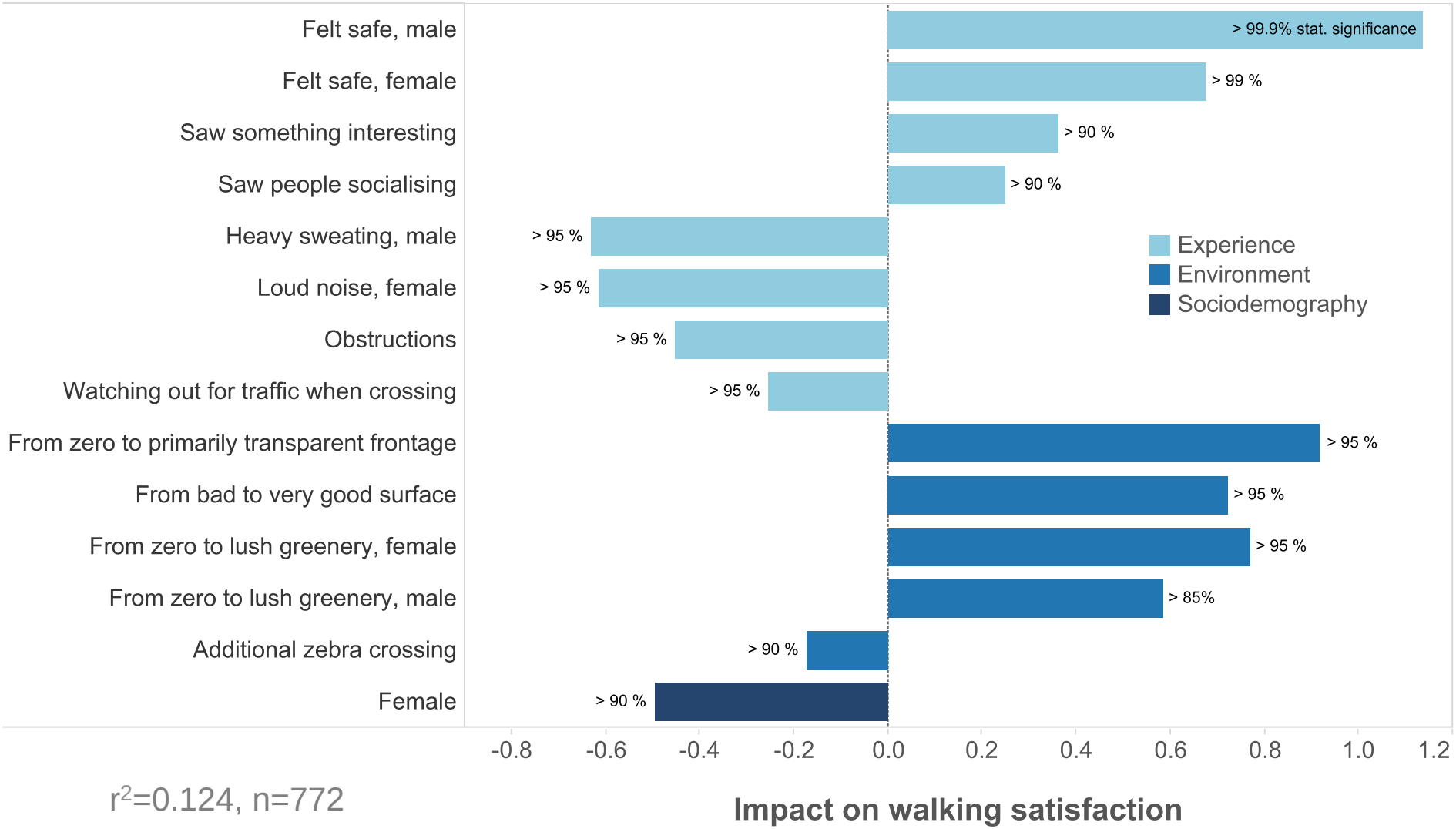
None of the activity types statistically significantly explain walking distance

Pedestrian experience





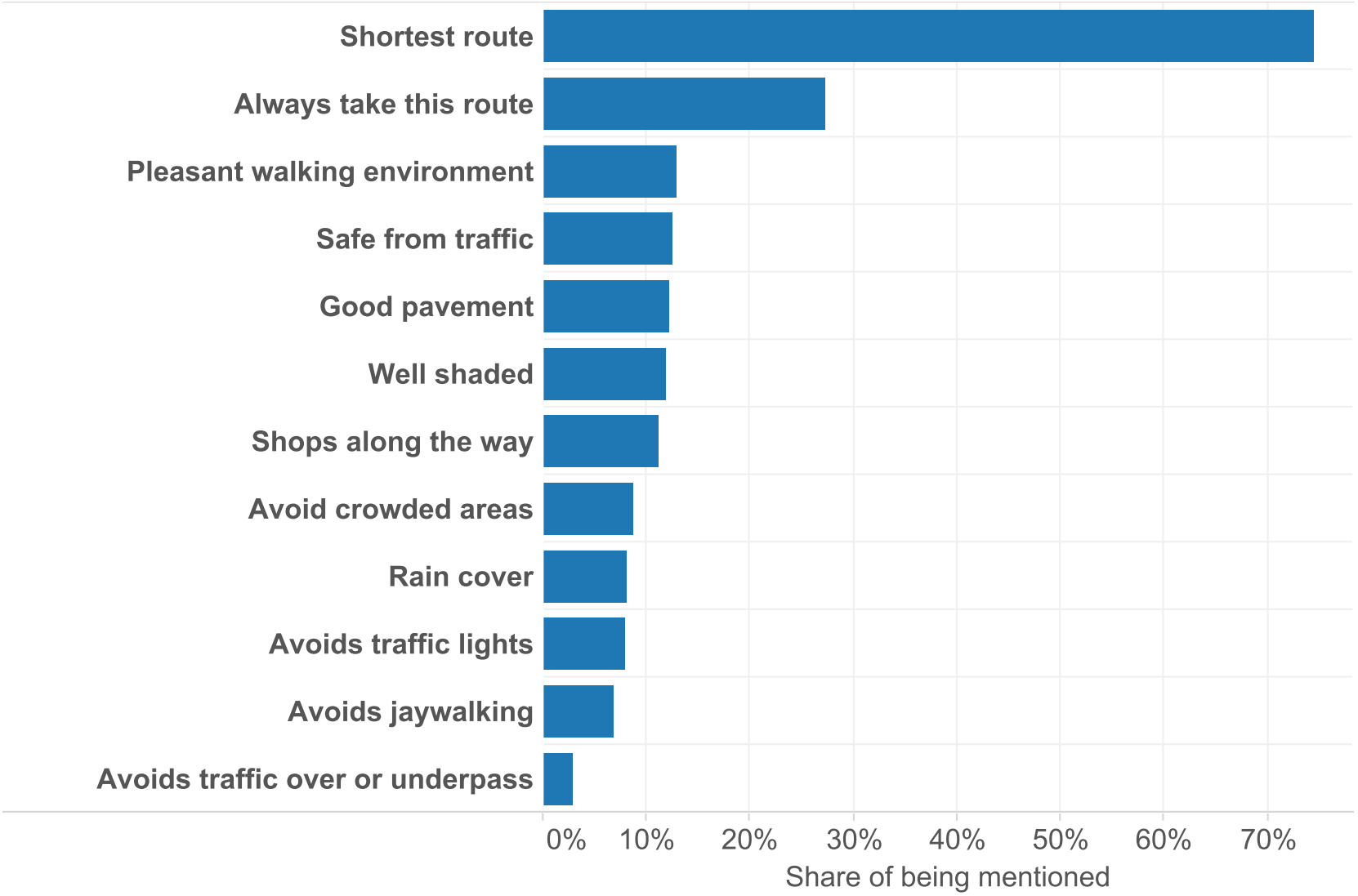
What impacts walking satisfaction?



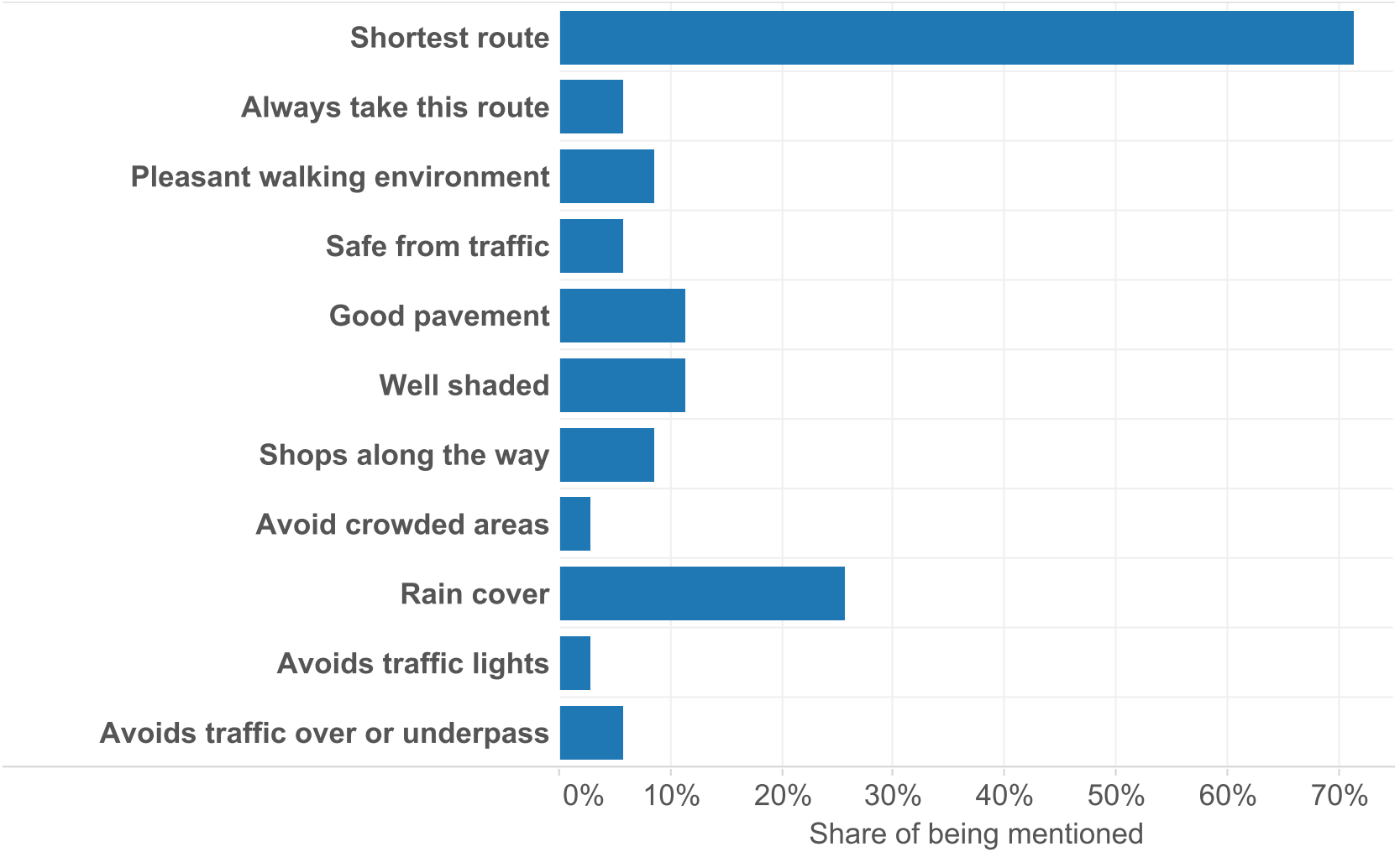
r^2=0.124, n=772

Other variables that have been tested include: walking frequency, ethnicity, age, activity before and after, human scale, imageability, obstruction, , maintenance, width, Enclosure, slipperiness, shade from greenery, availability of cover, horizontal and vertical separation, noise level, constructions site, weather, mode before and after,

Why this route, when it is sunny/cloudy?



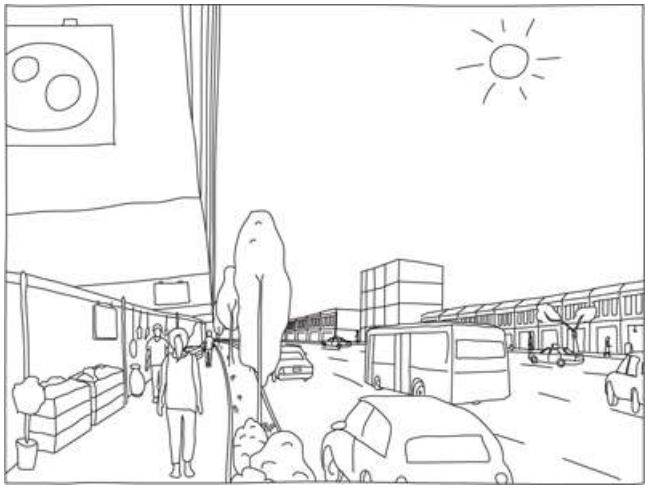
Why this route, when it is rainy?



