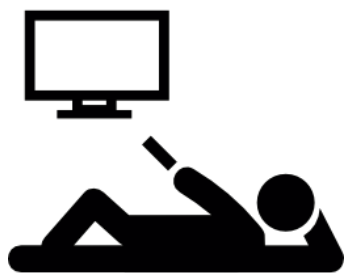




# ANALYSIS OF URBAN SPACE NETWORKS FOR RECREATIONAL PURPOSES BASED ON MOBILE SPORTS TRACKING APPLICATION DATA

Rusnė Šilerytė

Graduation Presentation  
2015 June 26





**obesity** (Wang et al., 2008);

**urban sprawl** (Van Herzele and Wiedemann, 2003);

**sustainability** (European Commission, 2011);

**competition between cities** (Braw, 2013);

**value of real estate** (Braw, 2013);





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**urban sprawl** (Van Herzele and Wiedemann, 2003);

**sustainability** (European Commission, 2011);

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**value of real estate** (Braw, 2013);

**walkability index**

Henderson (2005), Cohen et al. (2006, 2007) Leslie et al., (2007),  
Floyd et al. (2008), Maroko et al. (2009), Brown et al. (2009), van  
Dyck et al. (2010), Troped et al. (2010), Cutumisu (2011), Yamada et  
al. (2012)



## walkability index

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runability index

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## runability index

an indication of space potential to be used for **recreational active travels**

prediction of changes

encouragement of recreational activities

assurance of quality



**lack of scientific knowledge** how spaces

are used for recreation:

**data** collection is expensive and time

consuming;

cannot be performed the same way in different

countries;

cannot be performed on a big scale;

cannot be repeated often.

runability index

an indication of space potential to be used  
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**prediction of changes**

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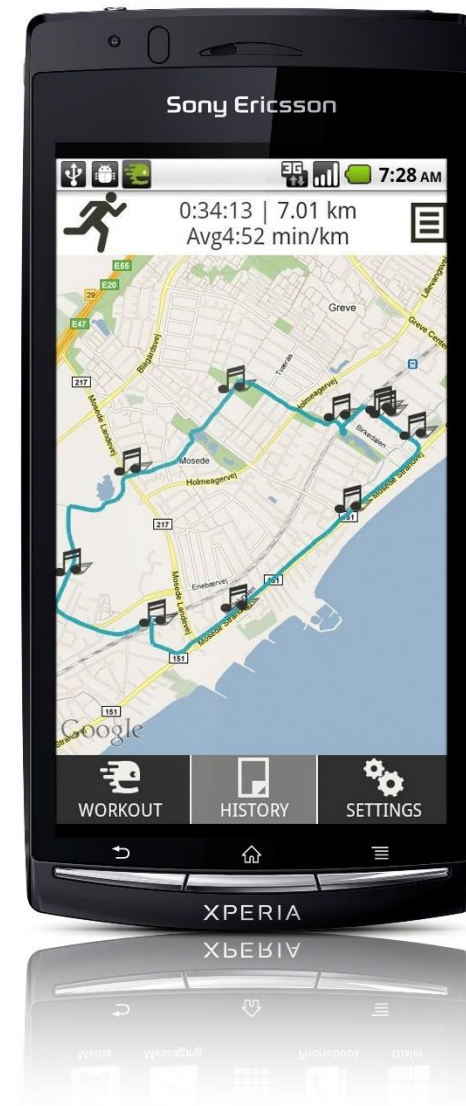
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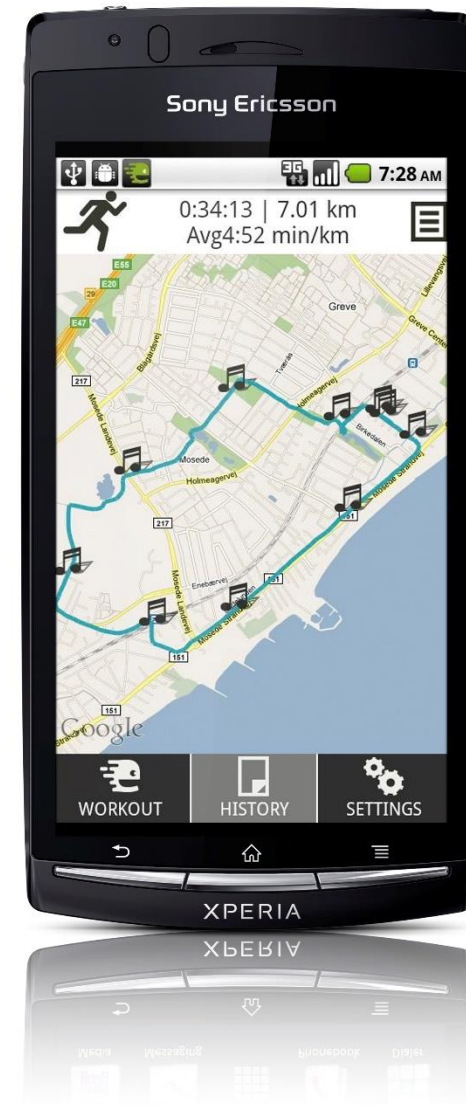
cannot be repeated often.



## Mobile Sports Tracking Application

data:

- big data
- public data
- crowdsourced data
- comparable data
- up-to-date data
- growing data



## Mobile Sports Tracking Application

data:

big data

public data

crowdsourced data

comparable data

up-to-date data

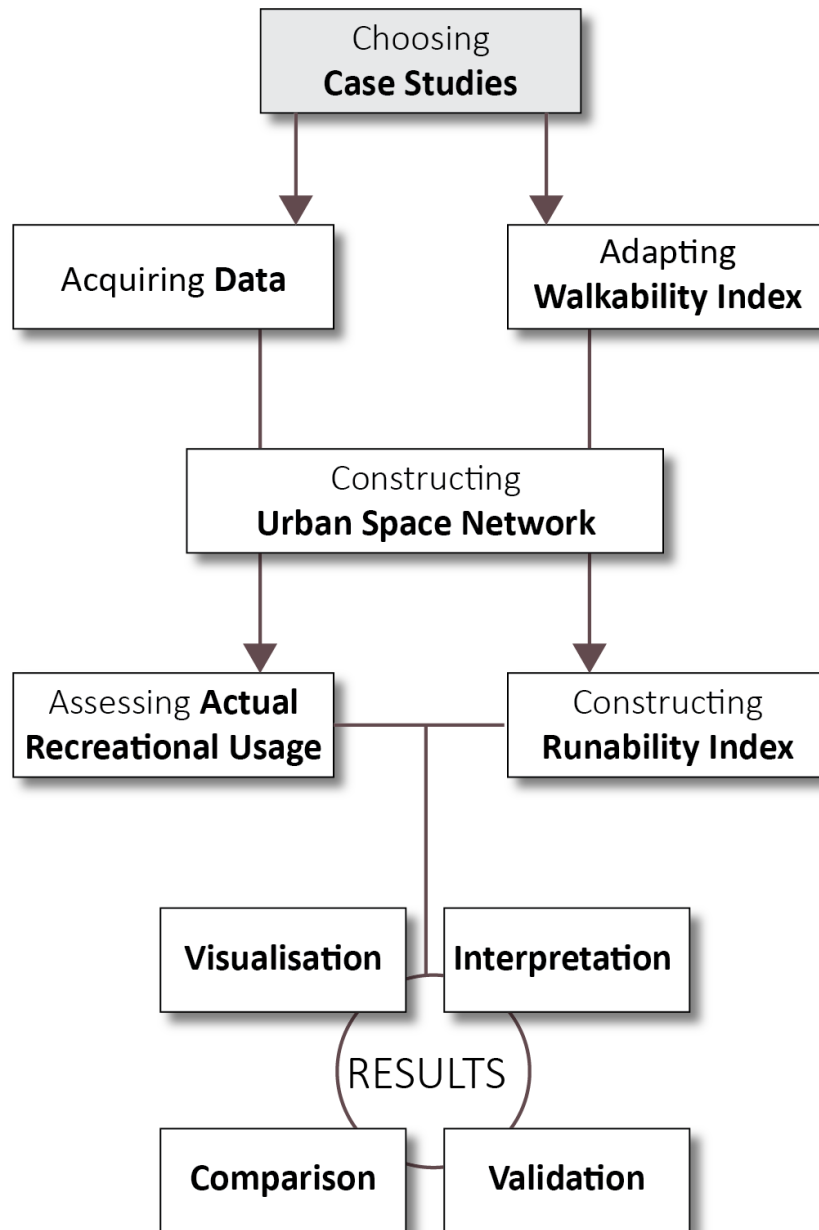
growing data

**no interface**

**data is very big**

**privacy issues**

**Euclidean space**



How can **GPS data**,  
generated by  
**mobile sports tracking applications**,  
be used  
to assess, analyse and **model**  
**the recreational usage**  
of an urban space **network**?

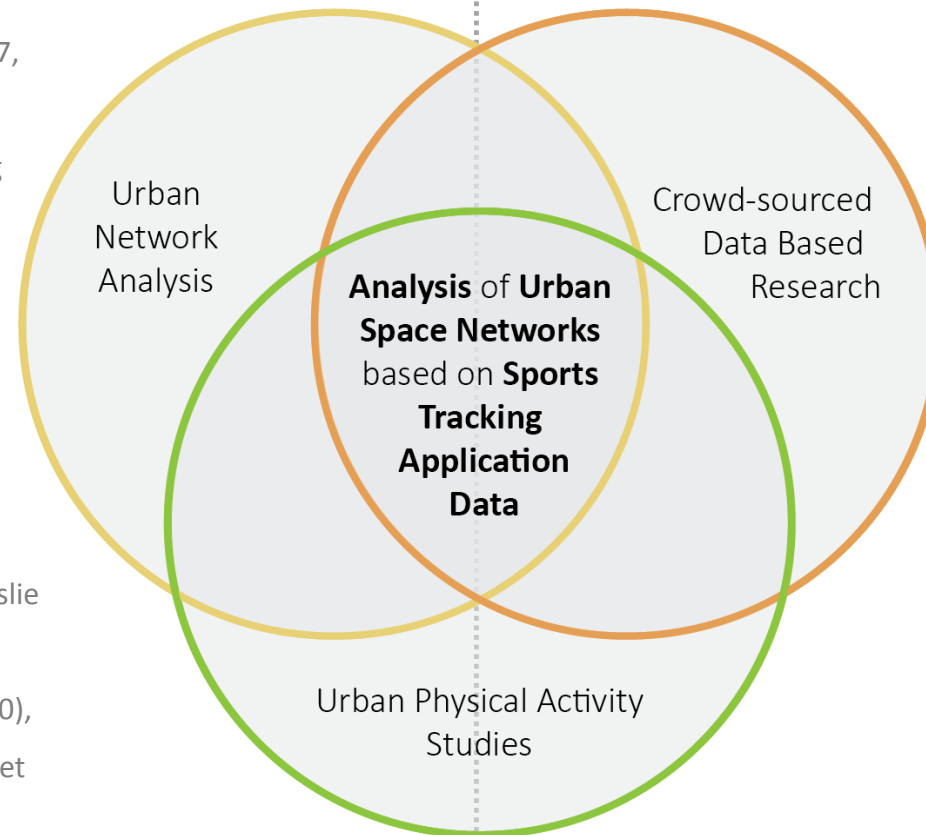


## Space Syntax, Page Rank, Random walk, eigenvector centrality...

Hillier & Hanson (1984), Hillier et al. (2005, 2007, 2009, 2012), Gauvin et al. (2005), Crucitti et al. (2006), Turner (2007), Gebel et al. (2007), Jiang (2009), Blanchard & Volchenkov (2008)

## Walkability Index

Henderson (2005), Cohen et al. (2006, 2007) Leslie et al., (2007), Floyd et al. (2008), Maroko et al. (2009), Brown et al. (2009), van Dyck et al. (2010), Troped et al. (2010), Cutumisu (2011), Yamada et al. (2012), Choi (2013)



## Open Street Map

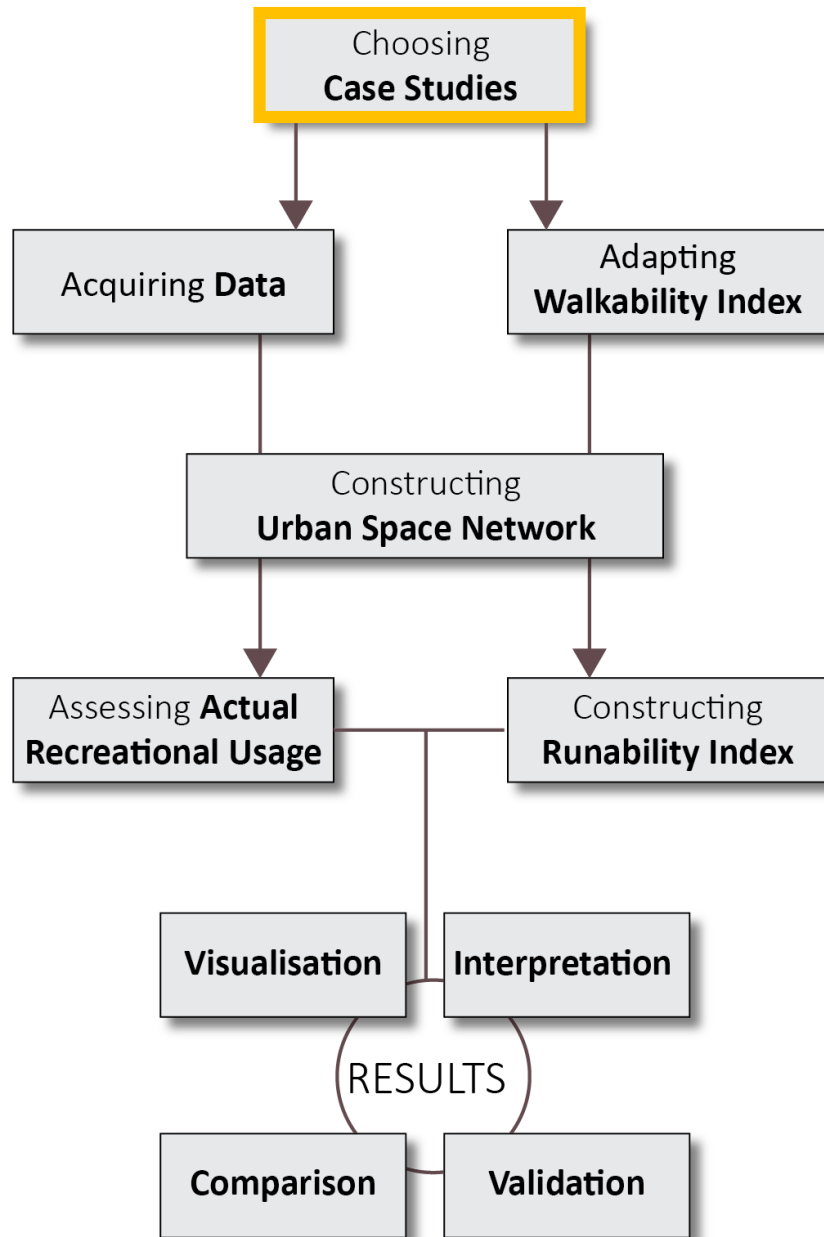
Chin et al. (2008), Girres and Touya (2010), Gil (2014), Mooney (2015)

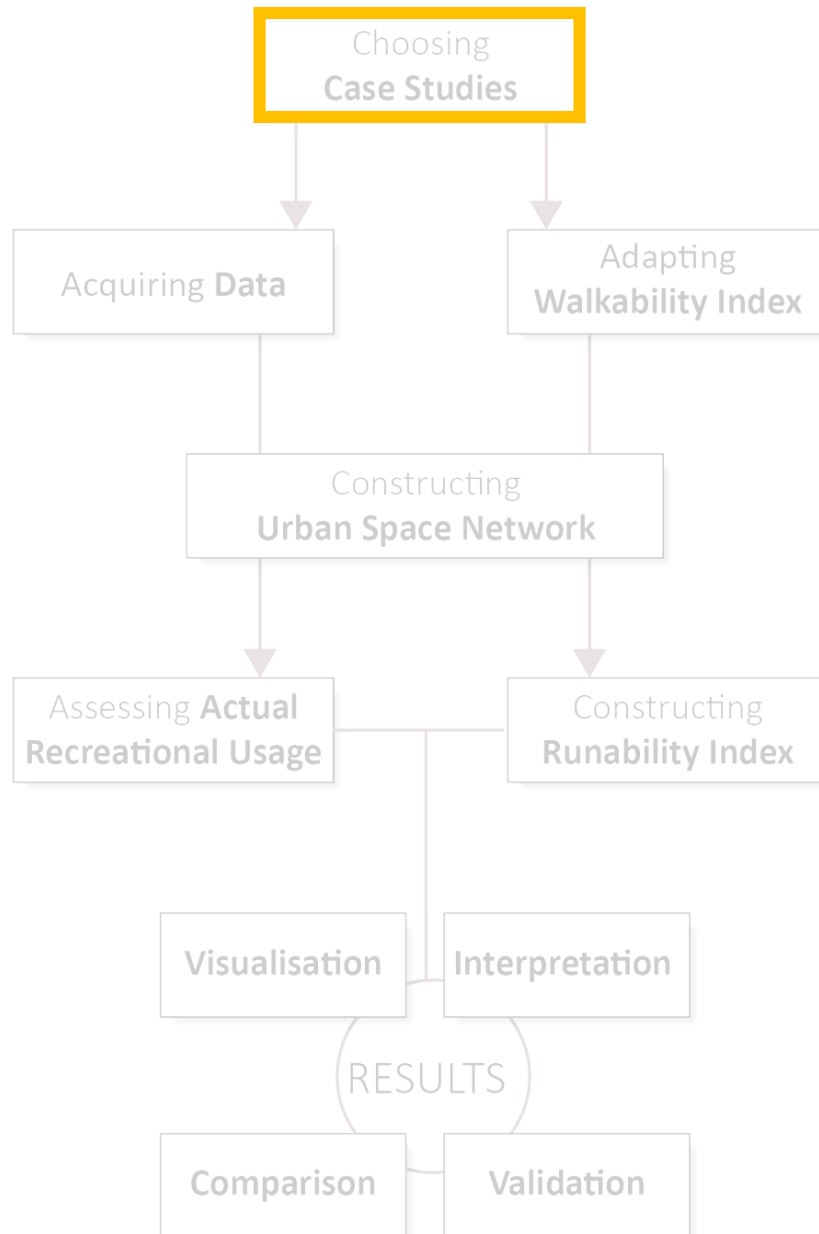
## Mobile tracking

Shoval (2008), Van der Spek et al. (2009; 2013; 2014), Zambonelli (2011)

## Sports tracking application data

Piorkowski (2009), Ferrari & Mamei (2011, 2013), Oksanen et al. (2013)



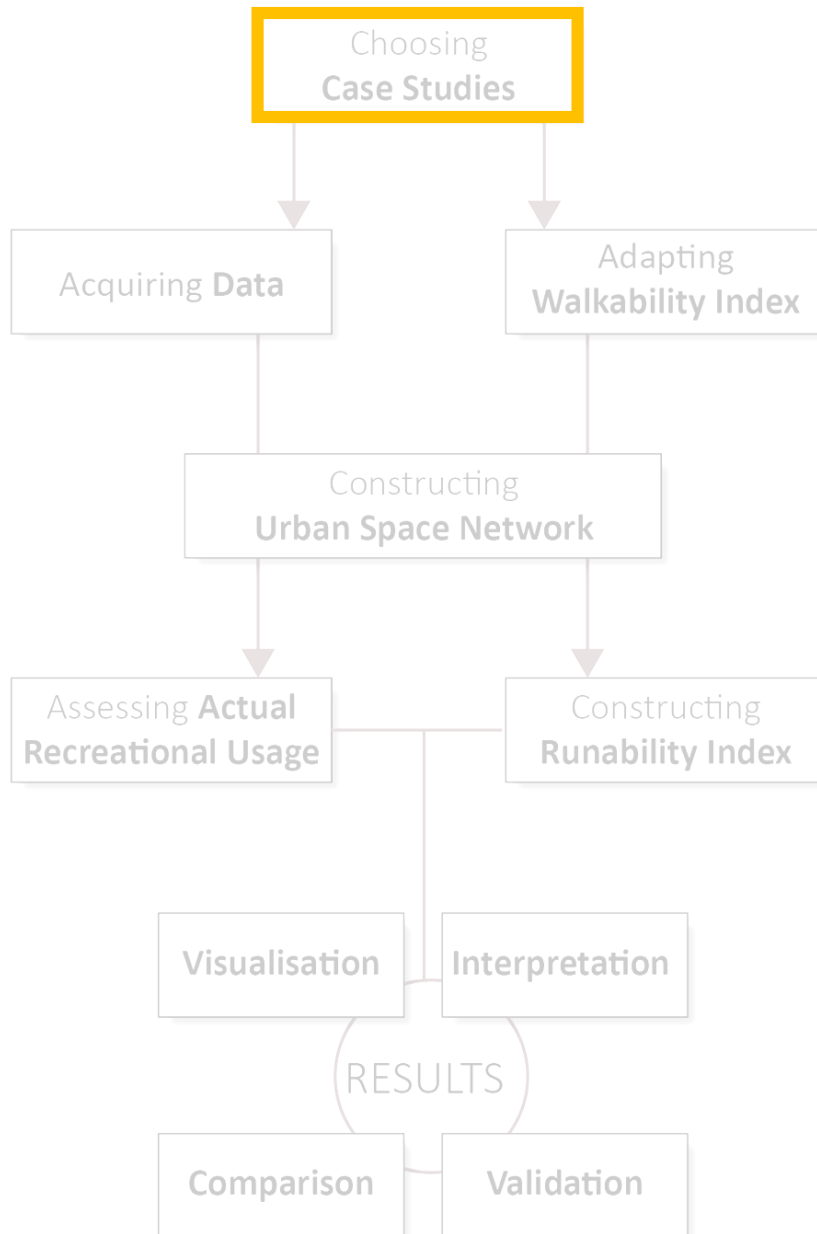


## Mobile Sports Tracking Application:

high popularity rate in Europe

free data access





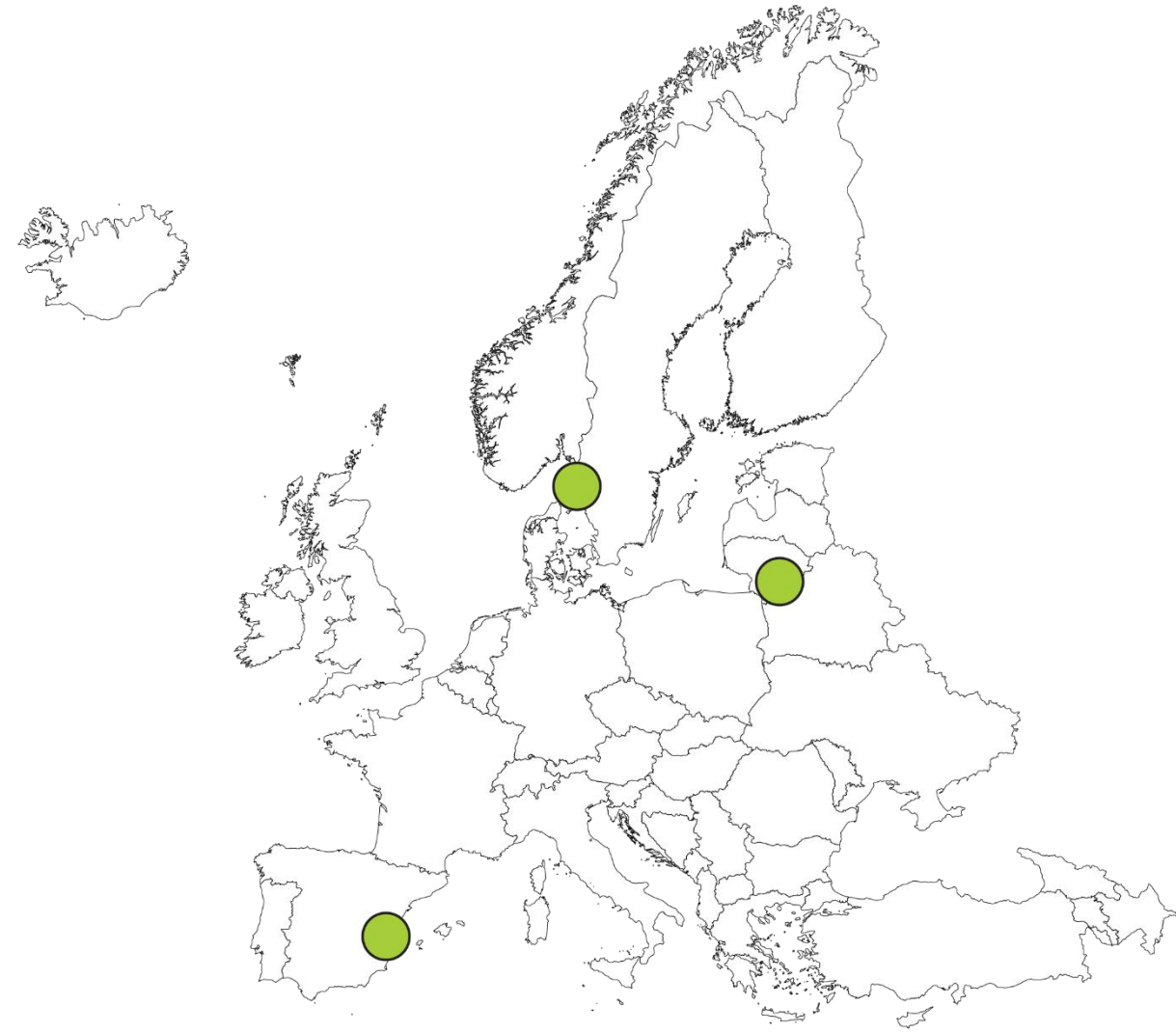
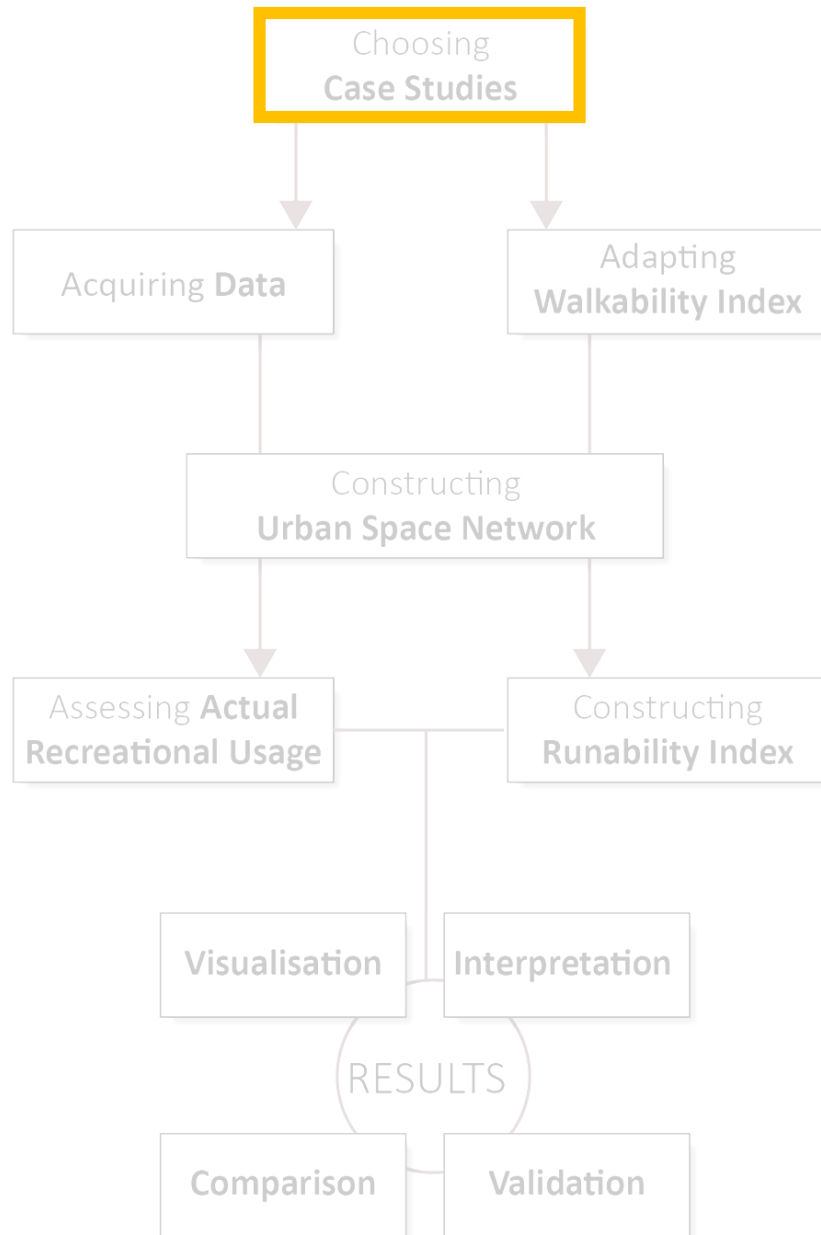
## Case Study Cities:

