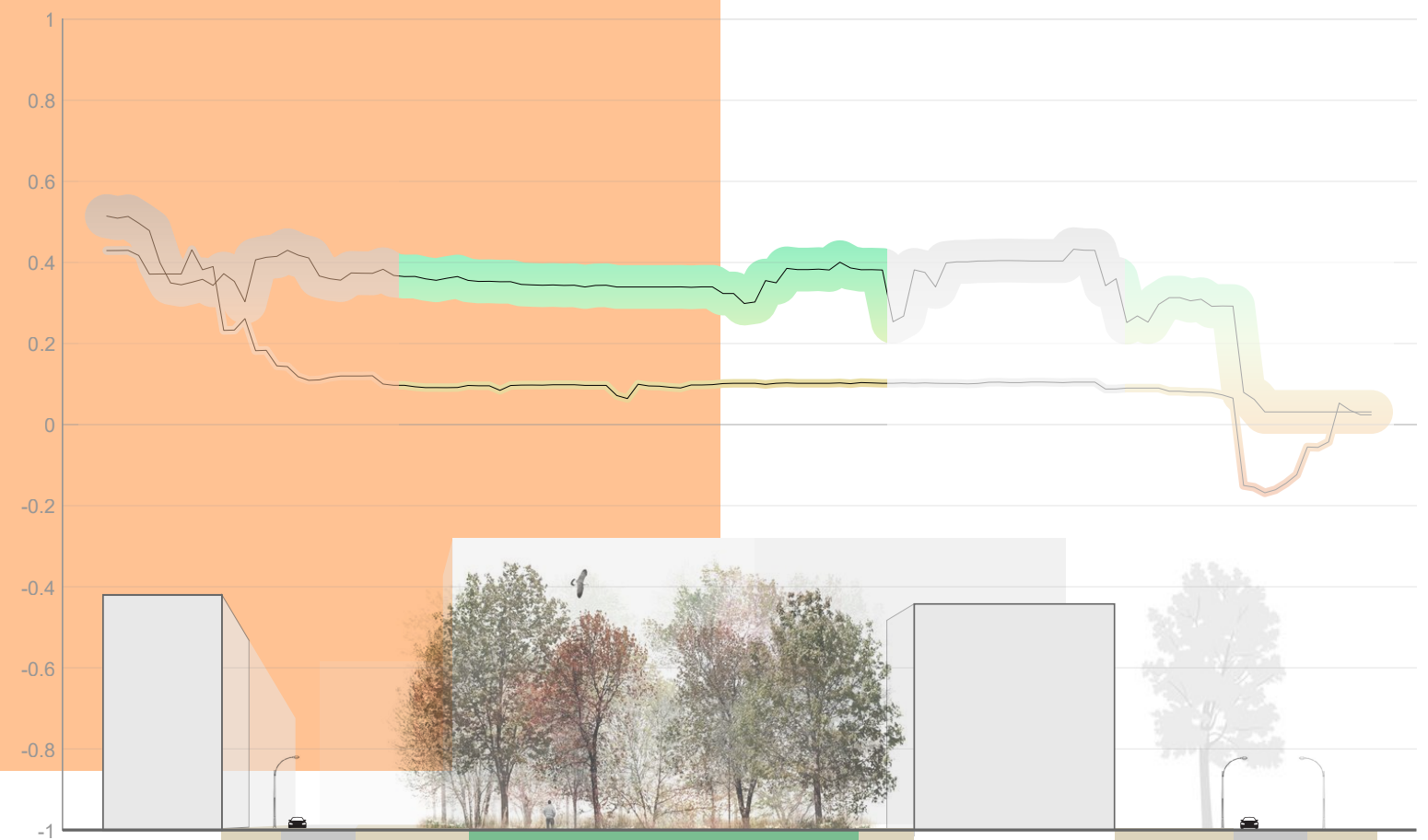


Beyond Noise

A Framework for a Design Tool
Predicting and Optimizing
Soundscape Design



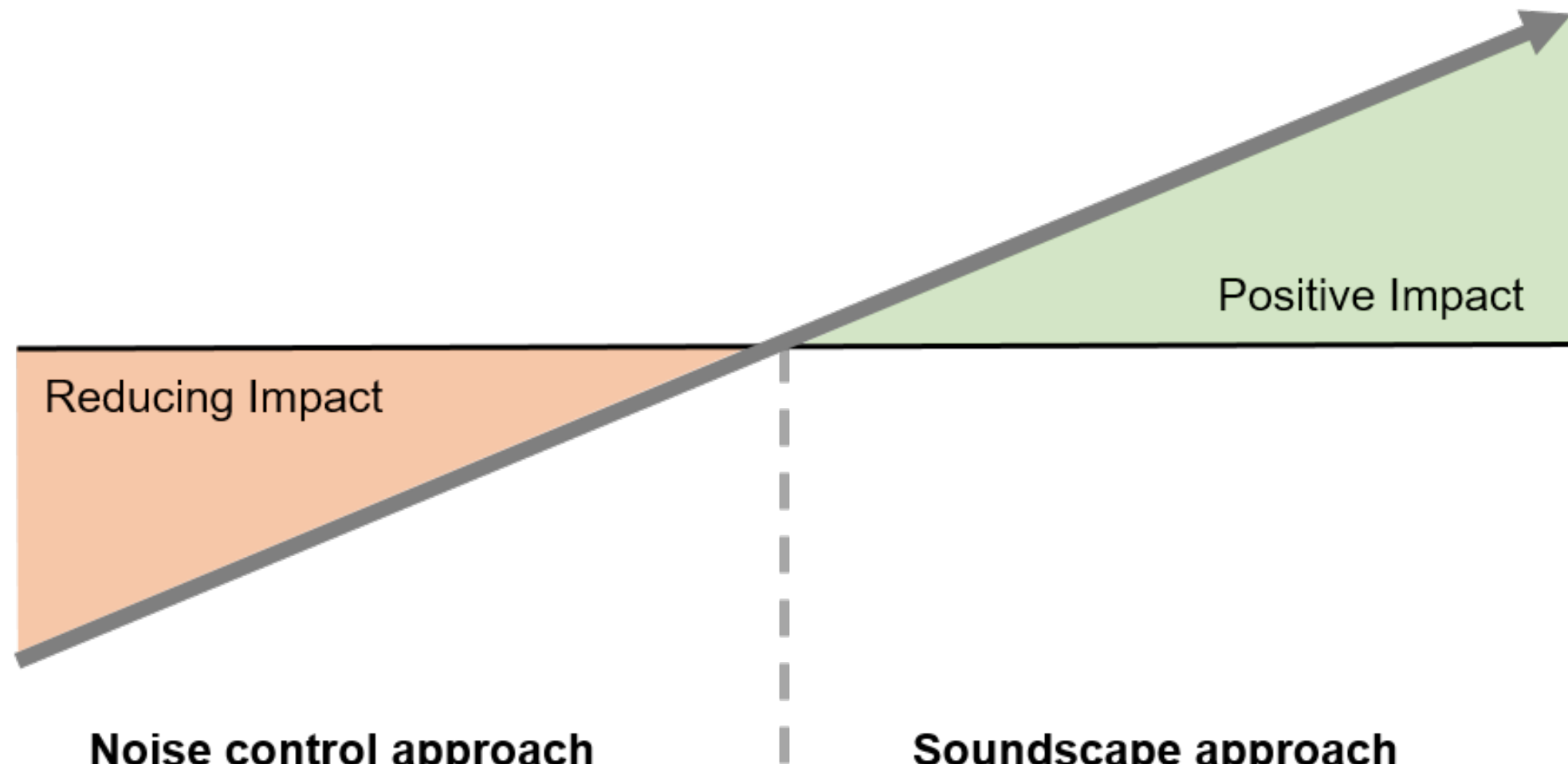
Niroda Vitusha Smit

18-06-2024

Msc. Building Techonolgy

First mentor: Martin Tenpierik

Second mentor: Michella Turrin

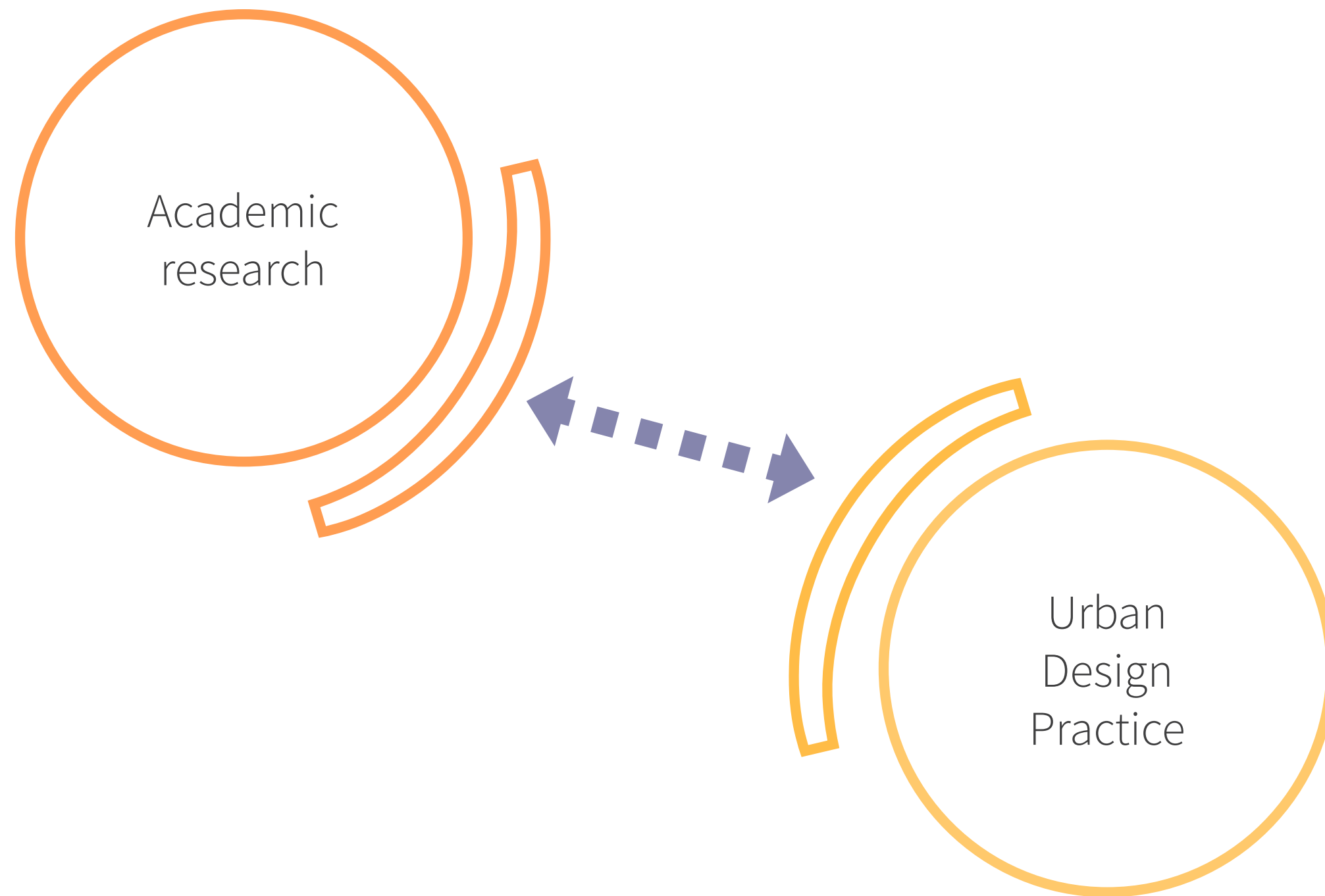


Noise control approach

- Minimise noise annoyance by reducing sound pressure levels
- Sound considered as unwanted (i.e. noise) regardless spectral and temporal composition and meaning

Soundscape approach

- Integrates psychological, (psycho)acoustical, physiological, and social factors to investigate how people experience the acoustic environment, in context
- Sound is differentiated according to people's preference and exploited as a design resource.



1
2
3
4
5
6
7

Introduction

Literature

Dataset

Choice of ML Model

Visualization & Application

Design Proposal

Conclusion

Research sub-questions

What is 'good' soundscape design?

What correlations exist between the identified soundscape indicators and descriptors of human perception of comfort or discomfort within urban environments?

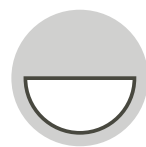
To what extent can computational design tools, in the shape of machine learning models, incorporate soundscape data to inform and shape urban design elements for improved soundscapes?

How do design iterations impact the perceived quality of soundscapes within urban environments?

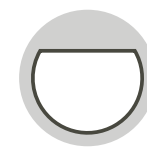
Methodology



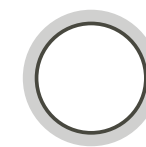
Dataset Sourcing
Selection
Statistical
analysis



Add Urban
design elements
Source data
Process data
Statistical
analysis for
validity

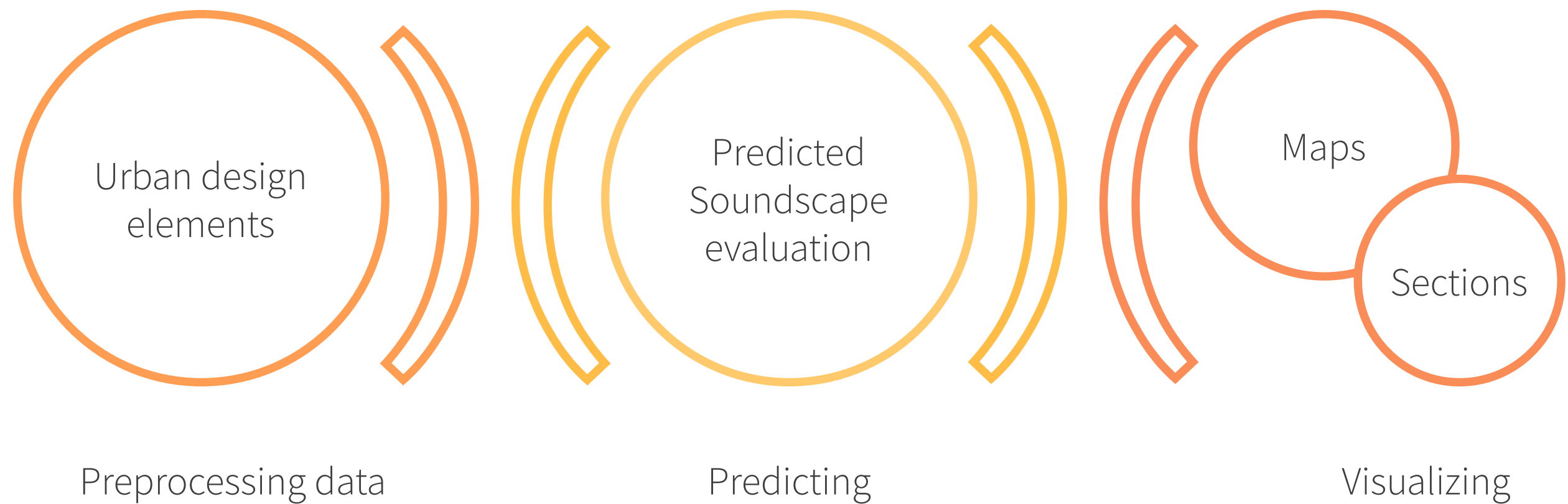


ML Model
selection
Testing
Evaluating
build into QGIS



Creating Design
tool
Preprocess data
create
pleasantness
prediction
Visualize
predicted
pleasantness on
a map

Objective for the Design tool



SOUNDSCAPES

- Definition
- Influences
- Environmental noise

URBAN DESIGN

- Sense of place
- Map making
- Scales & scale paradox

SOUNDSCAPE DESIGN

- Design strategies
- Interview with urban designer
- Urban design elements & soundscapes

MACHINE LEARNING

- Overview
- Types of ML
- Regression Models
- Handling outliers

MACHINE LEARNING IN SOUNDSCAPE DESIGN

- ML soundscape design
- Conceptual framework prediction model
- Review of existing prediction and mapping models

Environmental Noise

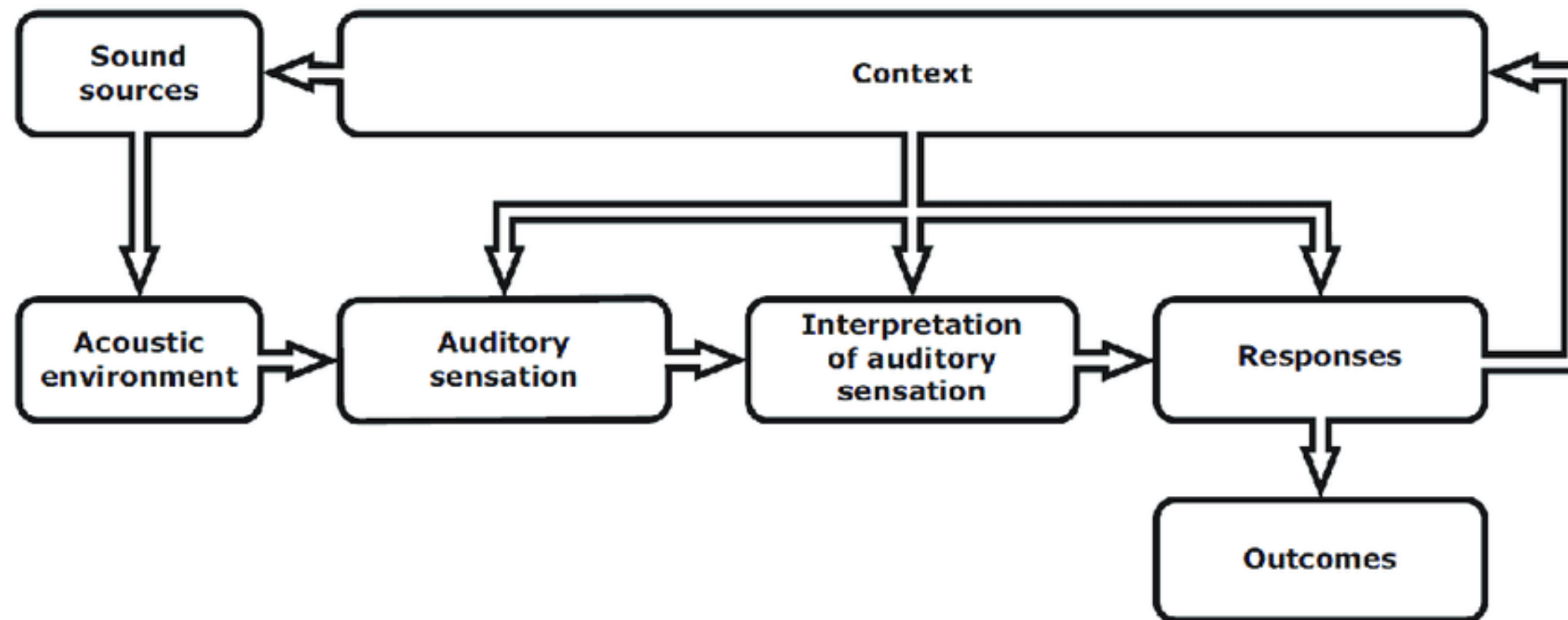
“noise emitted from all sources except for noise at the industrial workplace” (WHO)

$$L_{den} = 10 \log \left[\frac{1}{24} \left(12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{L_{evening}+5}{10}} + 8 * 10^{\frac{L_{night}+10}{10}} \right) \right] \text{ dB}$$

The WHO (2011) recommends reducing traffic noise levels to be below 53 dB L_{den}

Dutch regulations

Soundscapes



Soundscape & Context (From ISO- 12913-1:2014. Acoustics—Soundscape—Part 1 Definition and conceptual framework, 2018.)