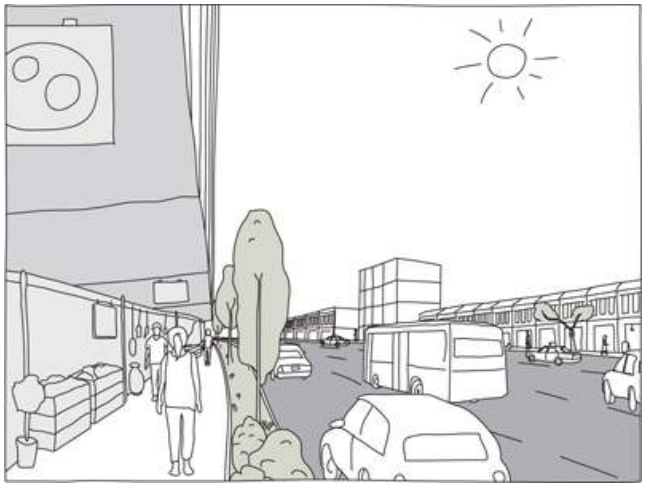
Stated preference survey

Using illustrations to depict different walking conditions in a choice experiment

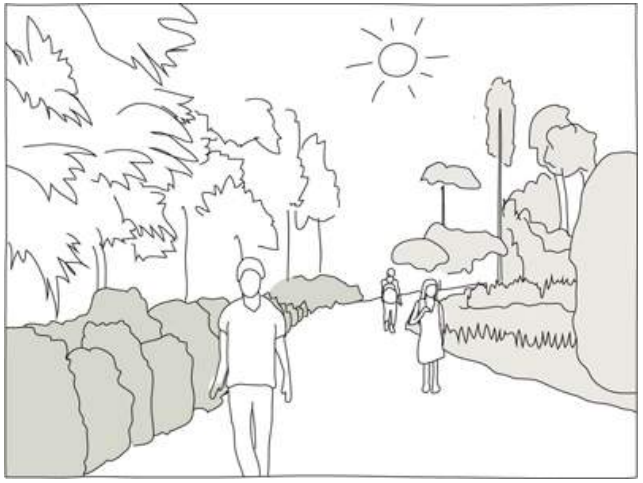
An illustration-based stated preference experiment



Some discussions at ISTSC



Other typical situations



Through a park

Underground / through block

Experiment design

Walking environment

Road

- Traffic
  - Minor (two way, 2 lanes) / Major (one way, 4 lanes)
- Greenery / horizontal separation
  - Yes / No
- Active frontage
  - with shops / without
- Rain cover
  - Yes / No

Park

- Greenery
  - Lush / little

Underground

- Scenery
  - With shops / without

Road crossing

Traffic lights

- 0 / 1 / 2

Overpasses

- 0 / 1

Inofficial crossing / jaywalk

- 2 lanes (two way) / 4 lanes (one way)

Underpass (only in subset)

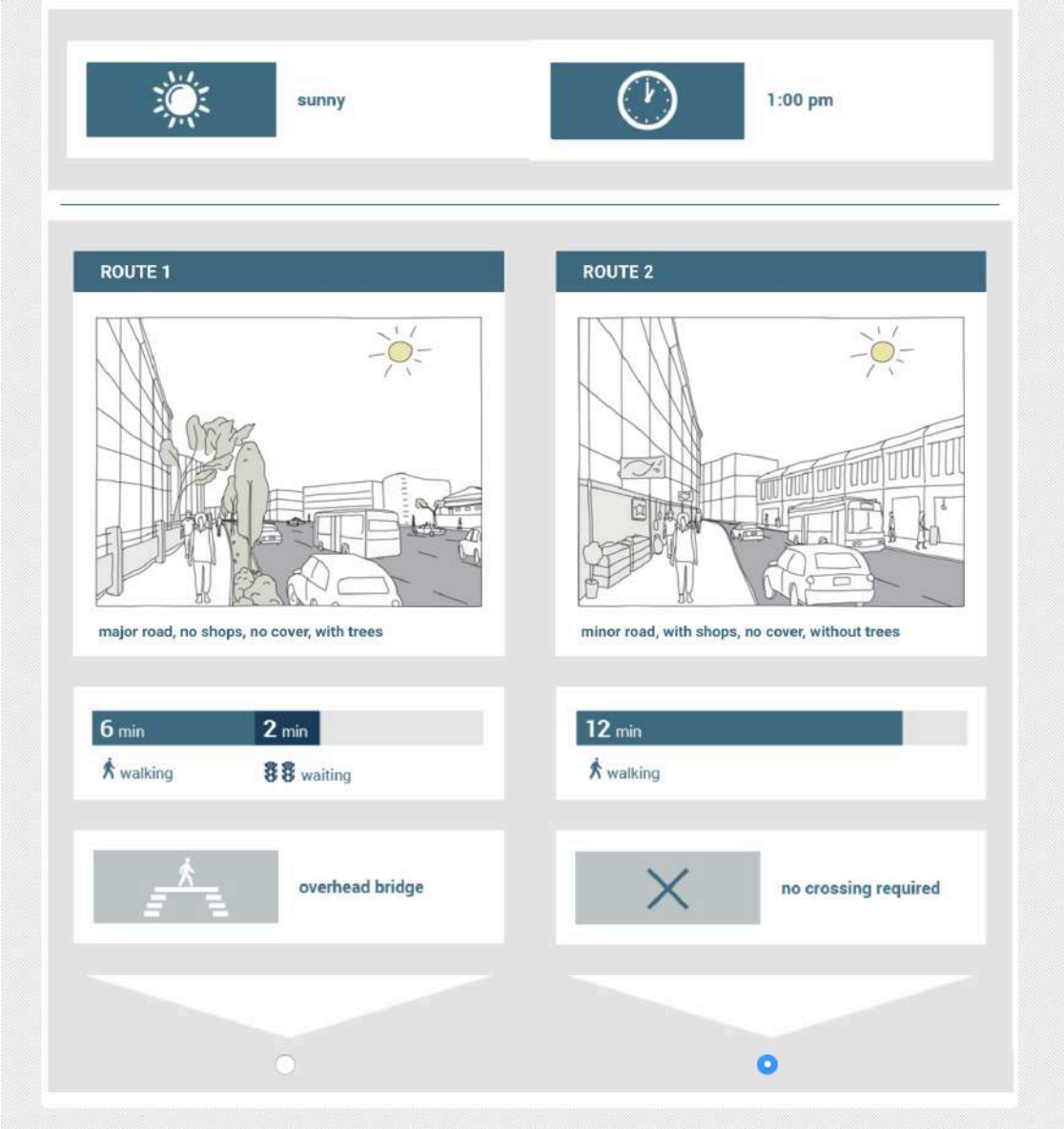
- with escalator / stairs

Other factors

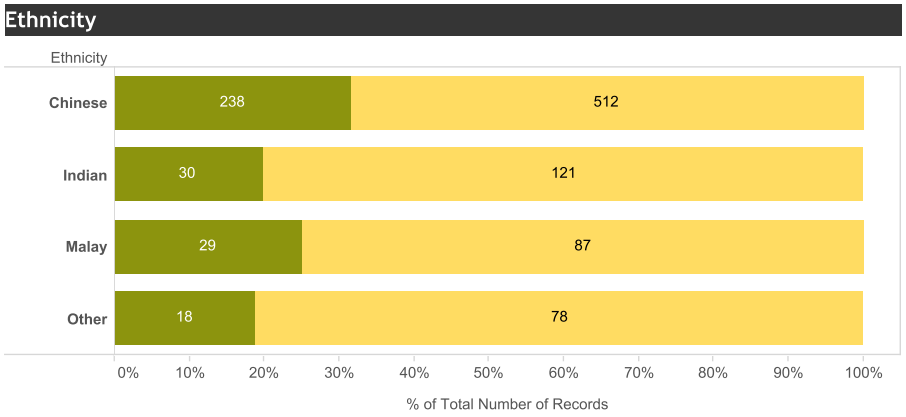
Weather

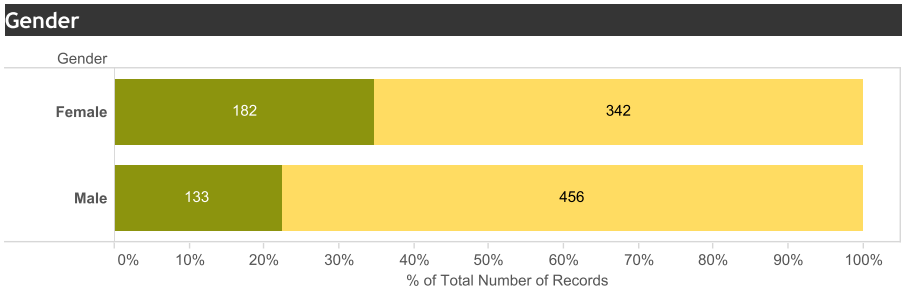
- Sunny / rainy / cloudy

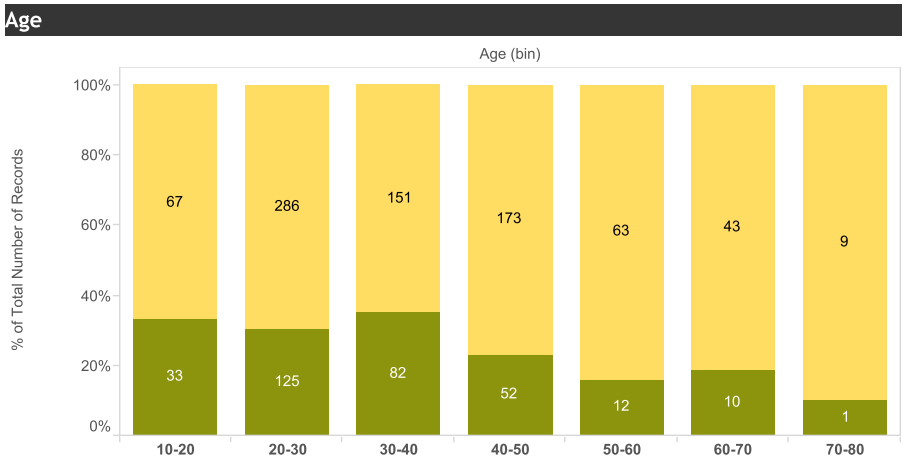
Which route would you prefer?



Response rates







Overall:

315 from 1113 recruited persons

-> 28.3 %

Specification of web-based route choice model

$$
\begin{aligned}
U = {} & \beta_t \cdot time \cdot (\\
& \left(1 + \beta_{min} \cdot minor + \beta_{maj} \cdot major + \beta_u \cdot under \cdot \left(1 + \beta_{u_r} \cdot rainy\right)\right) \cdot \\
& \left(1 + \beta_g \cdot greenery\right) \cdot \\
& \left(1 + \beta_s \cdot shops\right) \cdot \\
& \left(1 + \beta_c \cdot cover \cdot \left(1 + \beta_{c_s} \cdot sunny + \beta_{c_r} \cdot rainy\right)\right) + \\
& \beta_o \cdot overpass + \\
& \beta_{ol} \cdot overpass_{lift} + \\
& \beta_{j_2} \cdot jaywalk_{2lanes} + \\
& \beta_{tl} \cdot trafficlight_{wait}
\end{aligned}
$$