within EU

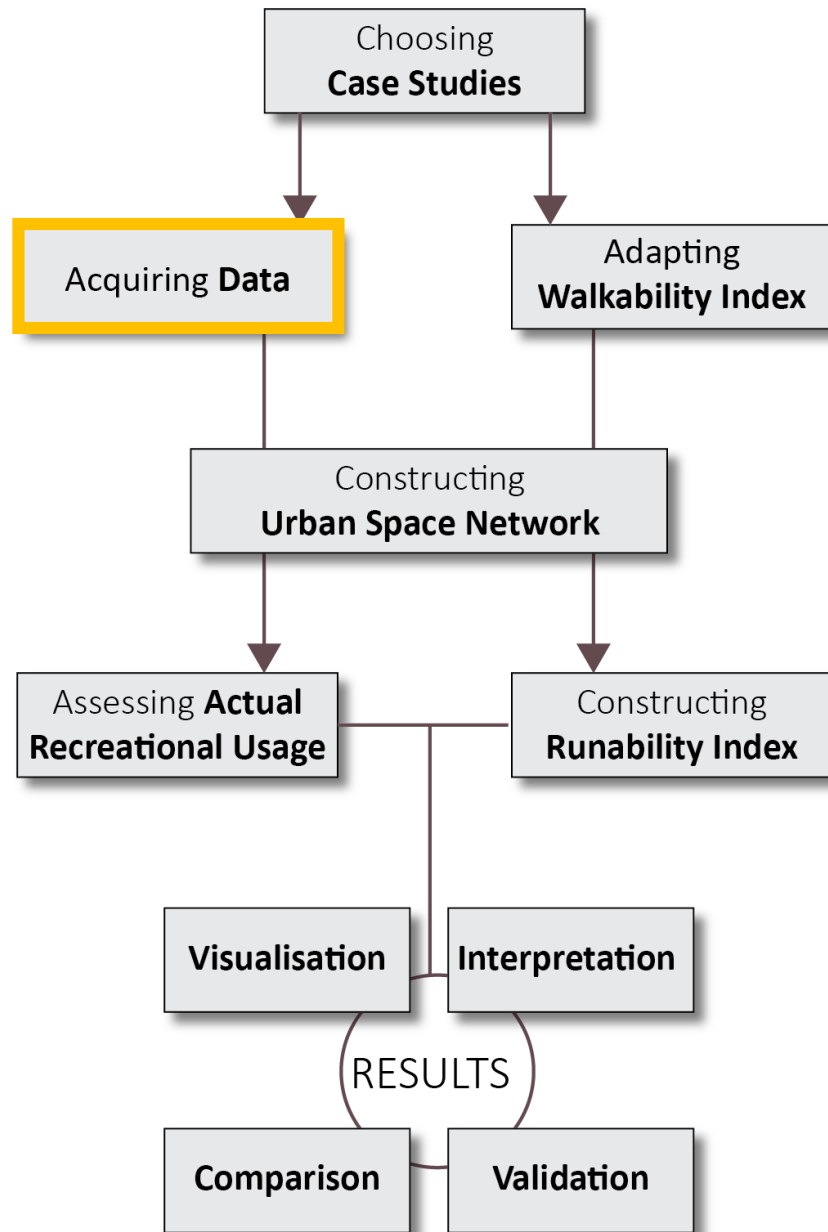
extra-large (500 000 – 1 000 000 inhabitants)

distinct characteristics

$$ratio = \frac{\text{distinct users}}{\text{population}}$$







```

627 "data": [
628   {
629     "values": {
630       "distance": 0.0,
631       "duration": 0
632     },
633     "lng": 4.319285,
634     "lat": 52.078257
635   },
636   {
637     "values": {
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639       "duration": 21773,
640       "alt": 49.36667
641     },
642     "lng": 4.319285,
643     "lat": 52.078257
644   },
645   {
646     "values": {
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651     },
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661     },
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663     "lat": 52.07756891018813
664   },
665   {
666     "values": {
667       "distance": 0.2585522,
668       "duration": 87092,
669       "speed": 12.7693,
670       "alt": 51.875
671     },
672     "lng": 4.318061908047622,
673     "lat": 52.07789570018312
674   },

```

<https://www.endomondo.com/workouts/453360586>

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Upgrade  
Rusne Sileryte

[Workouts](#)
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## JAN2015

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[JAN](#)
[FEB](#)
[MAR](#)
[APR](#)
[MAY](#)
[JUN](#)
[JUL](#)
[AUG](#)
[SEP](#)
[OCT](#)
[NOV](#)
[DEC](#)
[JAN](#)

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

### Walking

Jan 2, 2015 12:35 PM

Summary

Social

HR Zones

Best Distances

DISTANCE

6.13 km

AVG. SPEED

3.4 km/h

CALORIES

385 kcal

MIN. ALTITUDE

-10 m

TOTAL ASCENT

154 m

WEATHER

Sunny

DURATION

1h:47m:03s

MAX. SPEED

28.2 km/h

HYDRATION

0.13L

MAX. ALTITUDE

58 m

TOTAL DESCENT

141 m

Weather data provided by  
AccuWeather.com

Unlock weather information and get access to the full Endomondo site with Endomondo Premium.

Click to add title

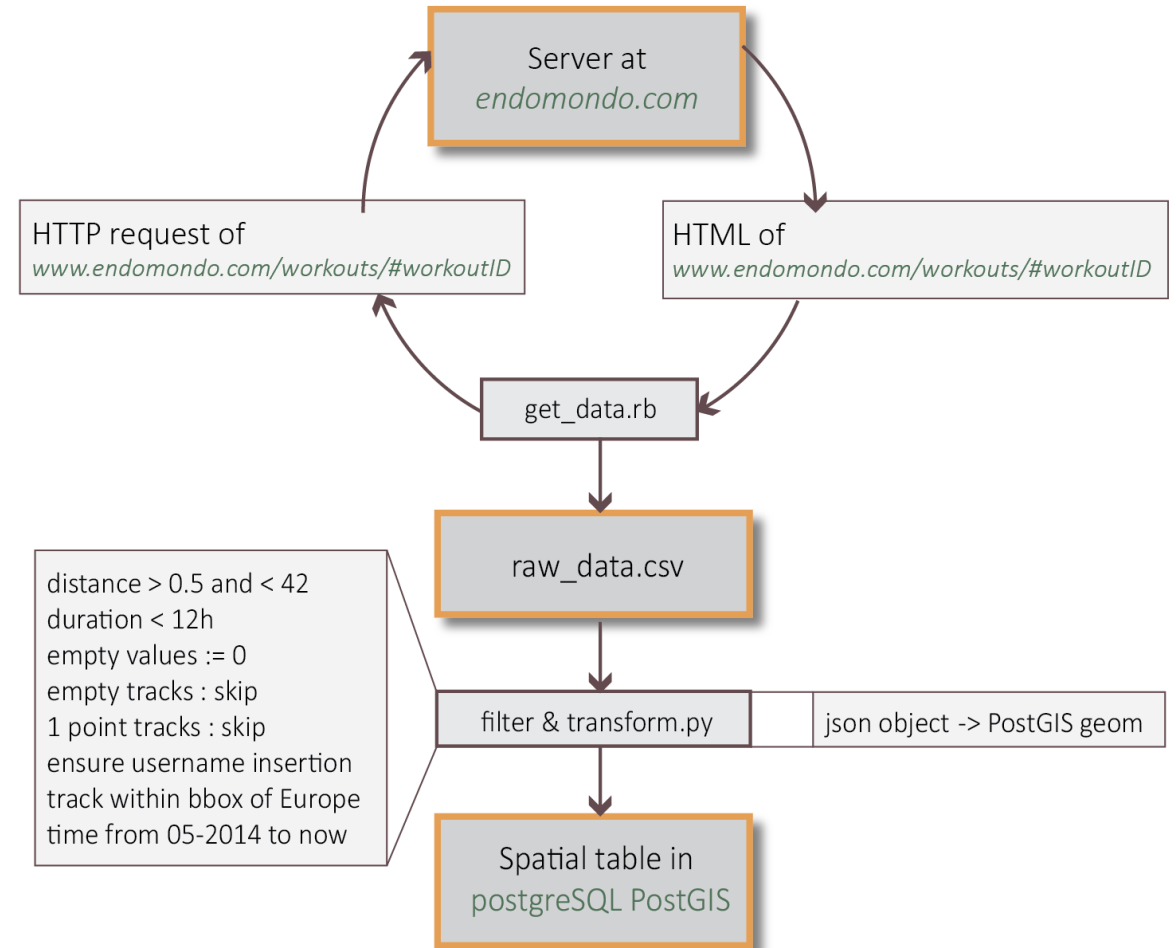
Add a tag

Click to add notes

```

627 "data": [
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673     "lat": 52.07789570018312
674   },

```



total data acquisition time: **1 248 h**

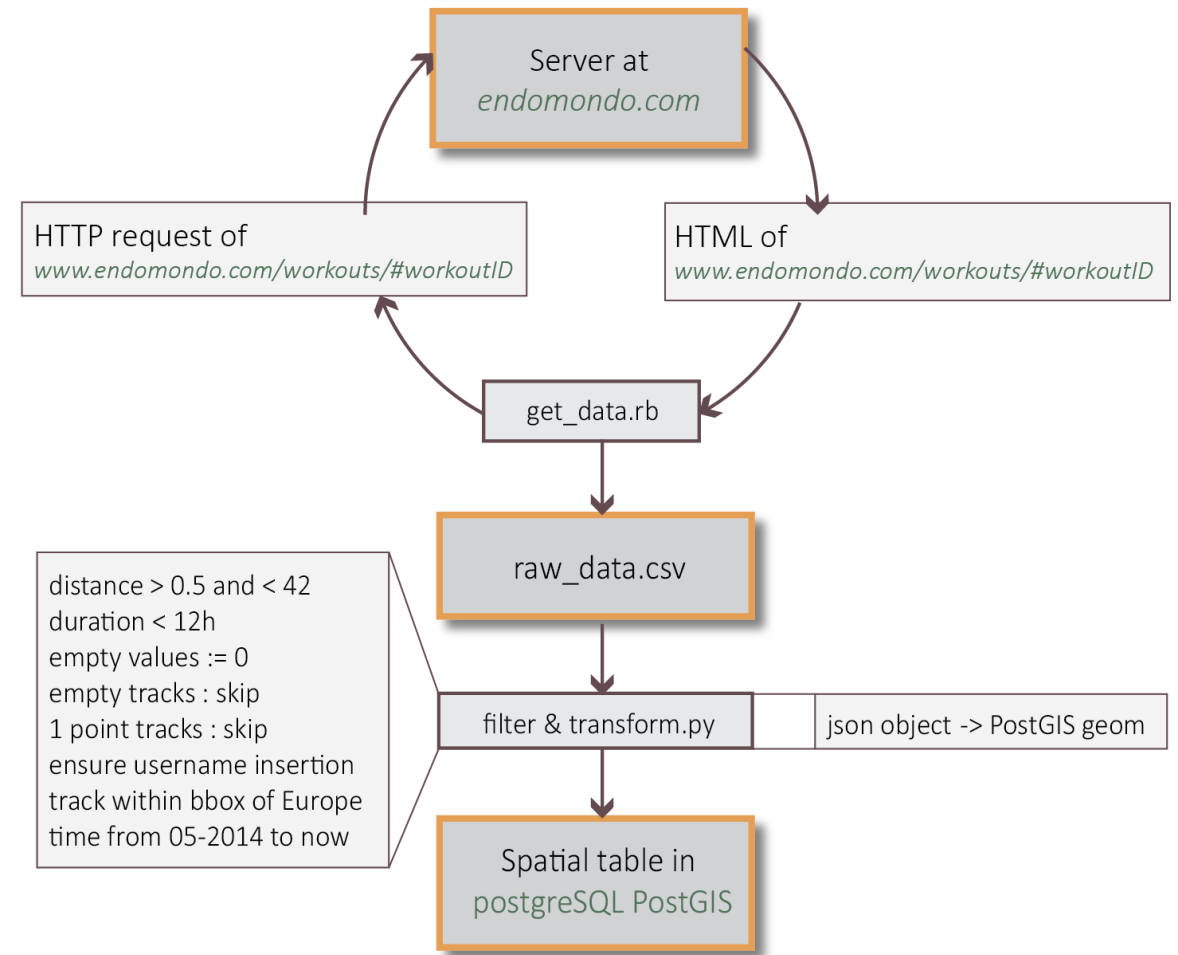
number of http requests sent: **15 600 000**

number of lines in .csv files: **5 964 008** (38%)

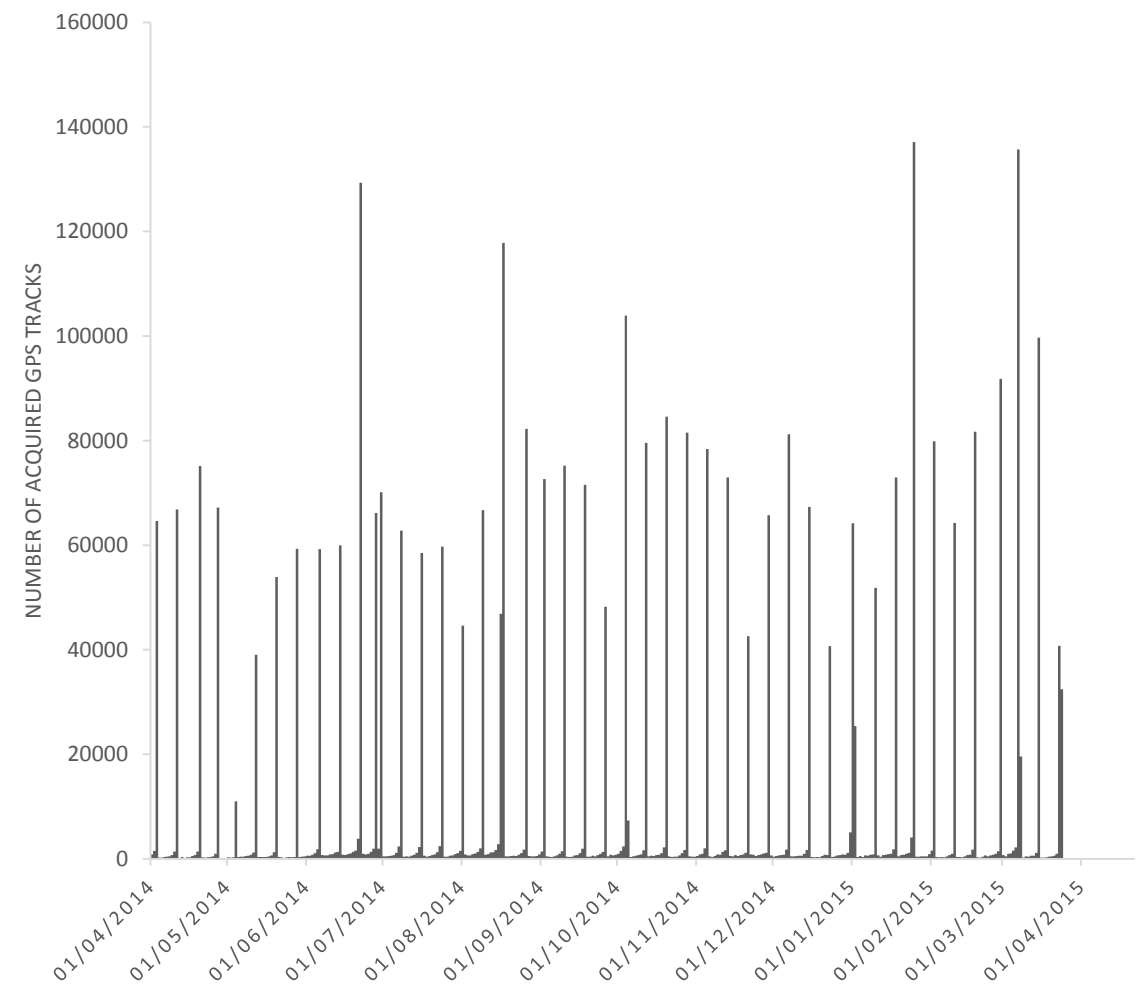
...that passed filter: **3 610 735** (23%)

distinct users registered: **911 588**

tracks per user: **4**

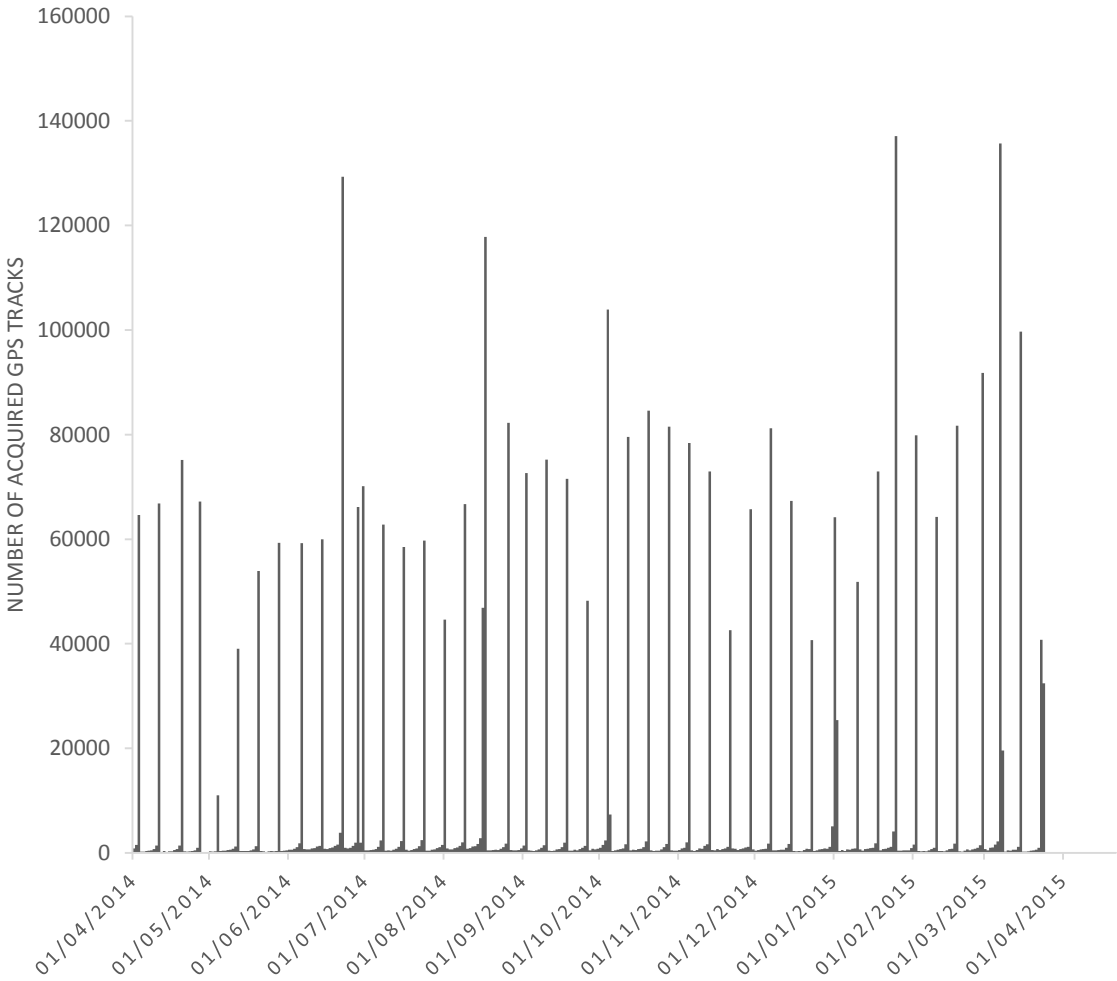


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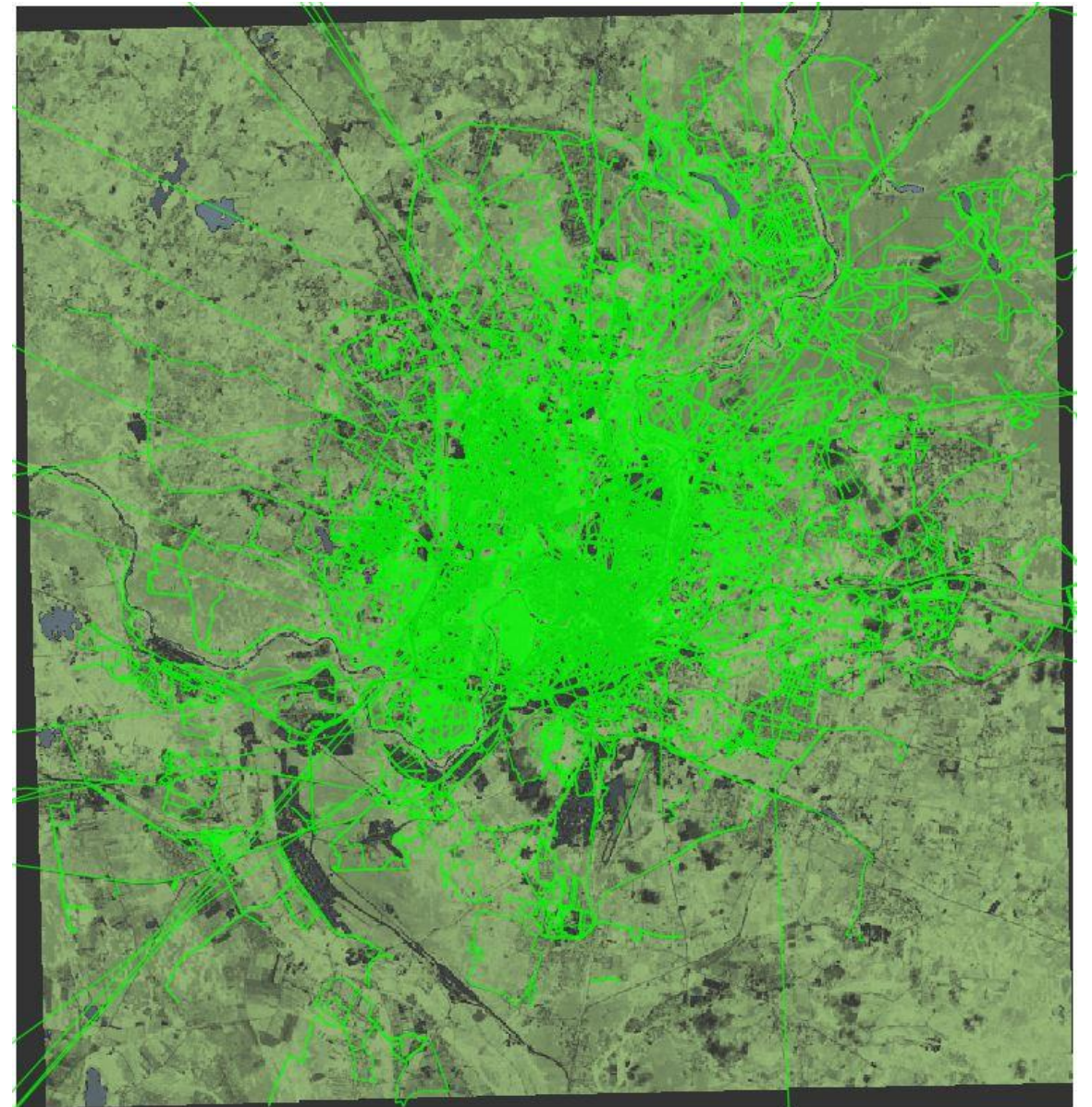