Soundscapes: Assessment

For each of the 8 scales below, to what extent do you agree or disagree that the present surrounding sound environment is...
Please tick off one response alternative per scale

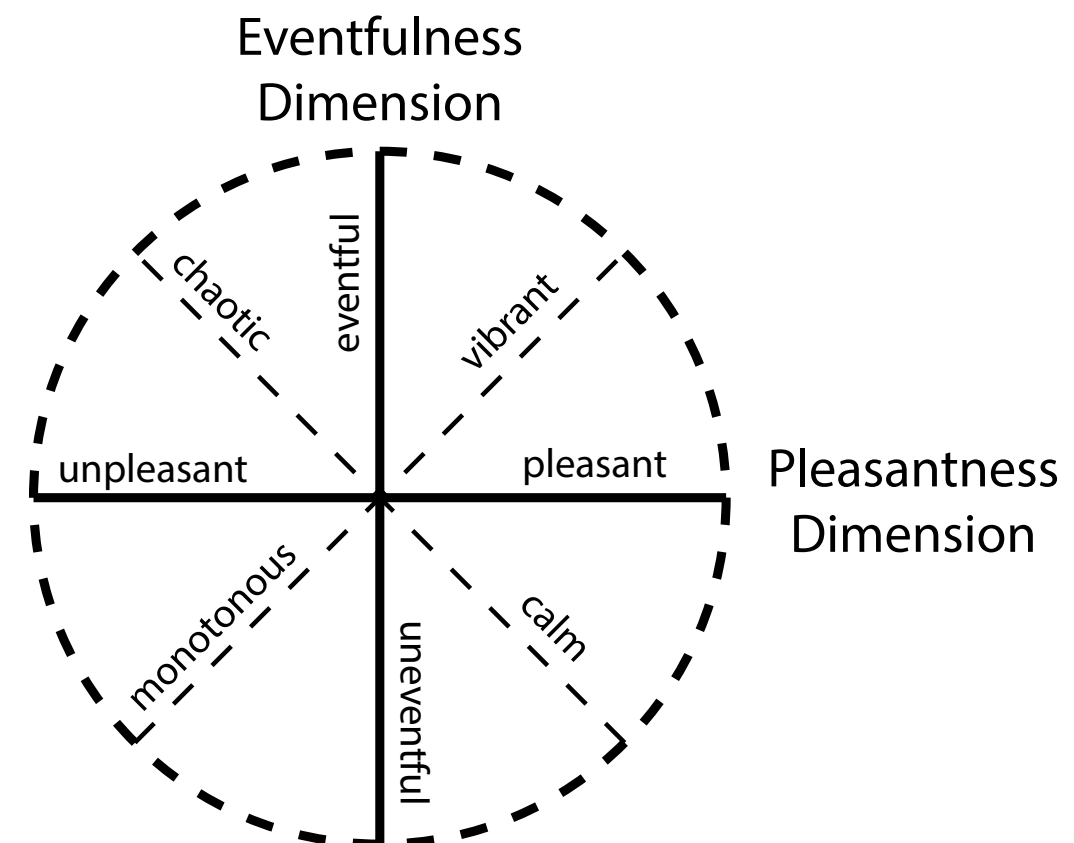
	Strongly agree	Agree	Neither agree, nor disagree	Disagree	Strongly disagree
- pleasant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- chaotic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- vibrant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- uneventful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- calm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- annoying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- eventful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- monotonous	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Questionnaire Likert scales for Perceived Affective Qualities (PAQ's) (From ISO- 12913-1. Acoustics—Soundscape—Part 2: Data collection and reporting requirements, 2018.)

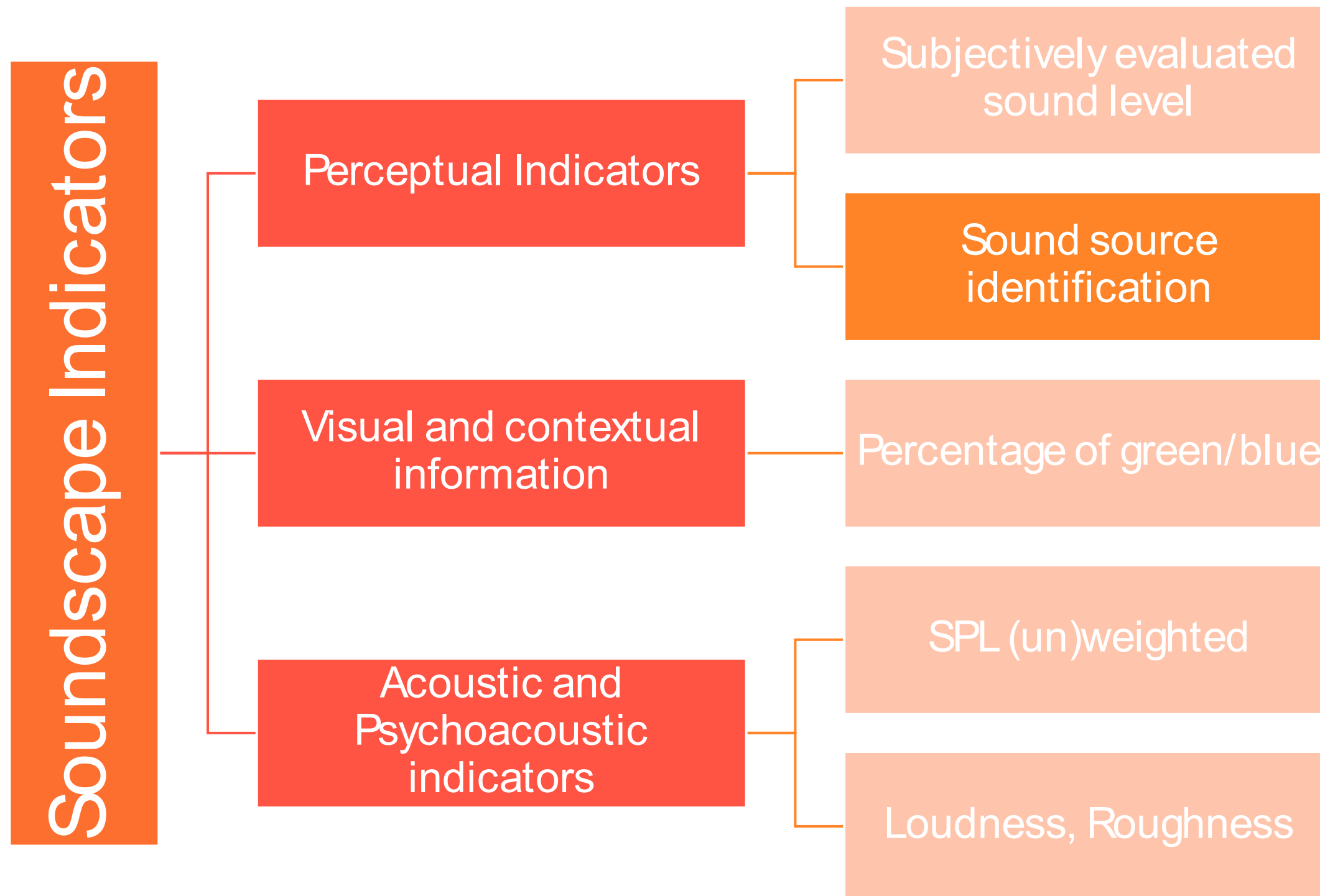
International Standardization Organization
(ISO) survey
Recollecting data

Soundscapes: Assessment

$$ISOPleasant = \frac{[(pleasant - annoying) + \cos 45^\circ * (calm - chaotic) + \cos 45^\circ * (vibrant - monotonous)]}{(4 + \sqrt{32})}$$



Two-dimensional representation of the PAQ's attributed to acoustic environments, inspired by Schulte-Fortkamp et al. (2023) ,by author



Soundscapes: Indicators

To what extent do you presently hear the following four types of sounds?

	Not at all	A little	Moderately	A lot	Dominates completely
Traffic noise (e.g. cars, buses, trains, airplanes)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other noise (e.g. sirens, construction, industry, loading of goods)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sounds from human beings (e.g. conversation, laughter, children at play, footsteps)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Natural sounds (e.g. singing birds, flowing water, wind in vegetation)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Questionnaire Likert scales for Soun Source types (From ISO- 12913-1. Acoustics—Soundscape—Part 2: Data collection and reporting requirements, 2018.)

Sound Source Identification

Urban Design

Urban design describes the process of designing cities with the goal of creating urban areas consisting of a high quality of life (Haberl, 2018).

Urban Design: Visualization & Maps

Maps can be seen as a form of visual communication — a special-purpose language for describing spatial relationships (de Jong, 2008).



Abstraction (left) and Reduction (right) (From bk1gr2 Stedebouw Inleiding 120218, p103)

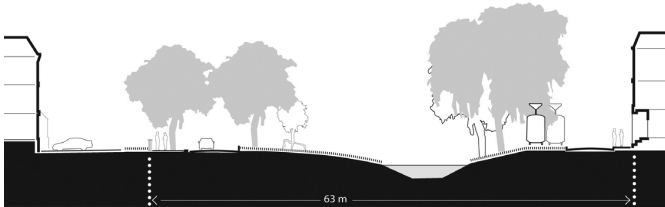
Urban Design: Scales

Human Experience
(3-30m)



Netwerk

Onderdelen (voortuinen, trottoirs, rijbanen, bermen etc.)

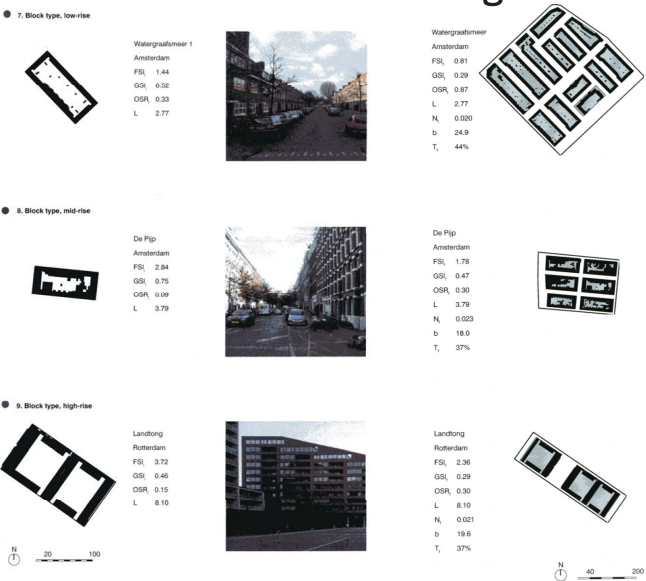


Human Experience (From bk1gr2 Stedebouw wk2 190218, p22)

Building Block
(30-300m)

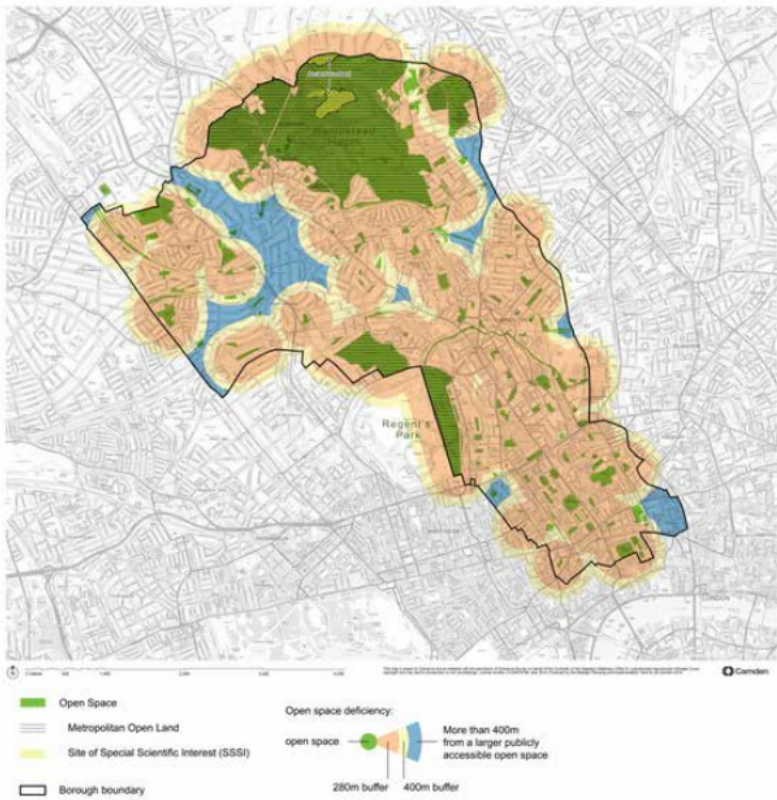


Eilanden Gesloten verkavelingen

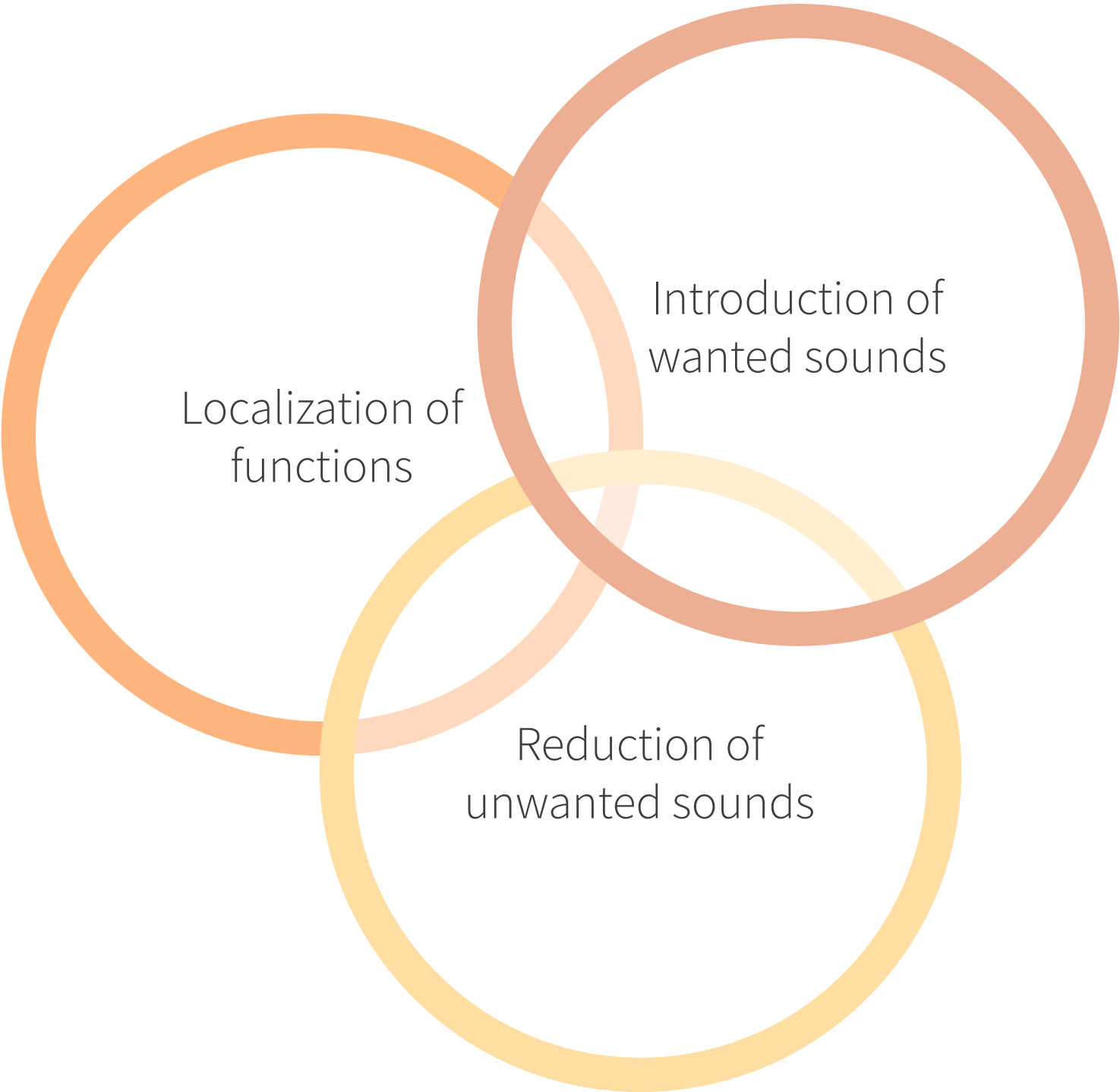


Building Blocks (From bk1gr2 Stedebouw wk2 190218, p19)

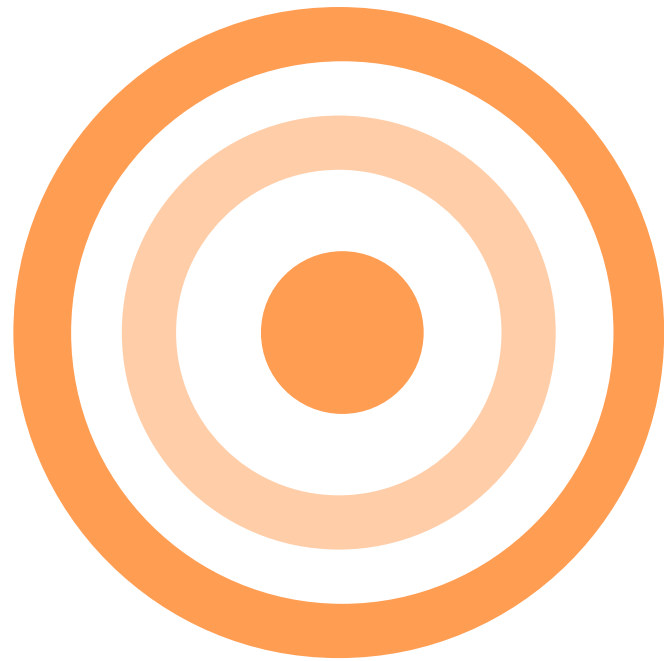
District
(300+m)



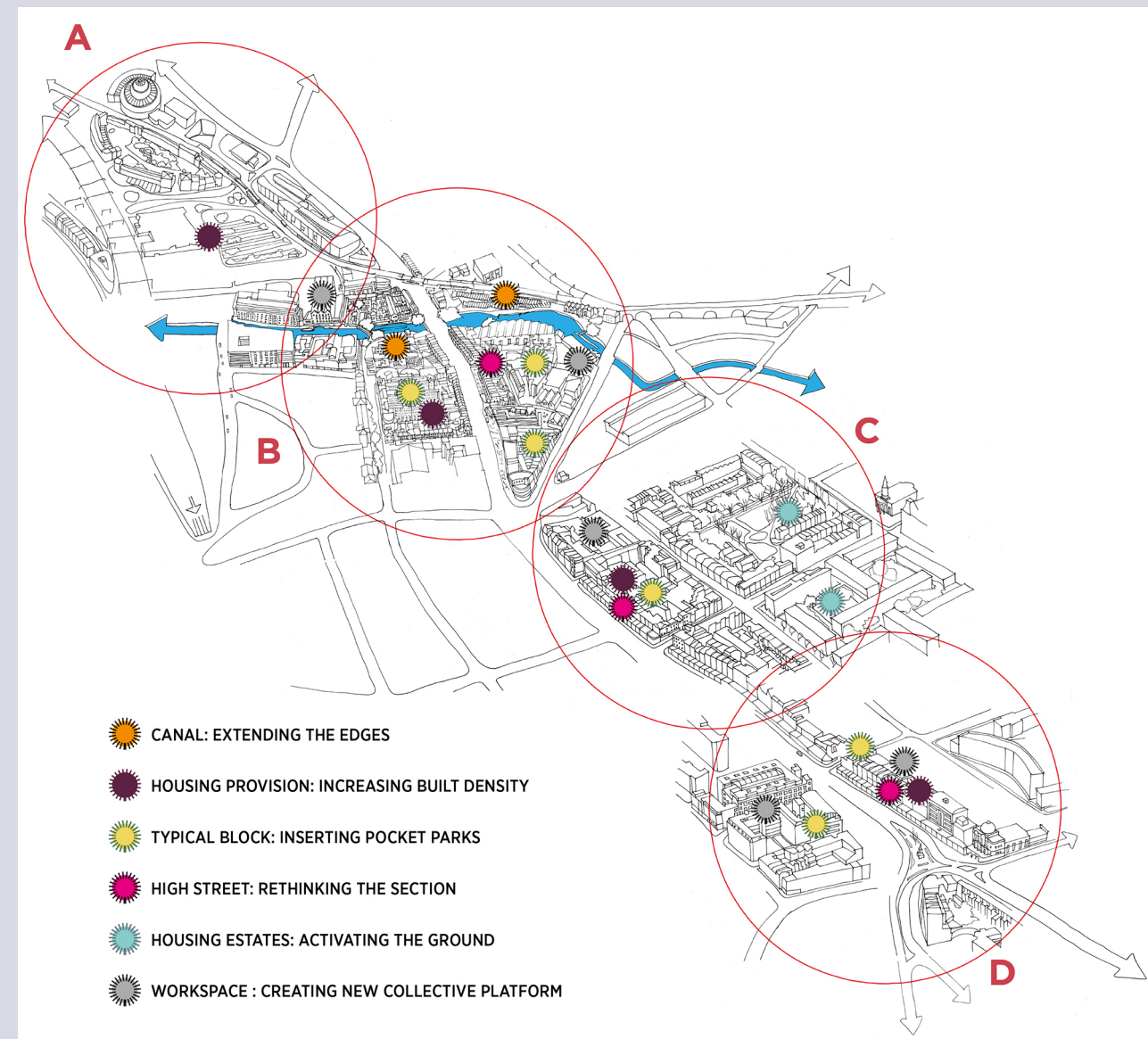
Access to public green spaces (Camden Local Plan, n.d.)