Results of choice model

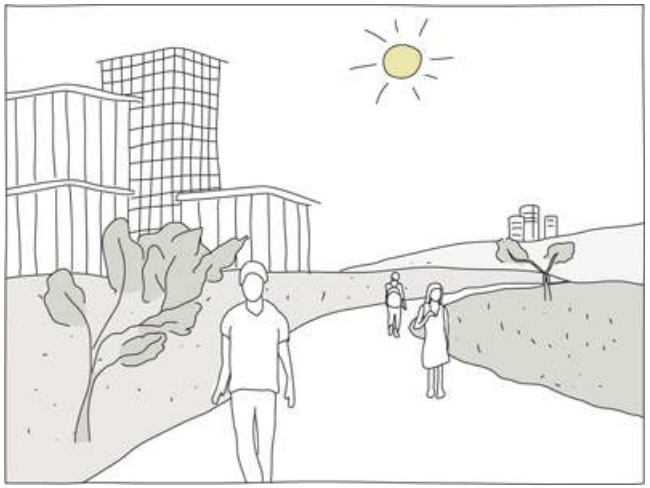
Parameters	Value	Sign.(>95%)
Walking time (through park, cloudy) [min]	-0.019	*
along major road	+59%	*
along minor road	+47%	*
cover	-18%	*
when rainy	-75%	*
when sunny	-51%	*
through block/underpass	-16%	*
when rainy	-66%	*
with greenery	-23%	*
with active frontage	-18%	*
Crossing 2-lane road	-0.015	*
Crossing 4-lane road	-0.094	*
Overpass	-0.082	*
Overpass with lift	-0.043	*
Trafficlight	-0.016	*

n = 2451, $\rho^2 = 0.131$

Numerical example

$$
\begin{aligned}
U = -0.00193 \cdot 10 \cdot (& \\
& \left(1 + \mathbf{0.473} \cdot \mathbf{minor} + \beta_{maj} \cdot 0 + \beta_u \cdot under \cdot \left(1 + \beta_{u_r} \cdot 0\right)\right) \cdot \\
& \left(1 + \mathbf{-0.228} \cdot \mathbf{greenery}\right) \cdot \\
& \left(1 + \mathbf{-0.175} \cdot \mathbf{shops}\right) \cdot \\
& \left(1 + \mathbf{-0.175} \cdot \mathbf{cover} \cdot \left(1 + \mathbf{1.9} \cdot \mathbf{sunny} + \beta_{c_r} \cdot 0\right)\right) + \\
& \beta_o \cdot 0 + \\
& \beta_{ol} \cdot 0 + \\
& \beta_{j_2} \cdot 0 + \\
& \beta_{j_4} \cdot 0 + \\
& \beta_{tl} \cdot 0 \\
= & -0.00193 \cdot 10 \cdot \mathbf{0.62}
\end{aligned}
$$

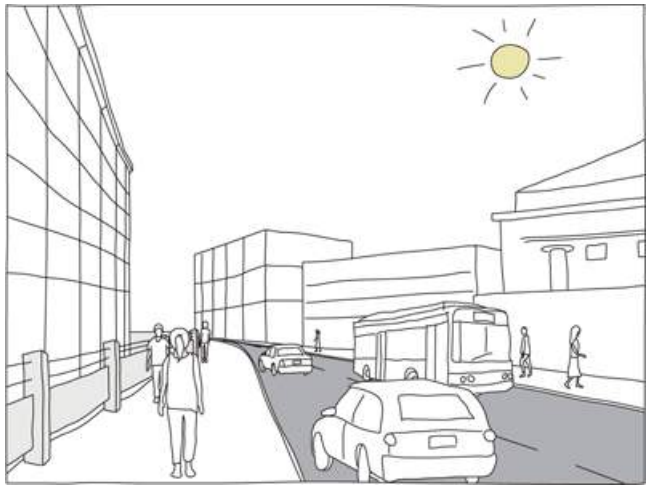
Interpretation of web-survey results



reference

10.0 min

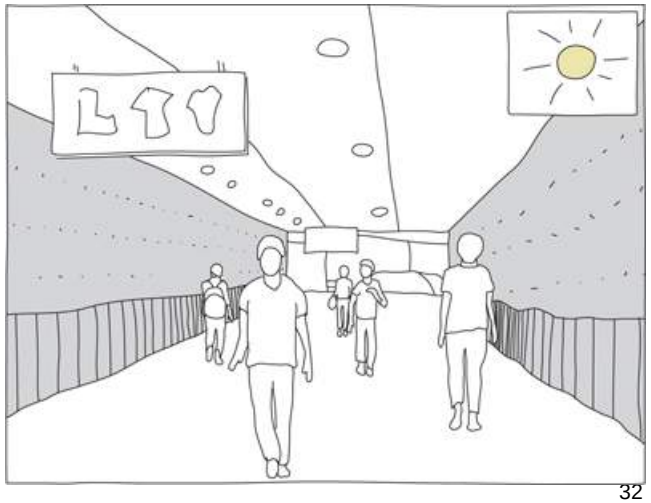
14.7 min



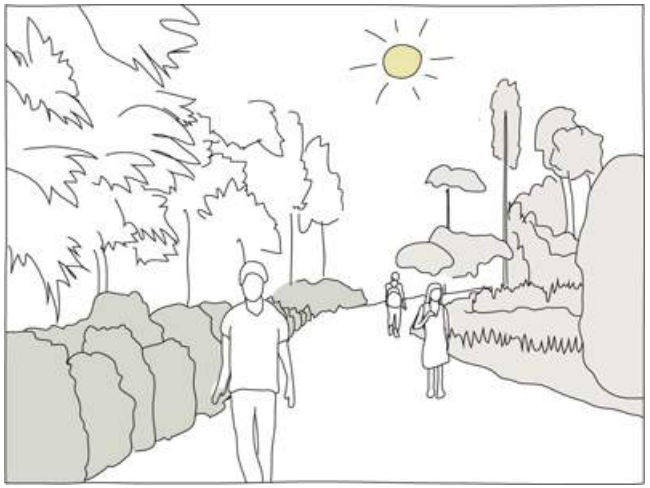
Reference case

15.3 min

8.4 min

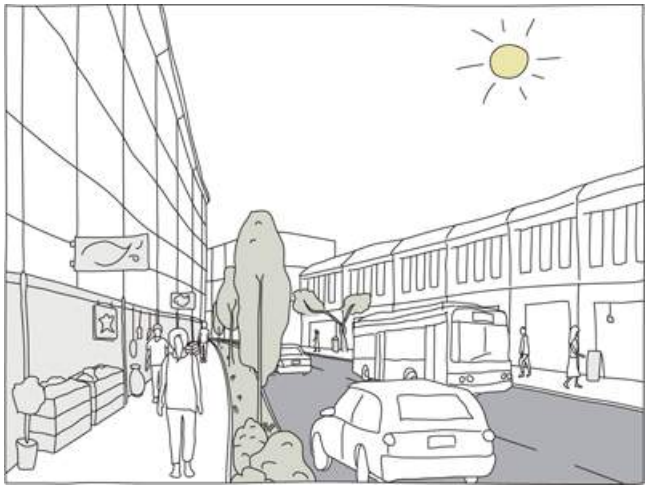


Interpretation of web-survey results

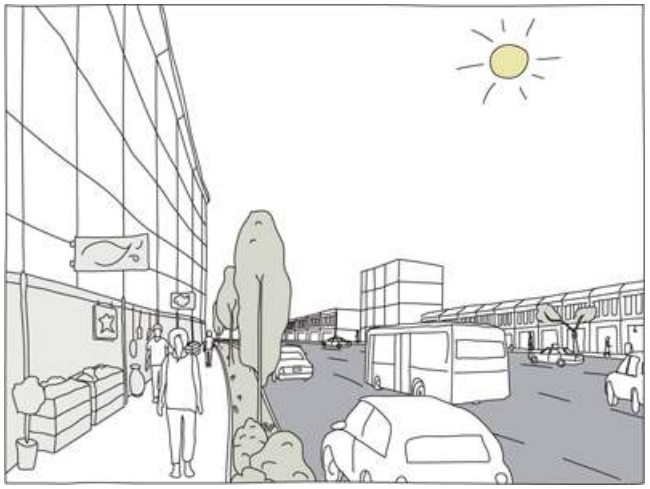


7.7 min

9.3 min



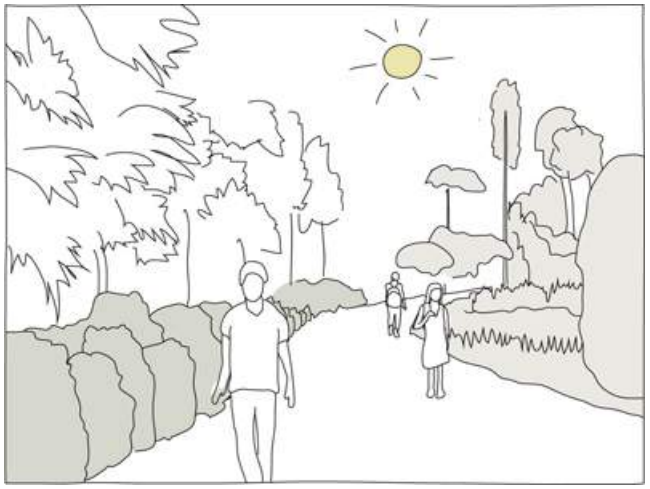
Add greenery (-23%) and shops (-18%)