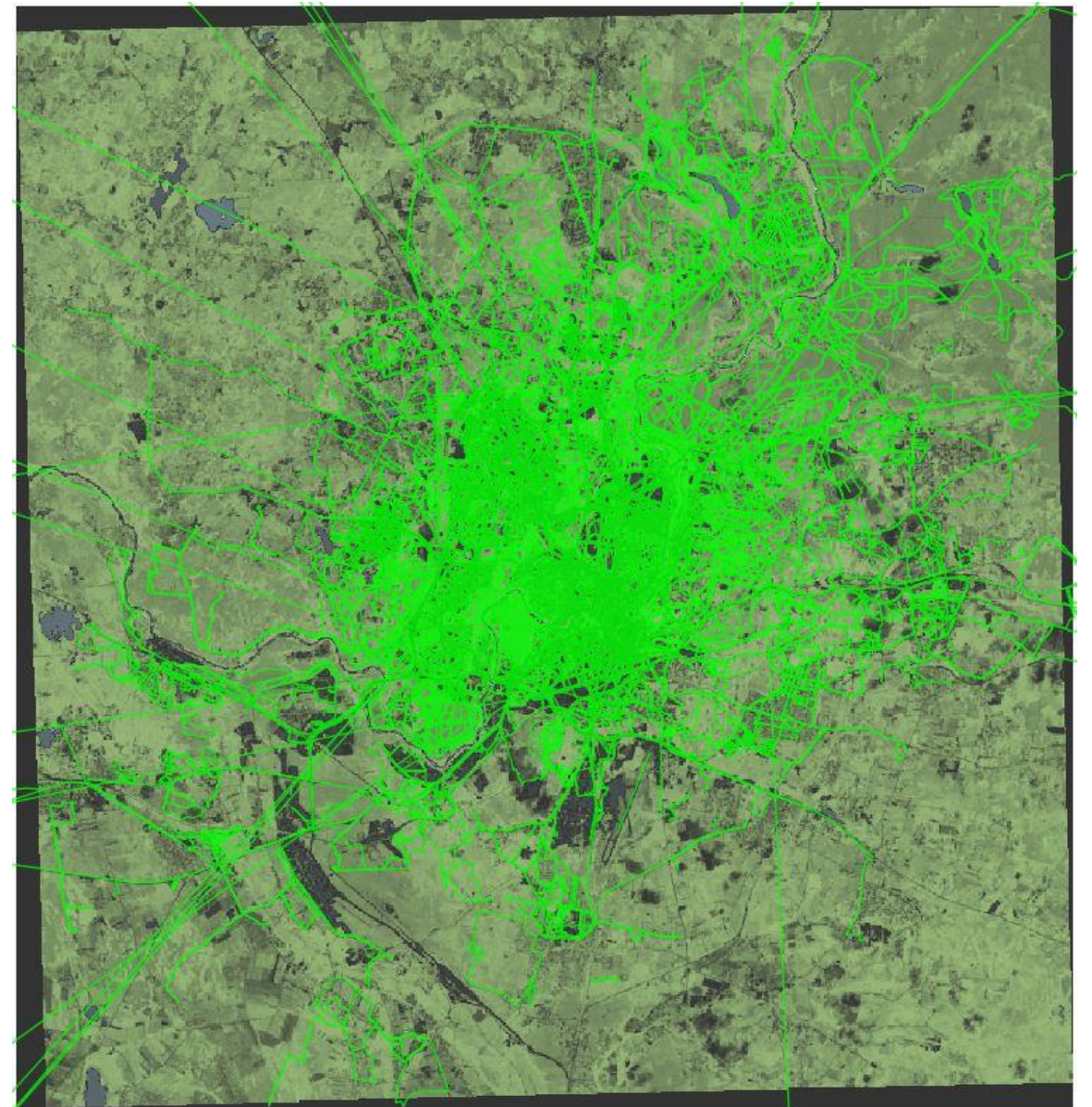
City	Population	No. of application users	No. of tracks	Ratio users/population
Vilnius	558 165	3950	10 165	0.007
Valencia	814 218	3583	9 443	0.005
Göteborg	520 374	2 195	6 720	0.004



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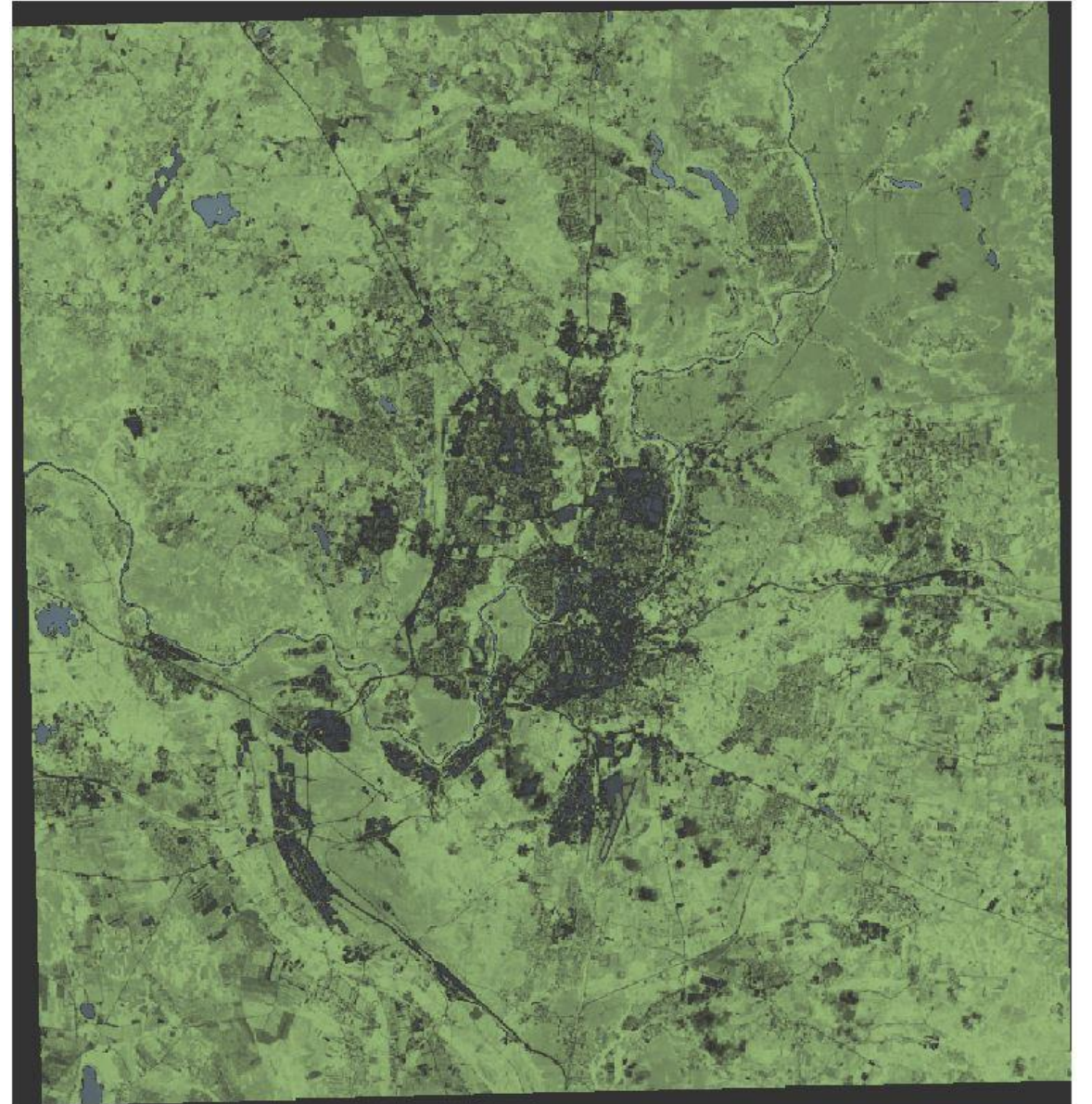






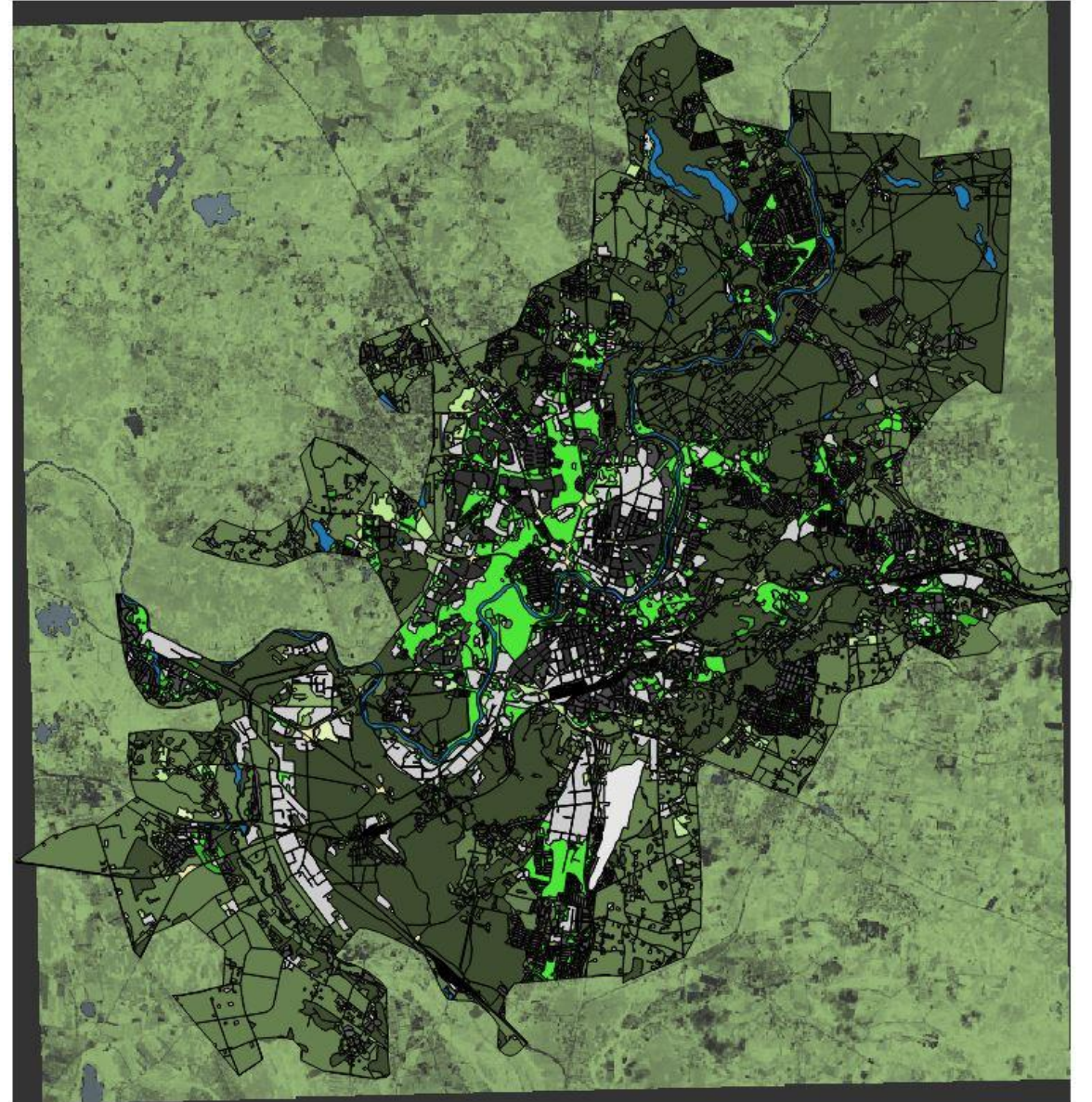


## LANDSAT 8



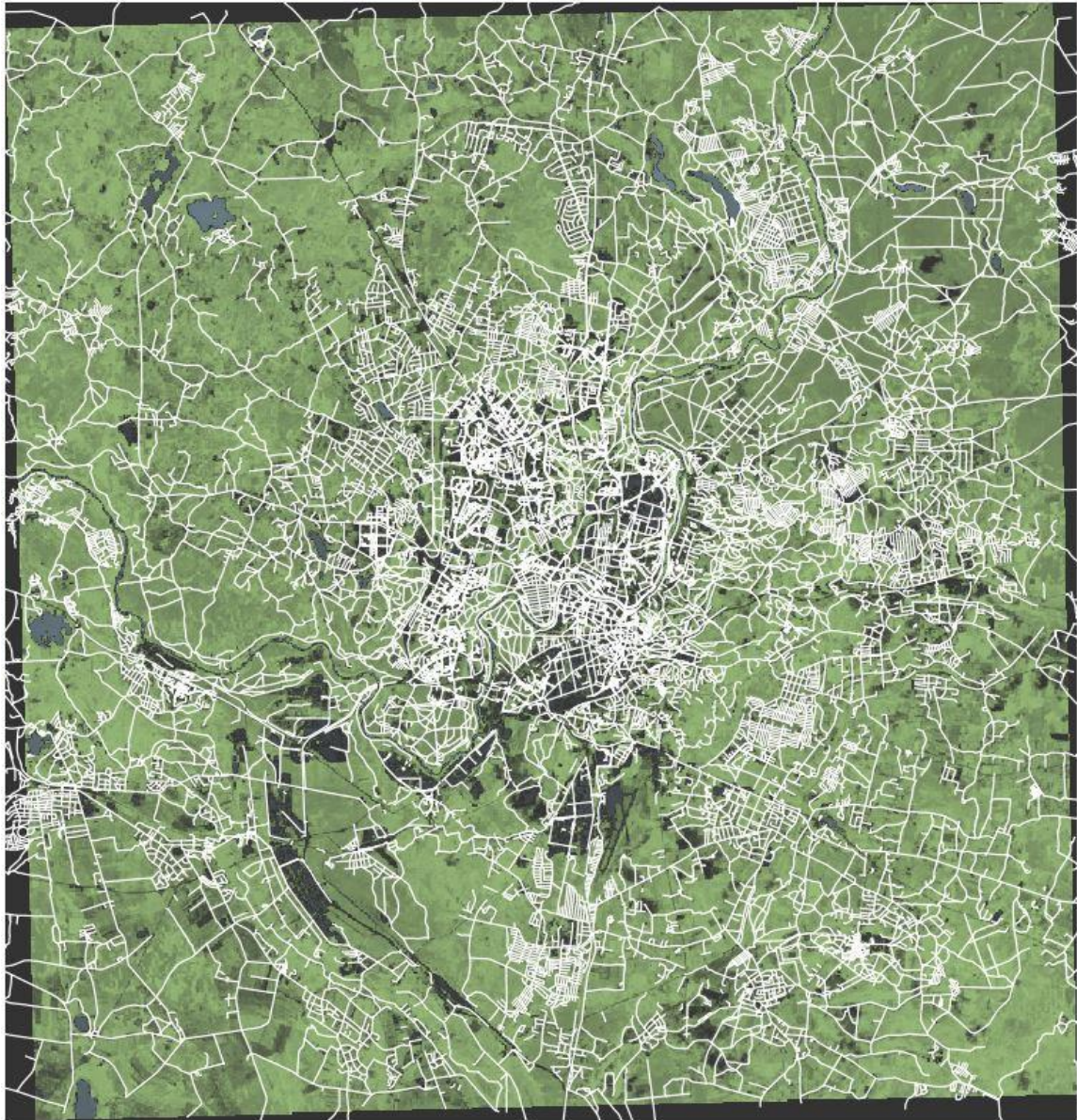


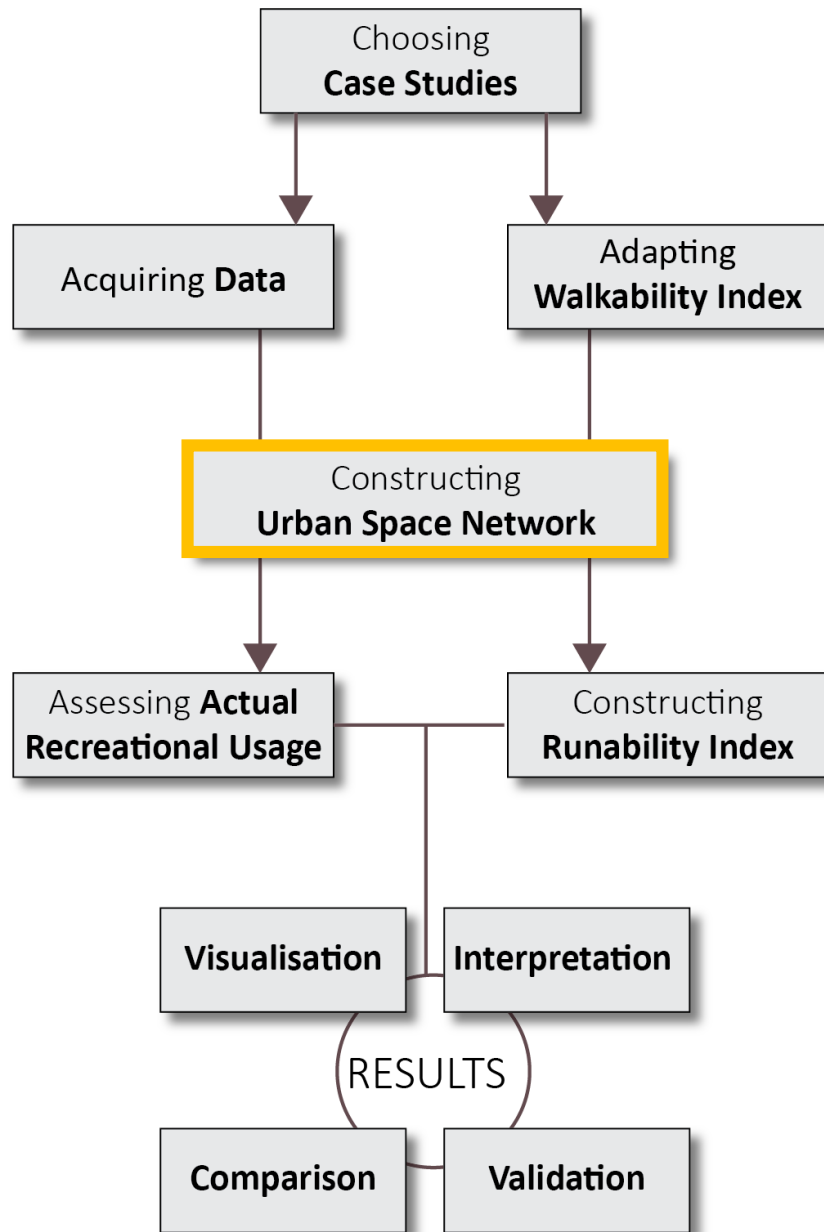
# EUROSTAT URBAN ATLAS



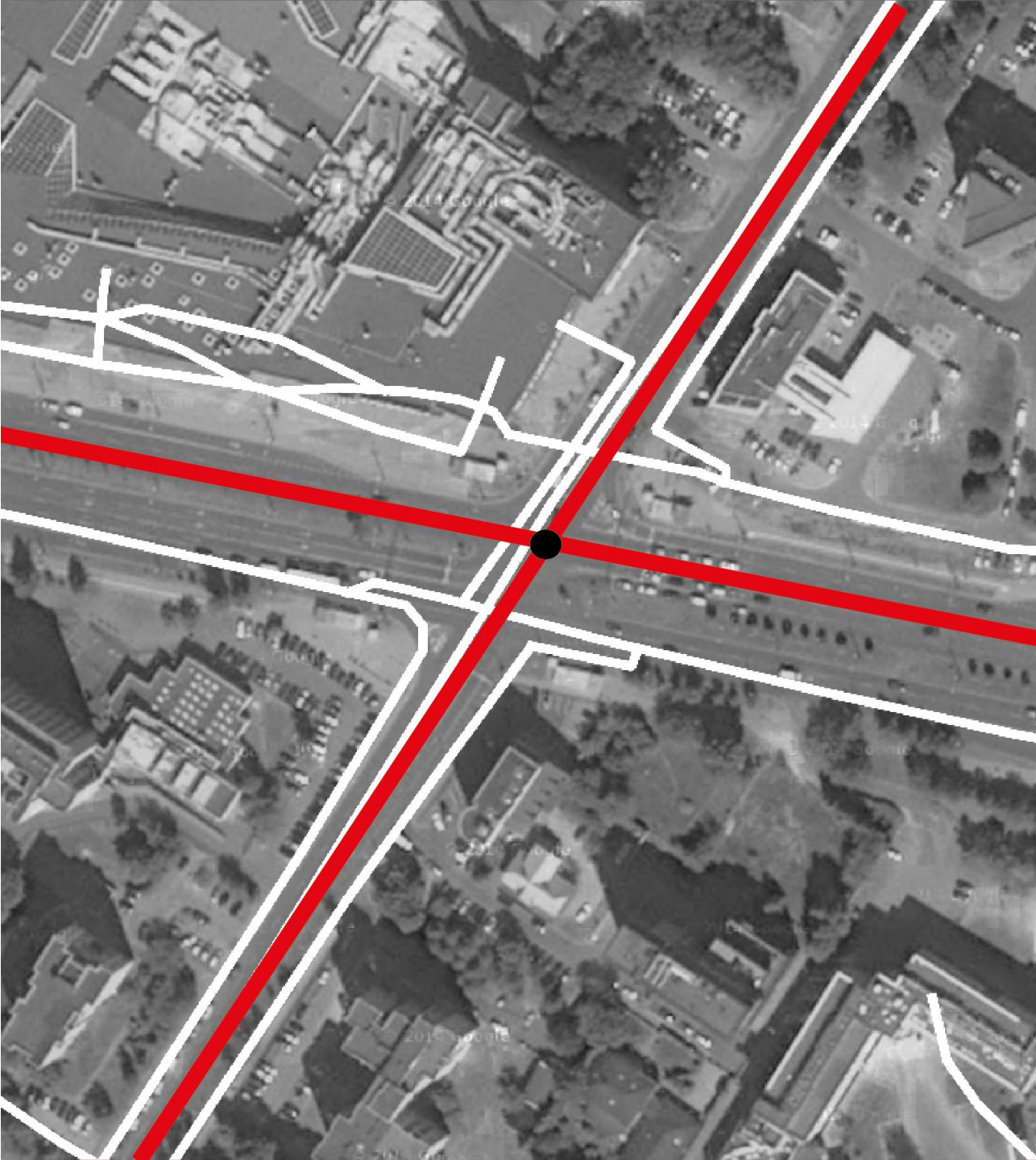


# OPEN STREET MAP









**paths for non-motorised** means of transport

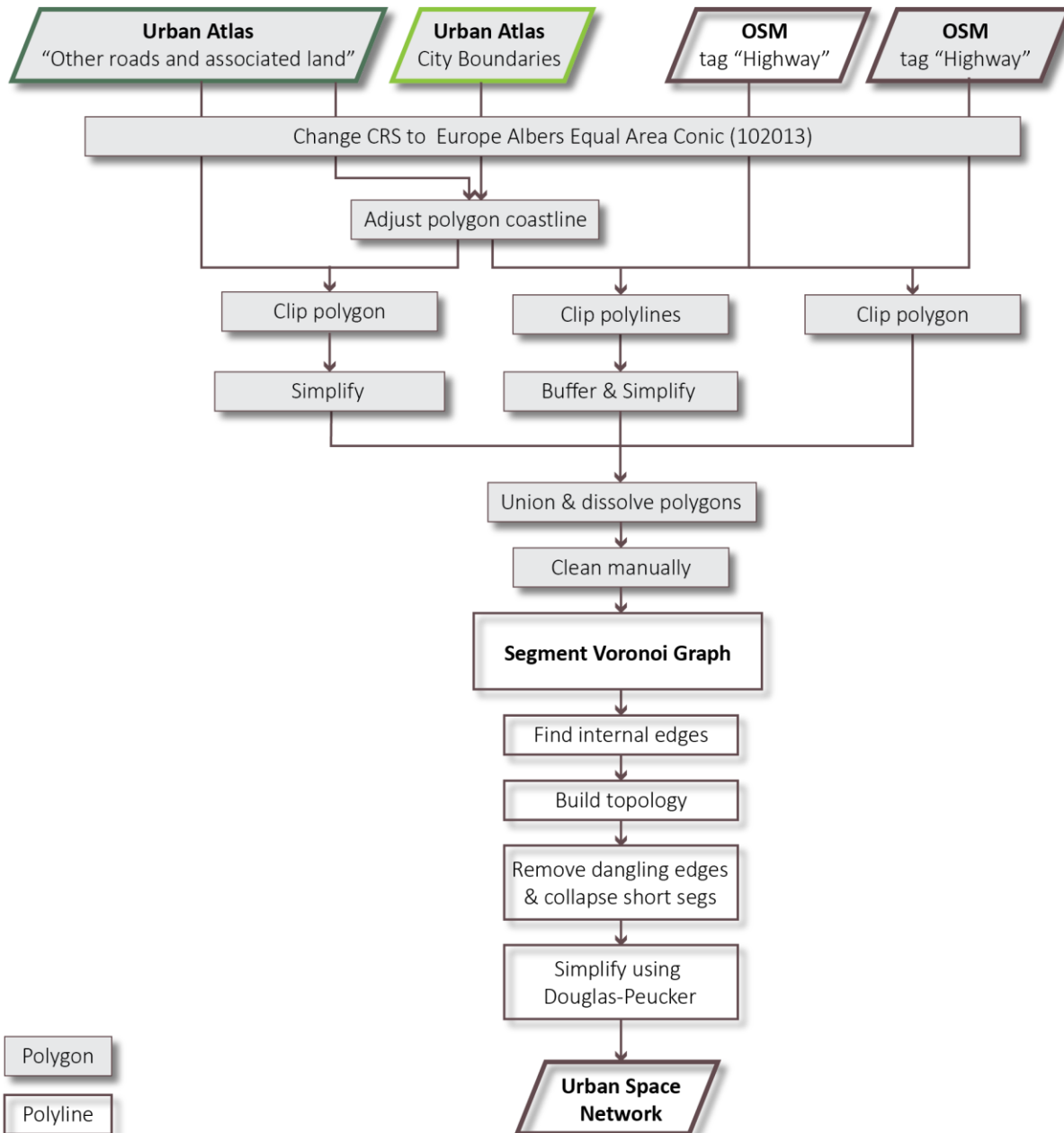
must be **generalised** with 30m granularity