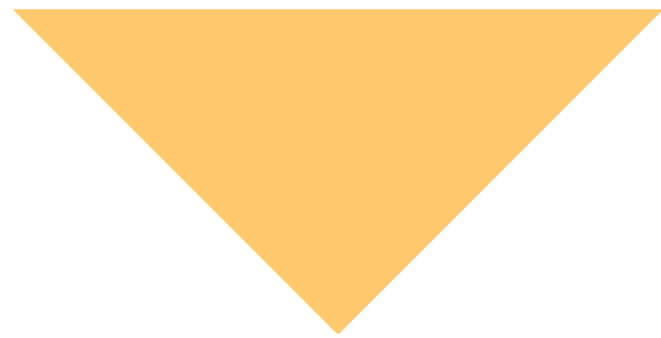
3 soundscape action strategies by author inspired by Cérwen (2017)



Localization of functions



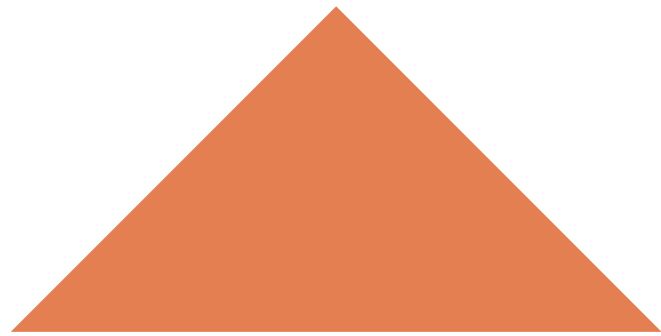
Camden Town Masterplan, Sheppard Robson (2024)



Reduction of unwanted sounds



Urban sound planning - the SONORUS project

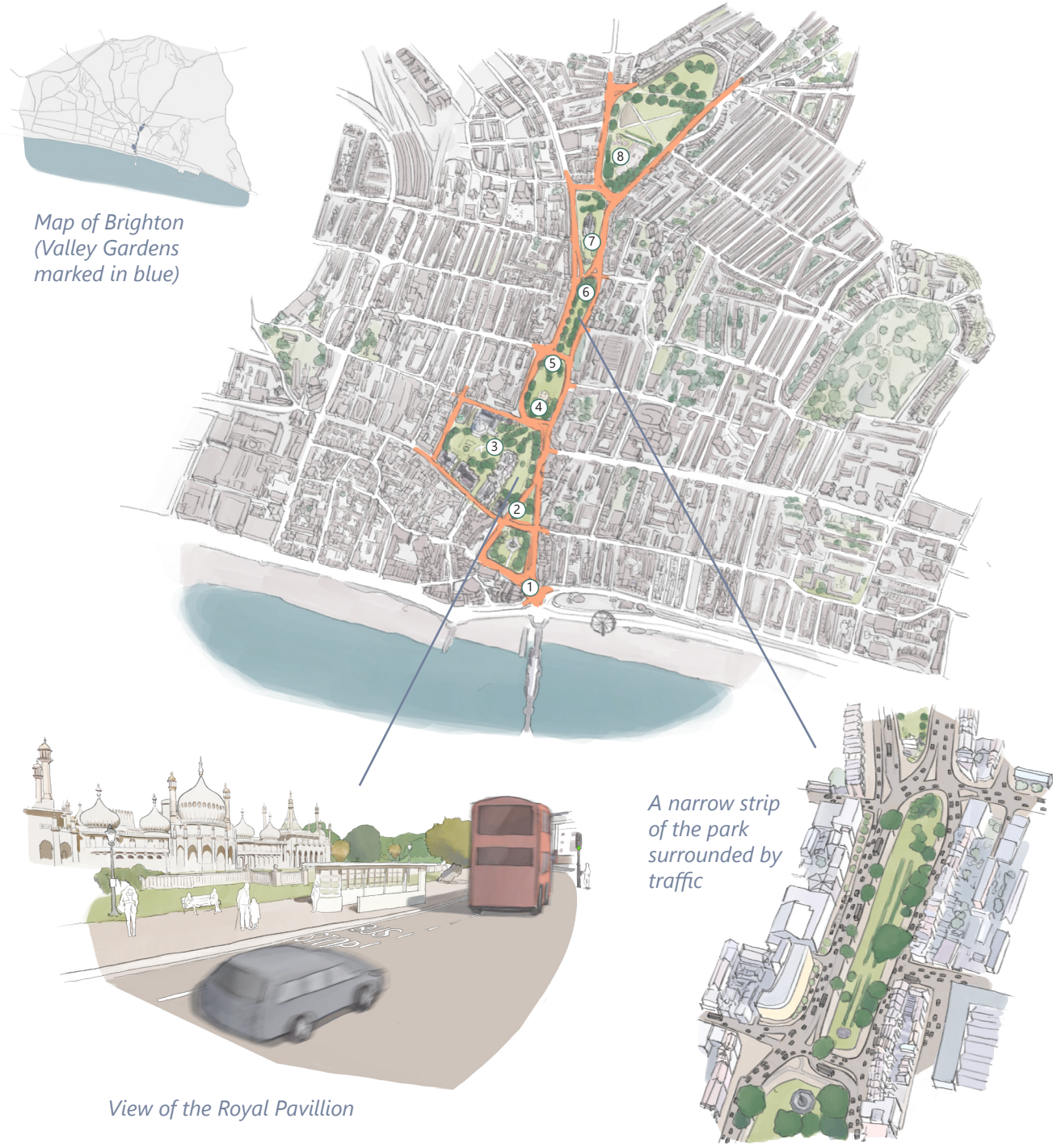


Introduction of wanted sounds



Urban sound planning - the SONORUS project

Soundscape design through different scales



Map of Brighton
(Valley Gardens
marked in blue)

View of the Royal Pavillion

A narrow strip
of the park
surrounded by
traffic

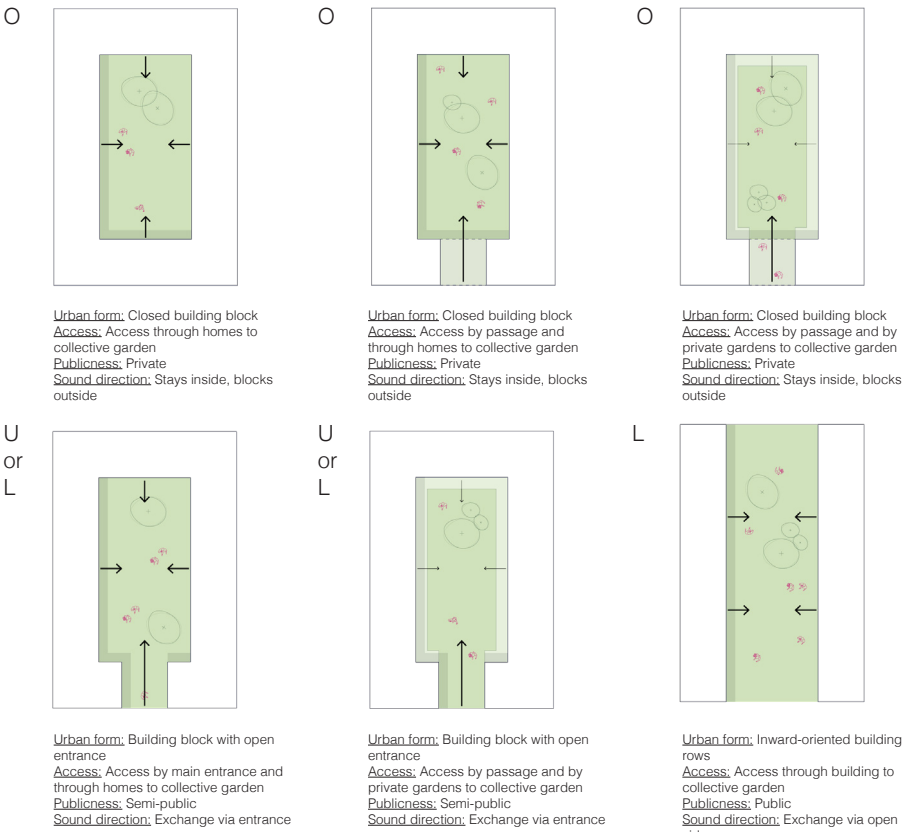
Greenery, fountains

Buildings

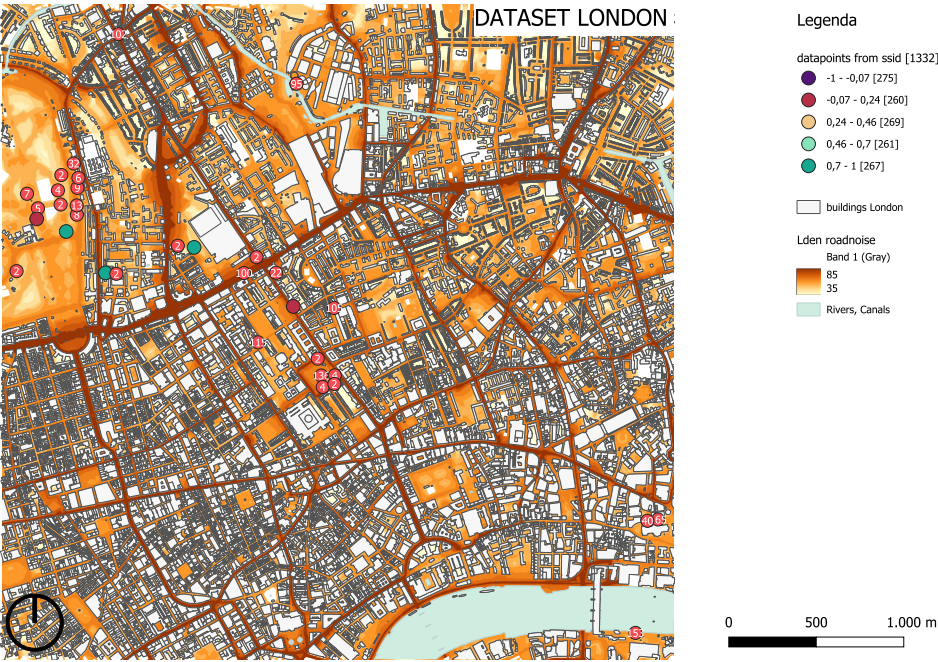
Roads



Green-Blue Map by, author

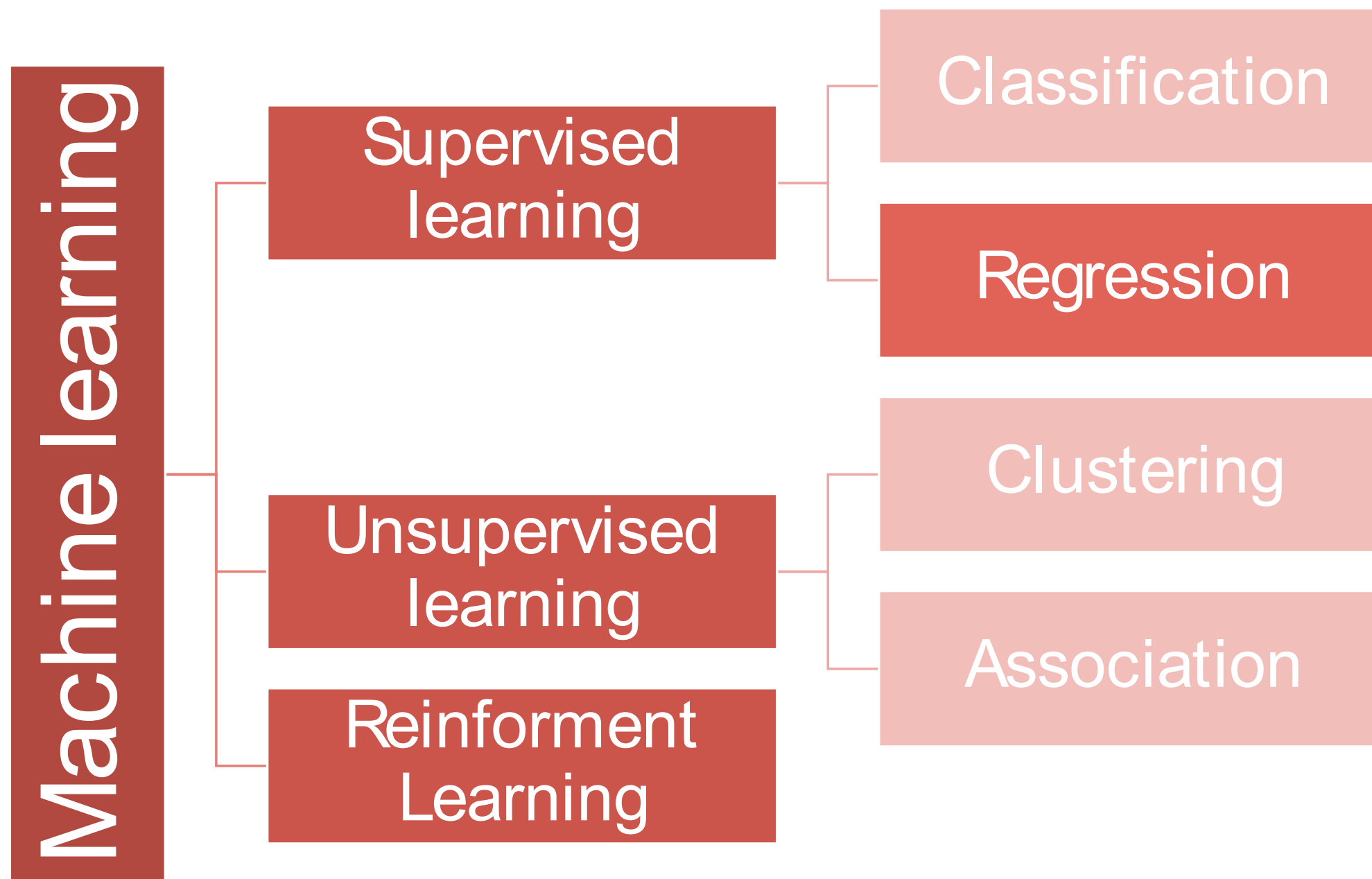


Building shapes and Urban Pockets, by van den Berg (2022)