11.9 min

6.6 min

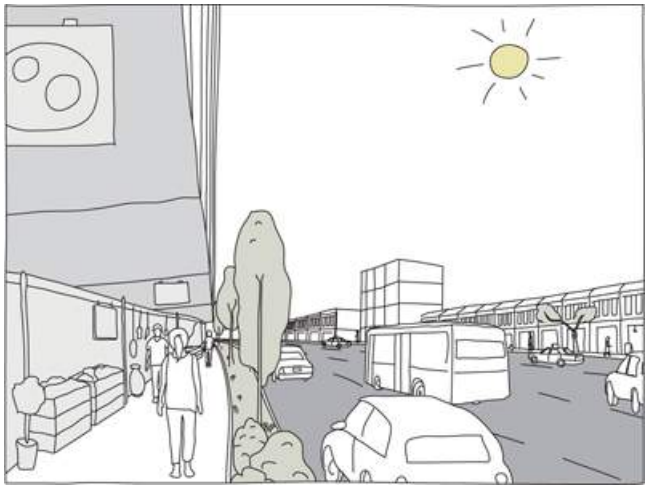
Interpretation of web-survey results



7.7 min

6.2 min

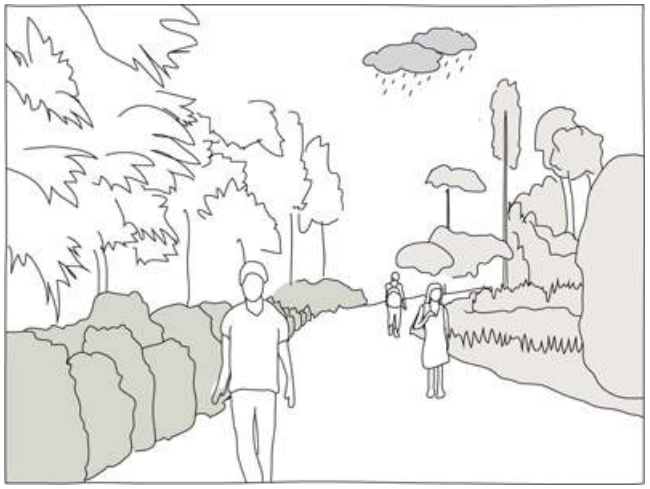
Add cover: -33% perceived walking time



6.8 min

6.6 min

Interpretation of web-survey results



14.8 min

reference

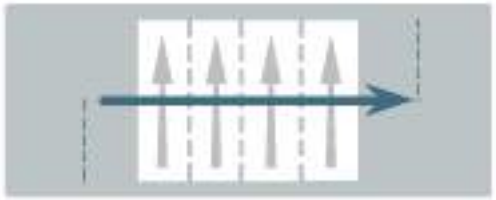
5.6 min

Tropical rain sets in

7.4 min

6.1 min

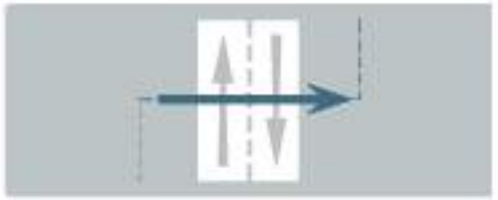
Crossings' equivalent of walking time



Jaywalking, 4 lanes

4.9 min

0.8 min



Jaywalking, 2 lanes

Overpass

4.2 min

2.2 min

Overpass with lift

Traffic light

1 min

2.0 min*

Underpass with stairs

1 min*

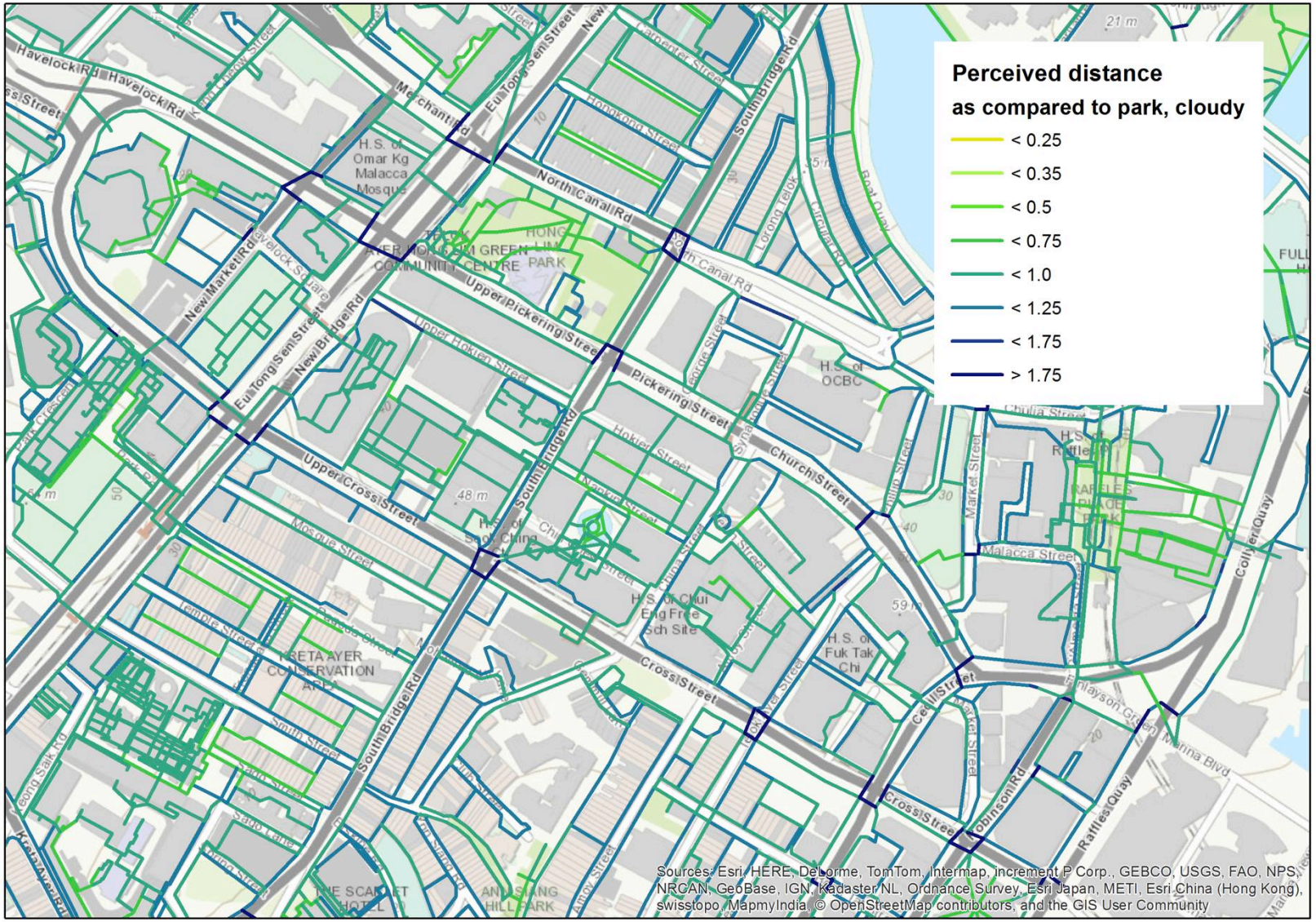
Underpass with Escalator

*stat. not significant as variable only available in subsample-> assumed values for walkability tool

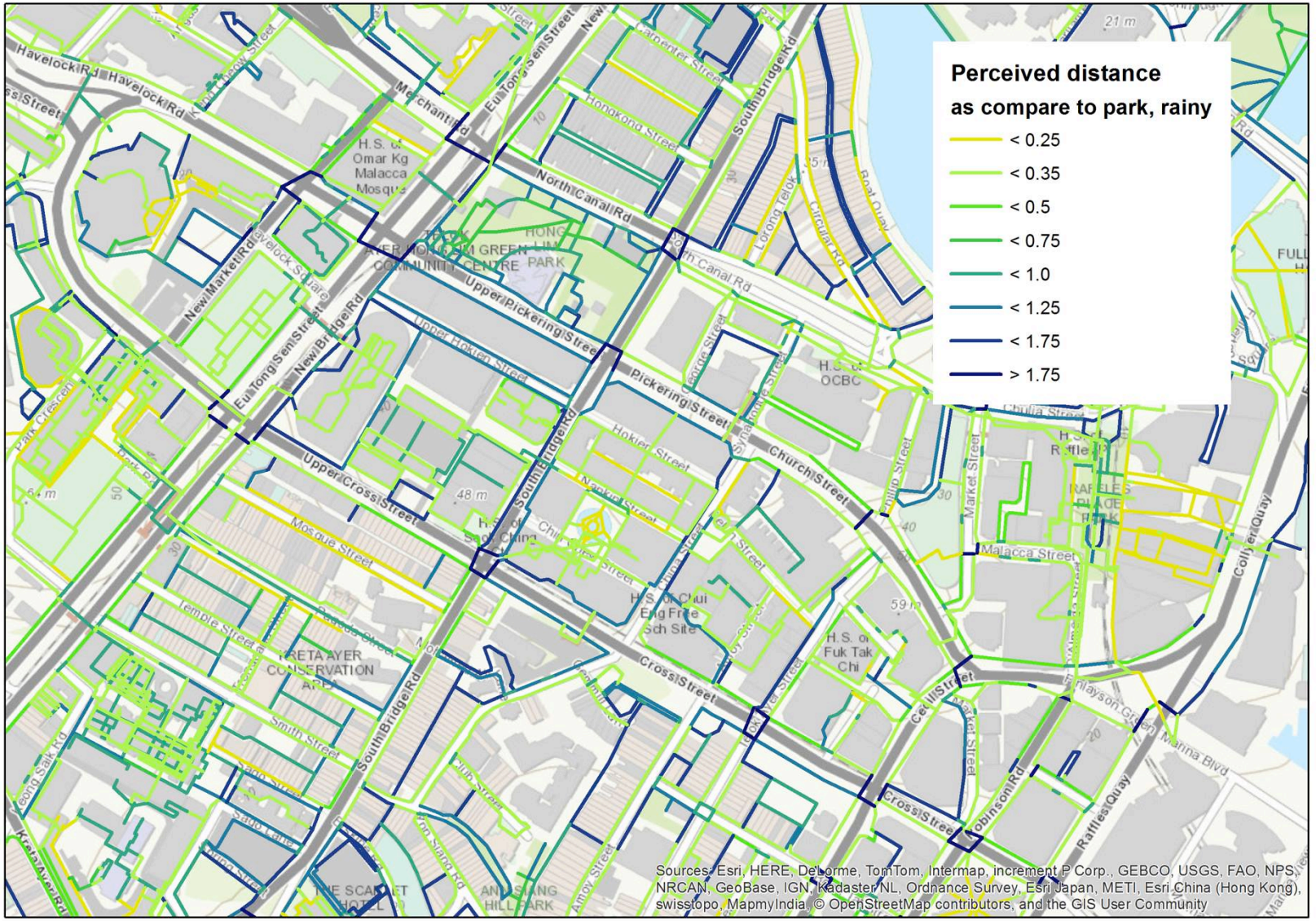
Synthesis

An ArcGIS add-in to plan for walkability

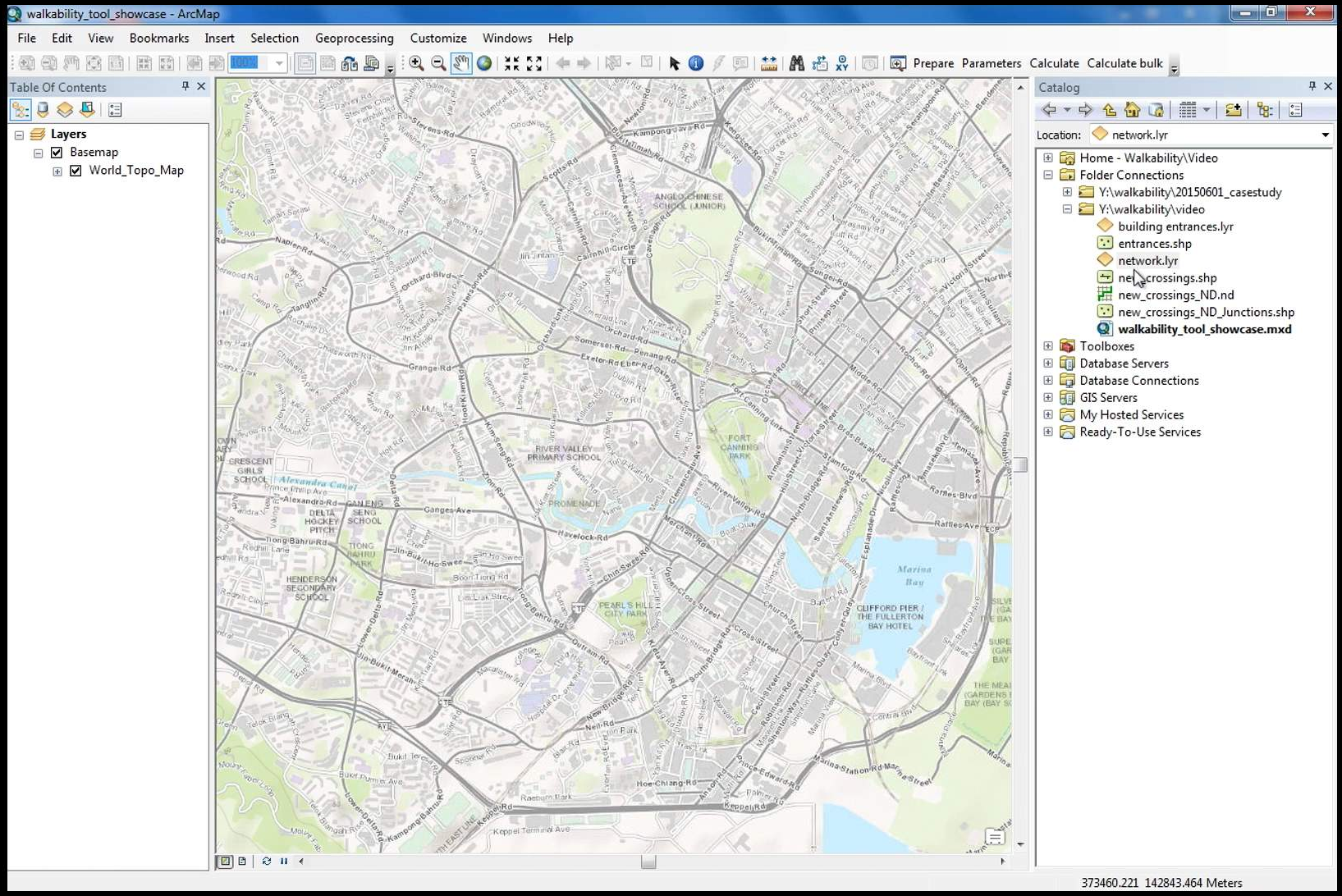
Heterogenity in perceived distance when it is cloudy…



… and rainy.

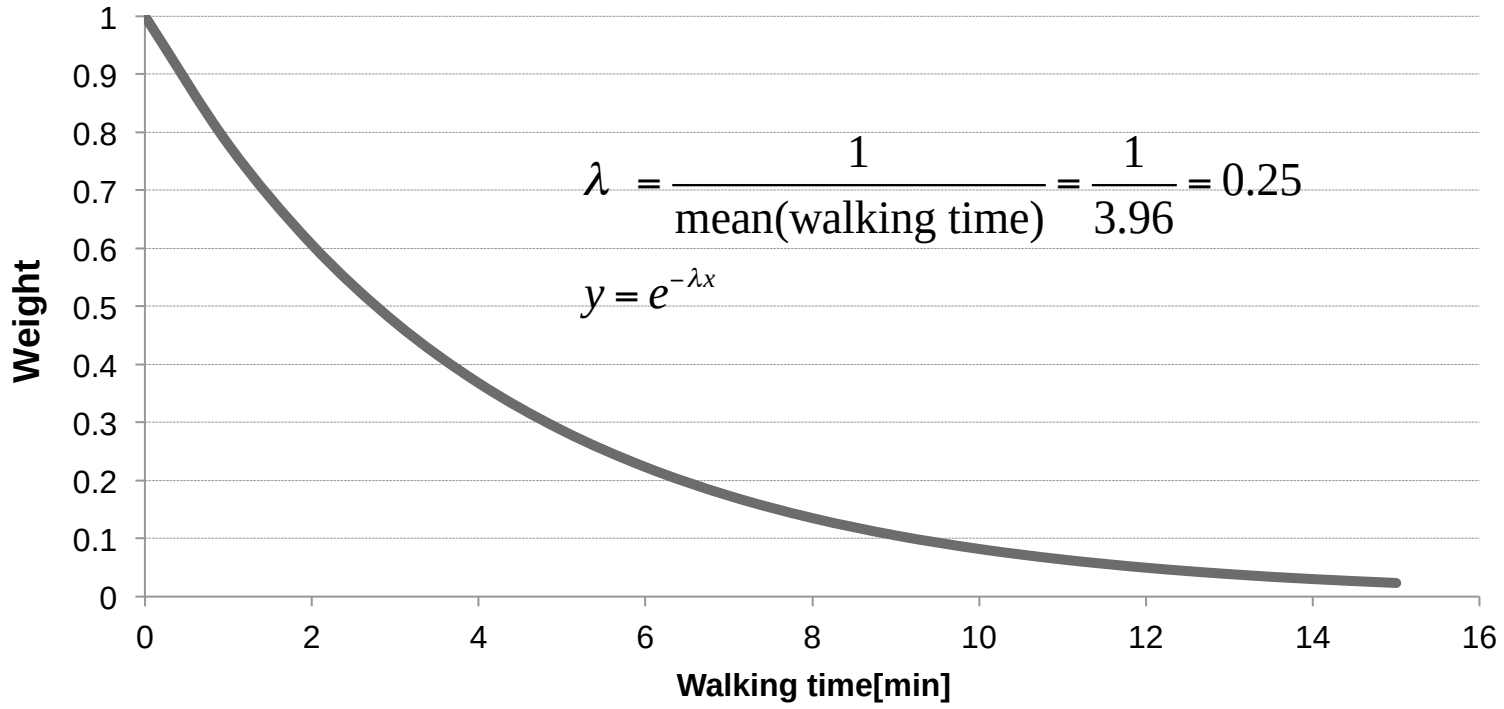

Perceived distance
as compare to park, rainy
< 0.25
< 0.35
< 0.5
< 0.75
< 1.0
< 1.25
< 1.75
> 1.75
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
0
100
200
400 Meters