**no** duplicates, pseudonodes or **invalid geometries**

**common datasets** for all cities

must be **up-to-date**





paths for non-motorised means of transport

must be generalised with 30m granularity

no duplicates, pseudonodes or invalid geometries

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must be up-to-date

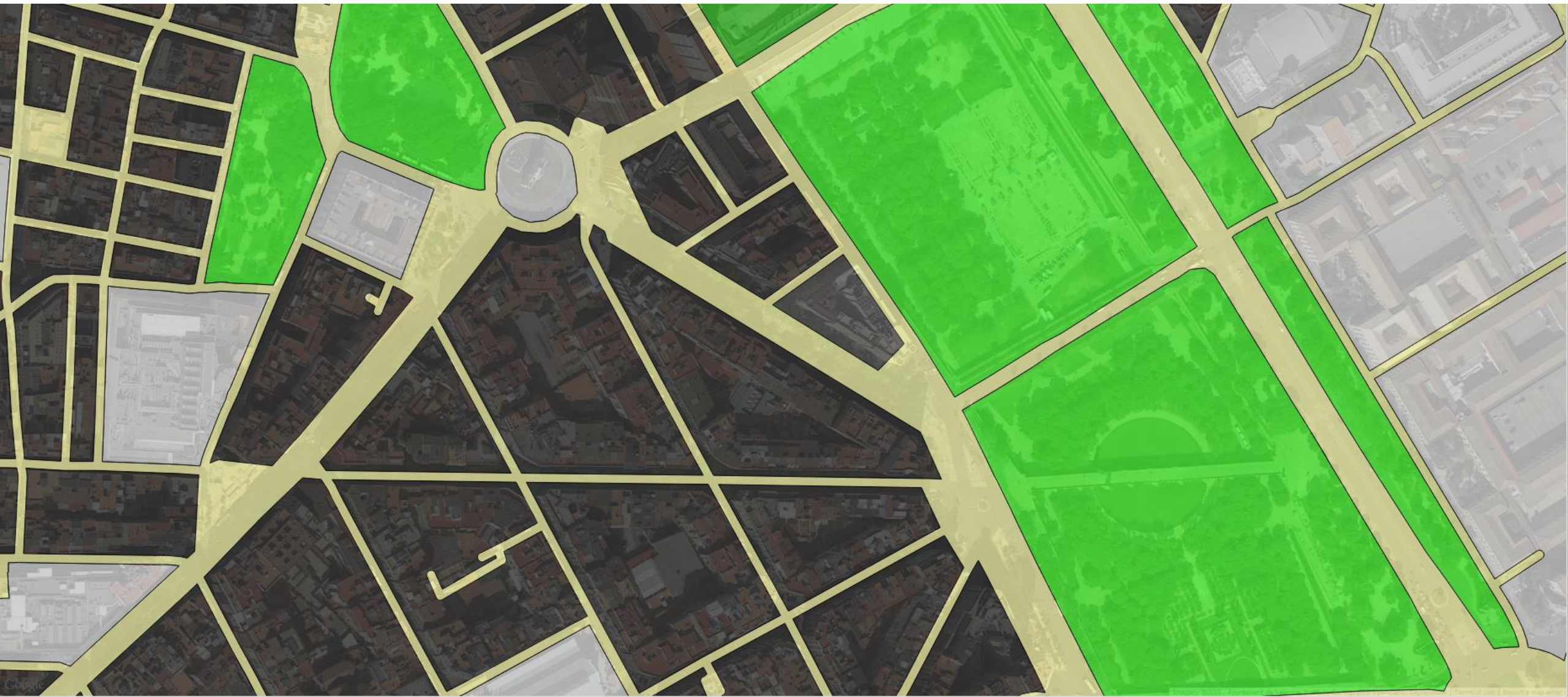




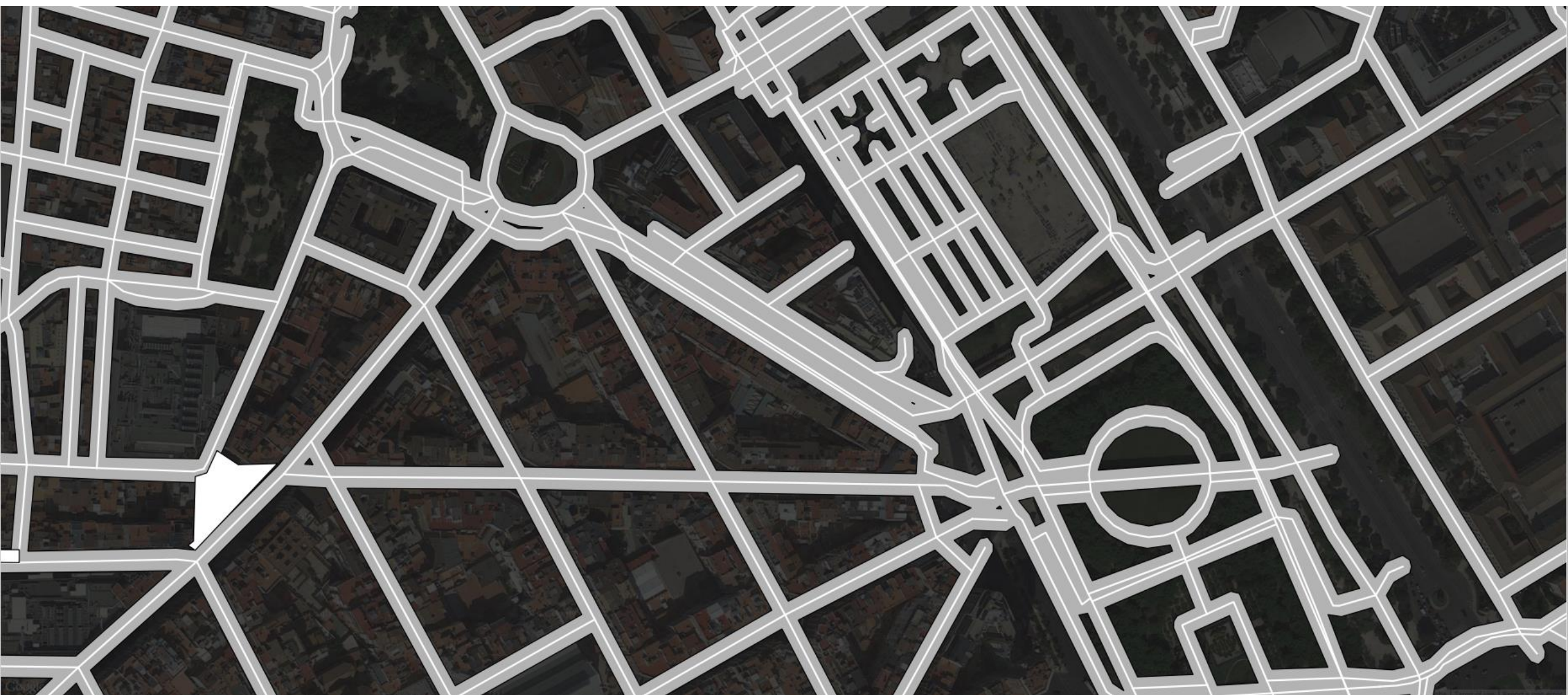
















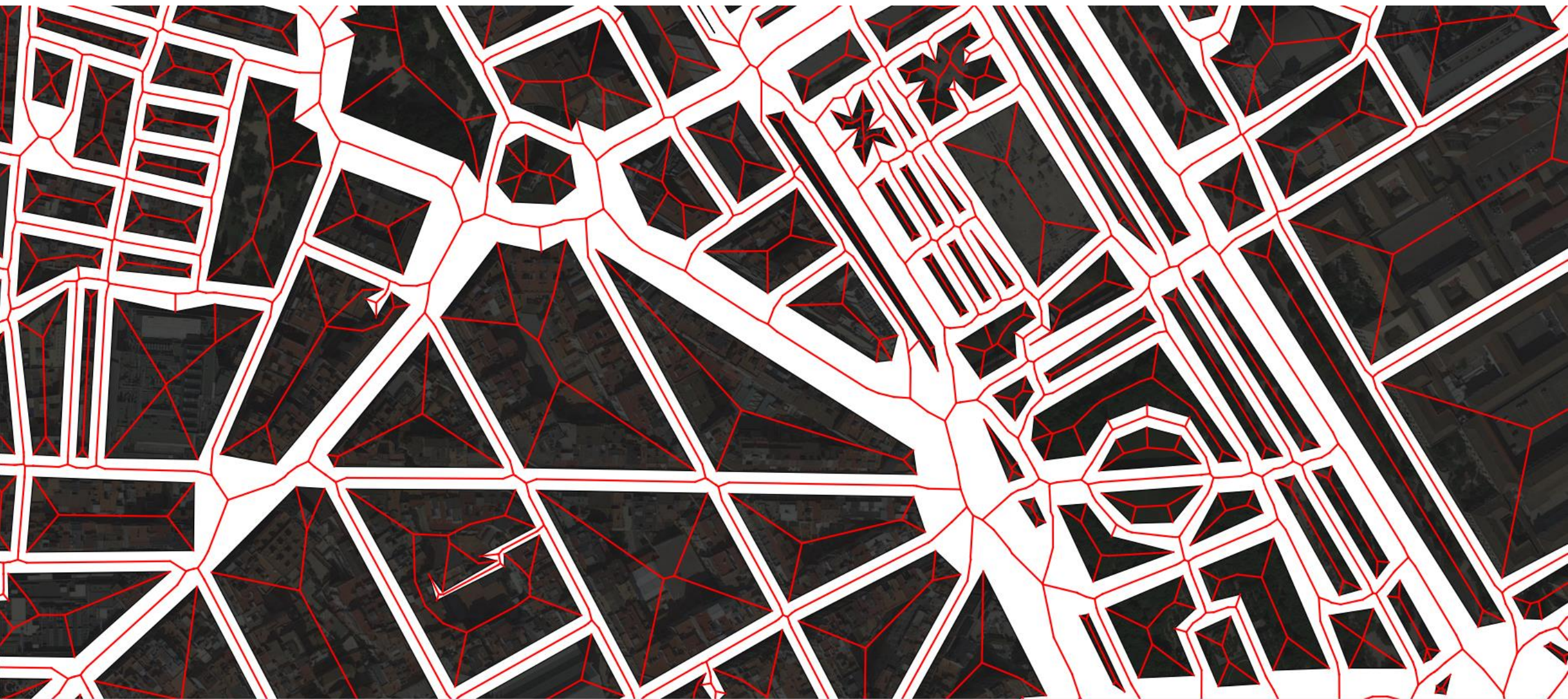




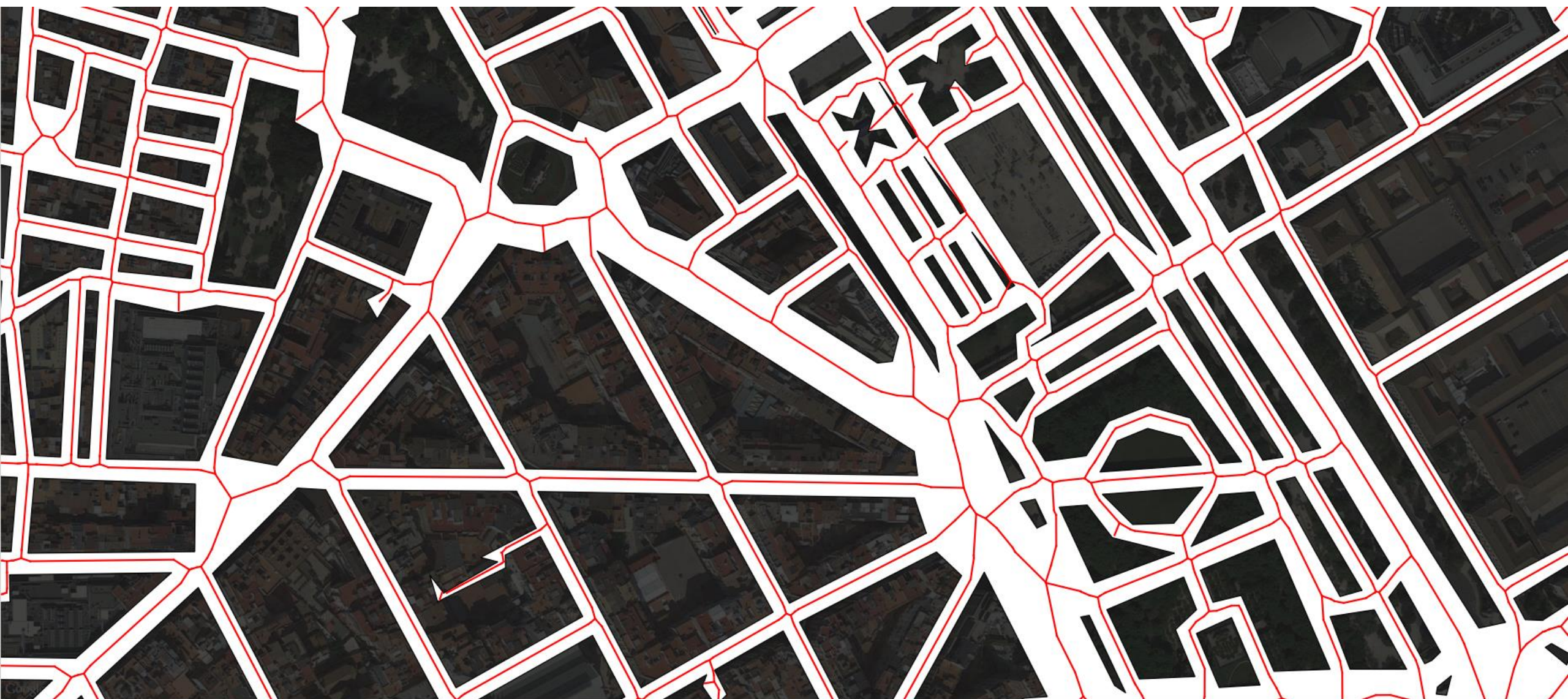












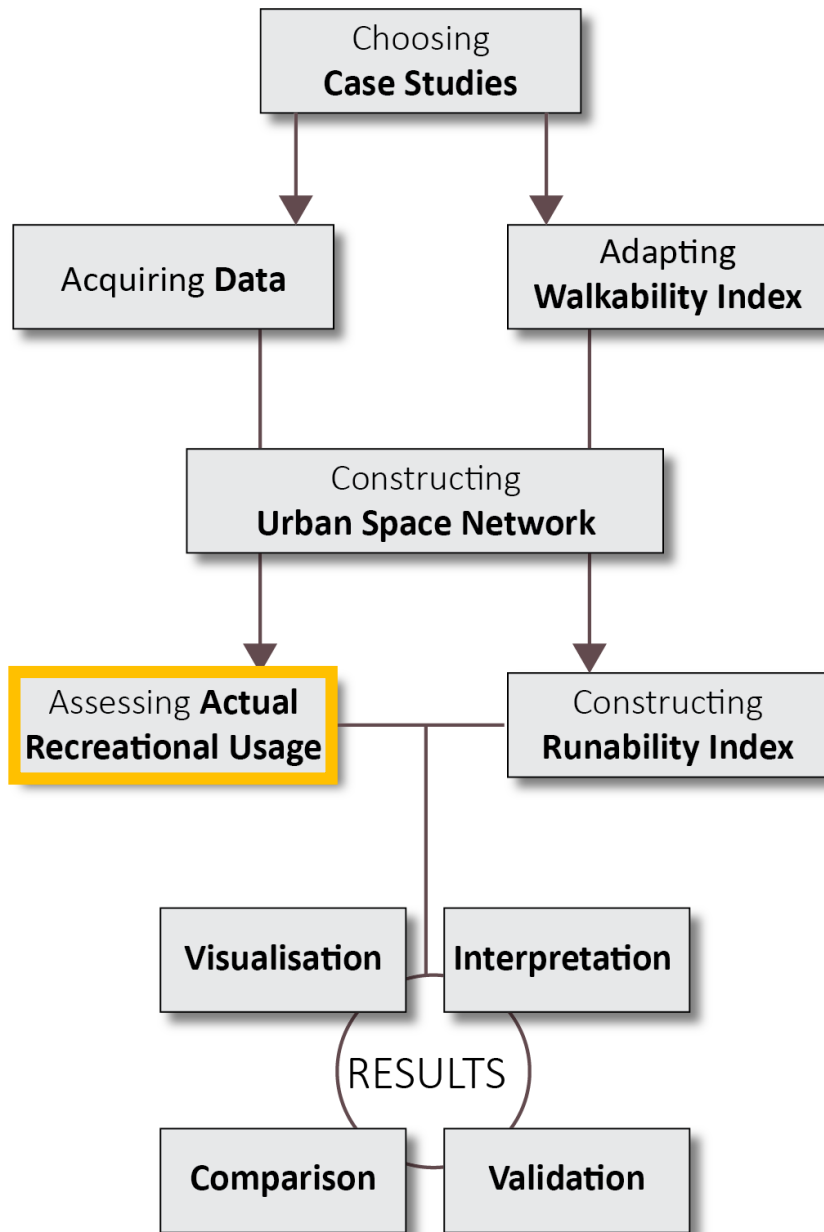




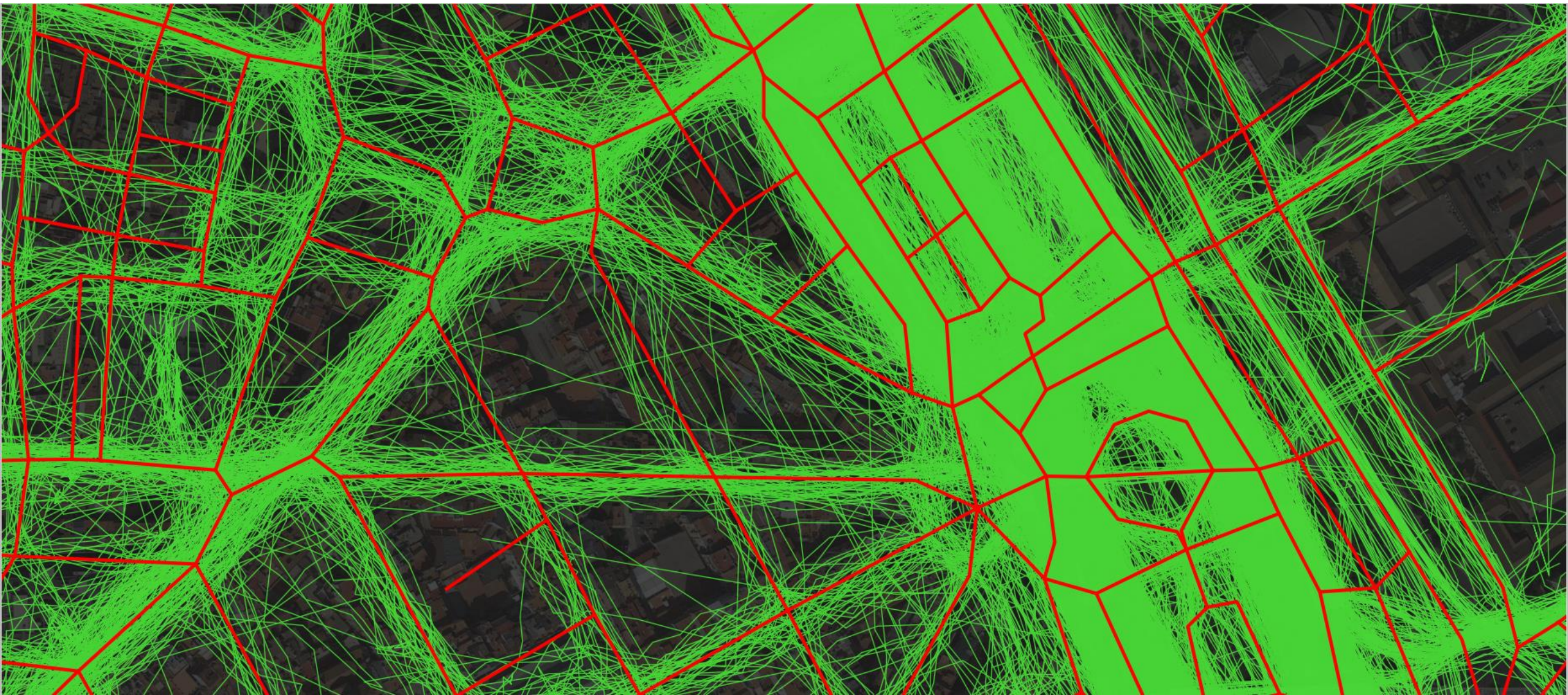




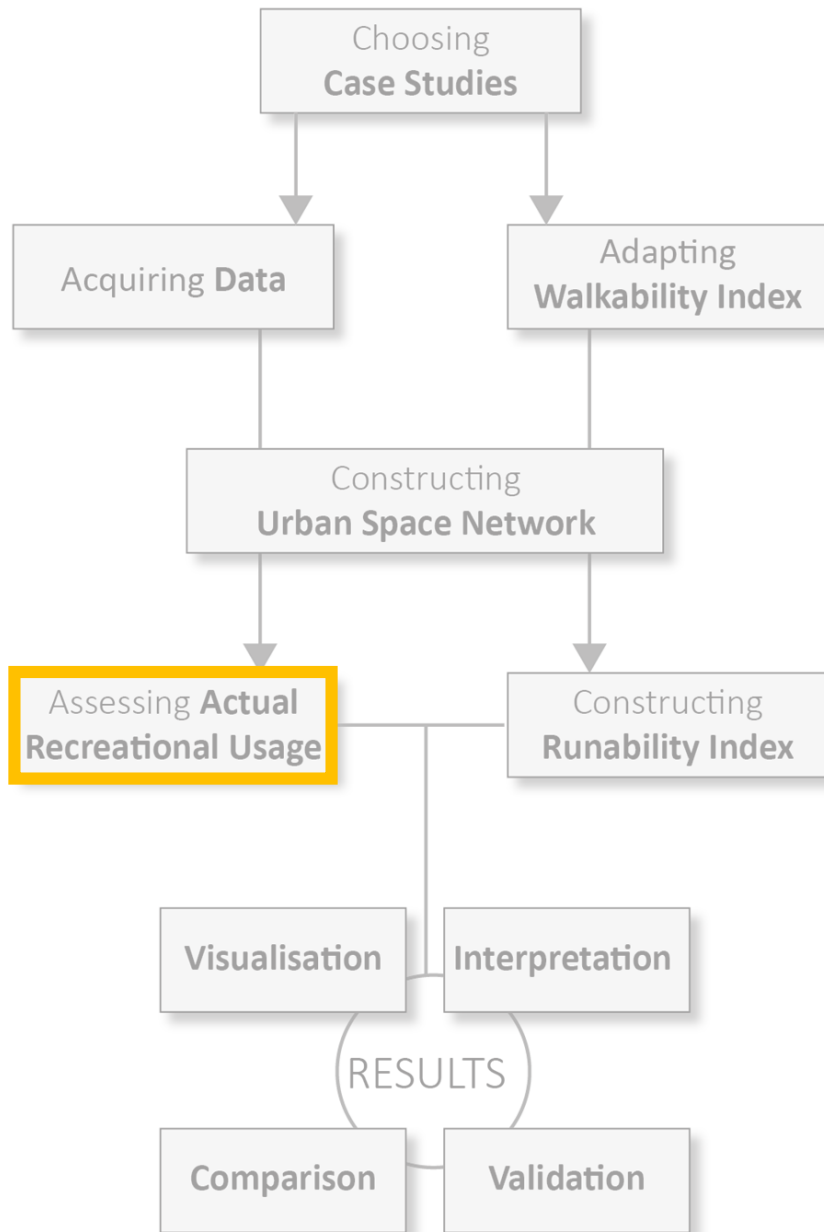












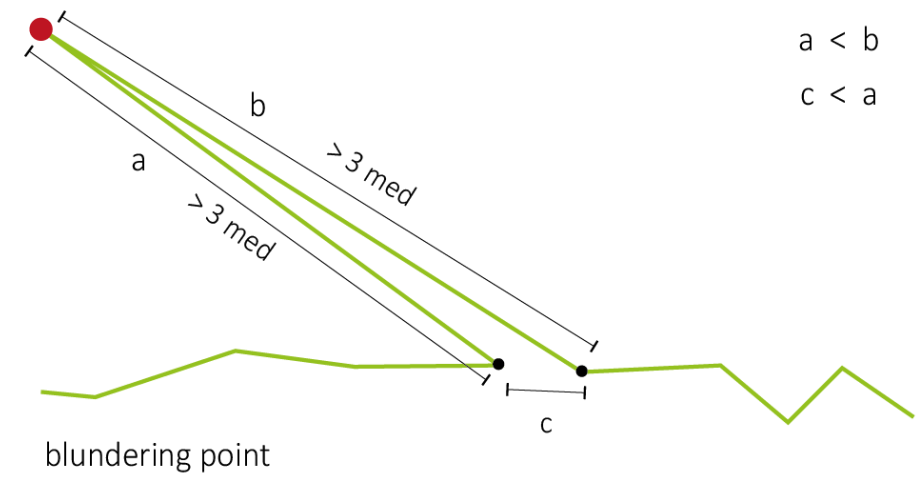
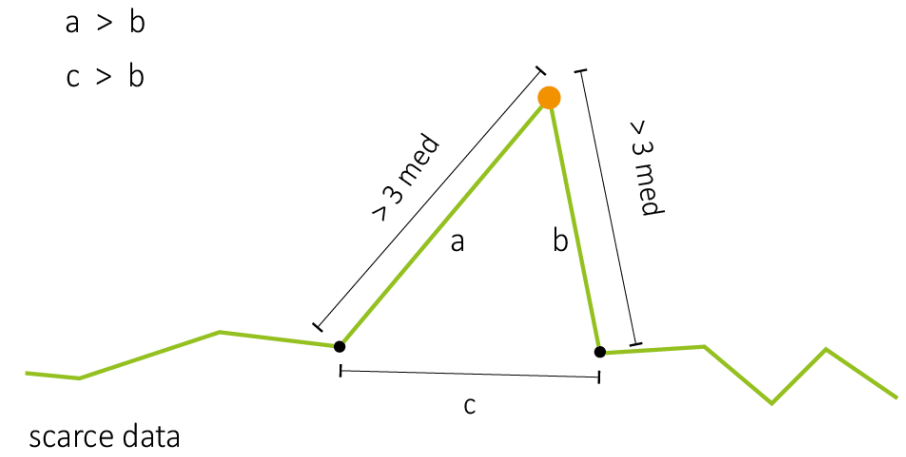
filtering outliers