L_{den} map, by author

Soundscape Design

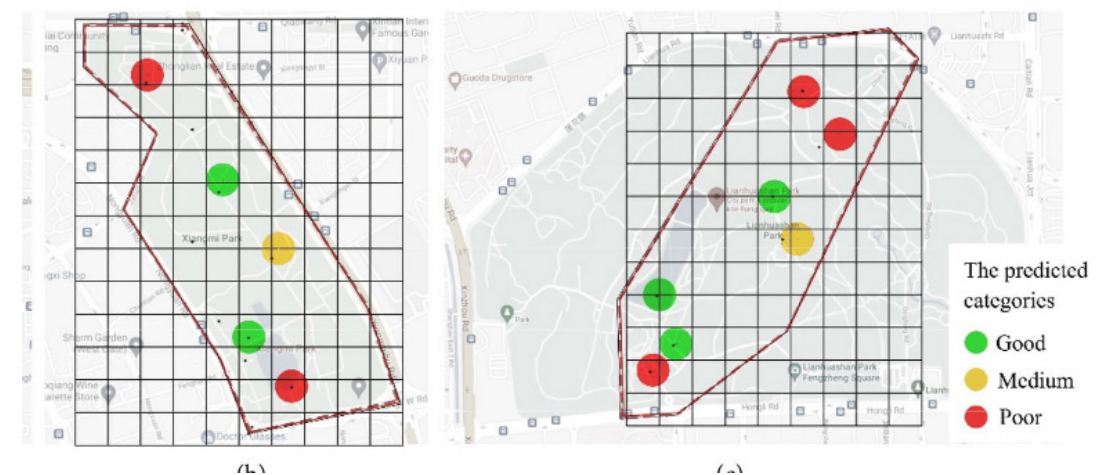


Machine Learning Types

Predictive Soundscape Visualization

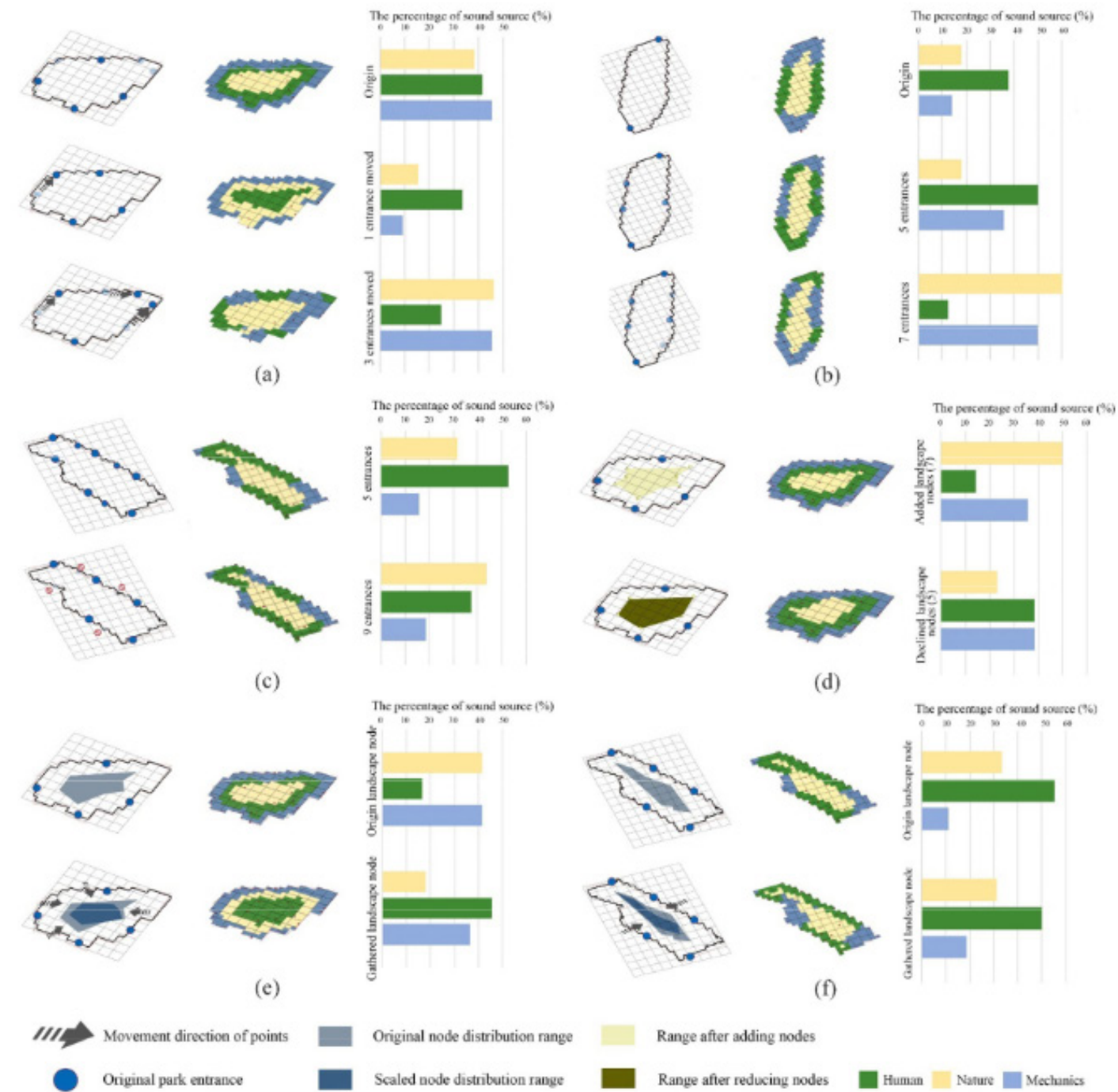


Urban soundscape maps modelled with geo-referenced data. Lavandier et al., 2016

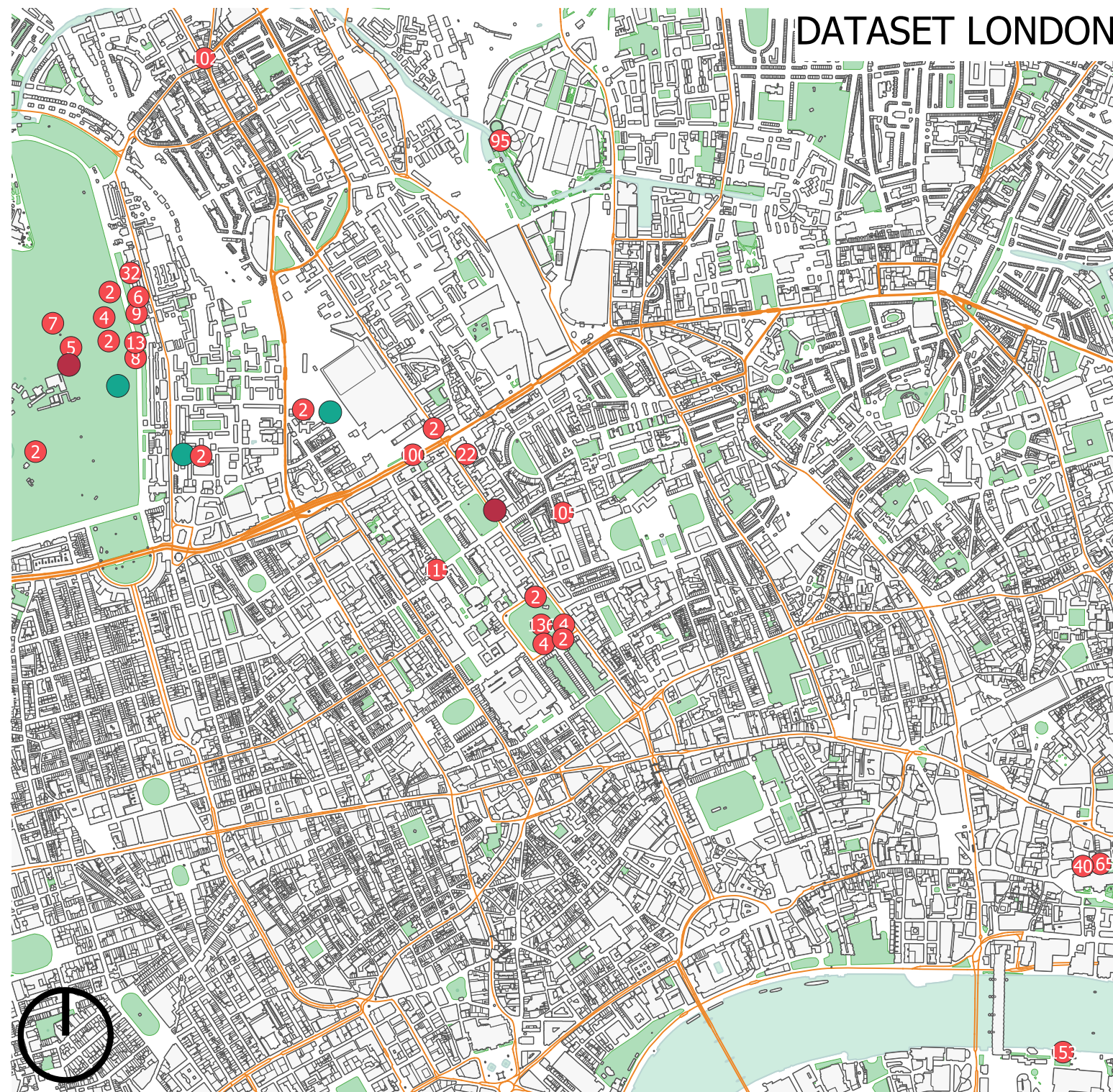


A visualized soundscape prediction model for design processes in urban parks. Yue et al., 2023.

Predictive Soundscape Mapping & Design



A visualized soundscape prediction model for design processes in urban parks.
Yue et al., 2023.



Legenda

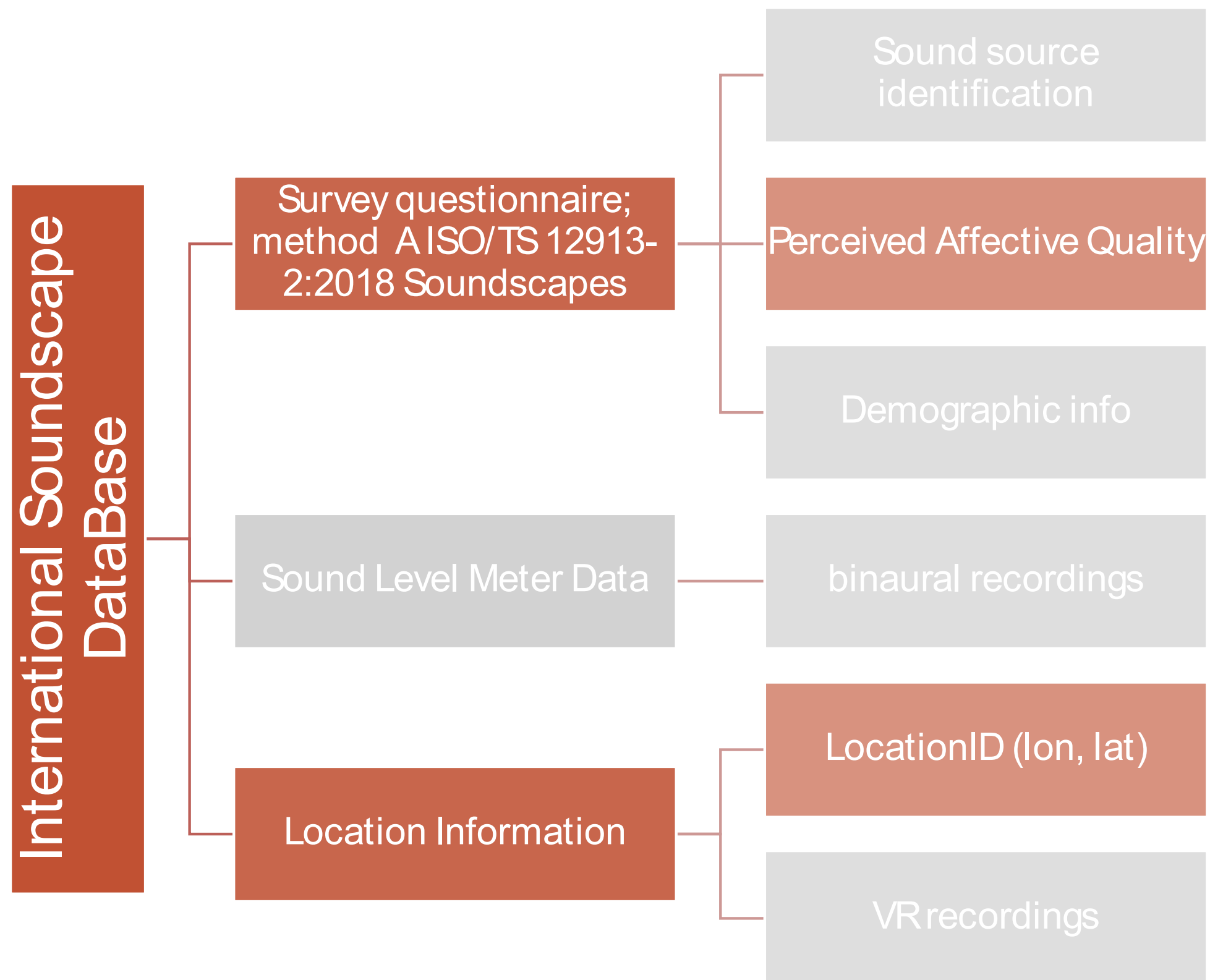
datapoints from ssid [1332]

- -1 - -0,07 [275]
- -0,07 - 0,24 [260]
- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]
- 0,7 - 1 [267]

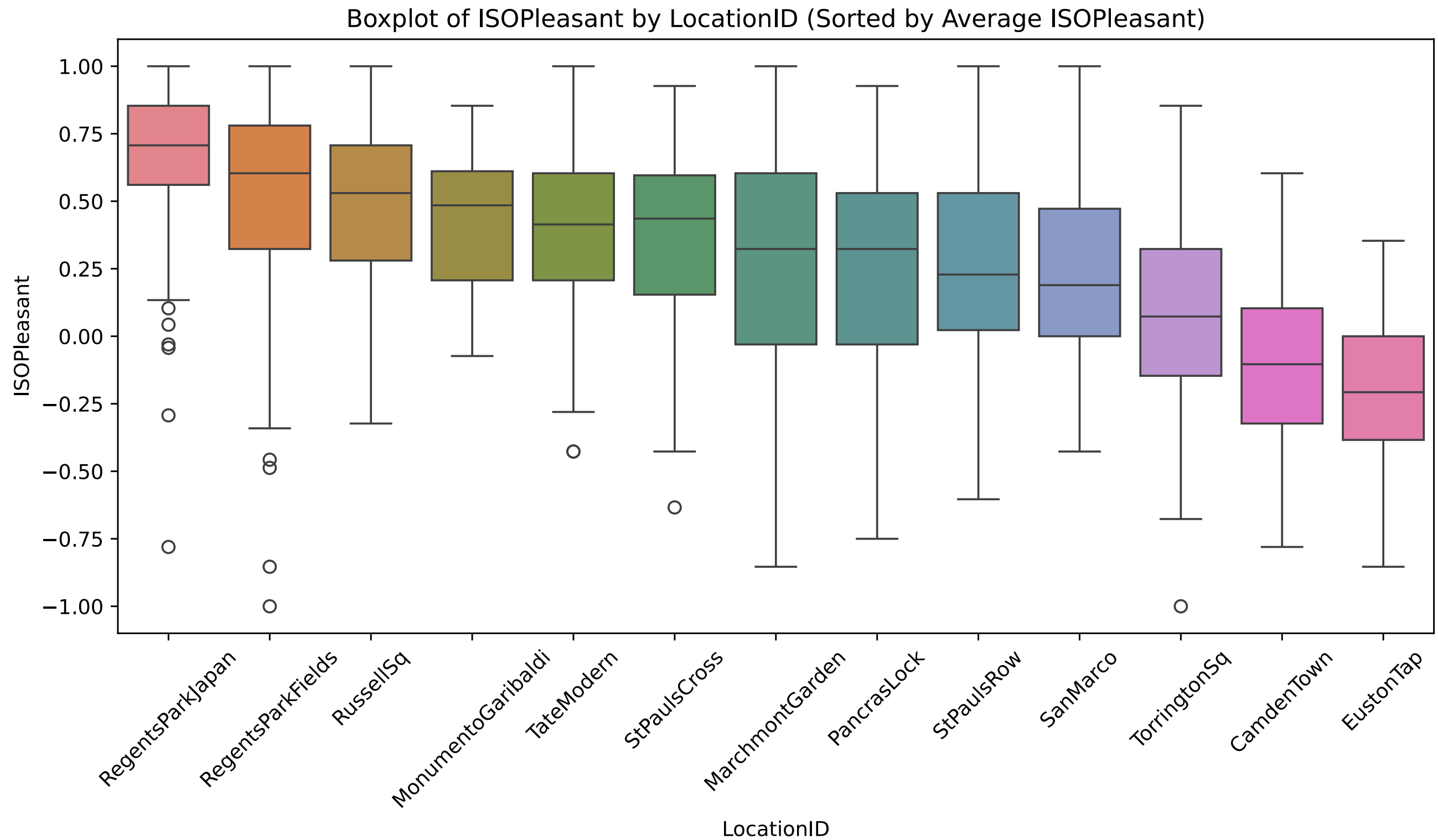
- buildings London
- Roads trunk
- Parks London
- Rivers, Canals