New ArcGIS add-in for planners



https://vimeo.com/132168191

Distance weighted accessibility

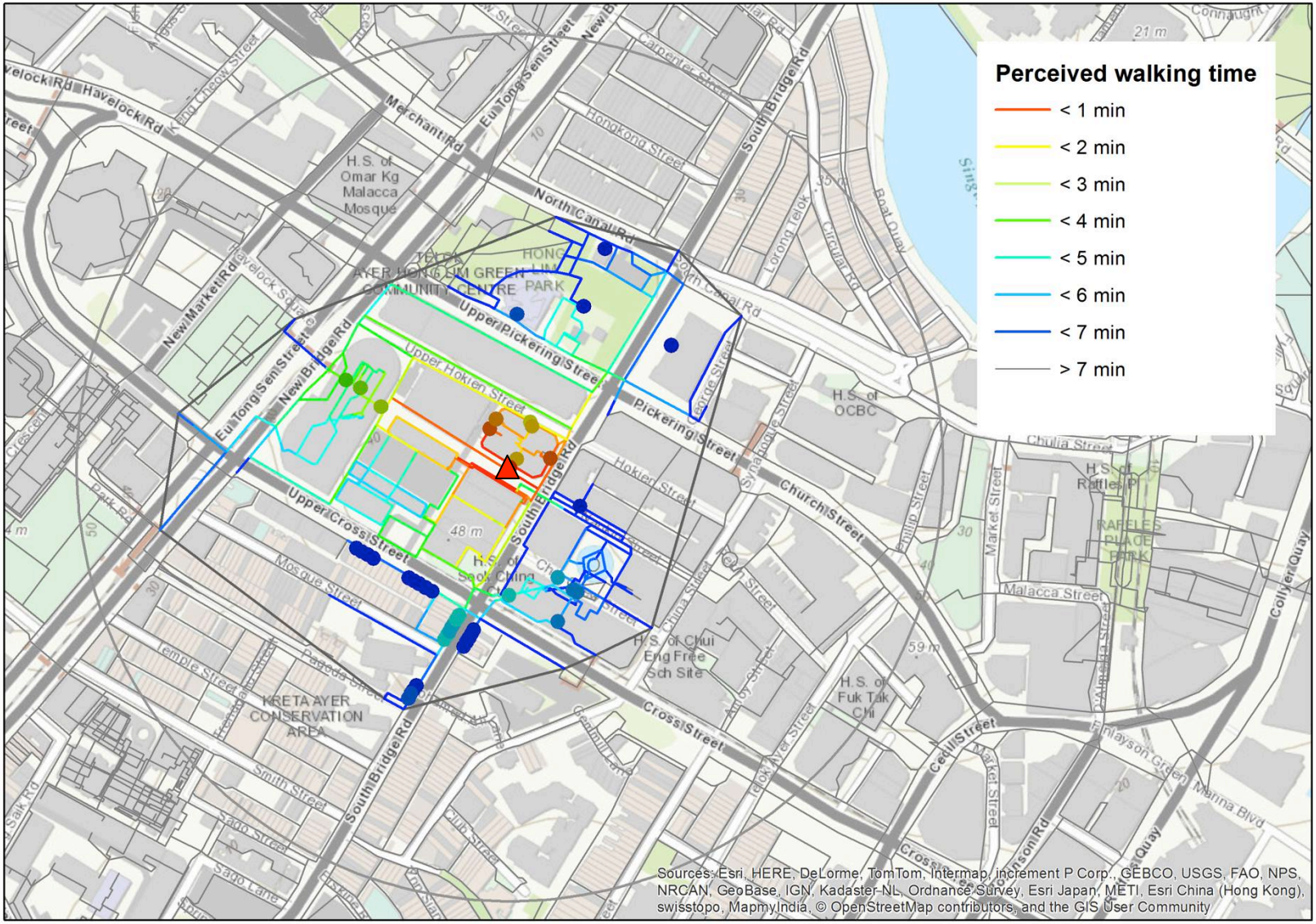


Weighted impact

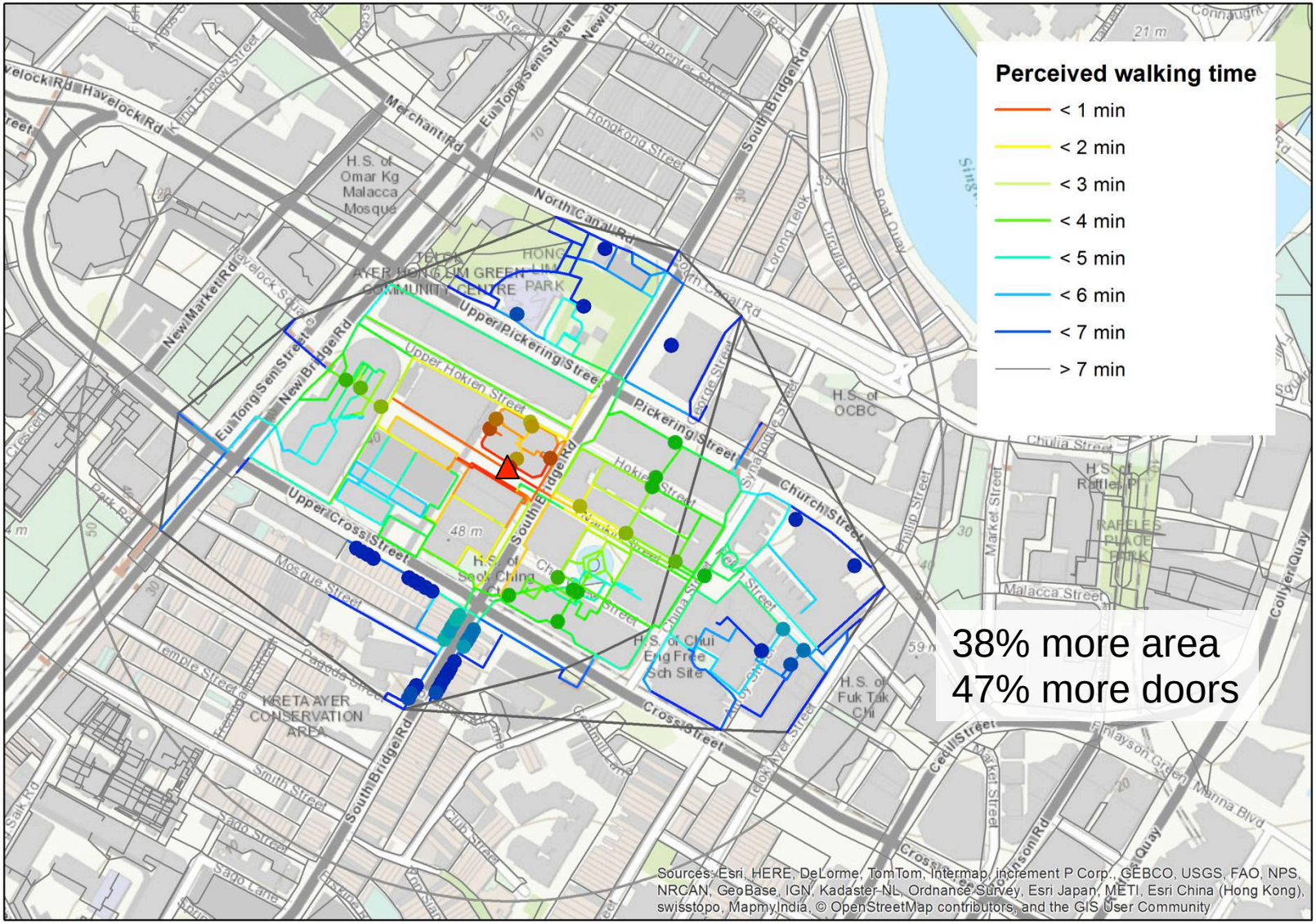
100% 28% 8% 2%

Connecting Hong Lim complex with Nankin Road

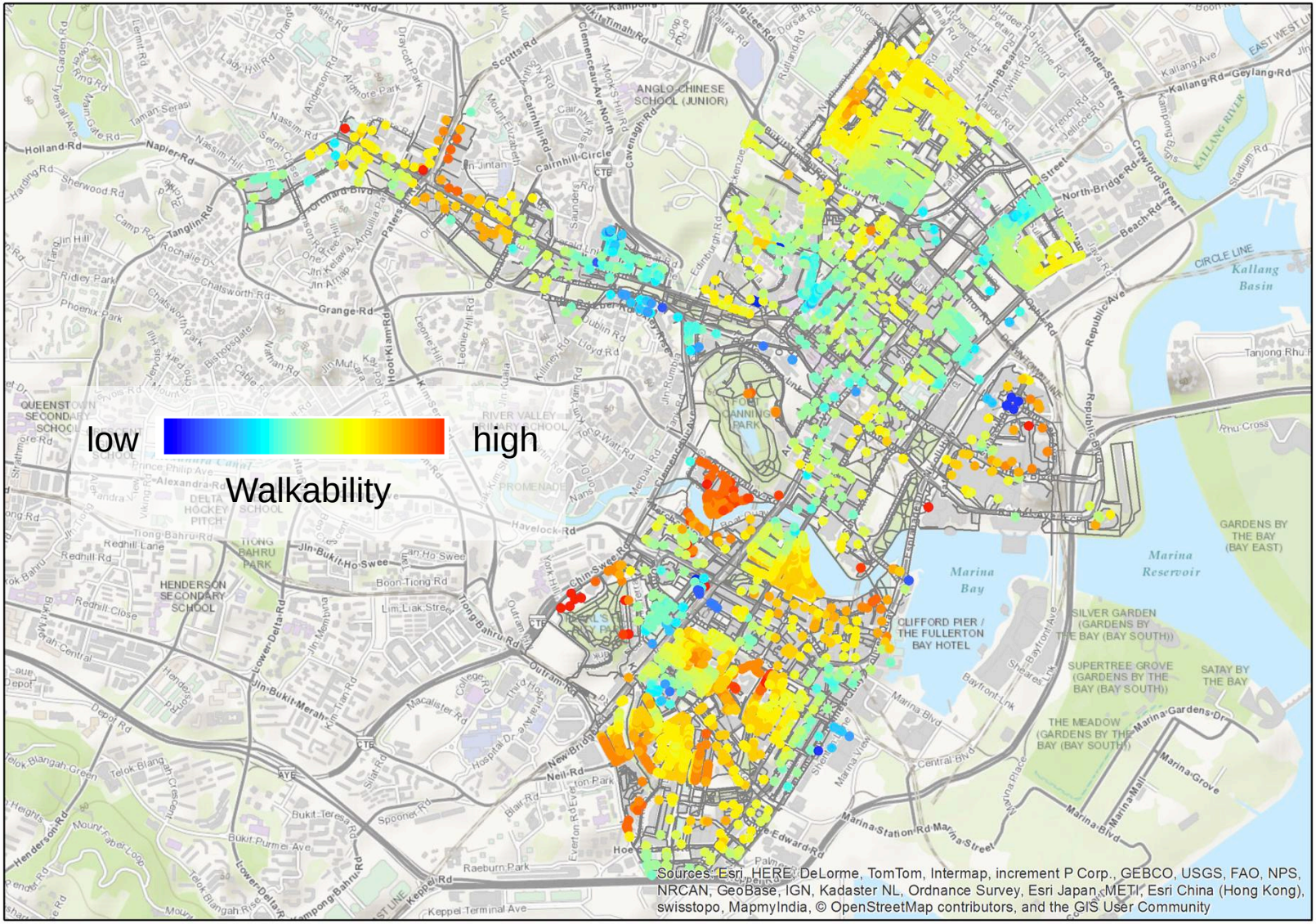
The barrier effect of the overhead bridge



The barrier effect of the overhead bridge



Walkability in Singapore



Remaining tasks and future research

Modelling of revelead preference data:

- Influence of turns, wayfinding
- Traffic lights
- Distance vs built environment attributes based on actual behavior

Other possible research avenues:

- Reported vs actual distance
- Structure equation modelling to explain perception of safety, comfort, interest
- Correlation of built environment attributes

Open questions:

- Influence of crowding and width of walkway
- Heterogeneity of built up environment
- Perceived cost of vertical movement
- Wind as a comfort factor

The team to make it happen

Michael van Eggermond
Spatial database, methodology

Sergio Ordonez
PhD student
App, ArcGIS add-in

Prof. Dr. Kay Axhausen
PI

Dr. Alex Erath
Survey, modelling, methodology

Kim Helmersen
Piloting

Atizaz Ali
Survey support, Network cleaning

Thank you!