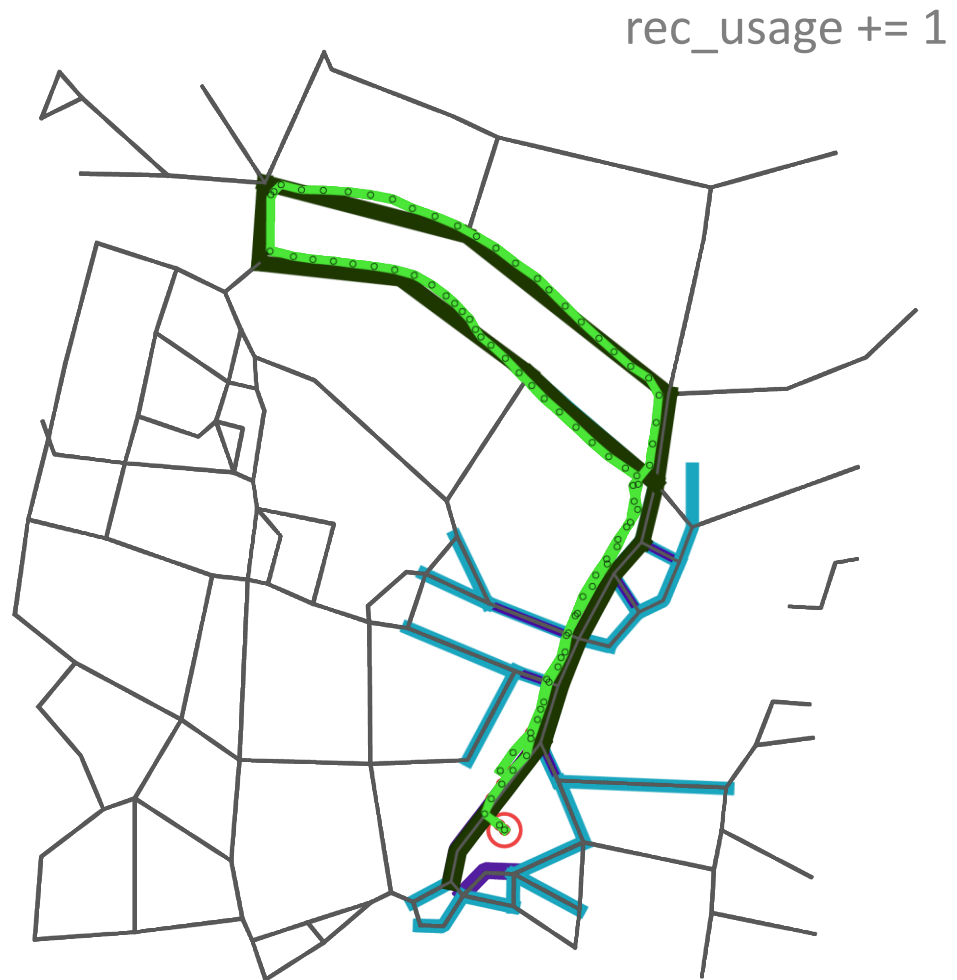
snapping to the network

evaluating actual recreational usage





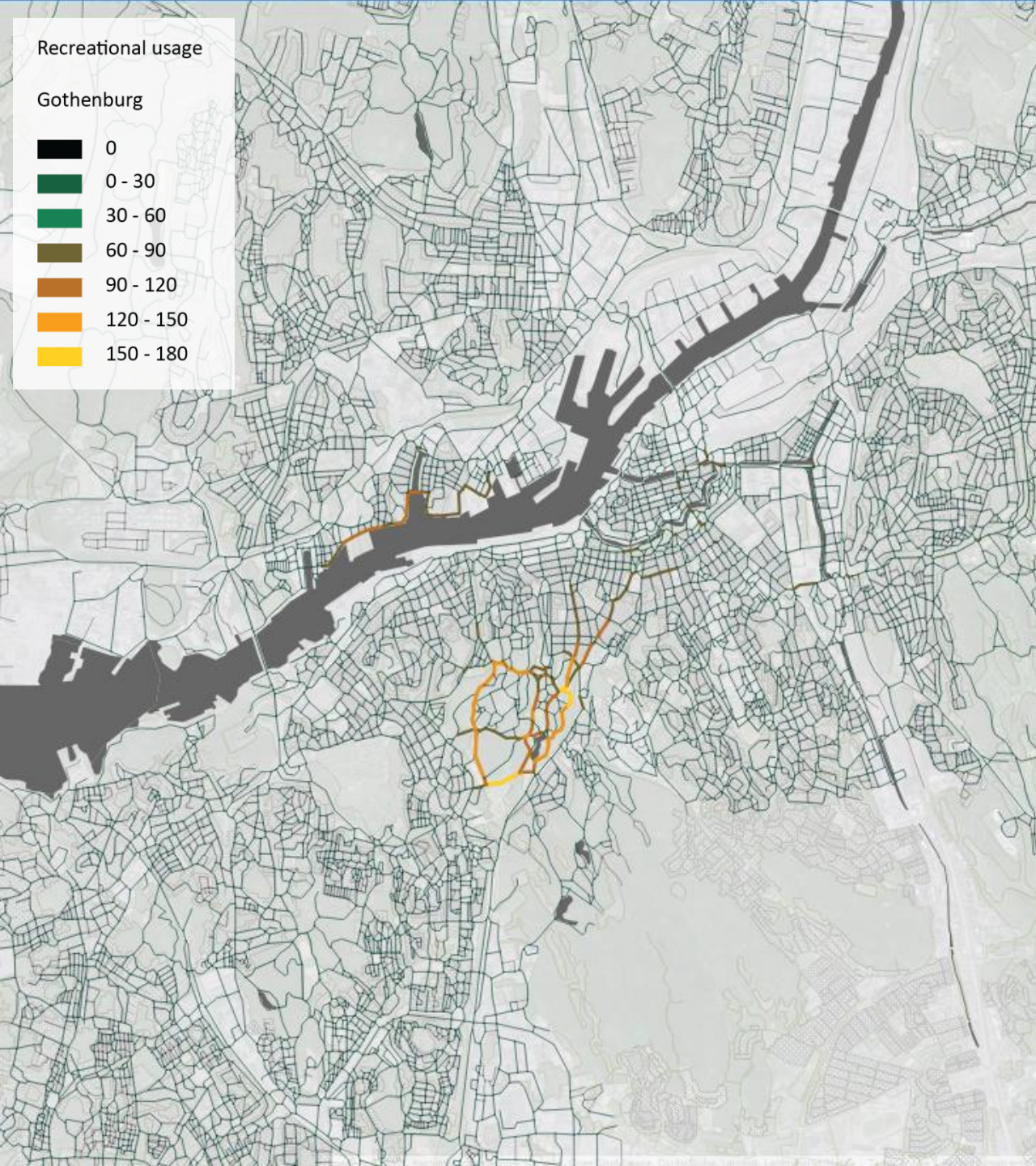




filtering outliers

snapping to the network

evaluating actual recreational usage

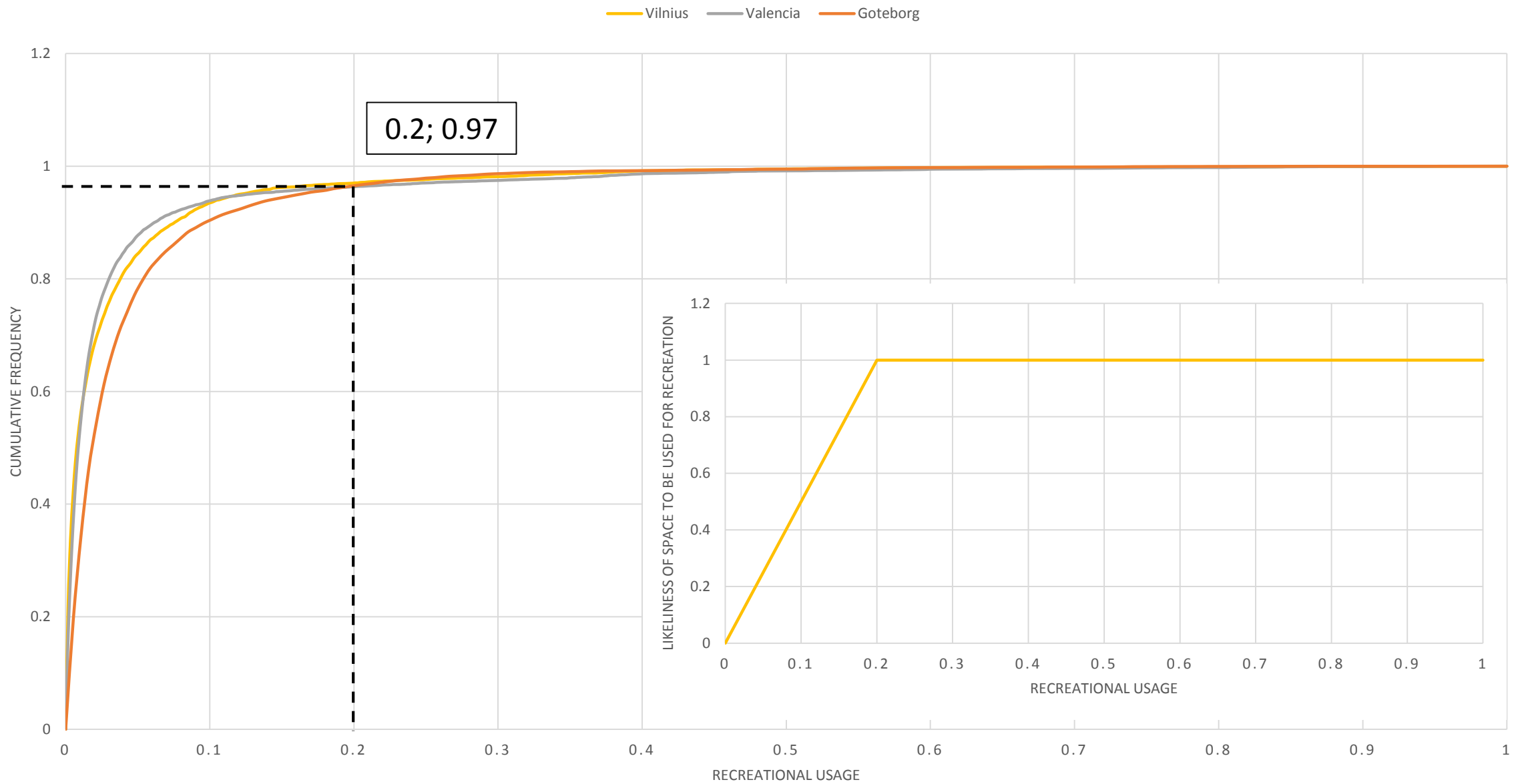


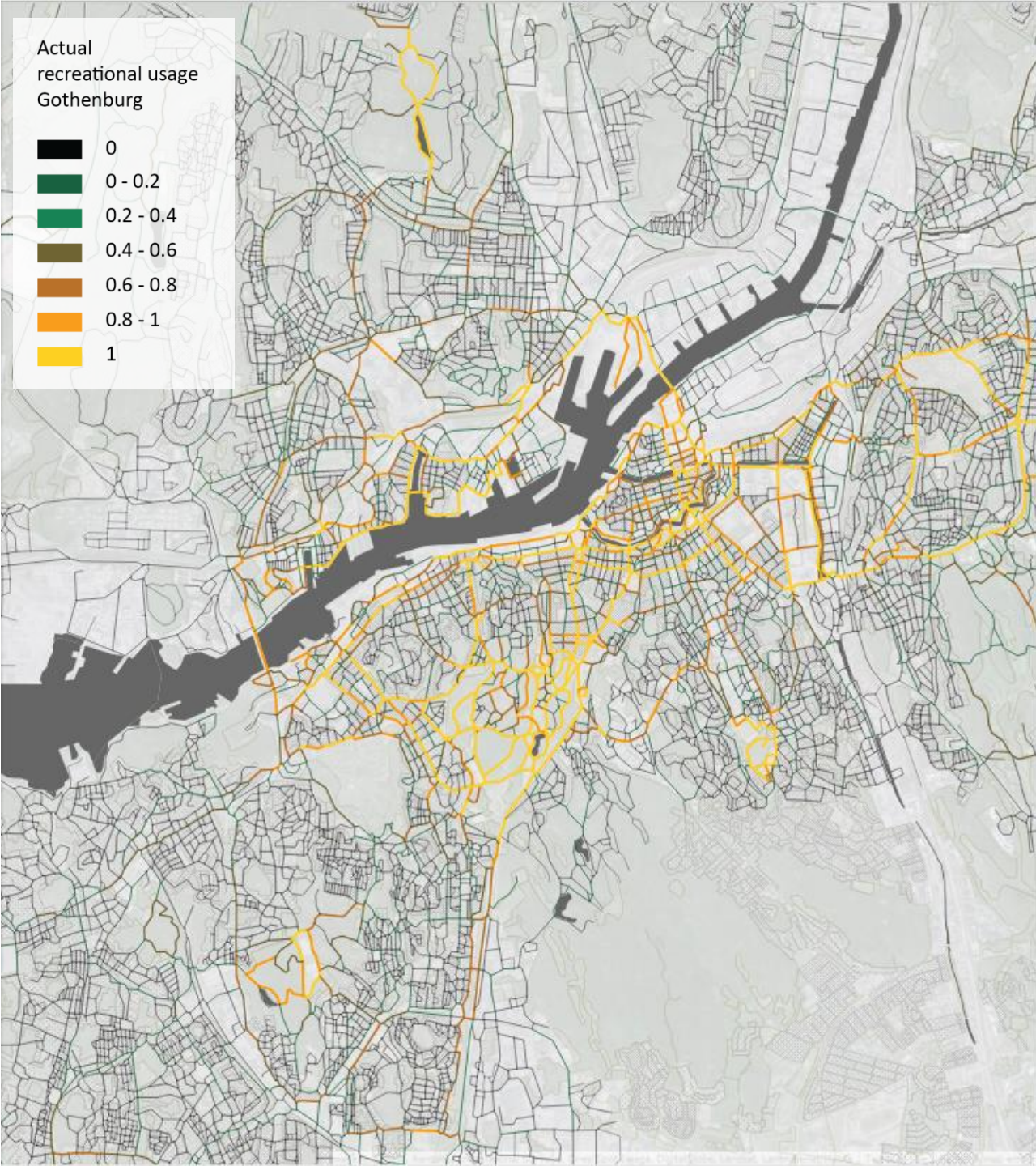
filtering outliers

snapping to the network

evaluating actual recreational usage





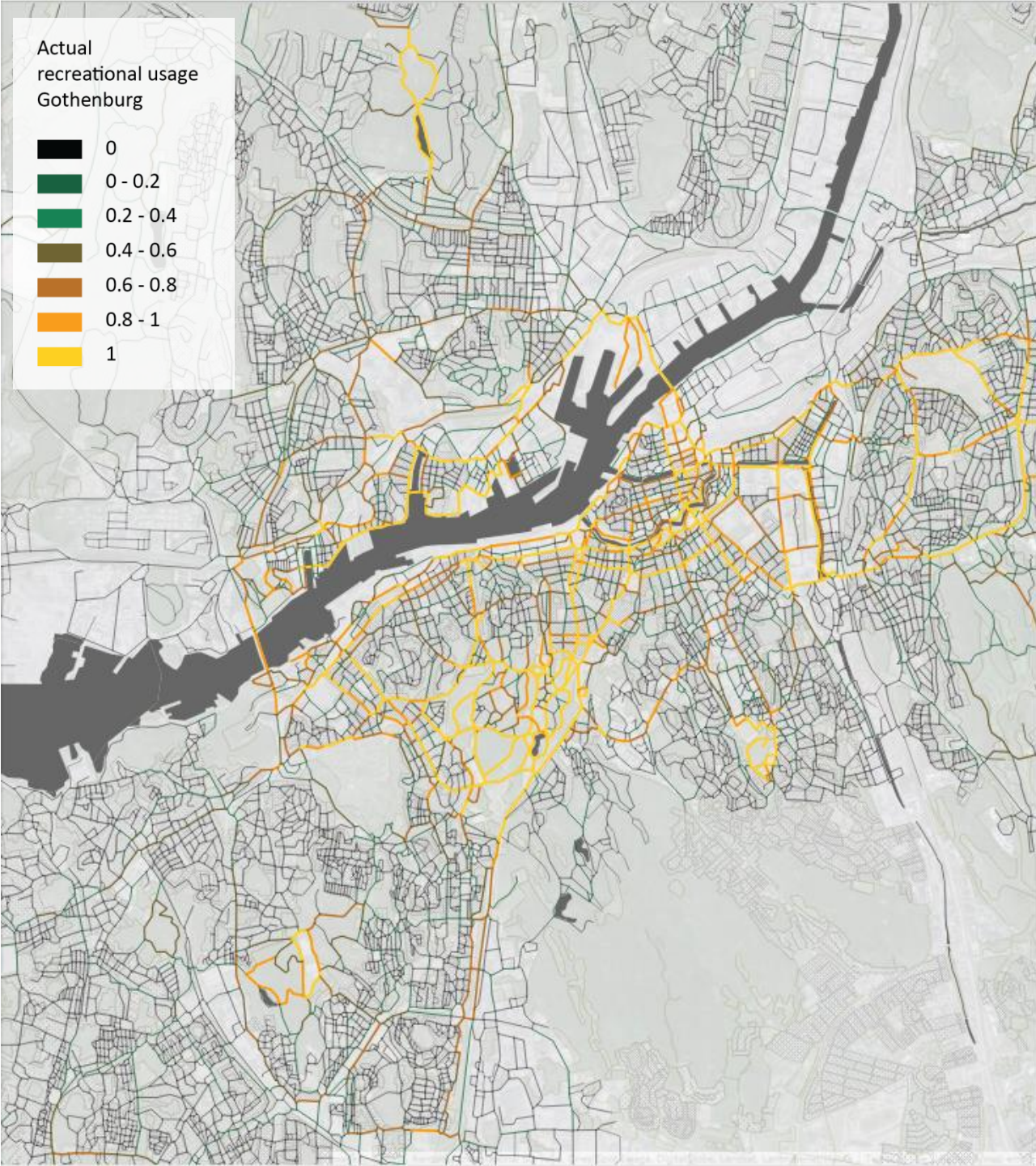


filtering outliers

snapping to the network

**evaluating actual recreational usage**





## application users:

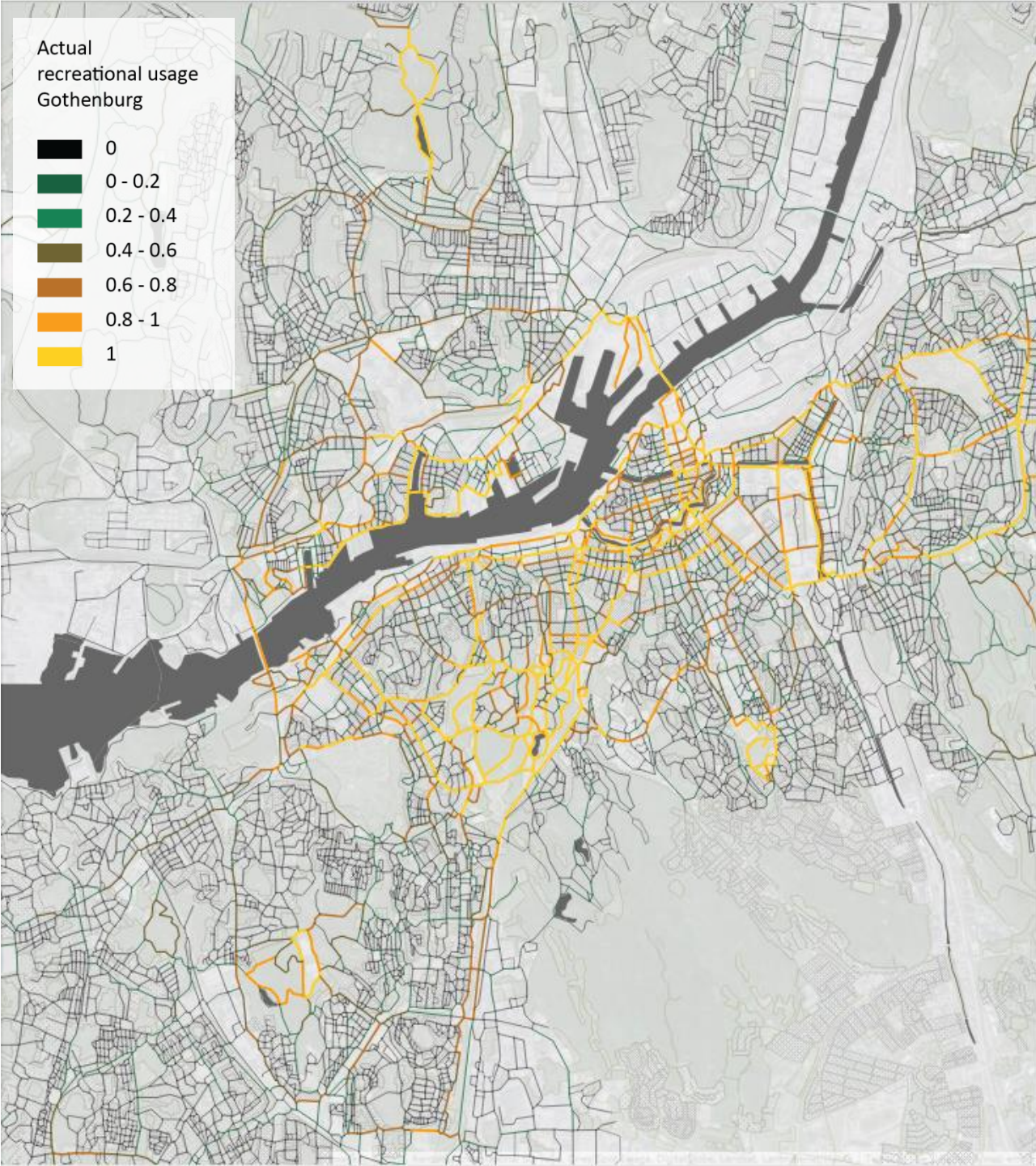
smart-device owners

75% men, 25% women

15 to 50 years old (97%)

## misuse of the application





Application use  
smart device owners

# BIG

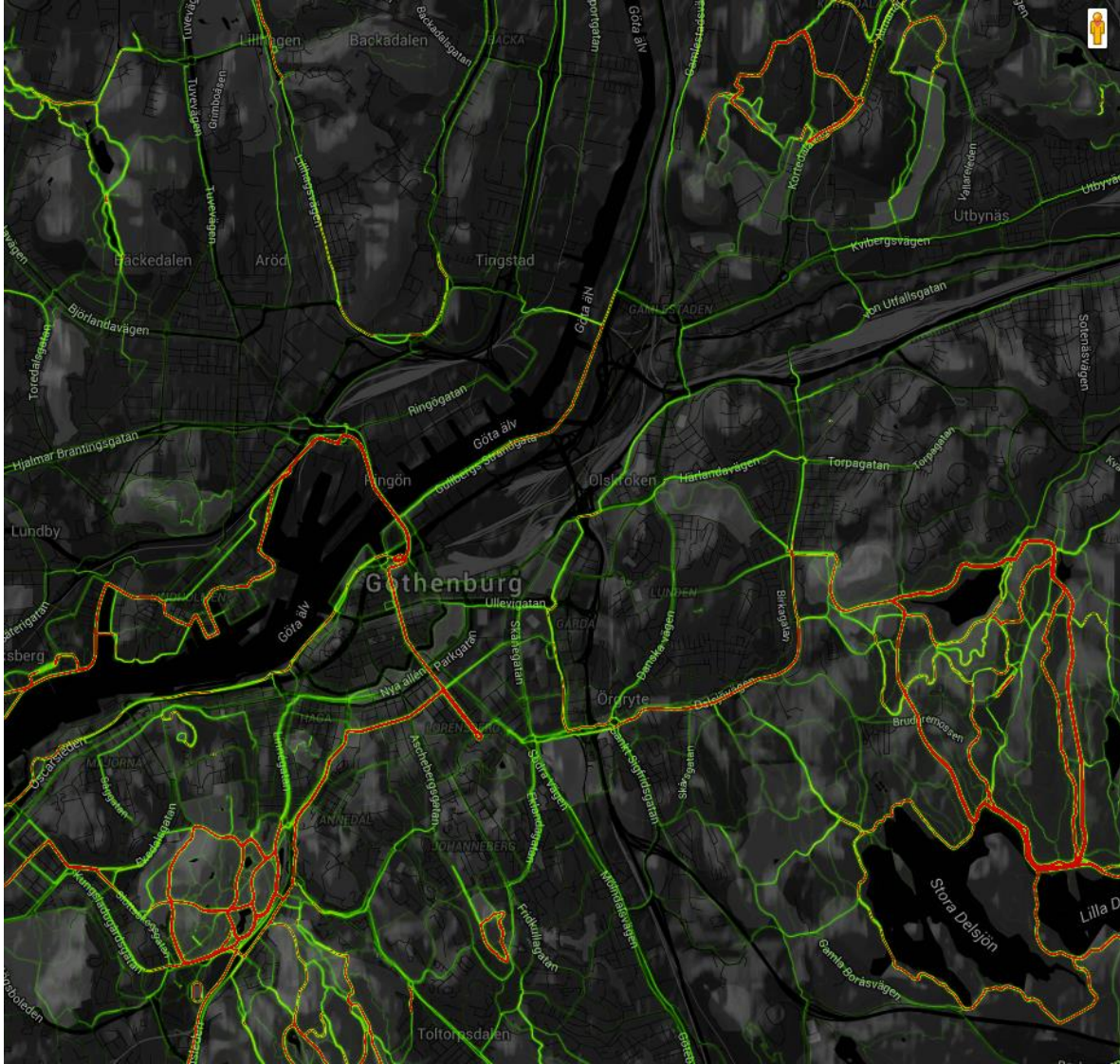
75% men, 25% women

15 to 50 years old (97%)