0 500 1.000 m

*International Soundscape Database,
plotted in London*

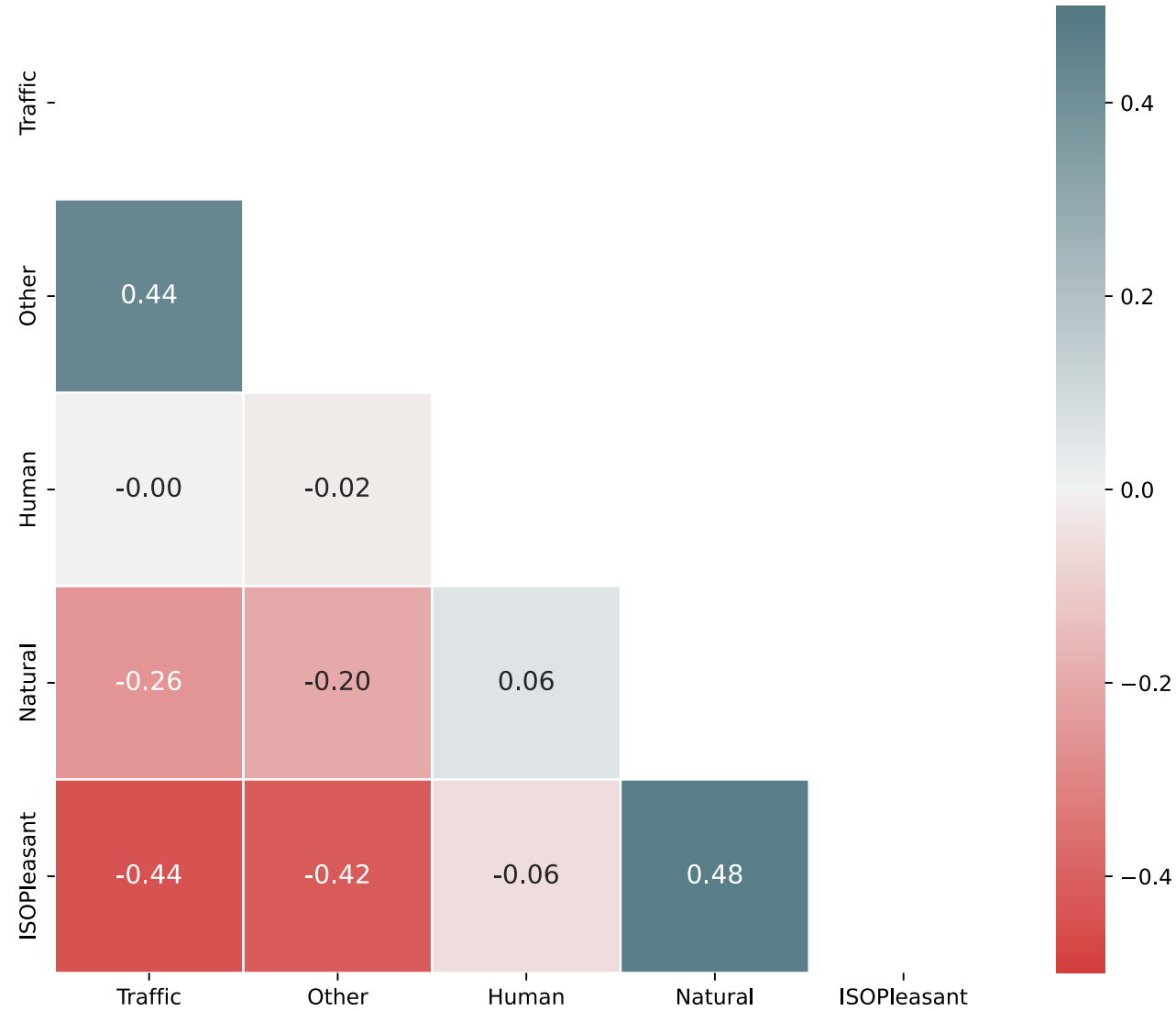


International Soundscape Database

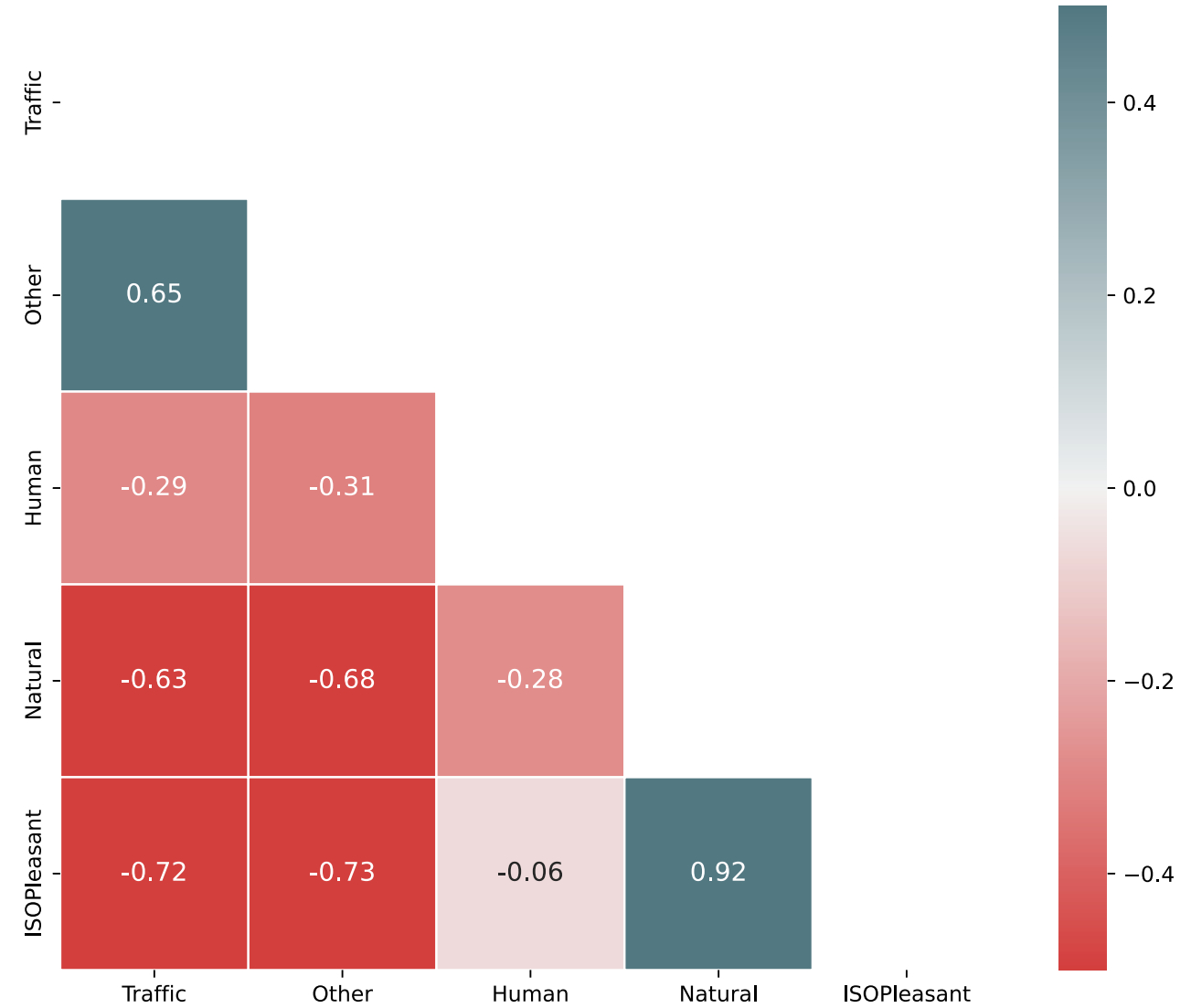


Statistical Analysis

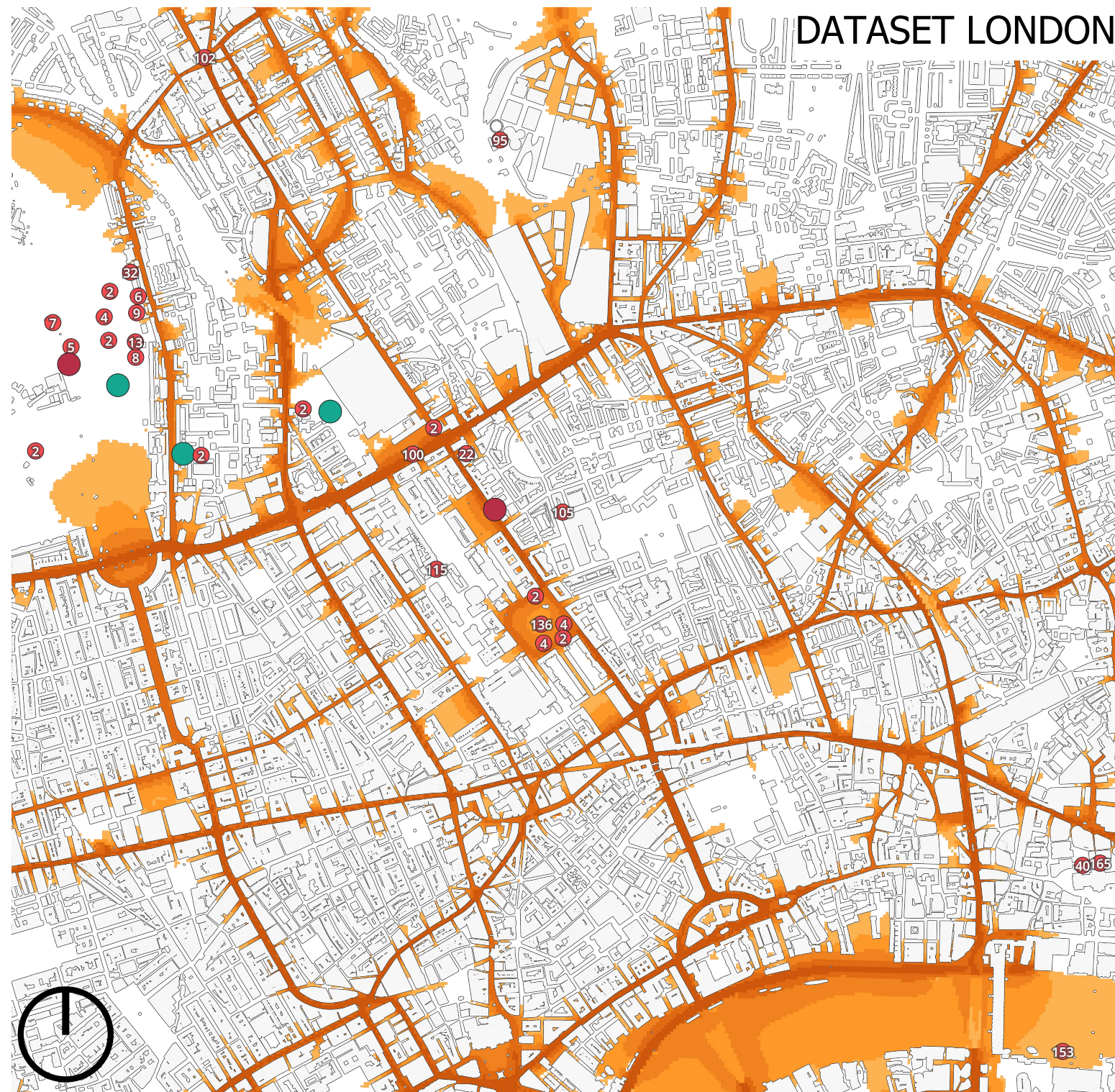
Spearman Correlation Heatmap 1: All Locations

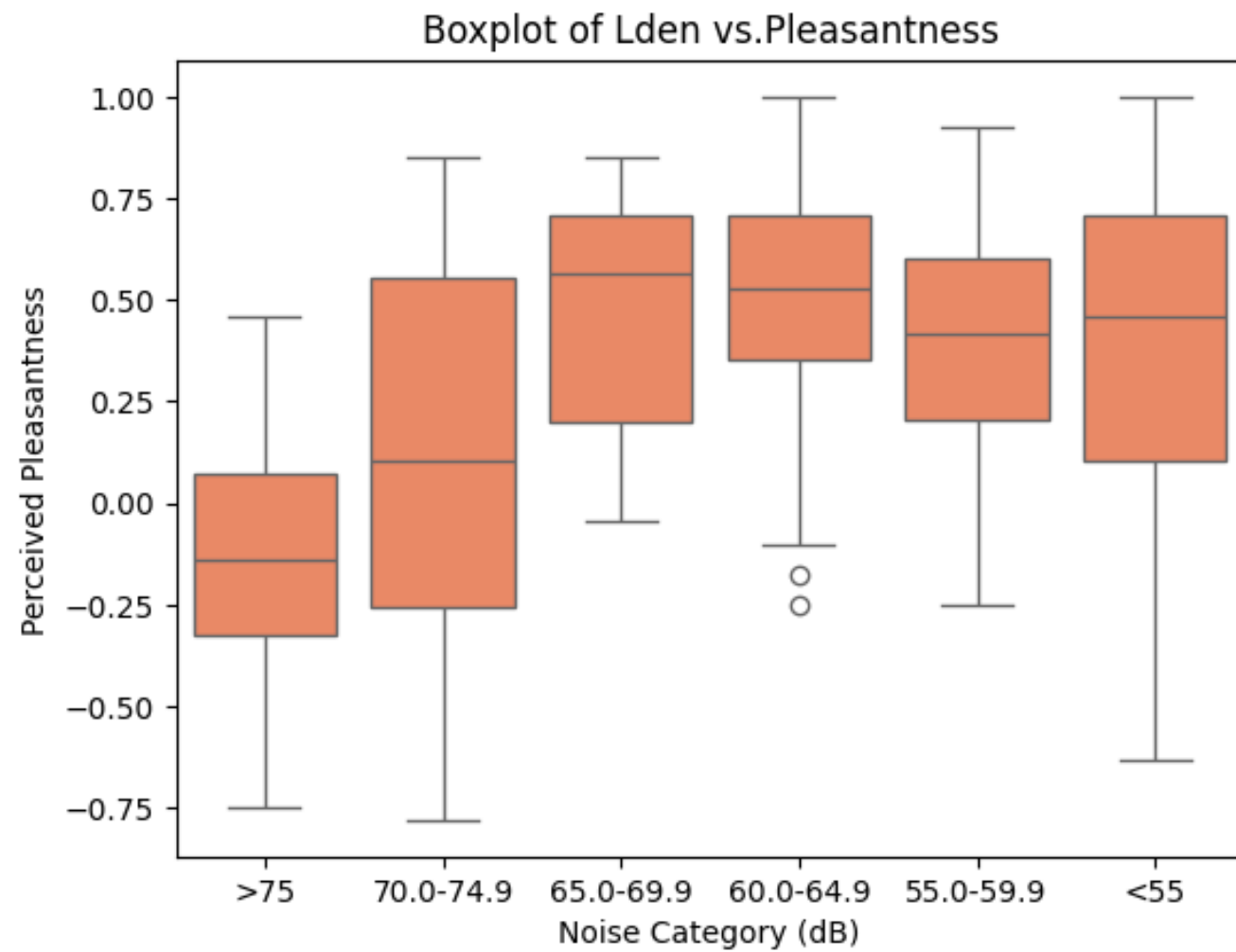


Spearman Correlation Heatmap 2: Mean of Locations

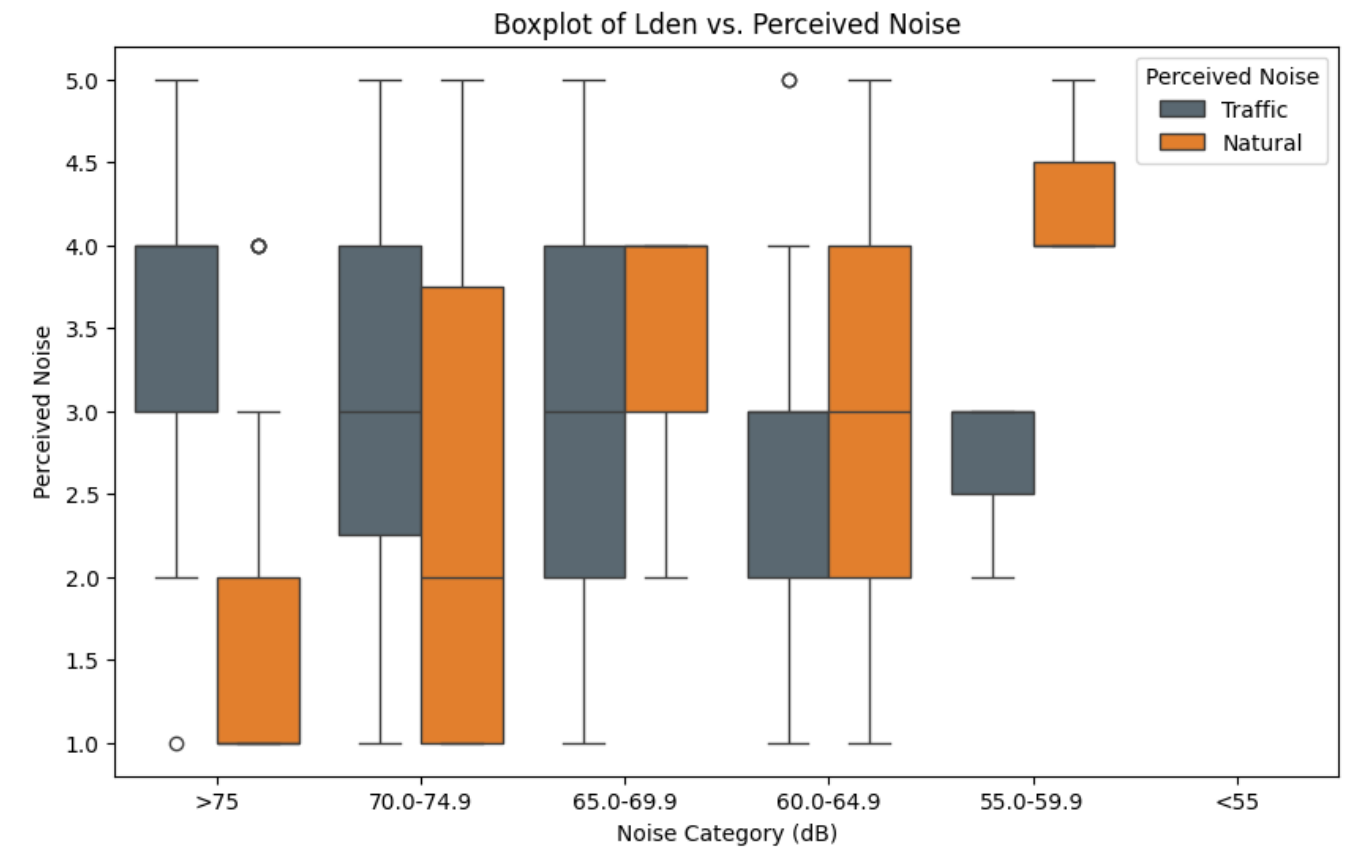


Spearman Correlations

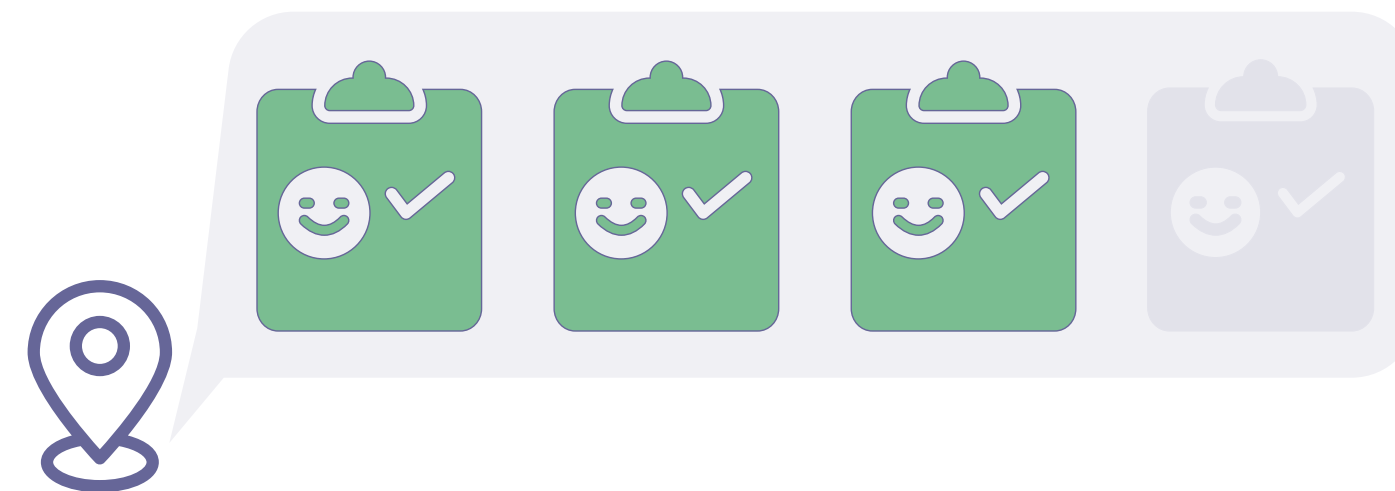
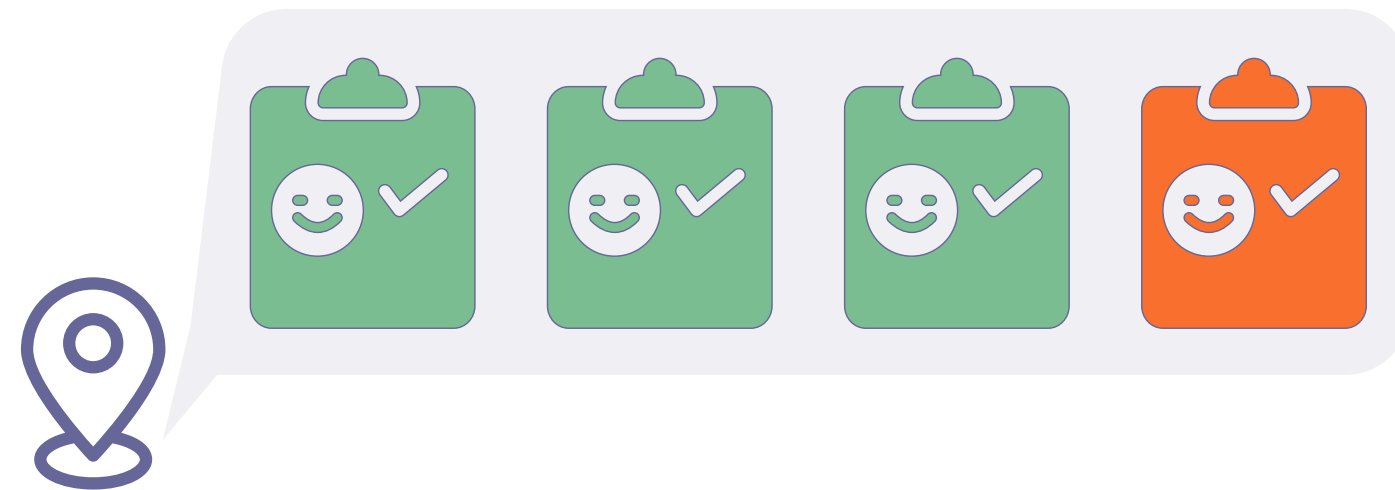




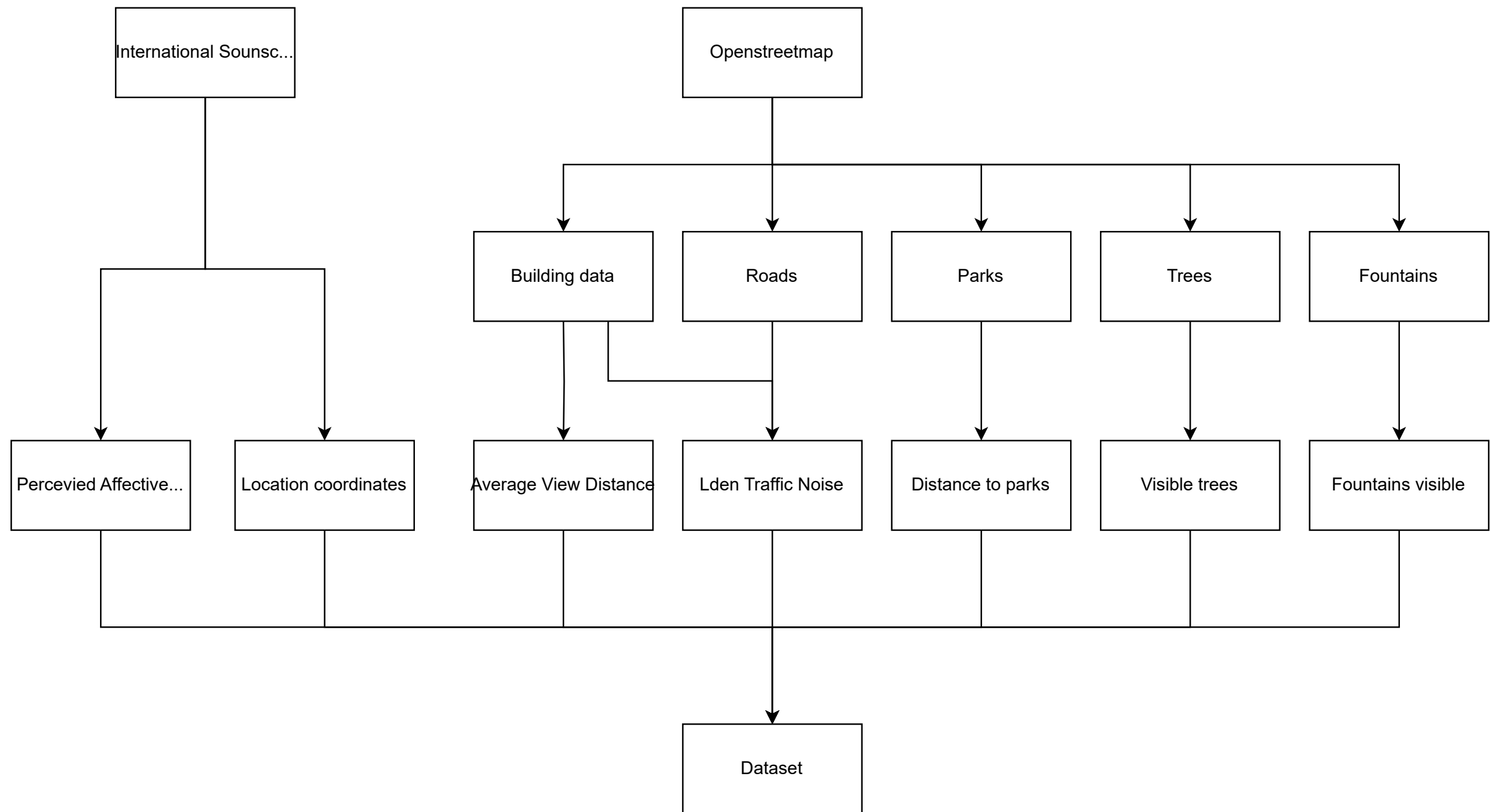
L_{den} from GLA (2017) and the perceived presence of Natural Sounds and Traffic Noise, by author