Future Cities Laboratory
www.futurecities.ethz.ch

@_fcl
@alex_erath

Case study

Adding zebra crossings around Robinson Road

Conclusion and policy recommendations

Key findings

Key findings

Who walks?

- Primarily public transport users
- No real segmentation by age, sex or ethnicity
- To get to various types of activities

How to plan for a good walking experience?

- Safe walking environment
- Create social, interesting environments
- Provide shelter from sun and rain

Key findings

Most frequently mentioned suggestions for improvement:

- More shade / cover
- Wider sidewalk
- Shorter waiting time at traffic lights
- More direct route

How to make a walk shorter?

Greenery: -23%

Covered walkway: - 17% / - 33 % / -75% (cloudy / sunny / rainy)

Underground: - 17 % (as compared to park)

Active frontage: -18%

Remaining tasks and future research

Model pedestrian route choice to better understand influence of:

- Influence of turns, wayfinding
- Traffic lights
- Distance vs built environment based on actual behavior

Open questions:

- Influence of crowding and width of walkway
- Heterogeneity of built up environment
- Perceived cost of vertical movement
- Wind as a comfort factor

Next steps

Role out of Walkability Tool

- Workshop in August 2015
- Preparation of ArcGIS geodatabase
- Archiving of survey data and models

Topics for potential next phase

- Walkability in new towns
- Understanding of destination choice
- Enhance Walkability tool
  - Link it to spatial databases, e.g. building inventory, MATSim
  - Map pedestrian potential
  - Model pedestrian flows

Appendices

Pedestrian network audit

Collecting information for 43km walkways

Network data collected by URA

At grade

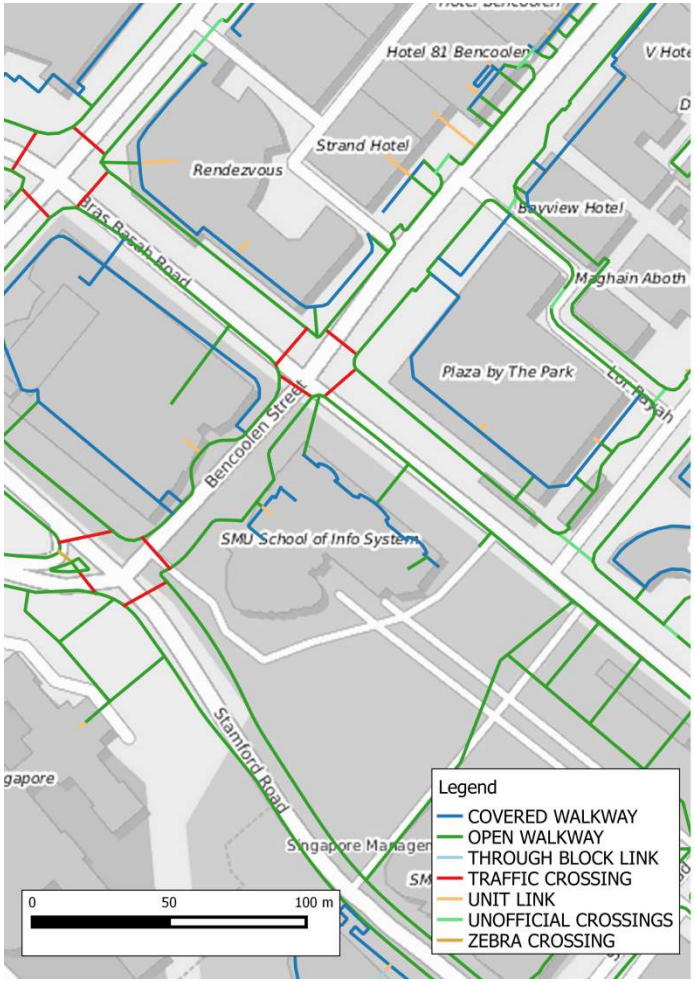
- Open walkway *(14005 features)*
- Covered walkway (*6195 features)*
- Through block link *(829 features)*
- Traffic crossing *(405 features)*
- Unit link *(4538 features)*
- Unofficial crossing *(1175 features)*
- Zebra crossing *(164 features)*

Below grade

Above grade

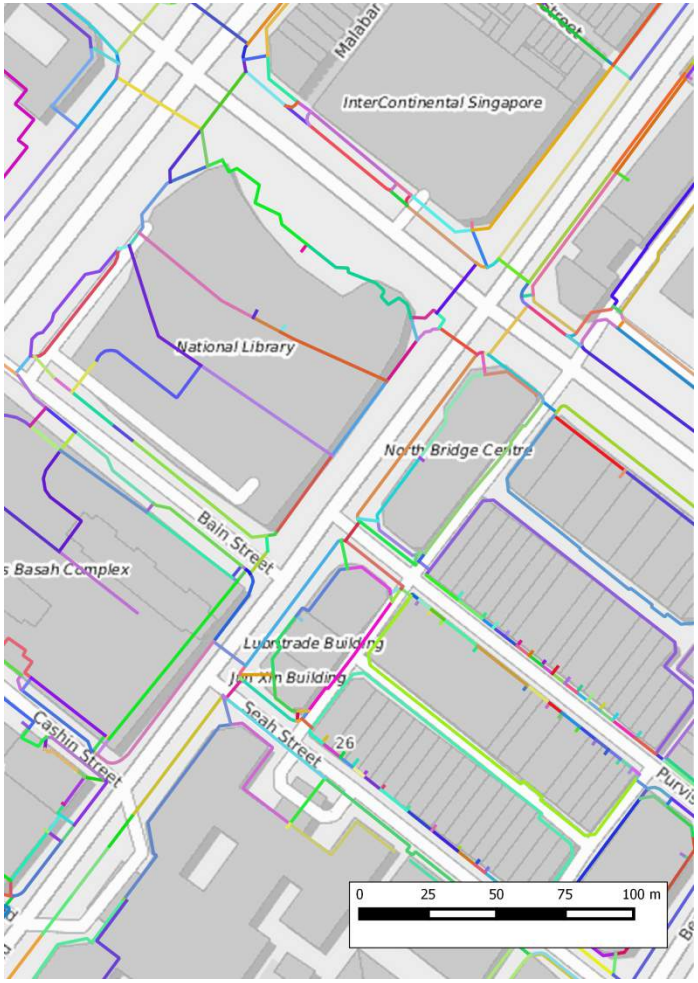
Access points

- Building entrances

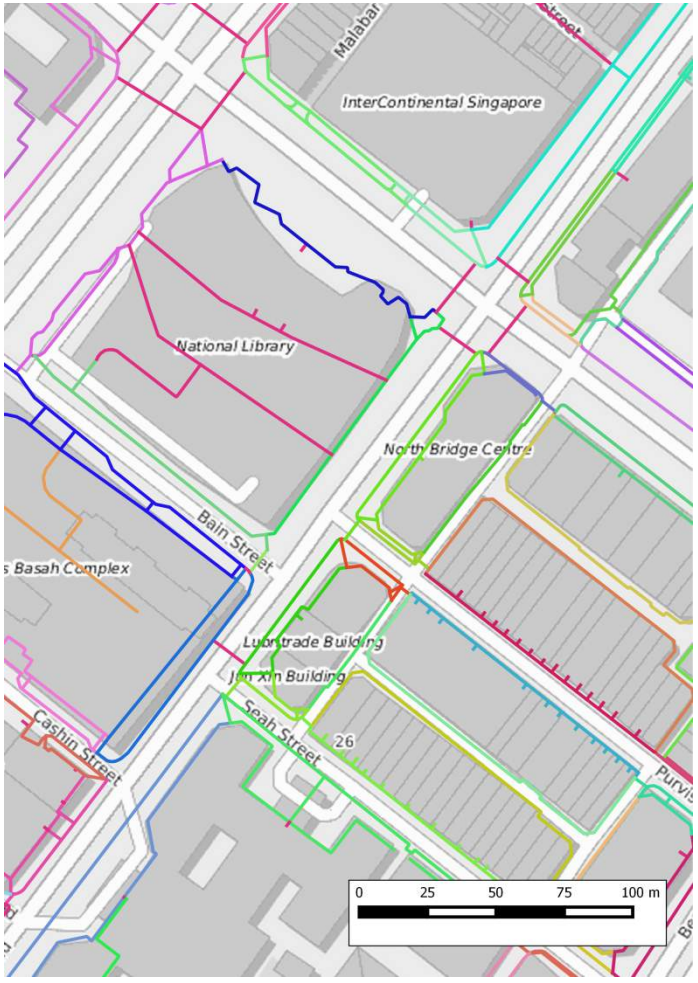


Simplification of network to collect characteristics

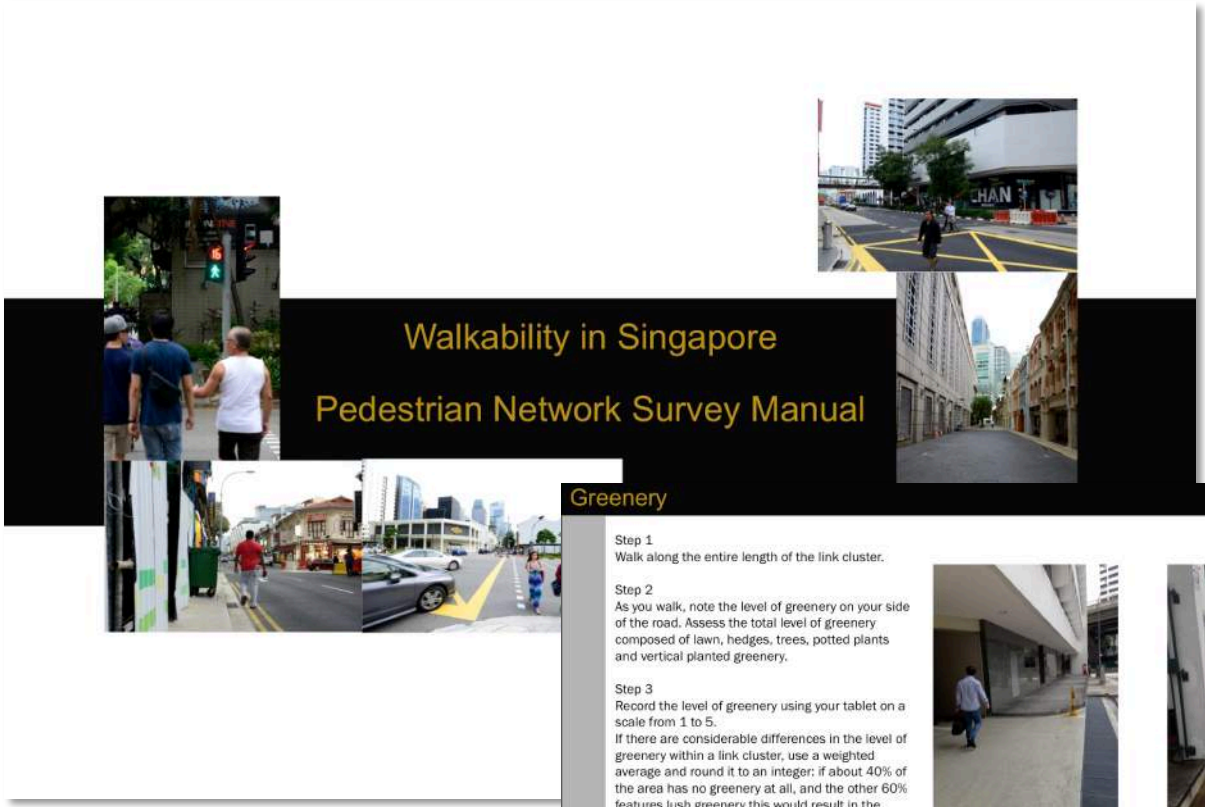
At grade network *(27311 features);*
Each color represents a feature