Analysis of the application

# DATA

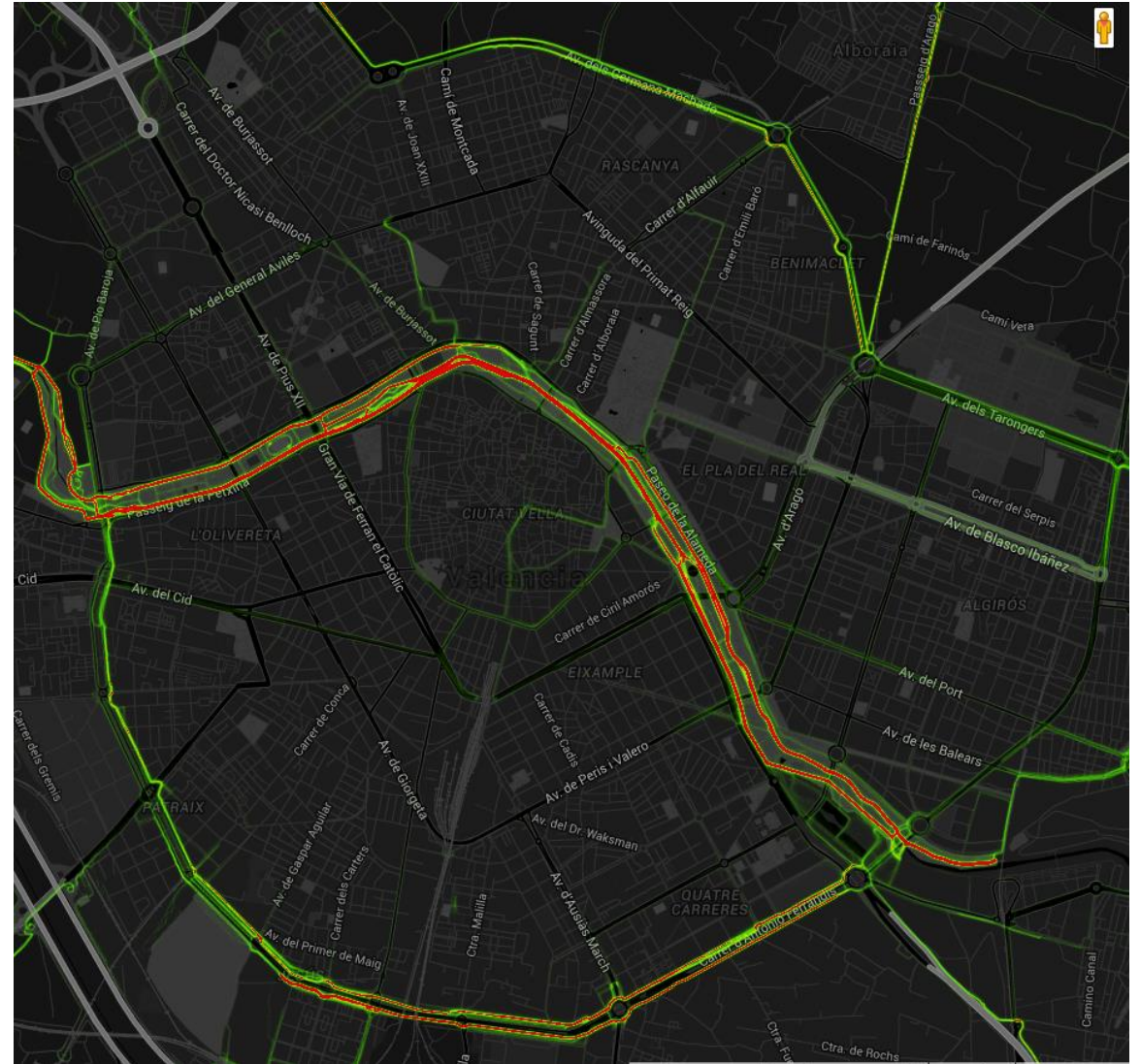
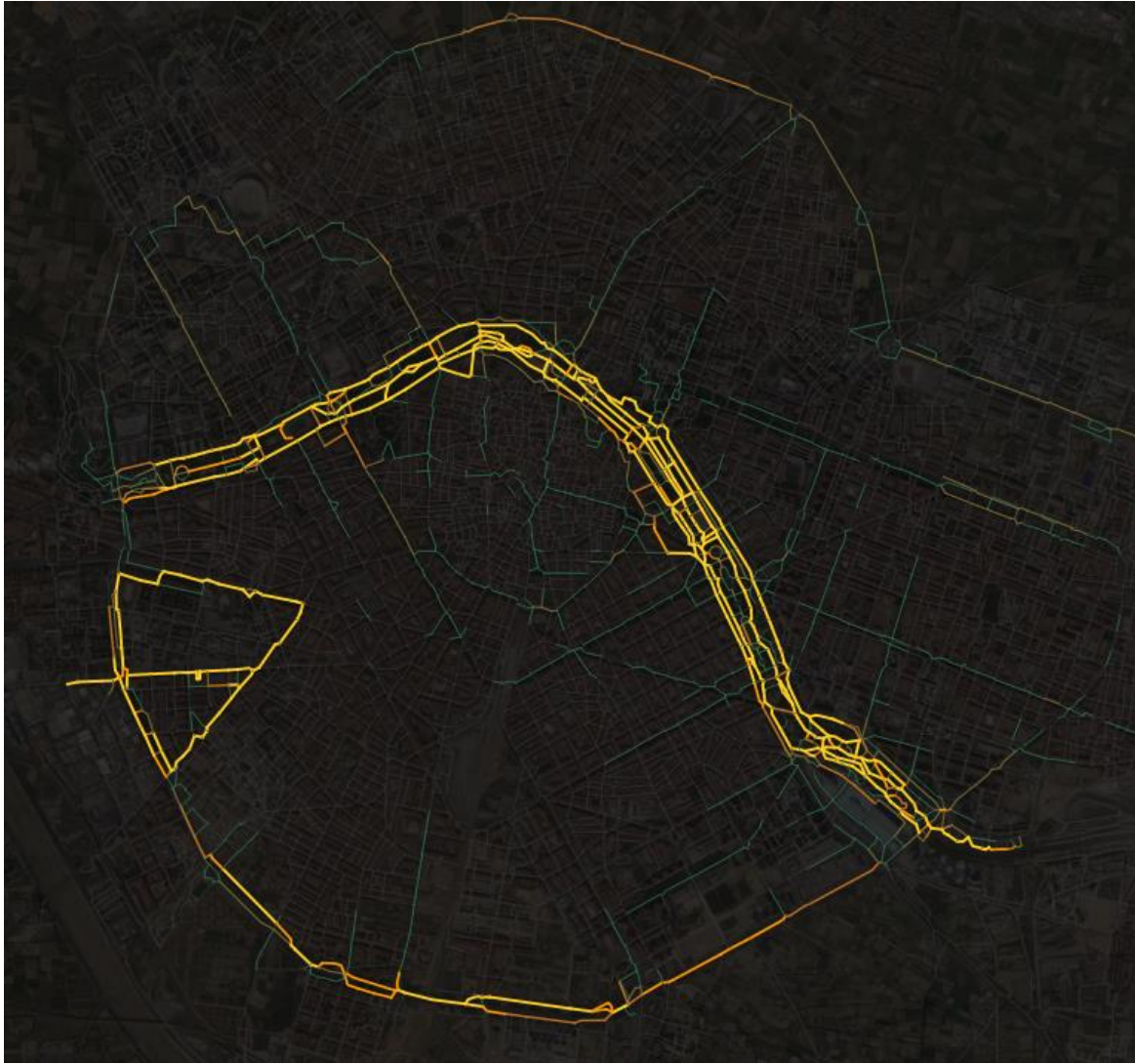


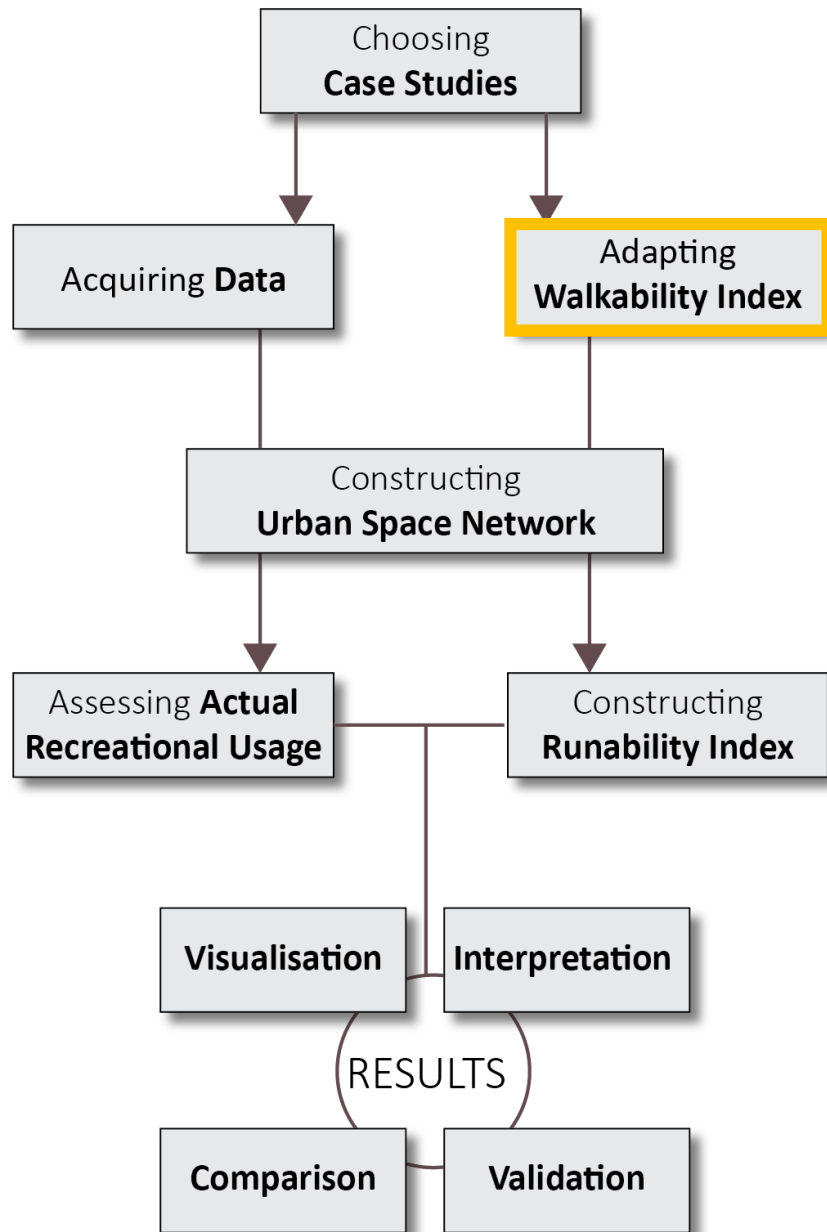












**where** recreational activities happen

**where** recreational activities do not happen

**WHY**

## walkability index:

land use mix

+

street connectivity (street network configuration)

+

population density

+

greenness

Henderson (2005), Cohen et al. (2006, 2007) Leslie et al., (2007), Floyd et al. (2008), Maroko et al. (2009), Brown et al. (2009), van Dyck et al. (2010), Troped et al. (2010), Cutumisu (2011), Yamada et al. (2012), Choi (2013)

## runability index:

land use mix (recreational&residential)

+

betweenness centrality

+

residential density

+

greenness

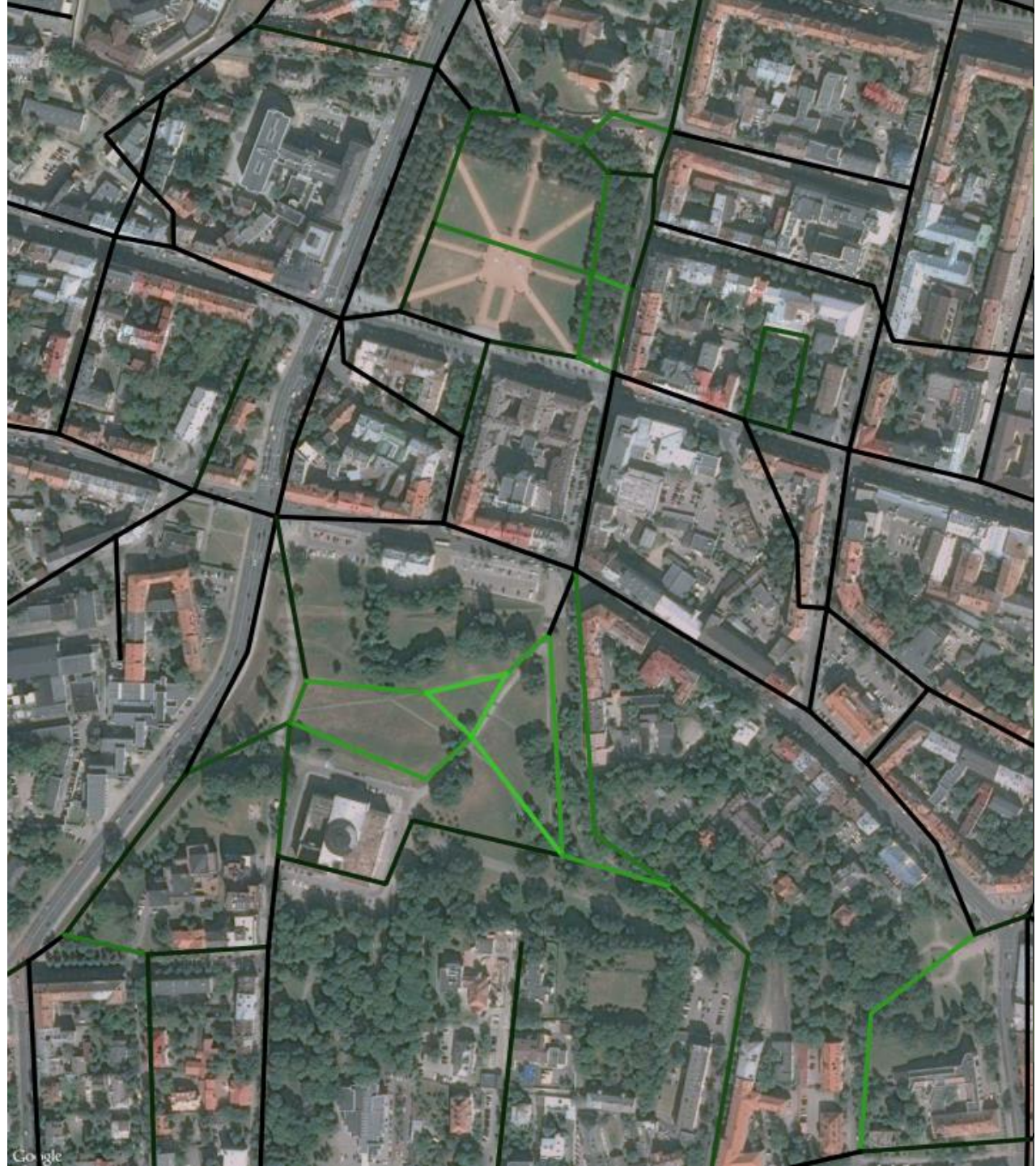


greenness

Normalised Difference Vegetation Index  
(NDVI)

average of NDVI values per street segment

normalised per each city



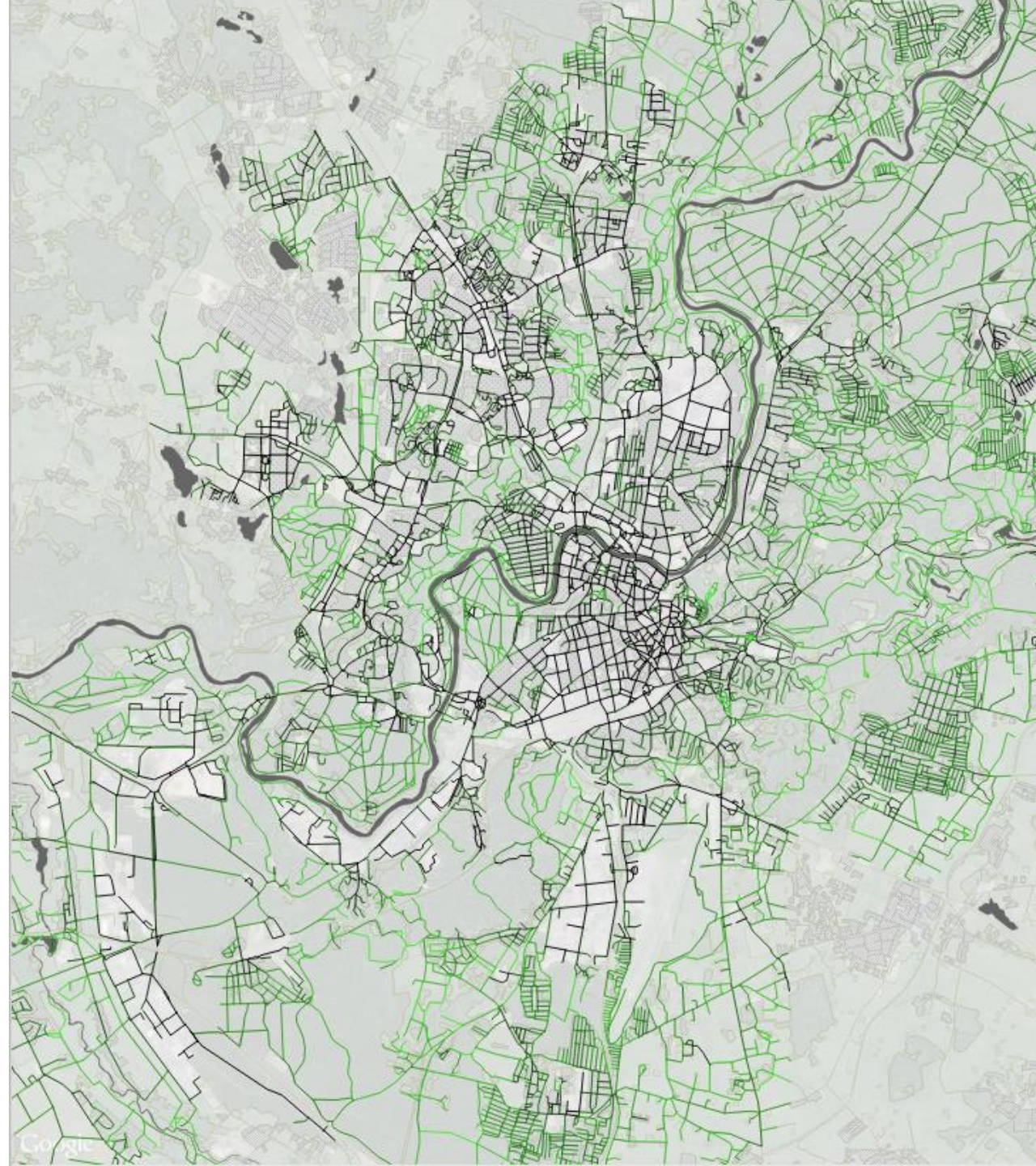


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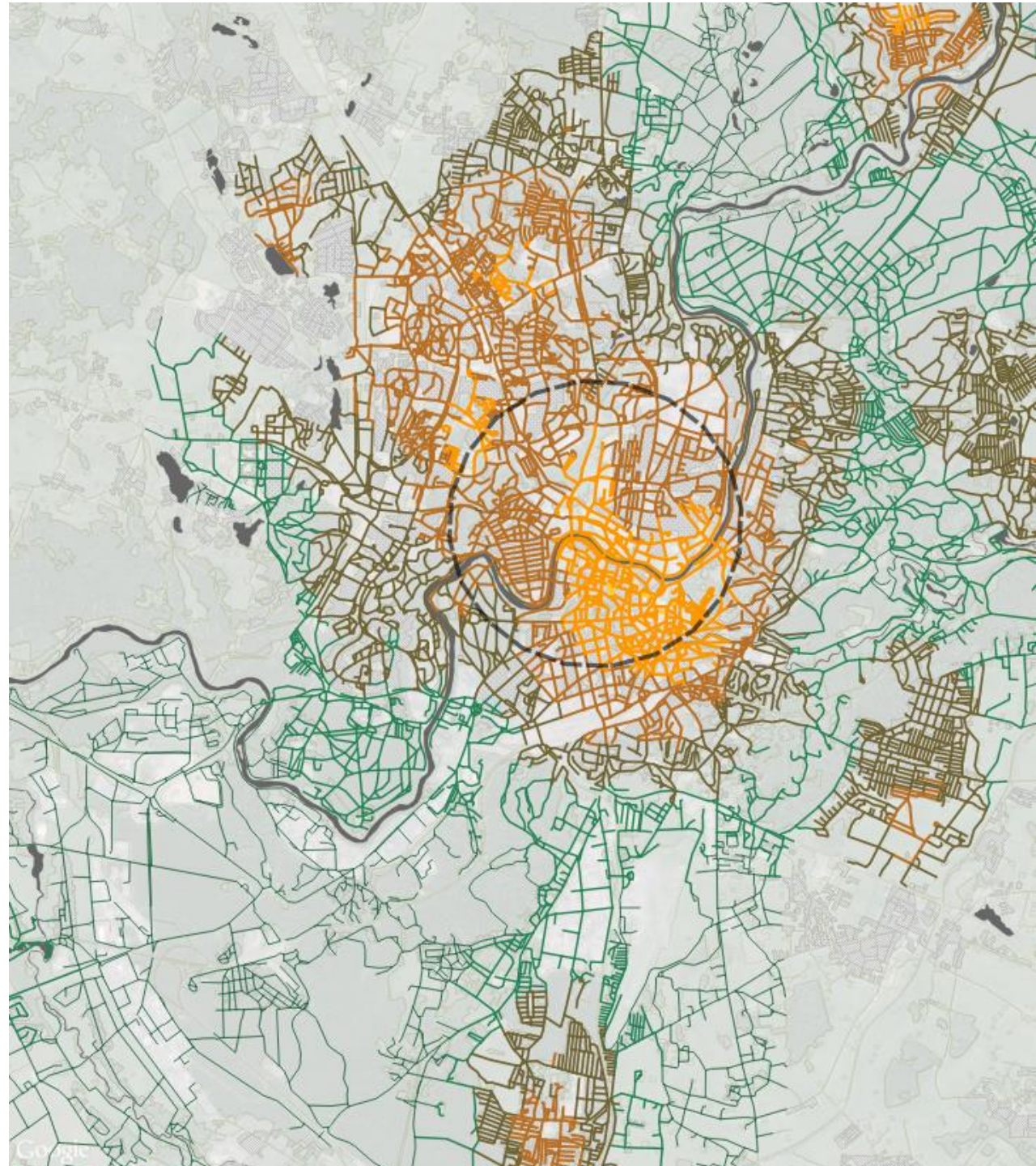


residential density

land covered with residential buildings

≠

population density





## land use mix

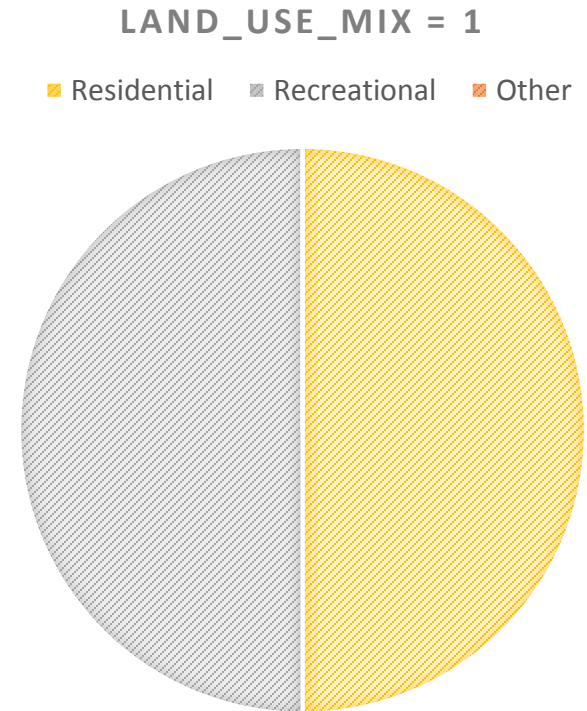
entropy score

$$land\_use\_mix = \frac{-1 \sum_i \frac{b_i}{a} * \ln(\frac{b_i}{\sum_i b_i})}{\ln(N)}$$

where

$b_i$  – area of a separate land use group within the buffer zone

$a$  – total area of a buffer



## land use mix

entropy score

$$land\_use\_mix = \frac{-1 \sum_i \frac{b_i}{a} * \ln(\frac{b_i}{\sum_i b_i})}{\ln(N)}$$