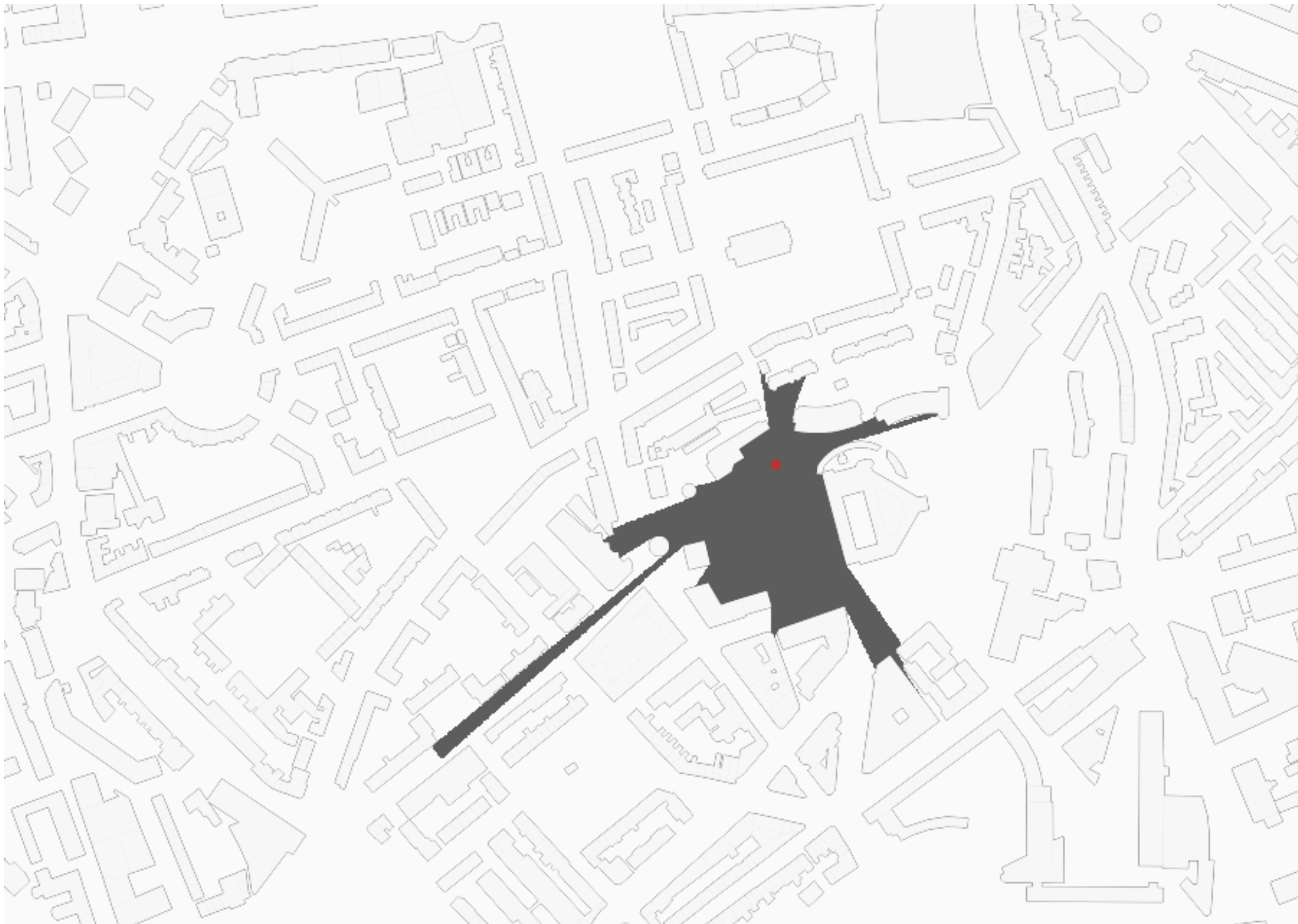
L_{den} from GLA (2017) and the perceived presence of Natural Sounds and Traffic Noise, by author



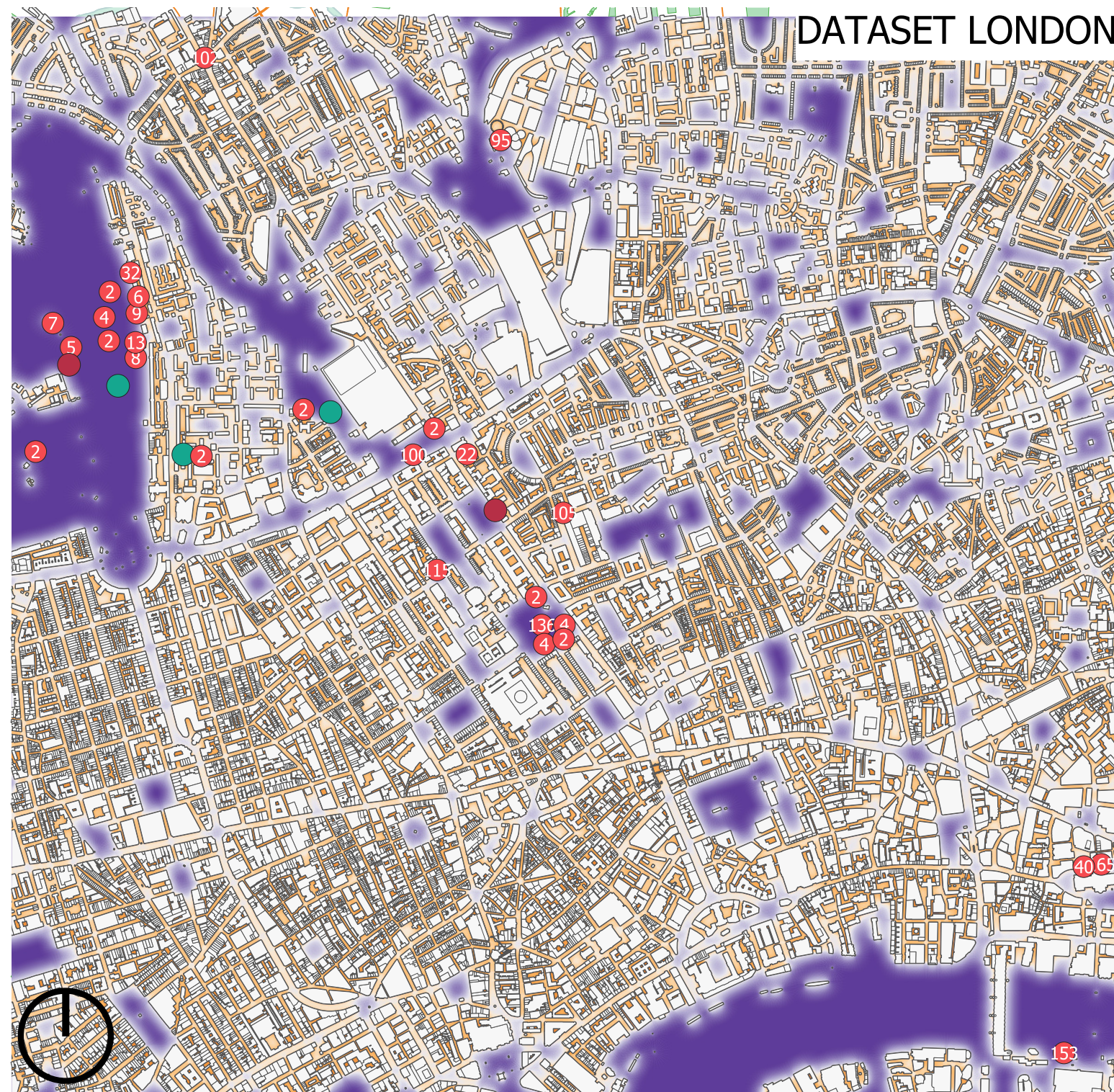
Remove contextual outliers



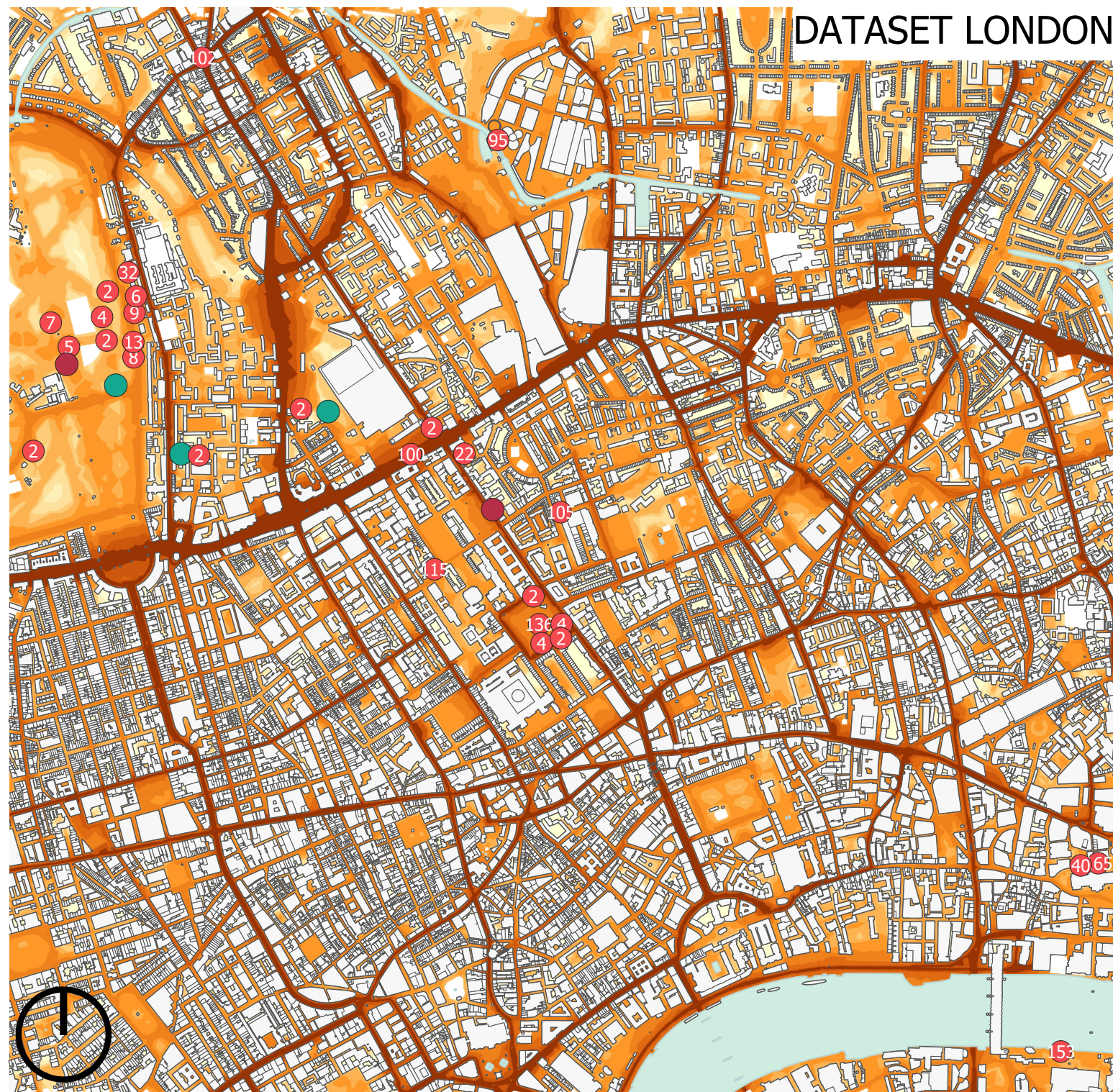
Full Dataset



Average View Distance



Average View Distance and Pleasantness:
 $rs[1327] = 0.36$ ($p < 0.001$)



Legenda

datapoints from ssid [1332]

- -1 - -0,07 [275]
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- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]
- 0,7 - 1 [267]

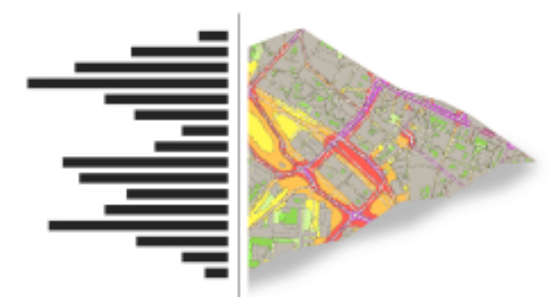
□ buildings London

Lden roadnoise

Band 1 (Gray)

- 85
- 35
- Rivers, Canals

0 500 1.000 m



L_{den} and Pleasantness: $rs[534] = -0.57$ ($p < 0.001$)
 L_{den} and Traffic Noise: $rs[534] = 0.50$ ($p < 0.001$)

L_{den} & Pleasantness: $rs[1327] = -0.27$ ($p < 0.001$)
 L_{den} & Traffic Noise: $rs[1327] = 0.29$ ($p < 0.001$)

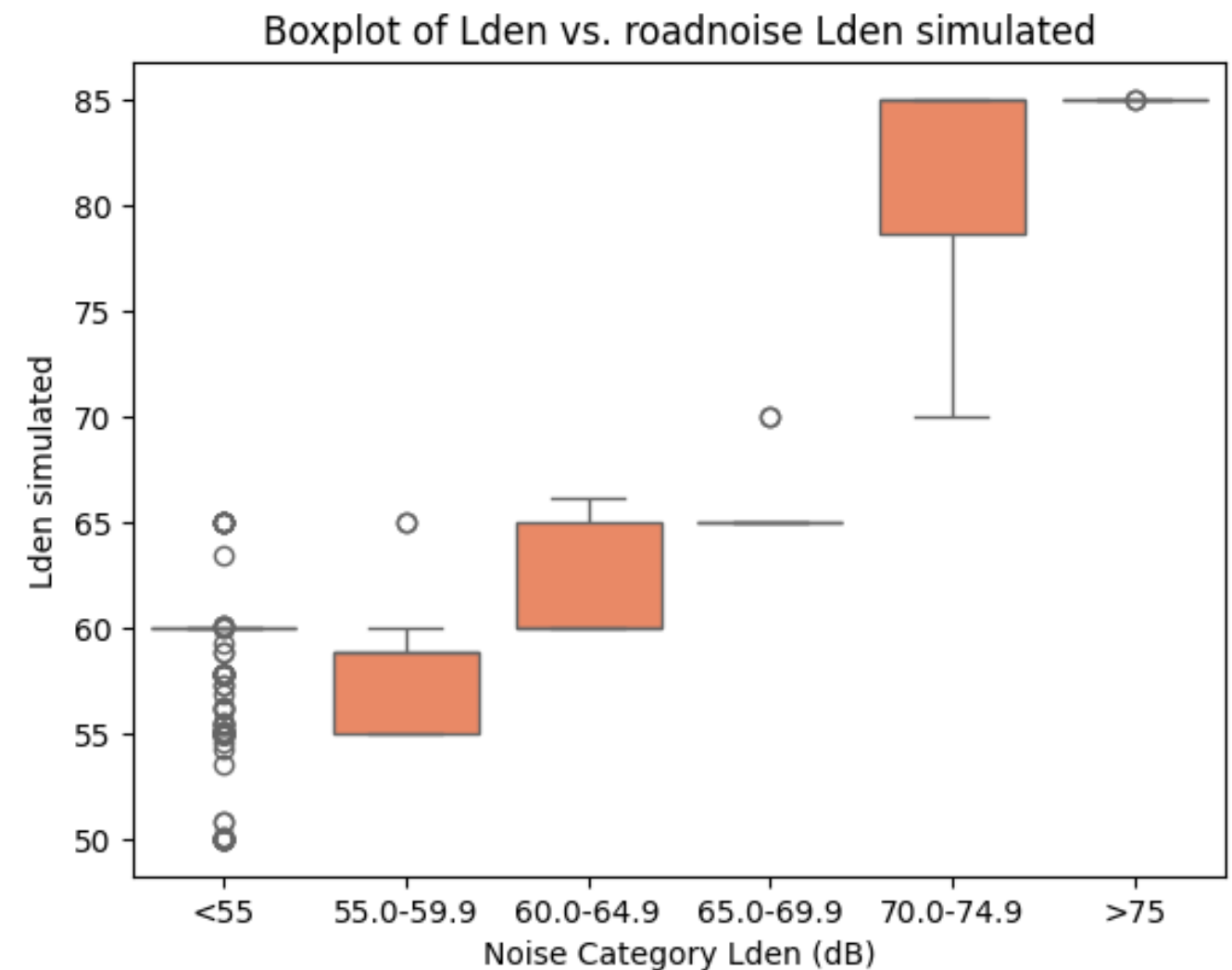
Validation

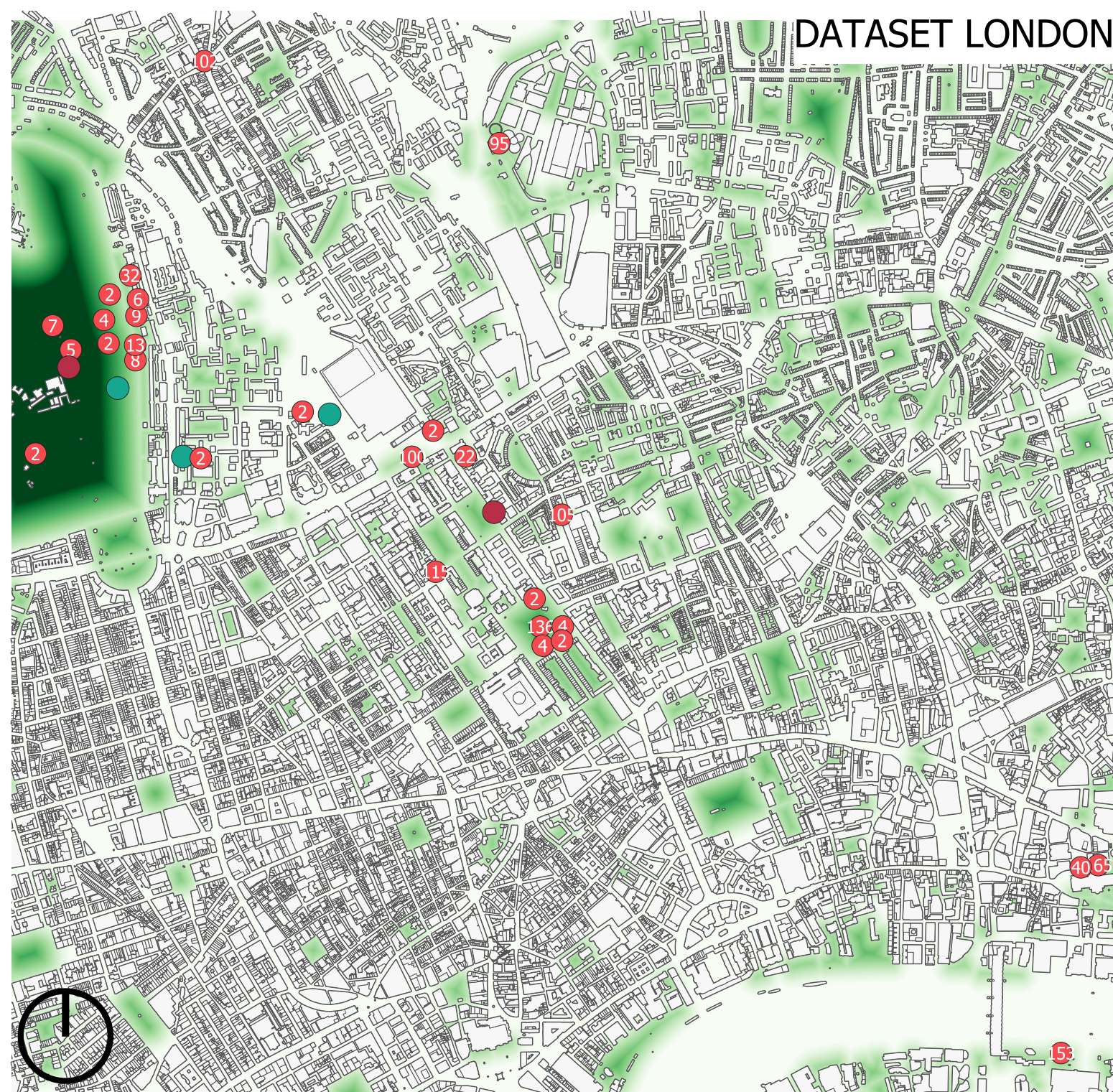
Created L_{den} map correlates strongly with L_{den} map from the GLA:
(excluding datapoints with L_{den} lower than 55dB)

$rs[534] = -0.97$, p-value: 0.0

Included:

$rs[1327] = -0.54$, p-value < 0.001





DATASET LONDON

Legenda

datapoints from ssid [1332]