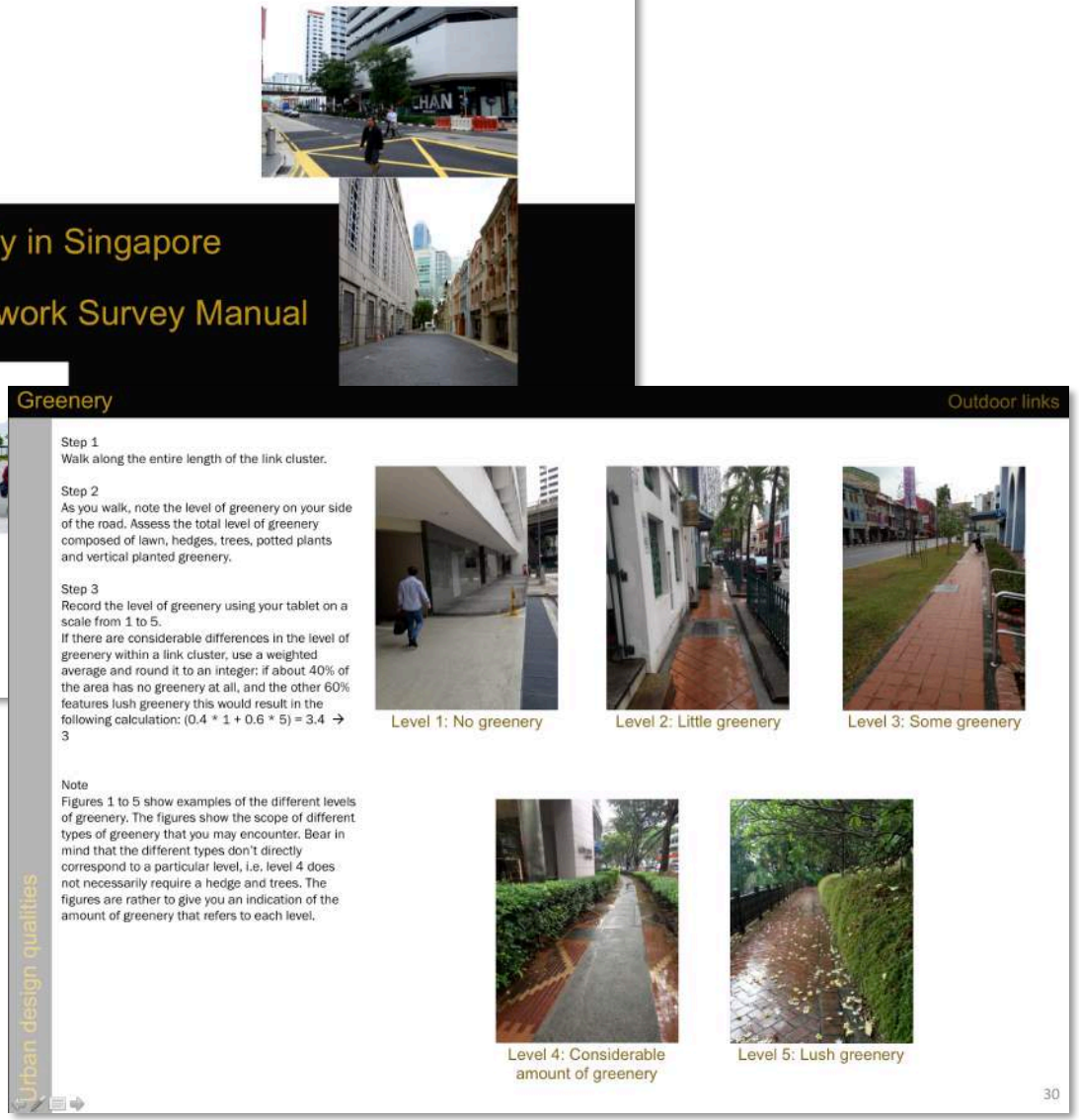


Link clusters *(2833 features);* ;
Each color represents a cluster



Developing a survey manual

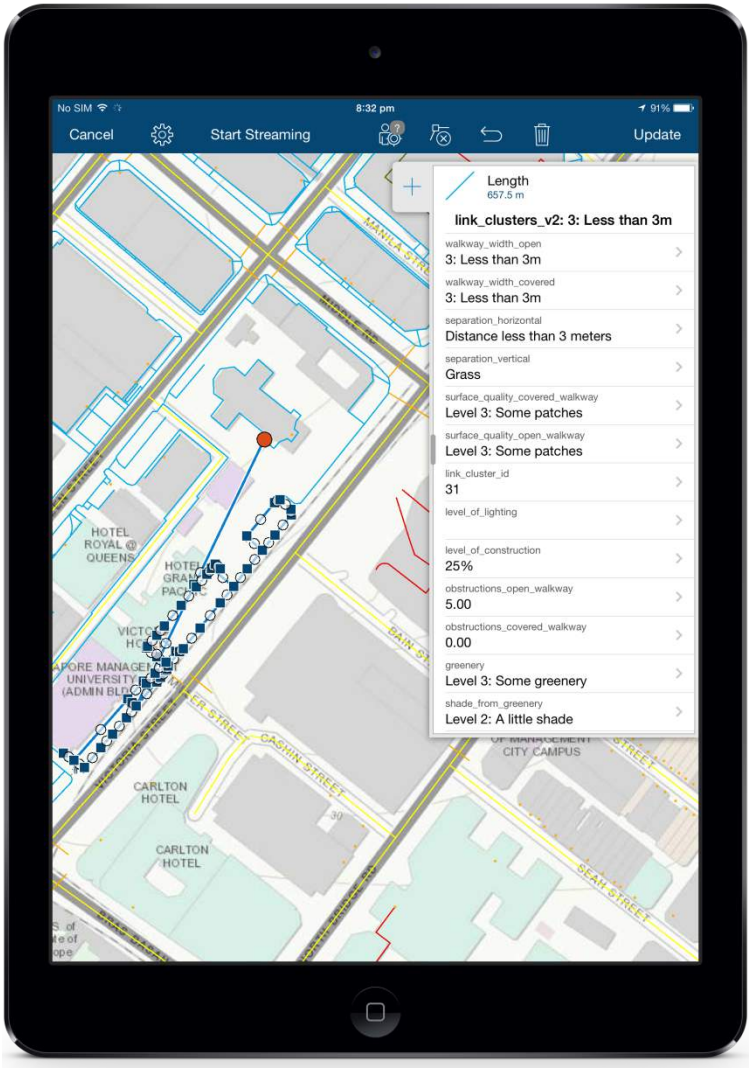




Collector for ArcGIS

Use your smartphone or tablet to collect and update information in the field, whether connected or disconnected.

Your update can include modifying the feature's attributes and location, as well as adding and deleting photos.



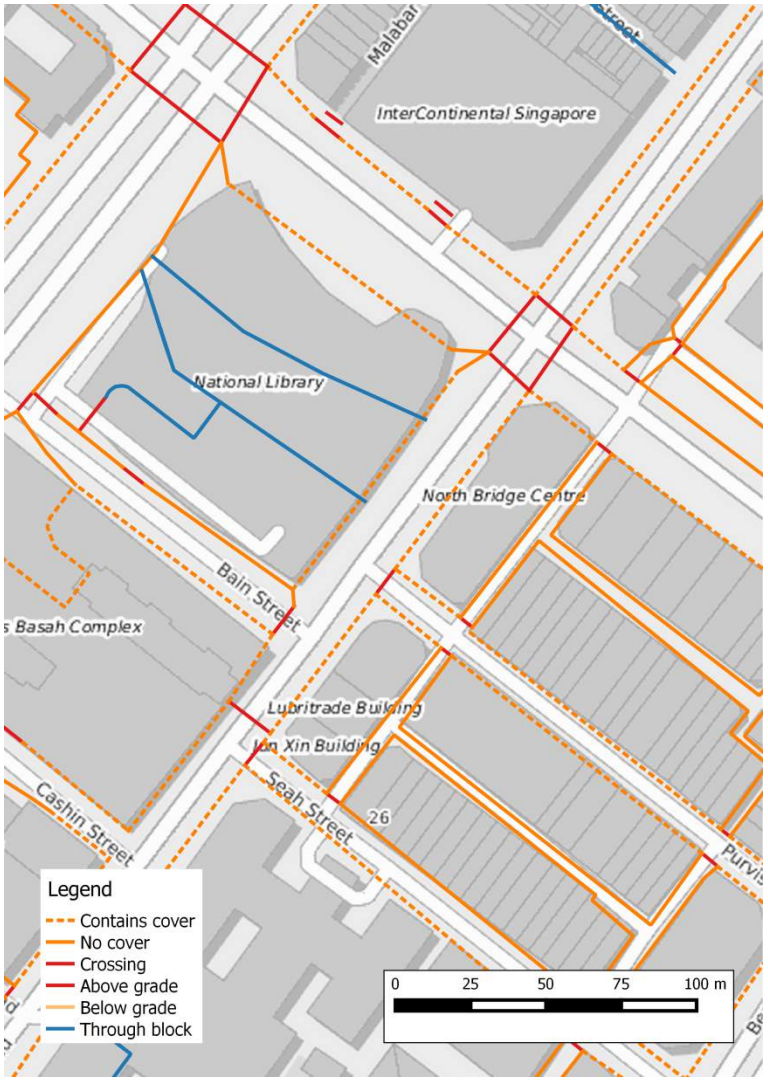
Simplification for analysis

Pedestrians choose their route from a number of distinct routes;

A network containing many links generates many similar route alternatives.

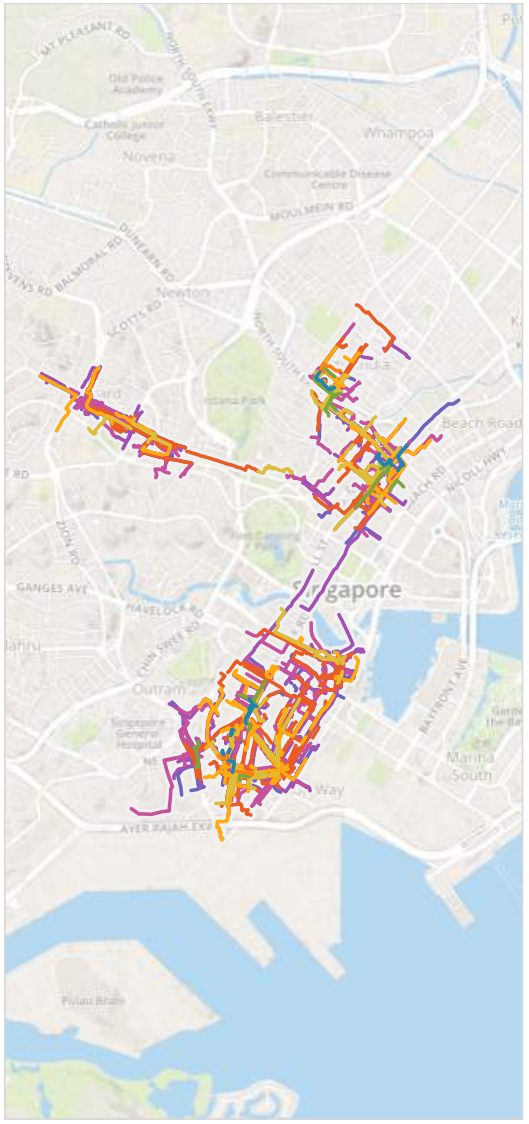
One can envisage this by **enumerating** the **number of routes** possible alongside a row of shophouses, where each covered and open walkway is a separate link.

The initial network is **redrawn** so that it is suitable for network analysis purposes, leading to **faster analysis**, and a network for which it is **easier to collect data** for.