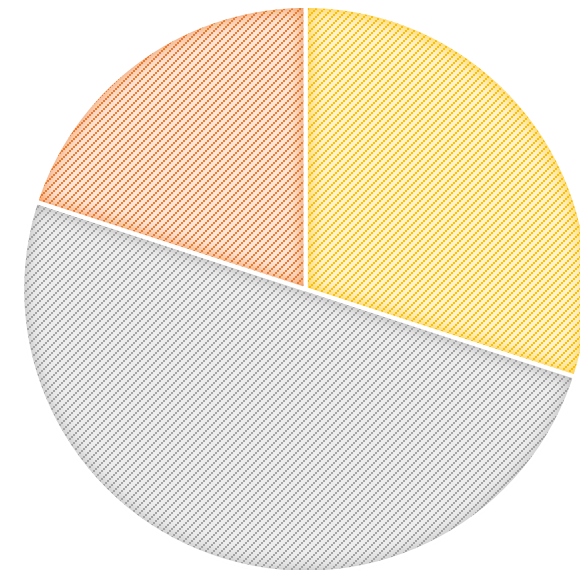
where

$b_i$  – area of a separate land use group within the buffer zone

$a$  – total area of a buffer

LAND\_USE\_MIX = 0.75

Residential Recreational Other





## land use mix

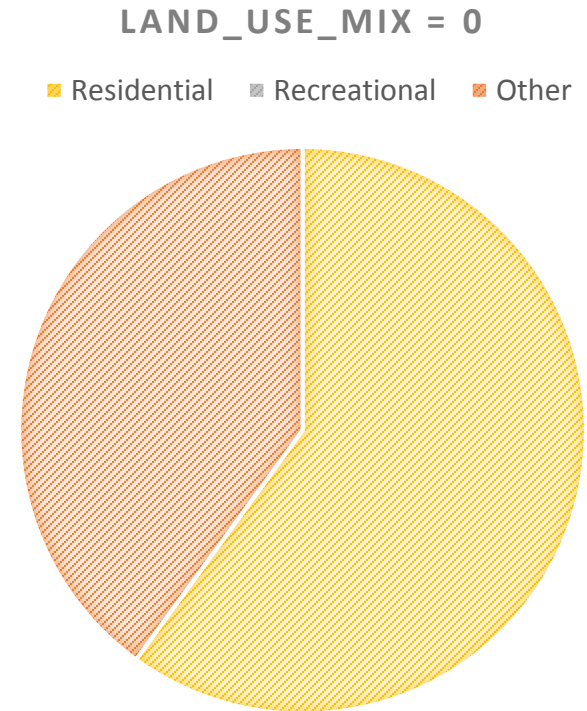
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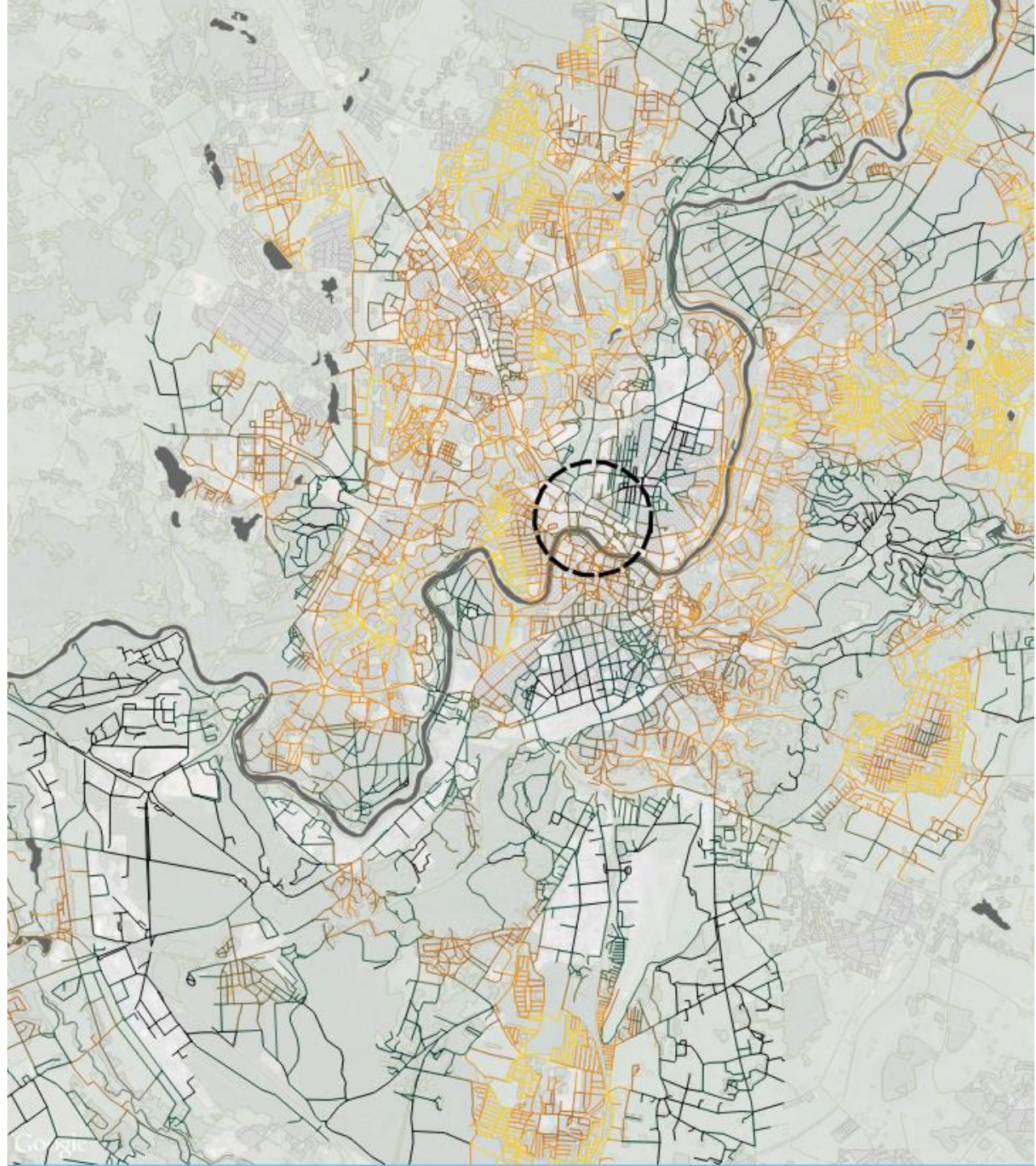
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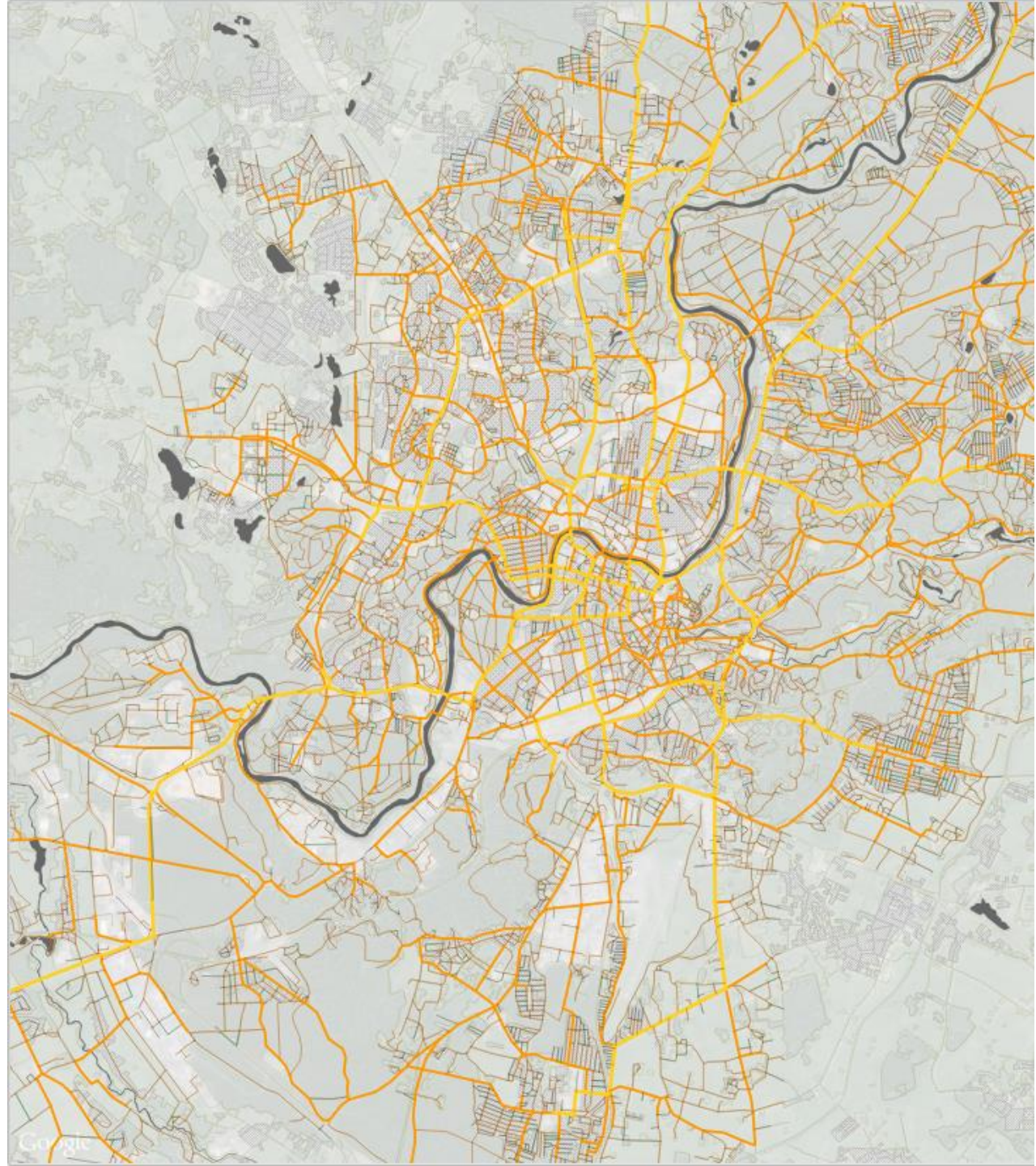
## betweenness centrality

### Normalised Angular Choice (NACH)

how often a network edge lies on a shortest path  
between all the nodes of the network, or its part within  
a certain radius, divided by the total sum of all possible  
shortest paths

when

shortest path = least angle change



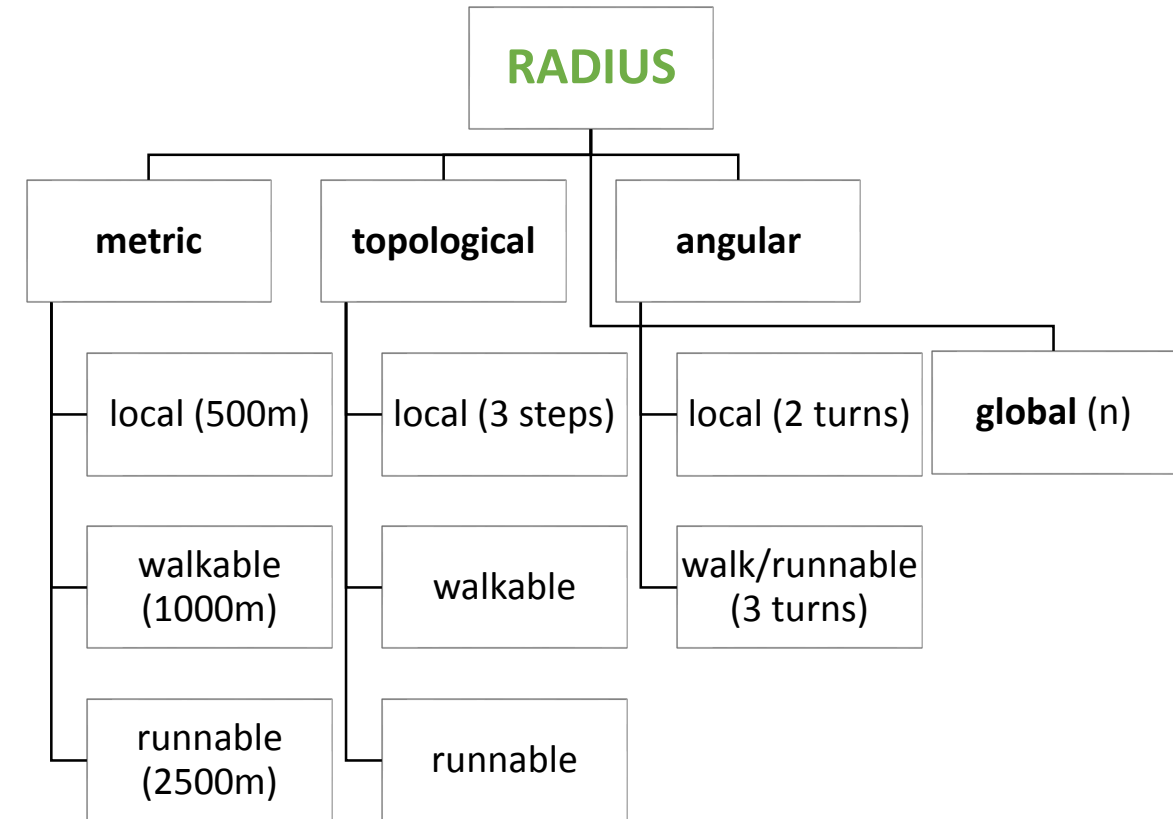
## betweenness centrality

### Normalised Angular Choice (NACH)

how often a network edge lies on a shortest path  
between all the nodes of the network, or its part within  
a certain radius, divided by the total sum of all possible  
shortest paths

when

shortest path = least angle change





## aggregators

arithmetic mean (greenness, landusemix, centrality, res.density)

geometric mean (greenness, landusemix, centrality, res.density)

fuzzy AND: min (greenness, landusemix, centrality, res.density)

fuzzy OR: max (greenness, landusemix, centrality, res.density)

1 (greenness)

x

1 (res\_density)

x

3 (land\_use\_mix)

x

9 (centrality)

x

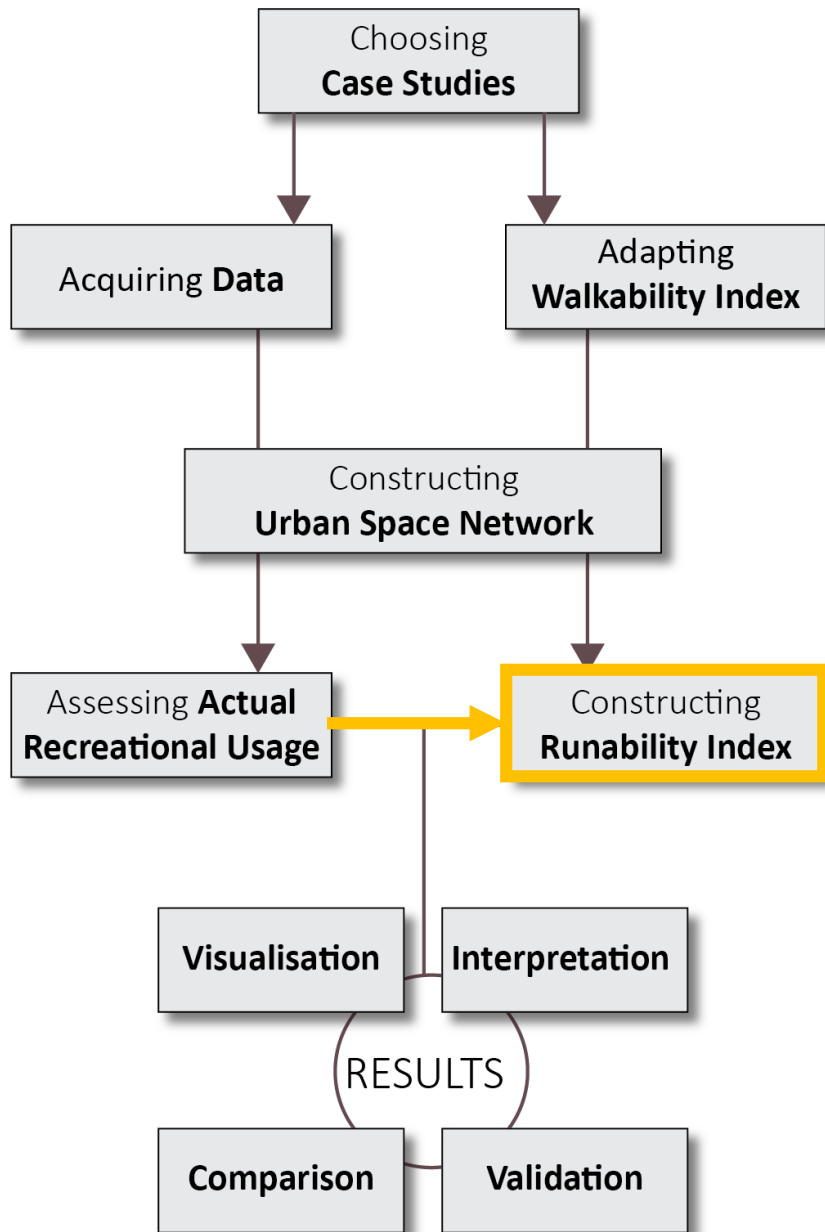
4 (aggregators)

=

108 Possibilities

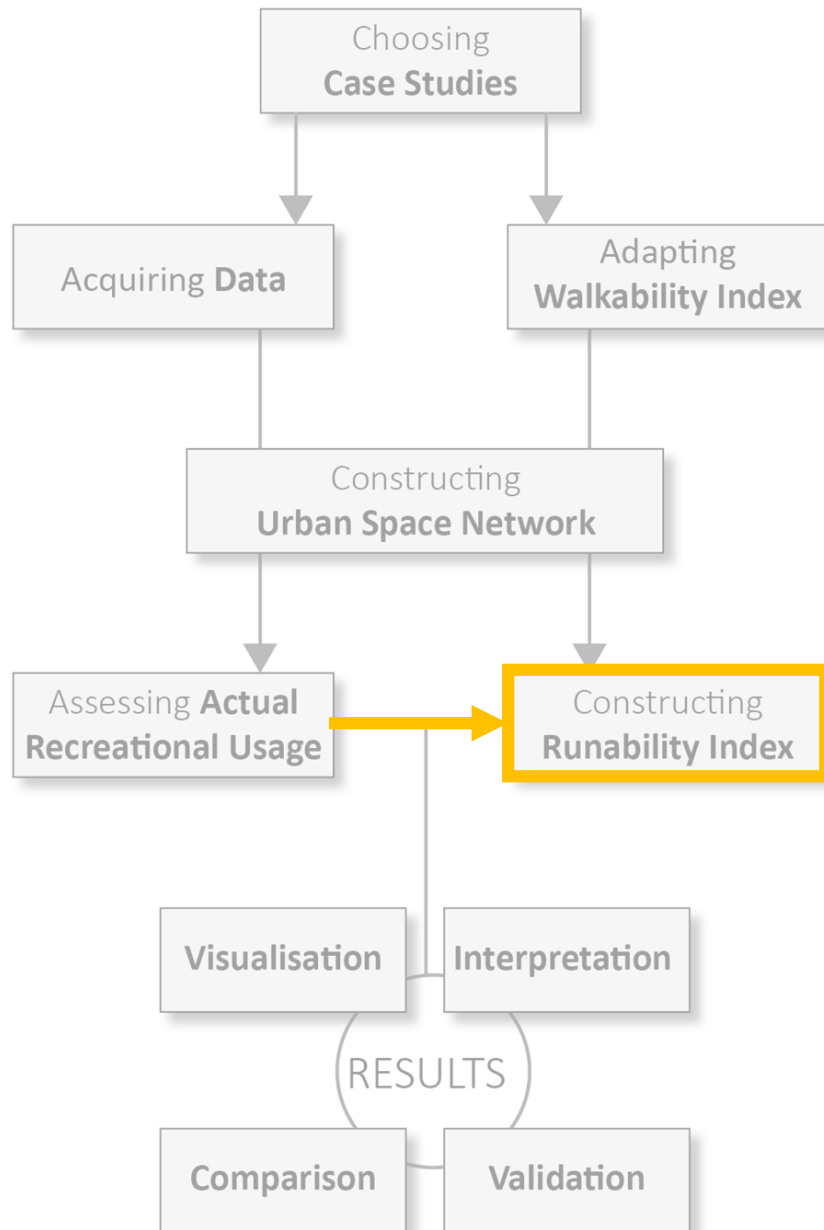
x

3 cities



$$\begin{aligned}
 &1 \text{ (greenness)} \\
 &\quad \times \\
 &1 \text{ (res\_density)} \\
 &\quad \times \\
 &3 \text{ (land\_use\_mix)} \\
 &\quad \times \\
 &9 \text{ (centrality)} \\
 &\quad \times \\
 &4 \text{ (aggregators)} \\
 &= \\
 &108 \text{ Possibilities} \\
 &\quad \times \\
 &3 \text{ cities}
 \end{aligned}$$

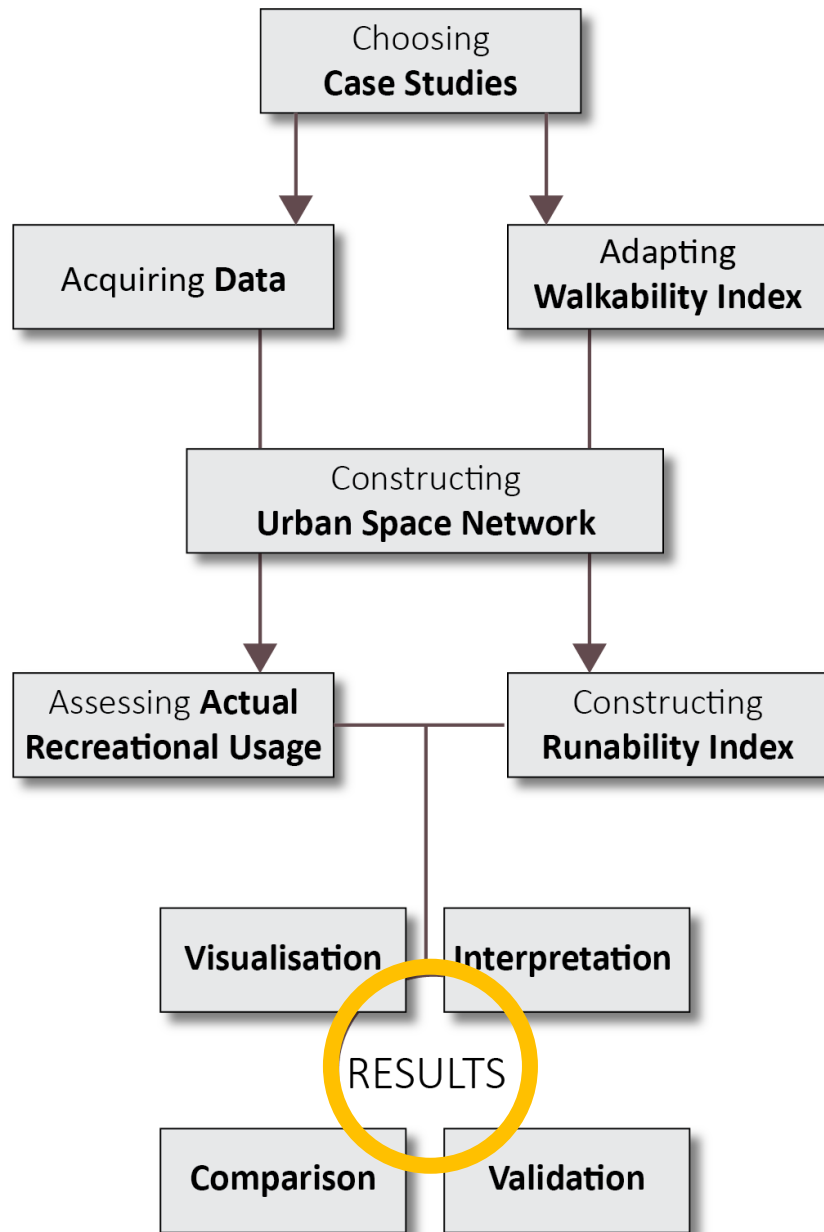




RMSE

R-squared

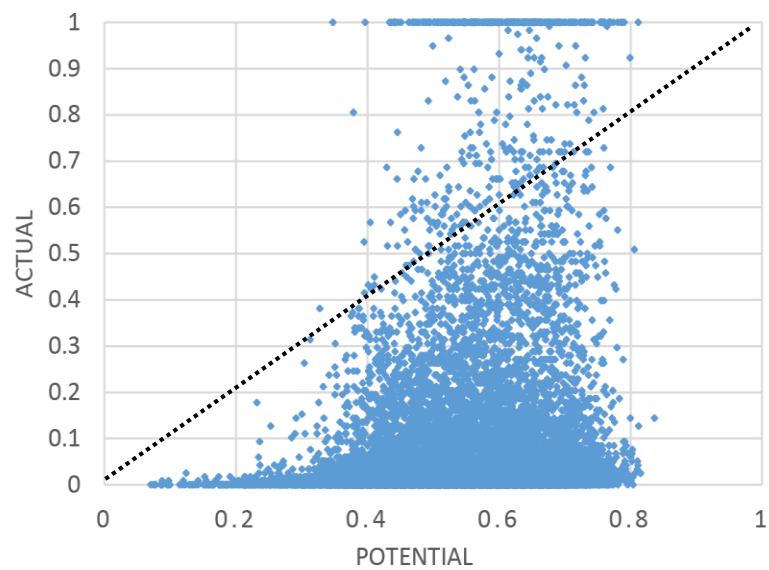
$$\frac{\text{Greenness} + \text{residential density } 2500\text{m} + \text{land use mix } 500\text{m } r + \text{NACH } n}{4}$$