- 1 - -0,07 [275]
- 0,07 - 0,24 [260]
- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]
- 0,7 - 1 [267]

buildings London

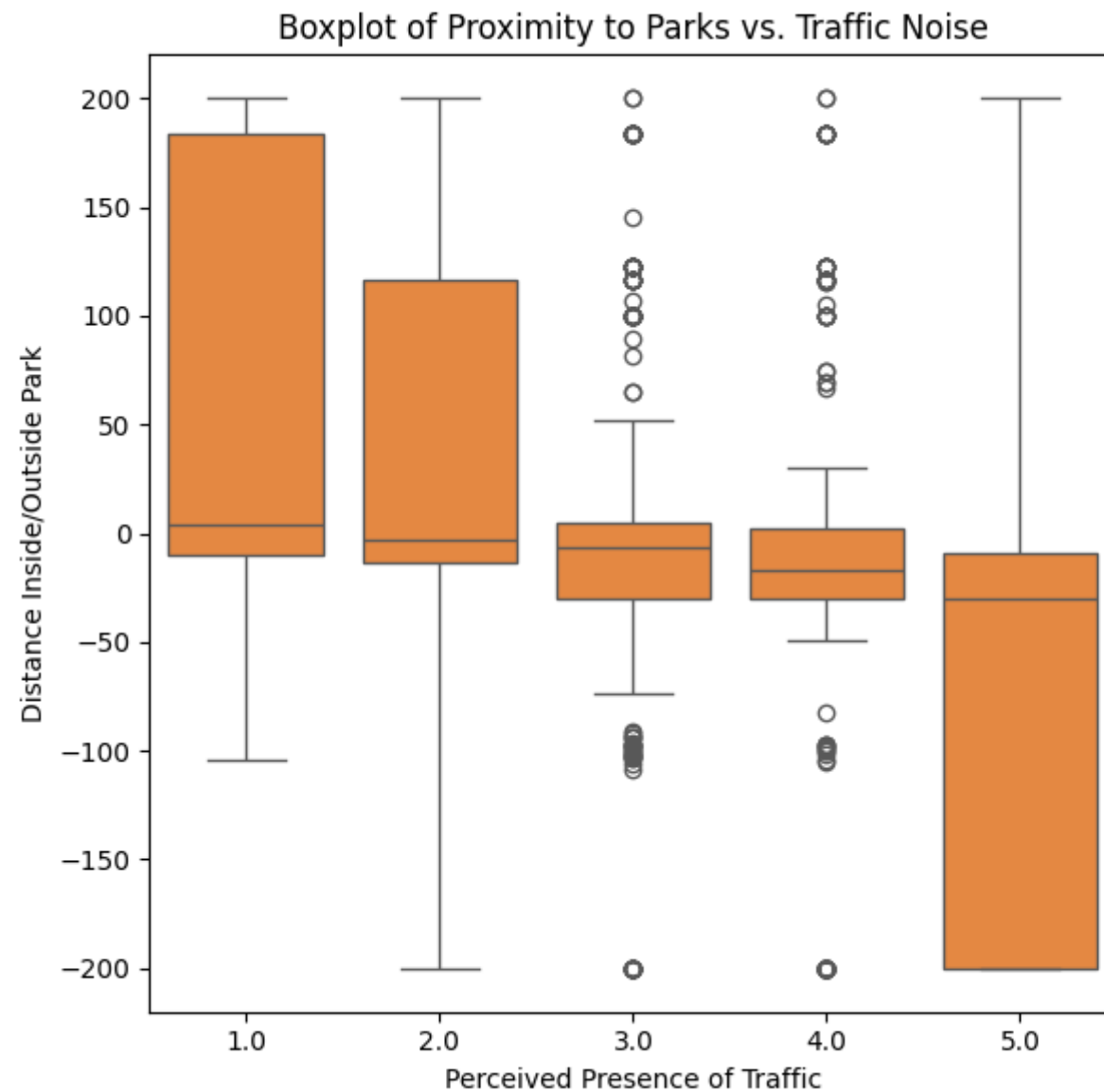
Parks London

Band 1 (Gray)

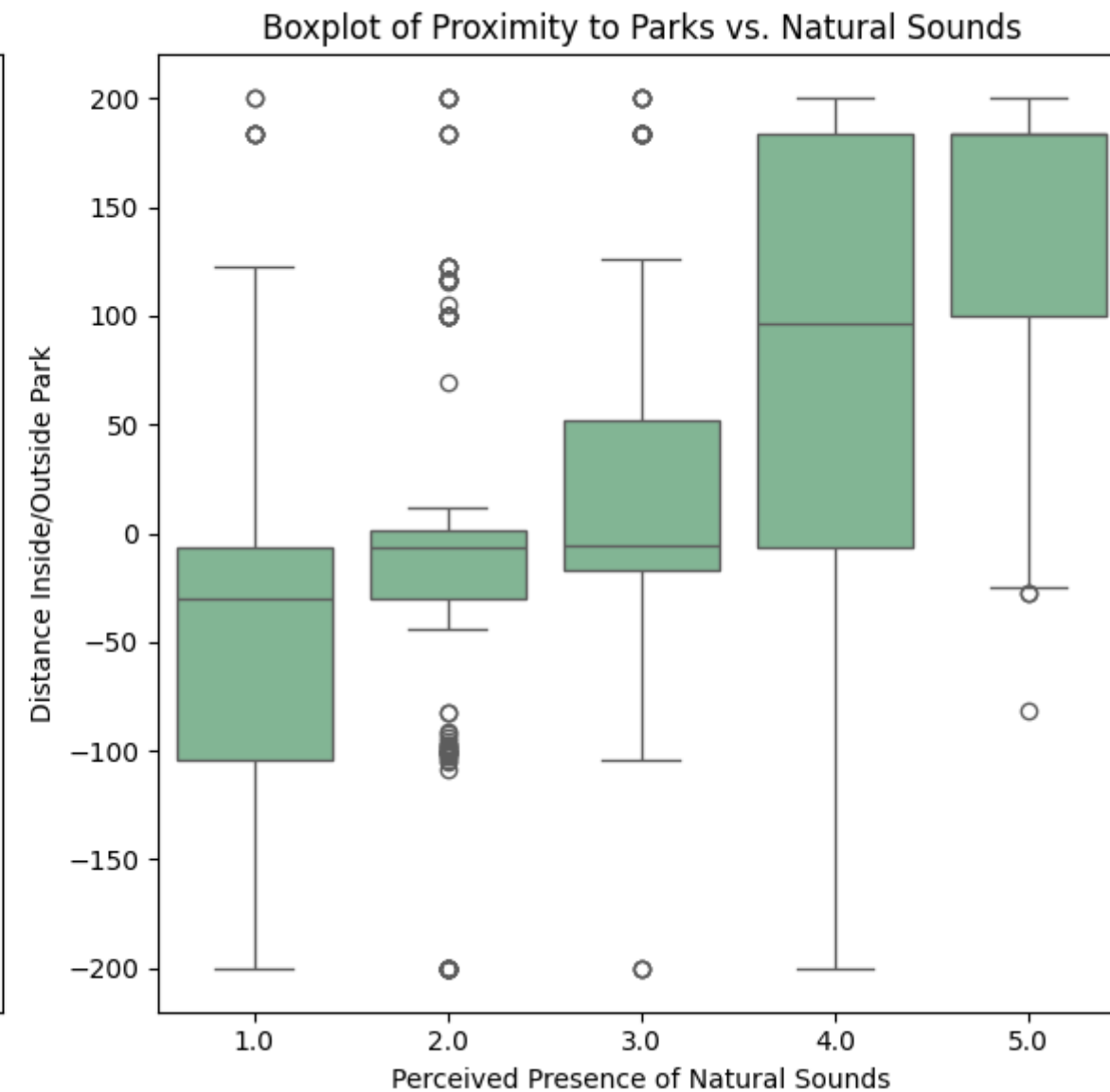
200
-100

0 500 1.000 m

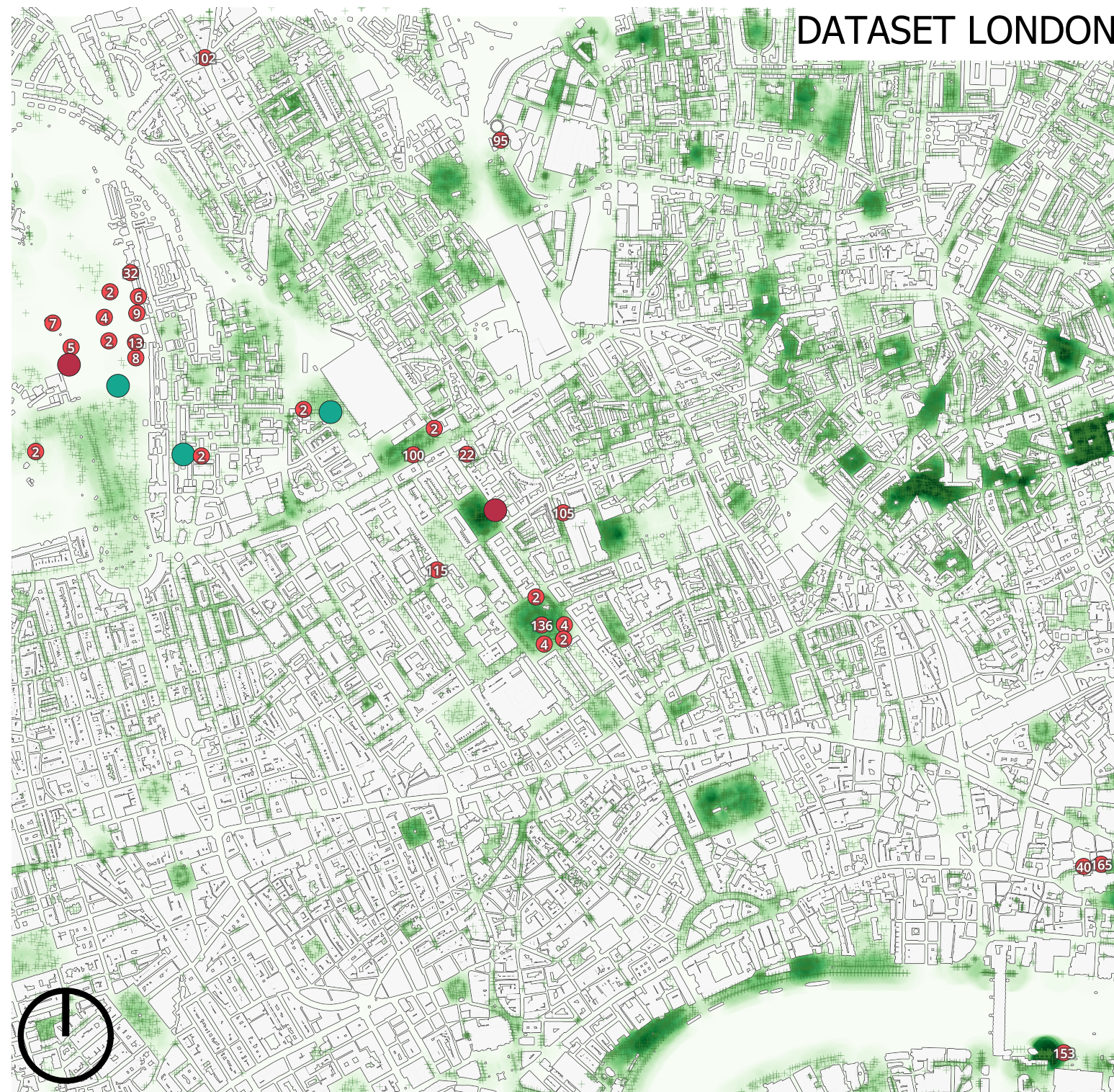
Parks proximity and Pleasantness
rs[1327]= 0.48 (p < 0.001)



Perceived presences of Traffic noise and the distance inside / outside Parks
 $rs[1327] = -0.34$, $p < 0.001$.



Perceived presence of Natural sounds and the distance inside / outside Parks
 $rs[1327] = 0.55$, $p\text{-value} < 0.001$.



Legenda

datapoints from ssid [1332]

- 1 - -0,07 [275]
- 0,07 - 0,24 [260]
- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]
- 0,7 - 1 [267]

trees_visibility_100m_london_b

Band 1 (Gray)

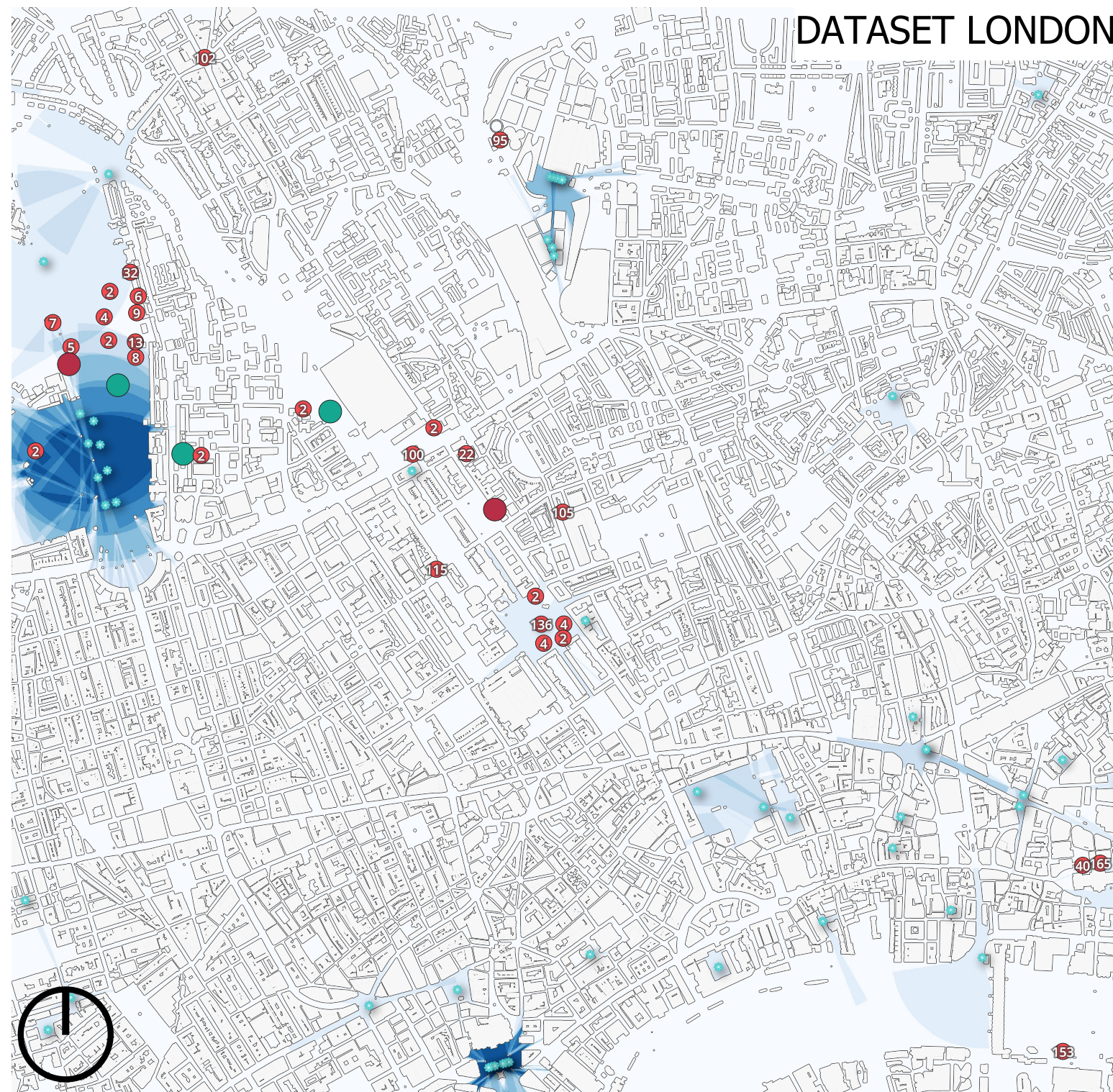


+ trees datasets combined

buildings London



Visibility of trees and pleasantness
 $rs[1327] = -0.02$, p-value: 0.45



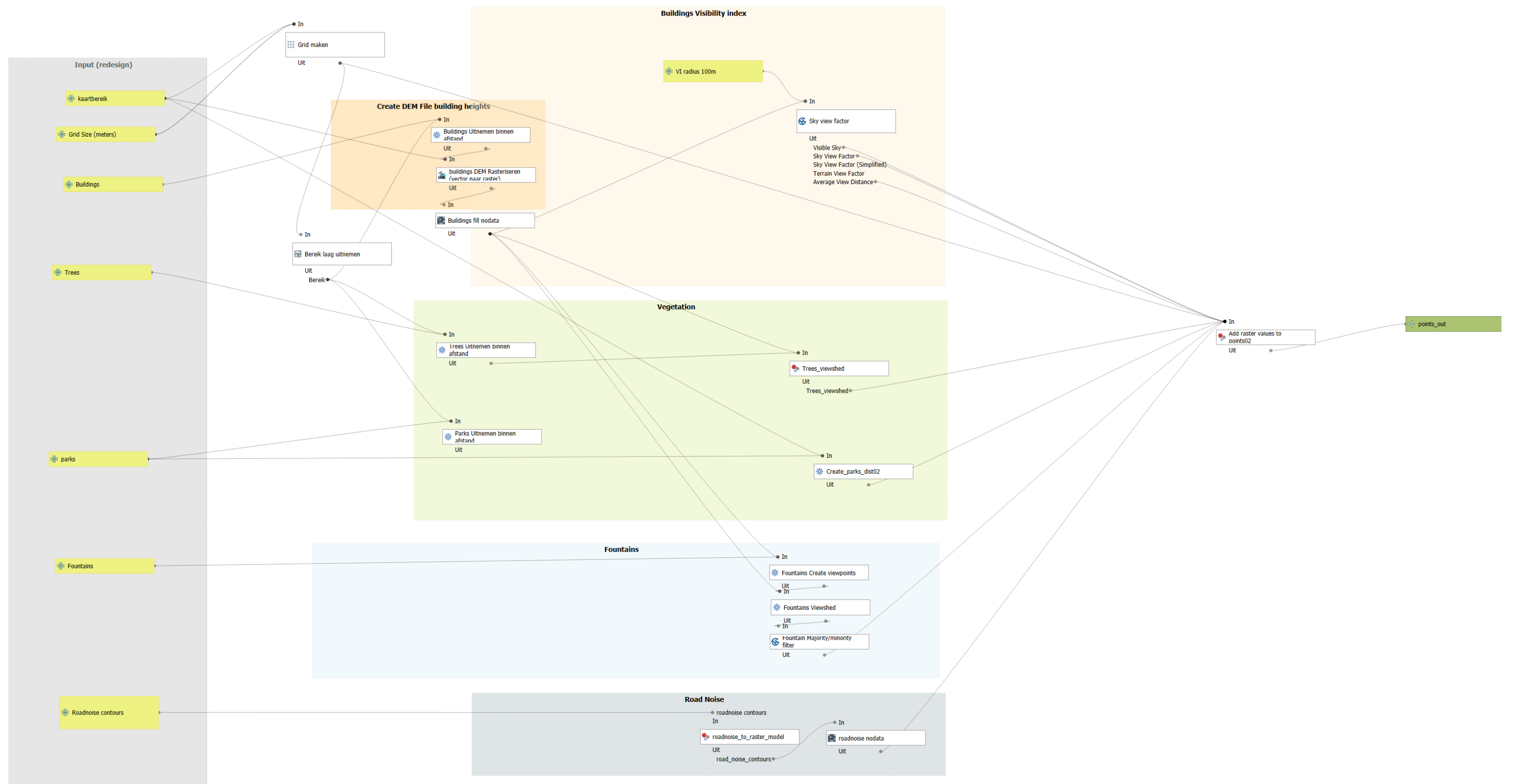
Legenda

datapoints from ssid [1332]

- -1 - -0,07 [275]
- -0,07 - 0,24 [260]
- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]
- 0,7 - 1 [267]

- buildings London
- ★ Fountains

Presence of fountains and pleasantness
 $rs[1327] = 0.42$, $p\text{-value} < 0.001$