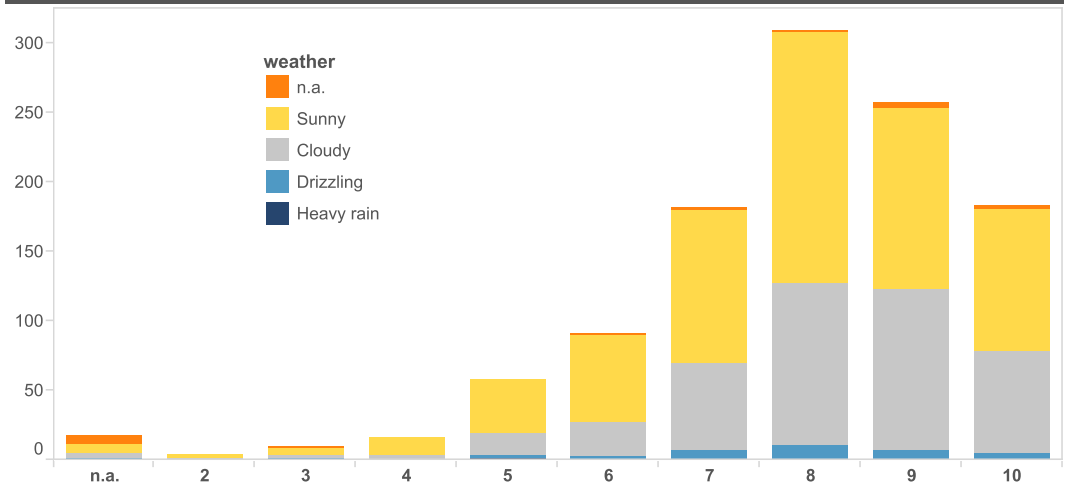


Pedestrian experience

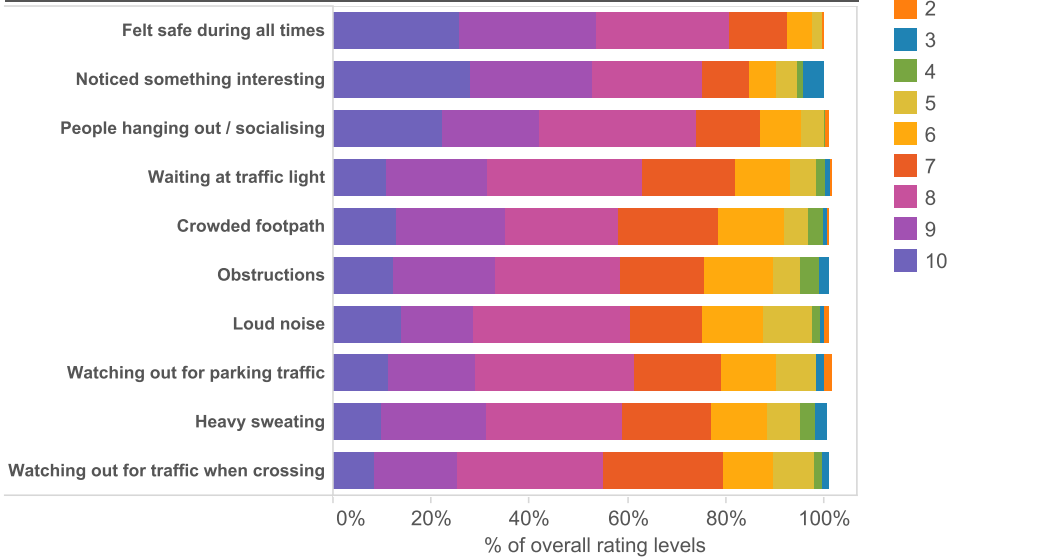
Pedestrian tracks by overall rating of walking experience



Rating of walking experience [0-10]

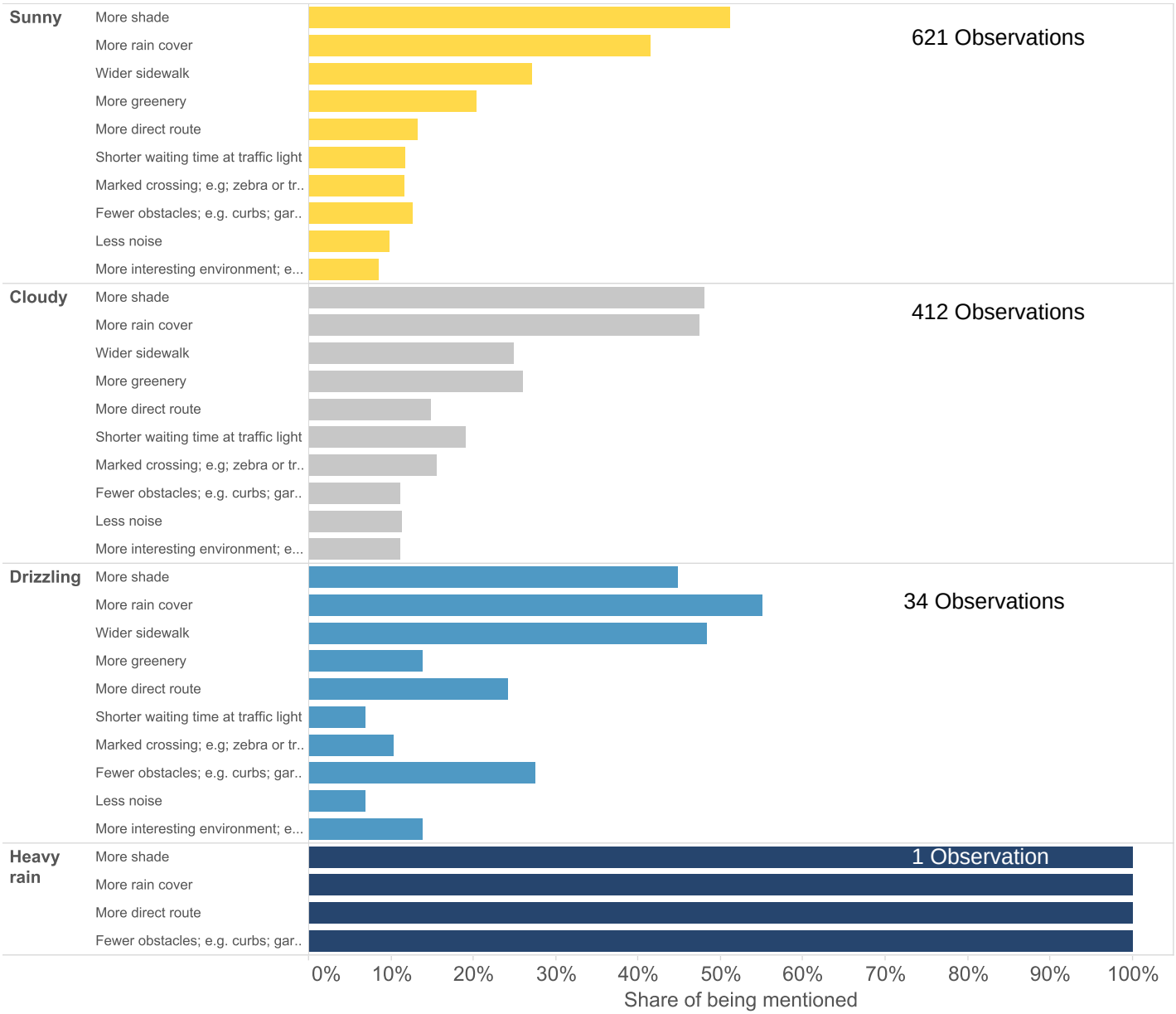


Experiences



Interactive graph available at:
https://public.tableau.com/views/Directorsmeeting/ExperienceMap_1024

And how to improve the experience?

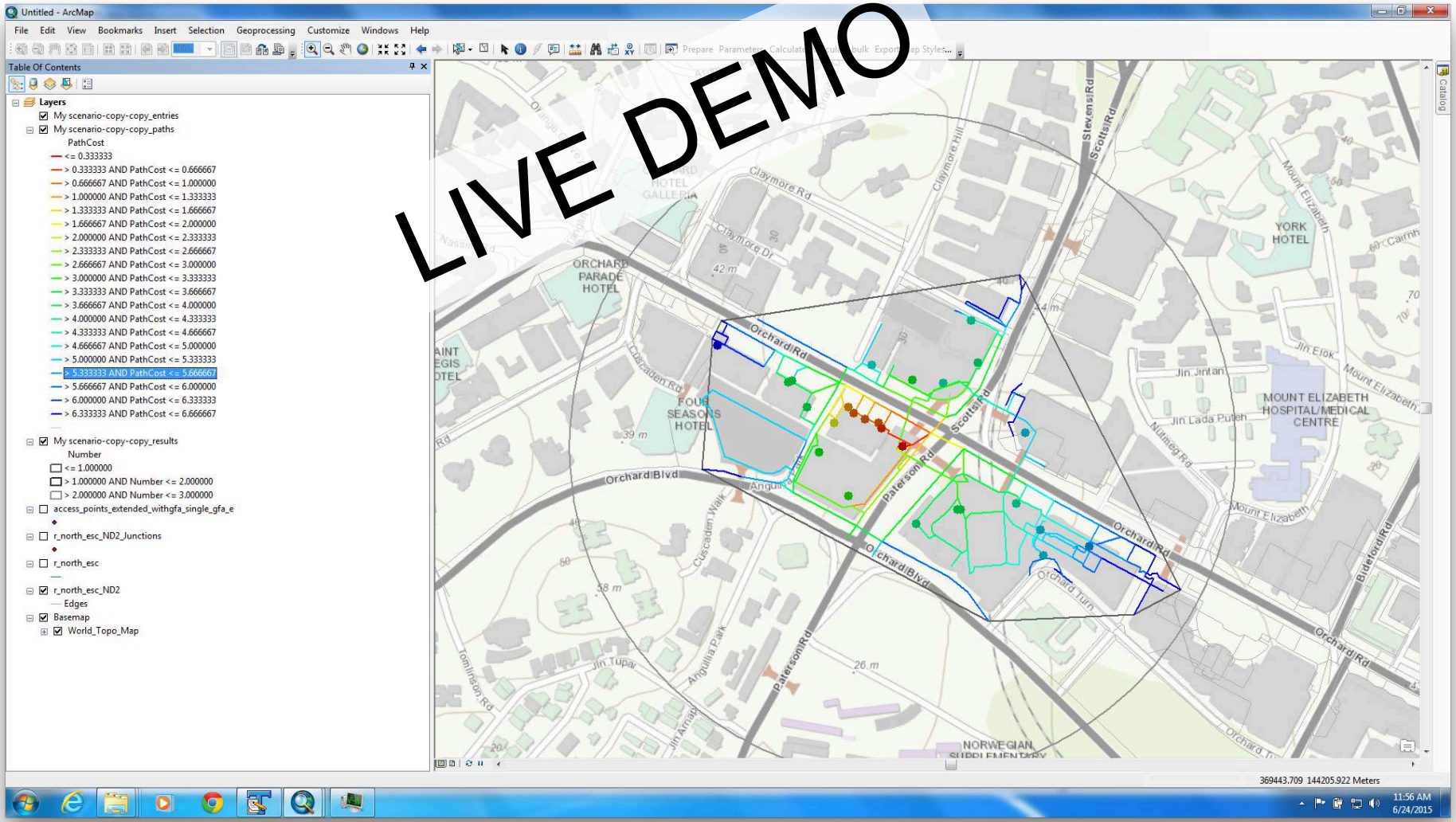


Behavioral models

From actual to perceived distance

Walkability Tool

A new ArcGIS add-in to compute walkability


Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
My scenario-copy-copy_entries
My scenario-copy-copy_paths
PathCost
<= 0.333333
> 0.333333 AND PathCost <= 0.666667
> 0.666667 AND PathCost <= 1.000000
> 1.000000 AND PathCost <= 1.333333
> 1.333333 AND PathCost <= 1.666667
> 1.666667 AND PathCost <= 2.000000
> 2.000000 AND PathCost <= 2.333333
> 2.333333 AND PathCost <= 2.666667
> 2.666667 AND PathCost <= 3.000000
> 3.000000 AND PathCost <= 3.333333
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> 4.000000 AND PathCost <= 4.333333
> 4.333333 AND PathCost <= 4.666667
> 4.666667 AND PathCost <= 5.000000
> 5.000000 AND PathCost <= 5.333333
> 5.333333 AND PathCost <= 5.666667
> 5.666667 AND PathCost <= 6.000000
> 6.000000 AND PathCost <= 6.333333
> 6.333333 AND PathCost <= 6.666667
My scenario-copy-copy_results
Number
<= 1.000000
> 1.000000 AND Number <= 2.000000
> 2.000000 AND Number <= 3.000000
access_points_extended_withgfa_single_gfa_e
r_north_esc_ND2_Junctions
r_north_esc
r_north_esc_ND2
Edges
Basemap
World_Topo_Map
LIVE DEMO
ORCHARD PARADE HOTEL
FOUR SEASONS HOTEL
YORK HOTEL
MOUNT ELIZABETH HOSPITAL/MEDICAL CENTRE
NORWEGIAN
Orchard Rd
Orchard Blvd
Scotts Rd
Paterson Rd
Claymore Rd
Mount Elizabeth
369443.709 144205.922 Meters
11:56 AM
6/24/2015