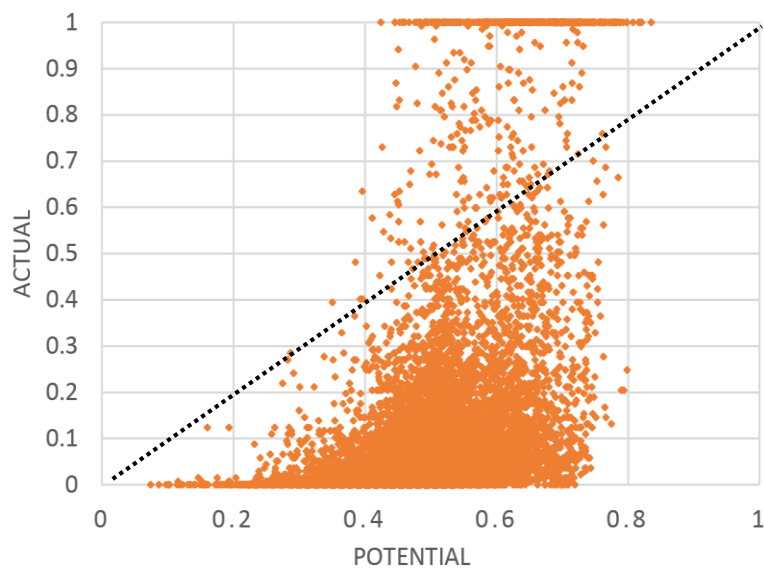


## VILNIUS

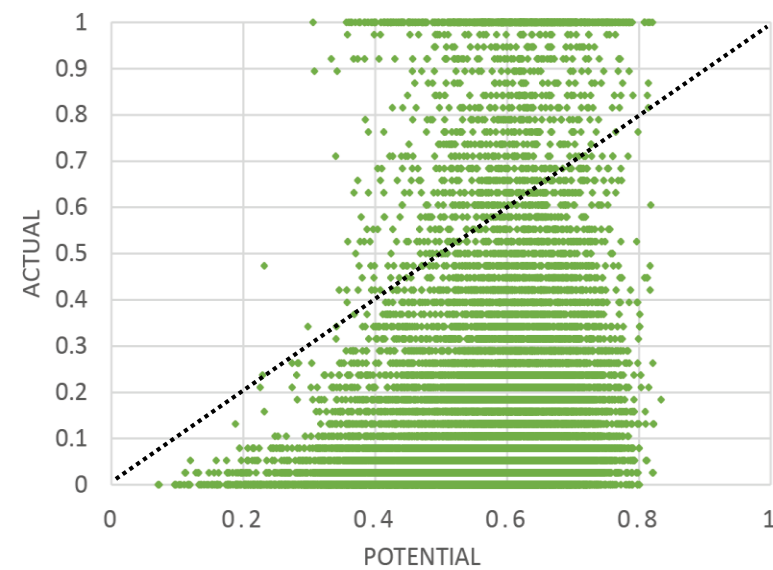
### ARITHMETIC MEAN



## VALENCIA

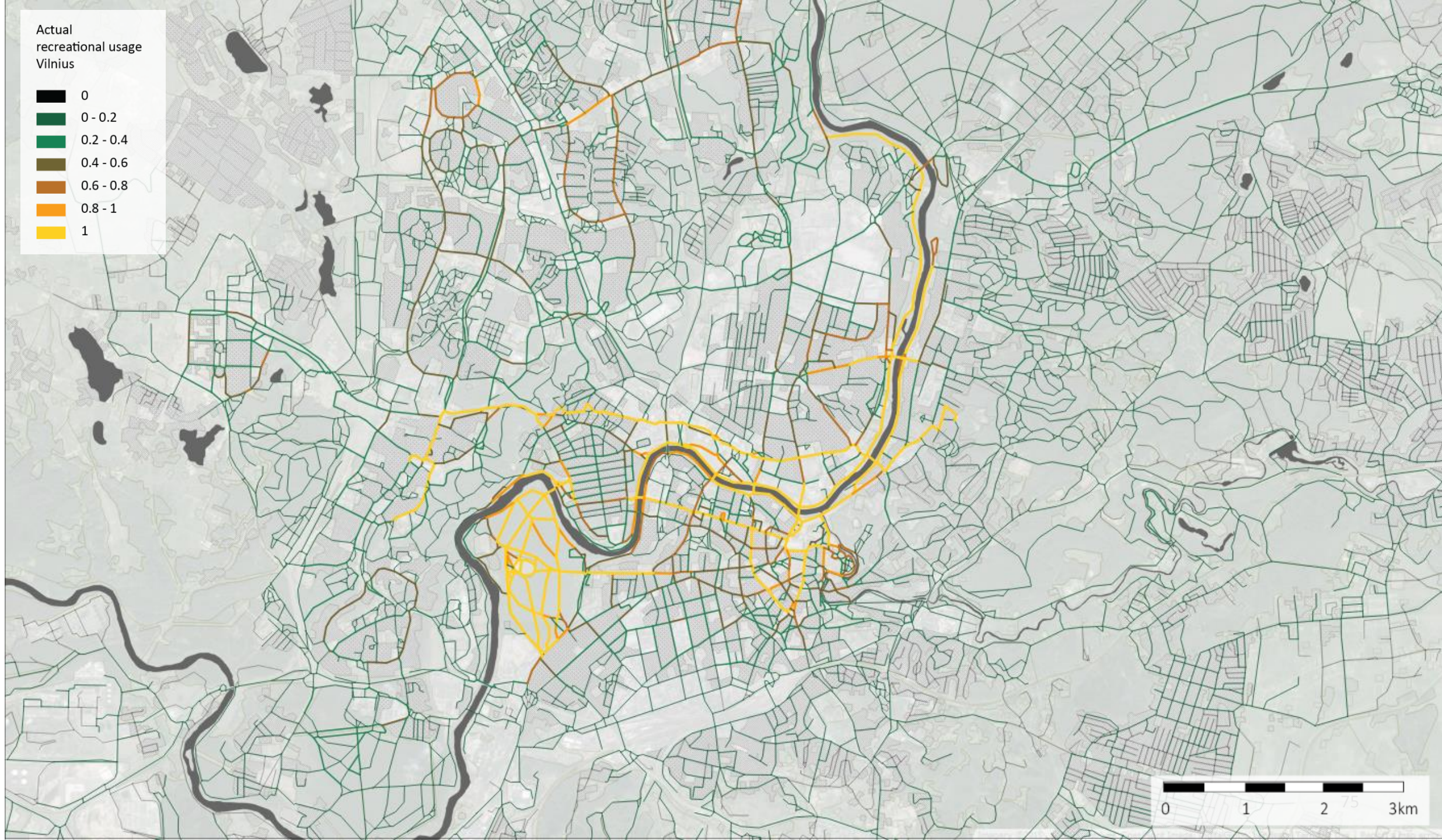
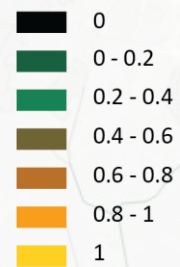


## GOTEBORG



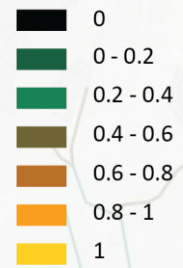


Actual  
recreational usage  
Vilnius





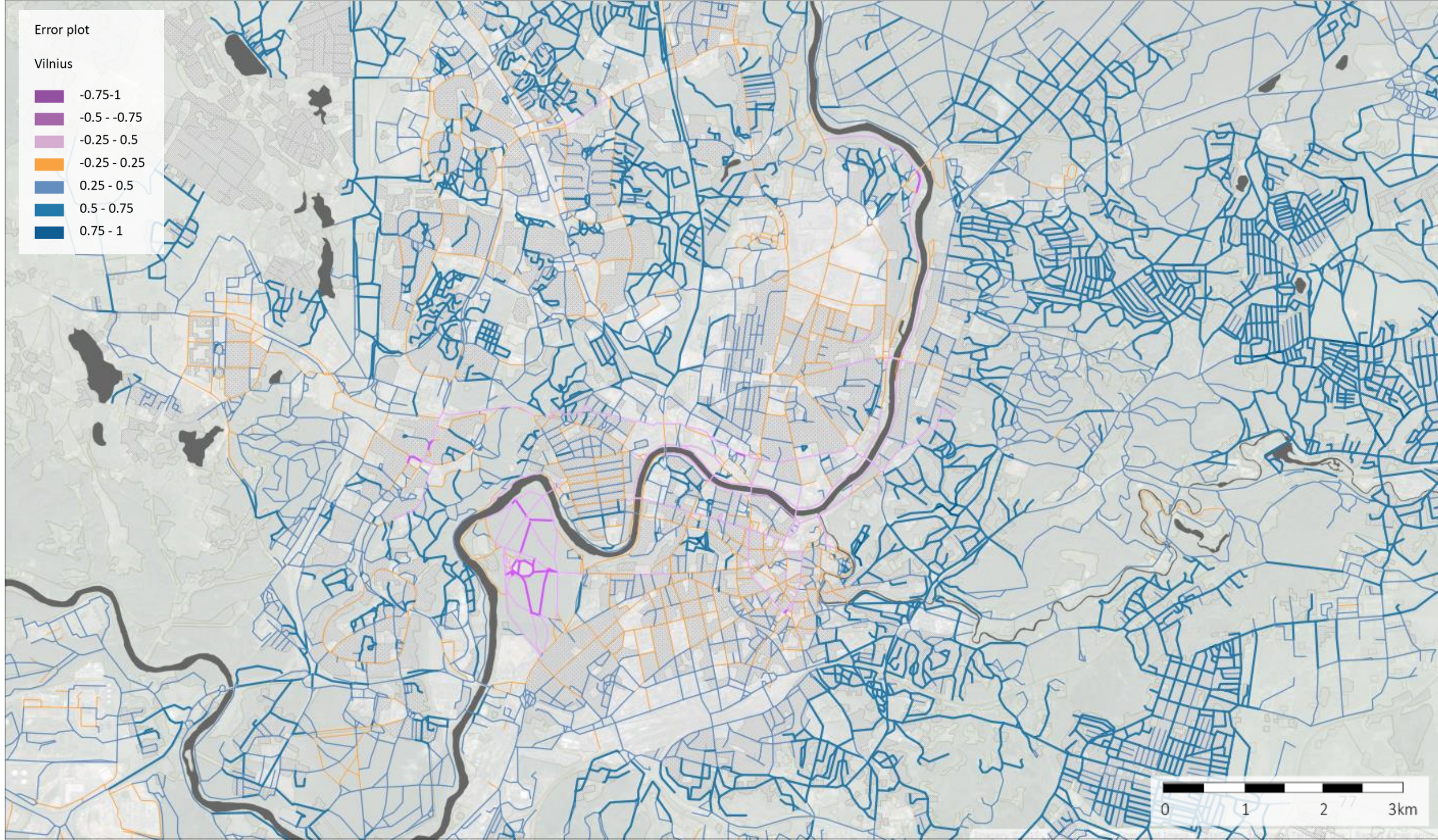
Predicted  
recreational usage  
Vilnius





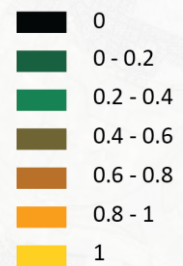
Error plot

Vilnius



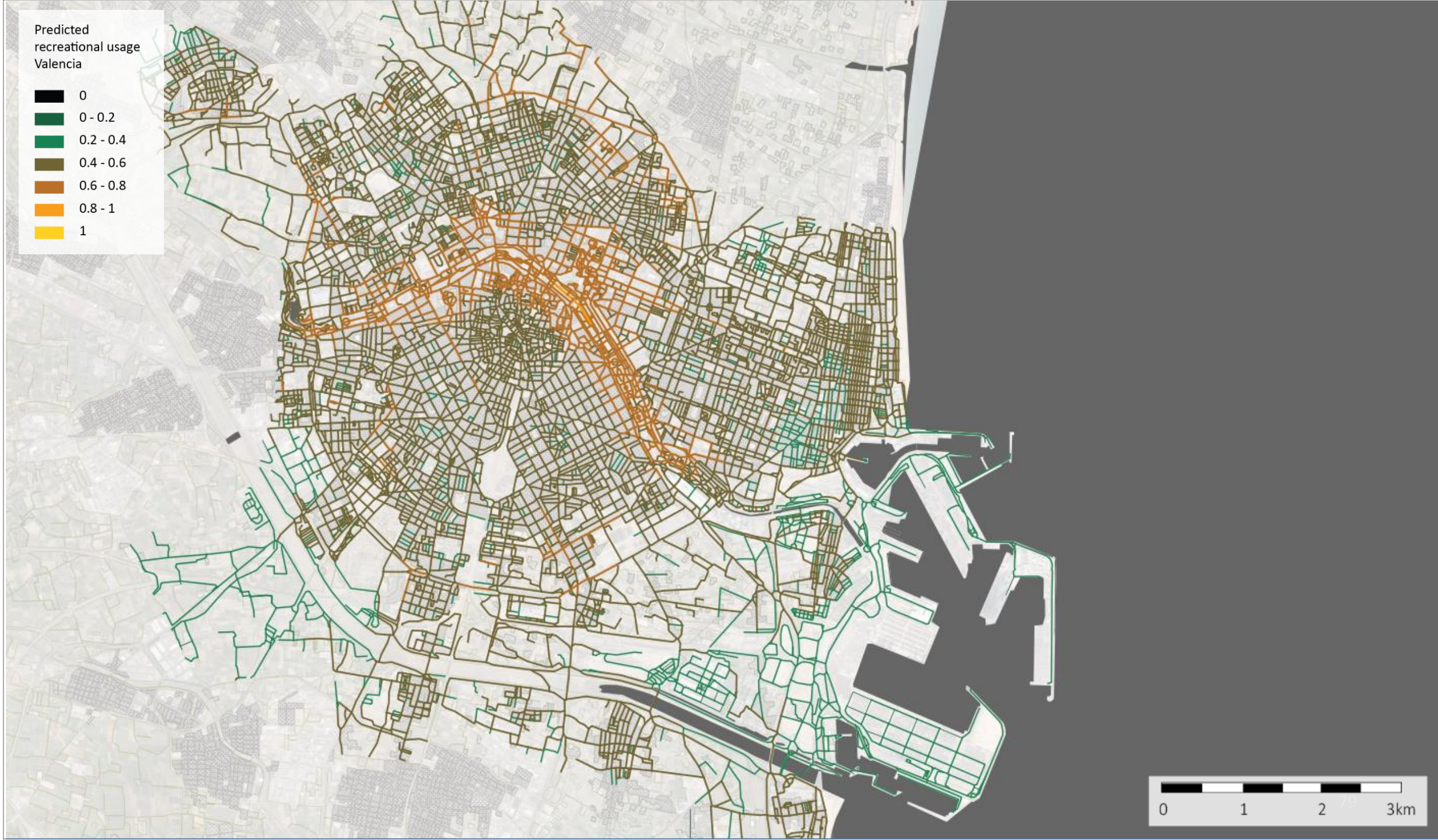
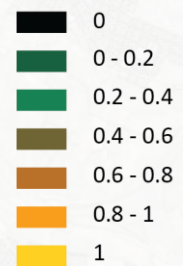


Actual  
recreational usage  
Valencia





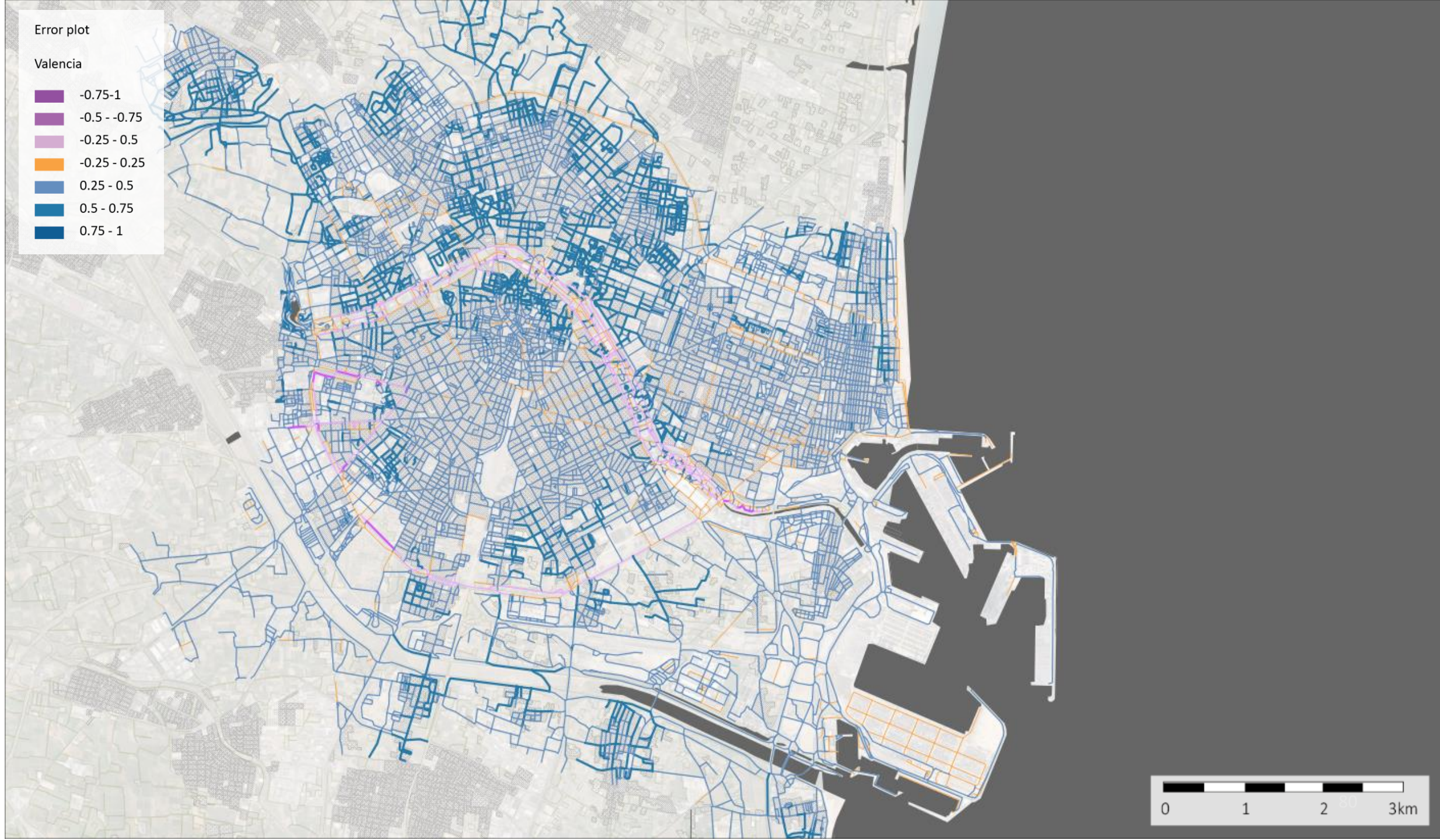
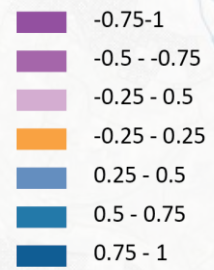
Predicted  
recreational usage  
Valencia





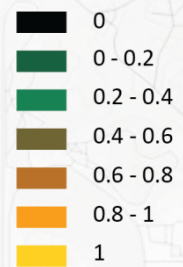
Error plot

Valencia



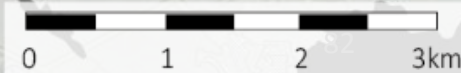
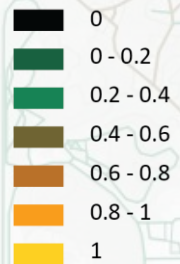


Actual  
recreational usage  
Gothenburg





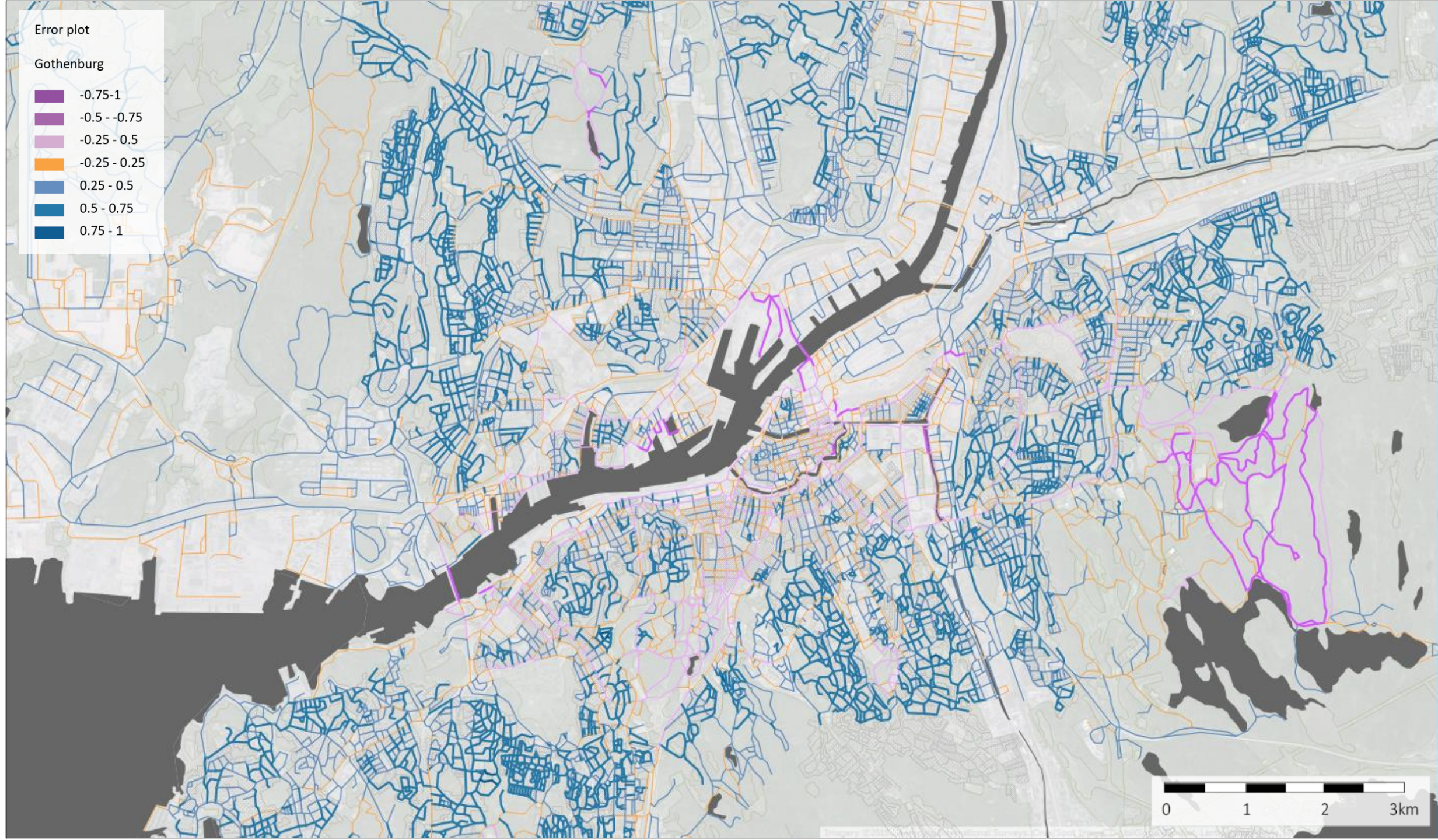
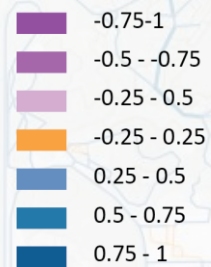
Predicted  
recreational usage  
Gothenburg



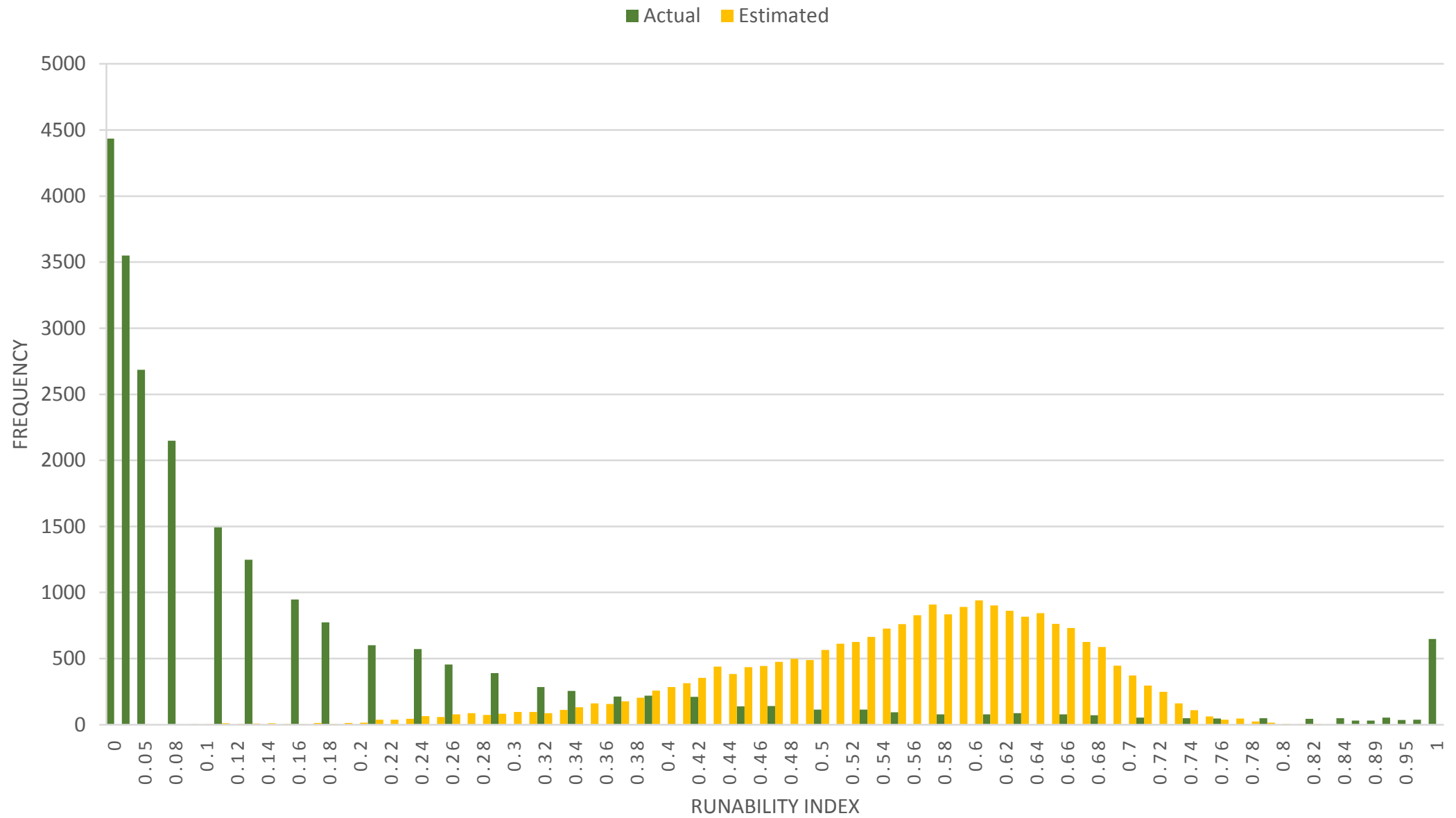


Error plot

Gothenburg







## runability index

predicts **were recreational activity does not happen**  
but fails at predicting where it does

**overestimates** urban territories-in-between

**underestimates** central parks and coastal paths:  
greenness vs. „blueness“

walkability index  $\neq$  runability index



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how would a person  
navigate in a network?

area-specific

general measure

walkable distance

### runability index

would a person  
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at all?

space-specific

needs to be calibrated  
for each particular city

runnable distance

How can **GPS data**,  
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be used  
to assess, analyse and **model**  
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to be used as a **ground truth**  
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of **Runability Index**,  
which aims to predict **space usability** for recreation,  
by means of **visualisation** and **statistical analysis**  
given that a **valid** underlying  
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## for the future research...

**collaboration** with a sports tracking **application**

**user statistics**

GPS tracks used to upgrade the **Urban Space Network**

varying buffer width

non planar network

heavy traffic streets – obstructions, not spaces

different recreational activities explored **separetely**

**other types of activities:** recreational cycling, orienteering, roller skiing, skateboarding, etc.

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## for the Runability Index

**additional factors:**

microclimatic characteristics,  
traffic,  
air pollution,  
presence of resting places,  
surface cover,  
width of a sidewalk,  
safety

**analysis in network space:**

not in a sense of being in an attractive area but in a sense of being connected to other attractive spaces

questions?

and i'd like to thank

**Pirouz Nourian**

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**Iris Theunisse**

Ravi Peters

*endomondo*