*compilation of input data in QGIS
modelbuilder*

Choice Regression model

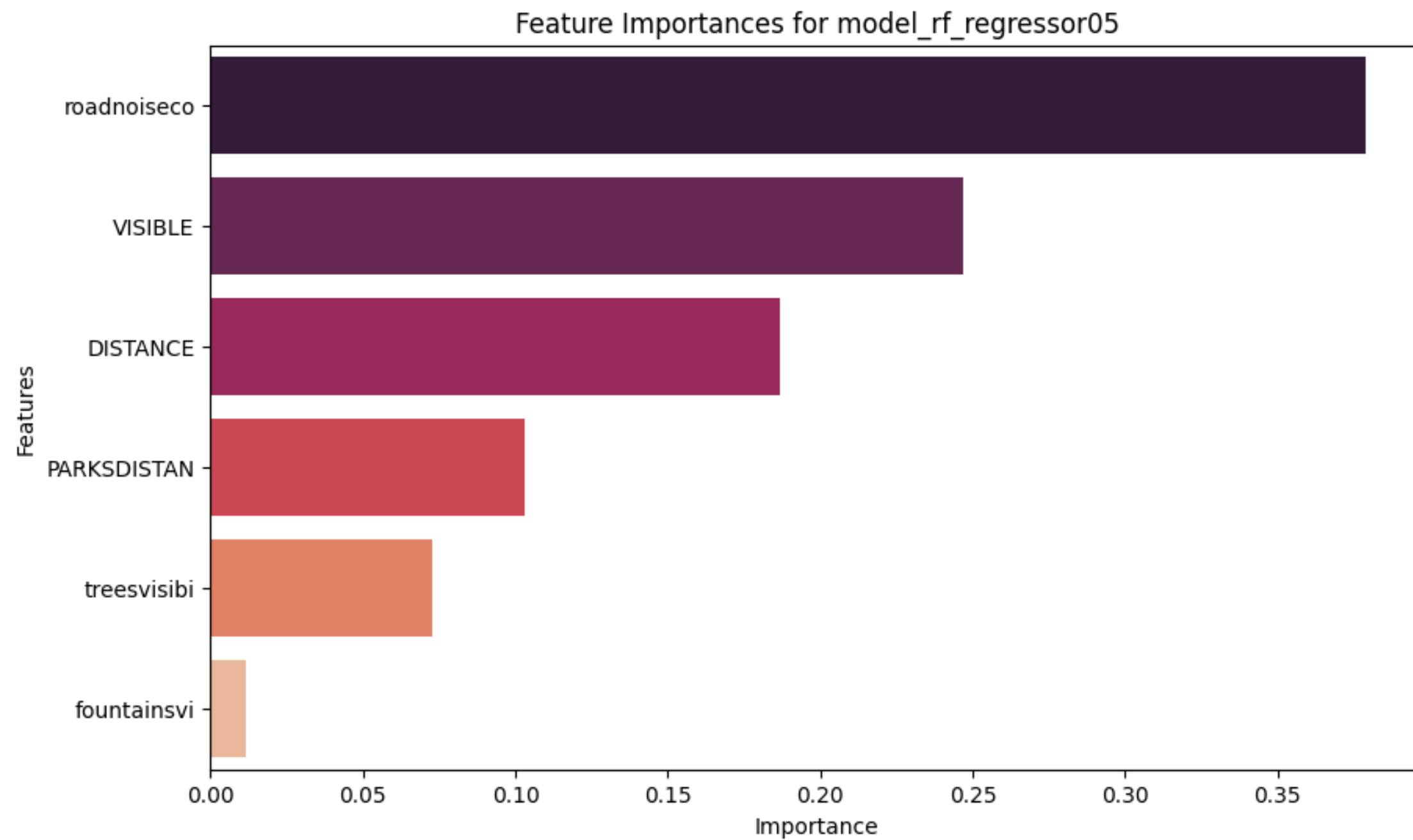
Regression: Labeled data, with a continious variable for ISO Pleasantness
Choice of Model: PyCaret

Metric	Value
Mean Absolute Error	0.25
Mean Squared Error	0.10
Root Mean Squared Error	0.31
R-squared	0.43



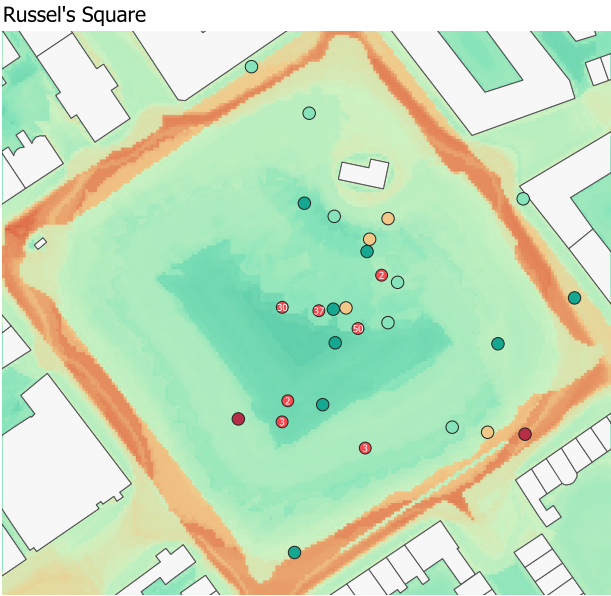
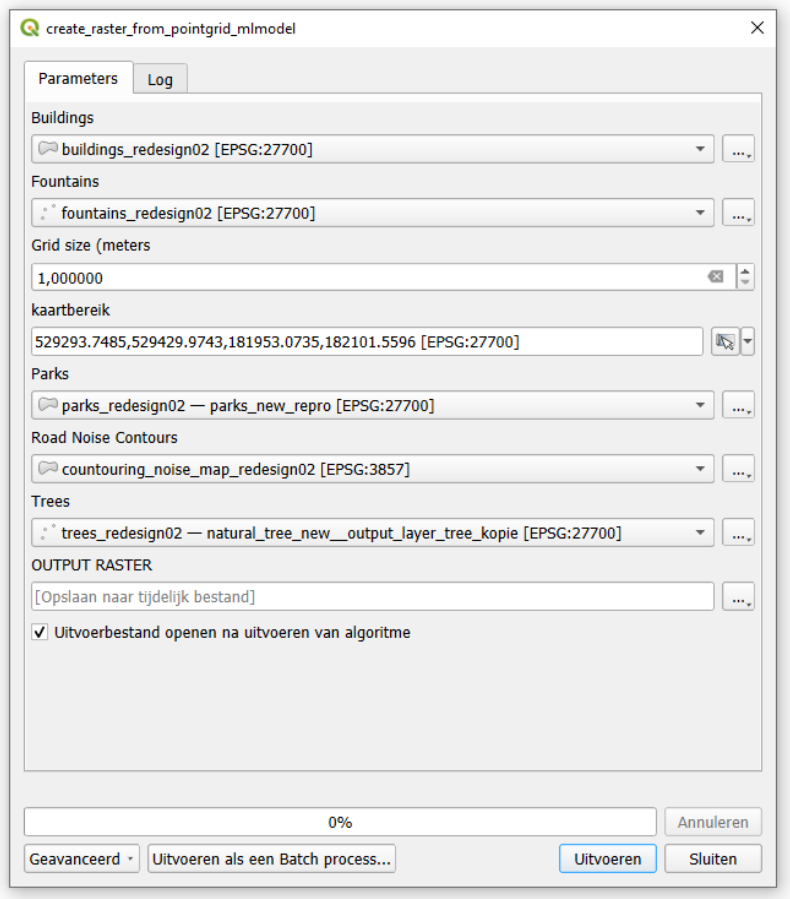
Prediction Error & Residuals Plot Random Forest Regressor created with PyCaret library, by author



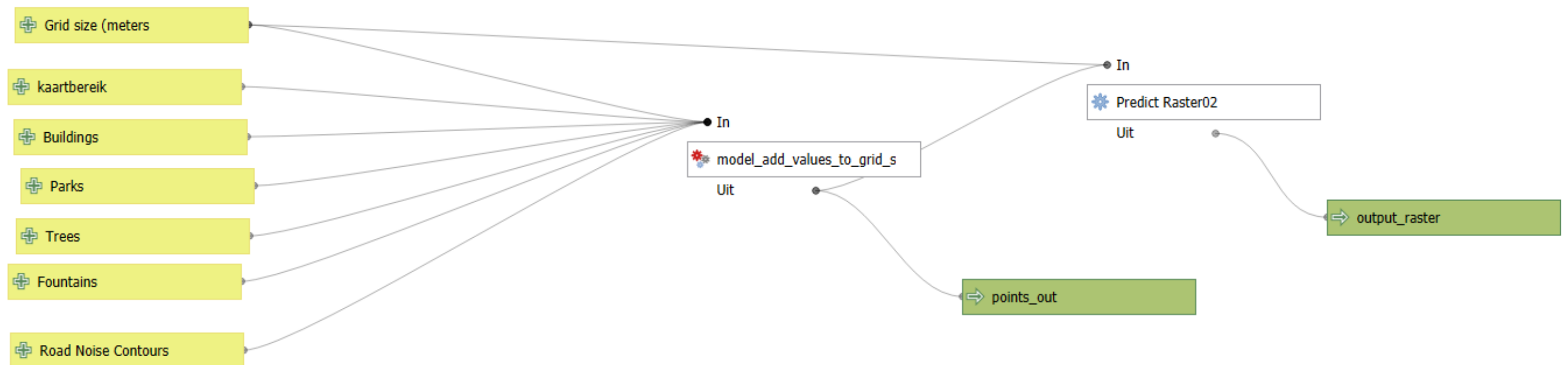


*Feature importance Random Forest Regressor
created with PyCaret plugin, by author*

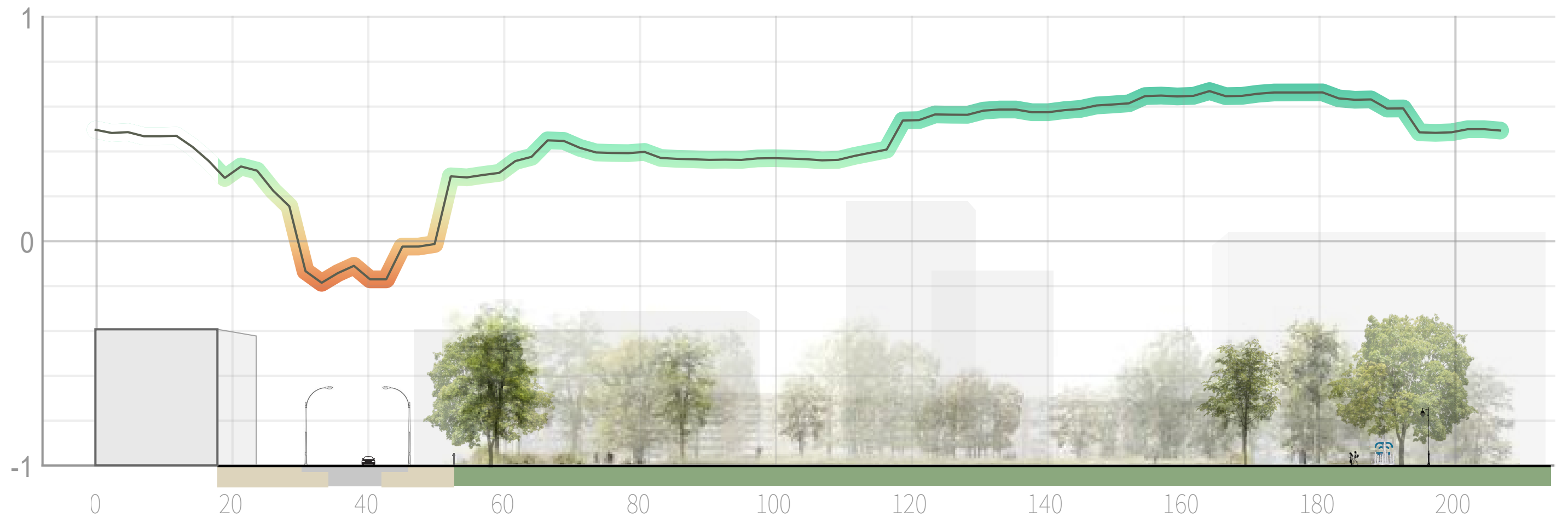
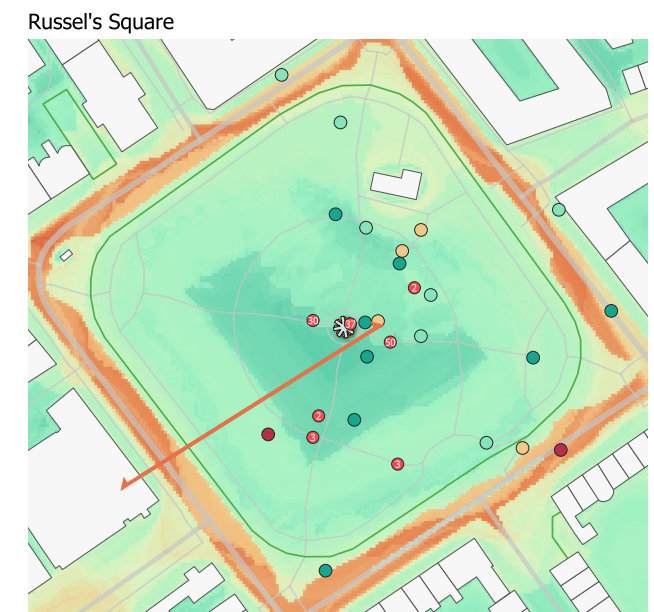
Beyond Noise



Visualization Predictions New Designs



Design Tool in QGIS Modelbuilder



Section from prediction map

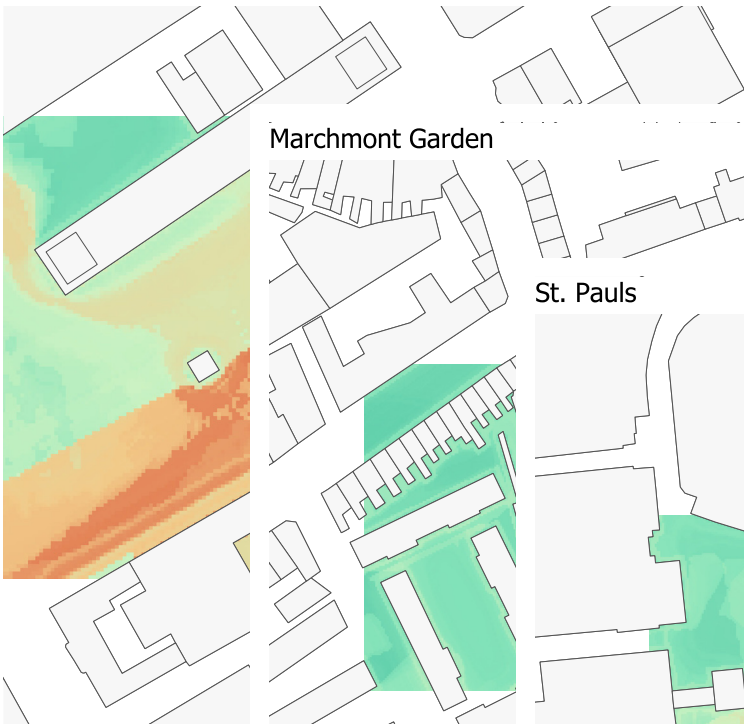
Camden Town



Legenda

datapoints from ssid [1332]
-1 - -0,07 [275]

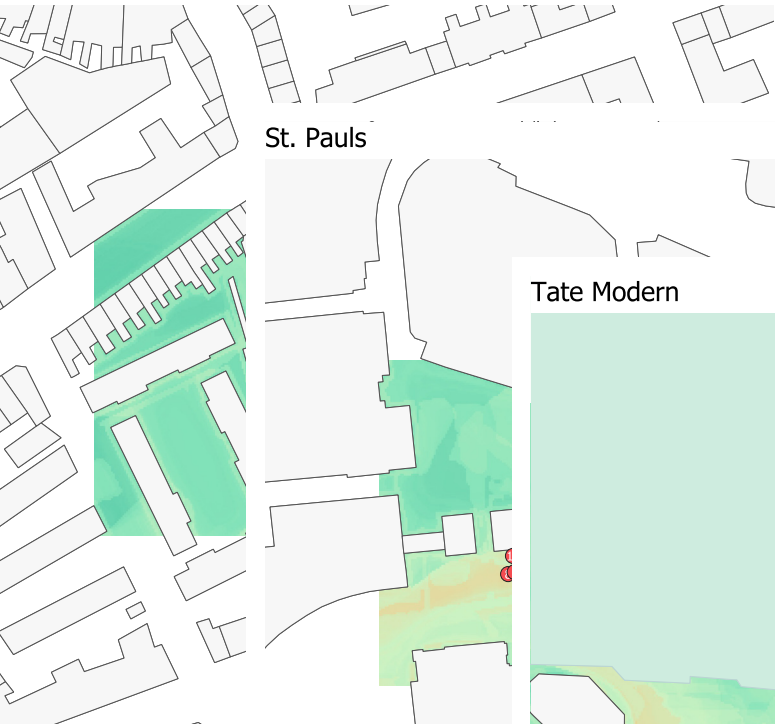
Euston Tap



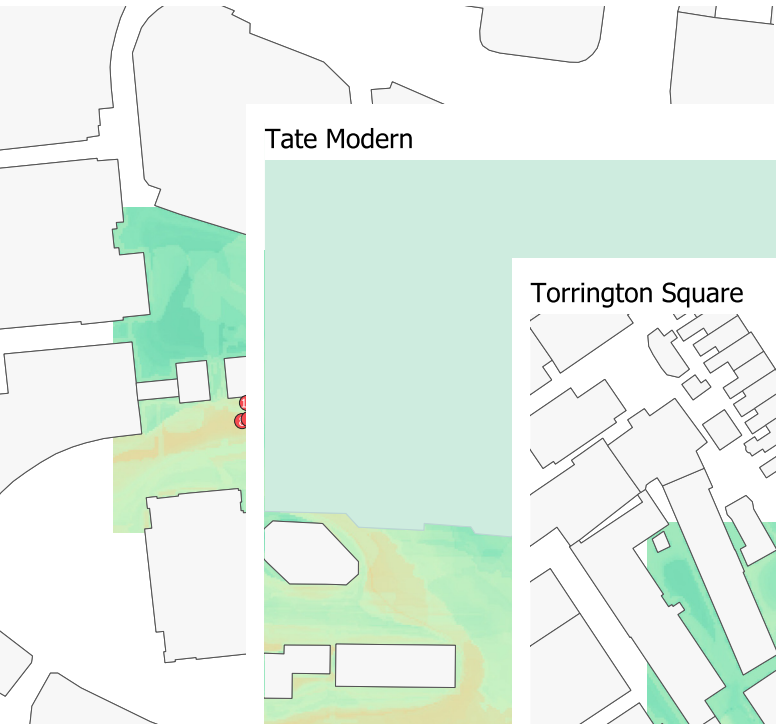
Legenda

datapoints from ssid [1332]
-1 - -0,07 [275]

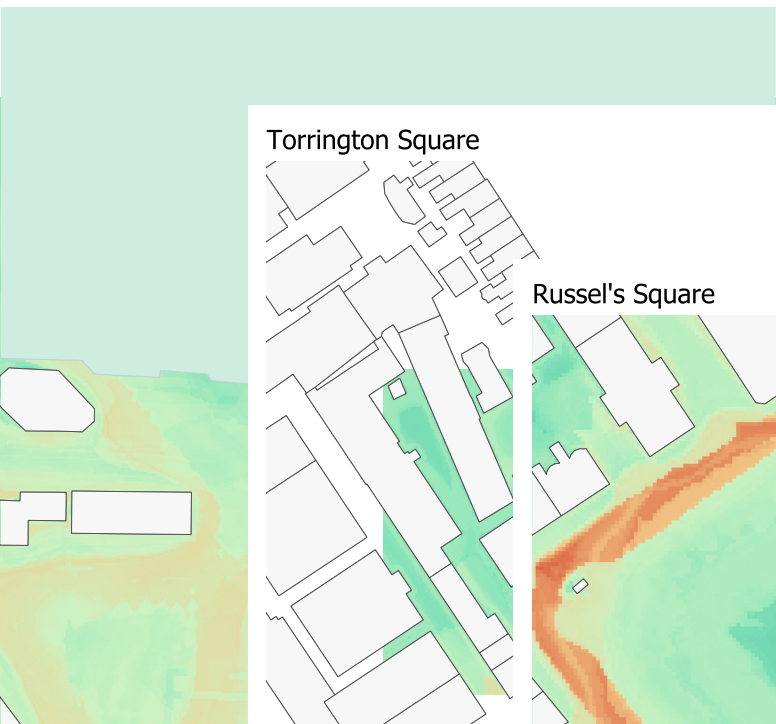
Marchmont Garden



St. Pauls



Tate Modern



Torrington Square



Russel's Square



Regents Park Fields



Legenda

datapoints from ssid [1332]
-1 - -0,07 [275]
-0,07 - 0,24 [260]
0,24 - 0,46 [269]
0,46 - 0,7 [261]
0,7 - 1 [267]

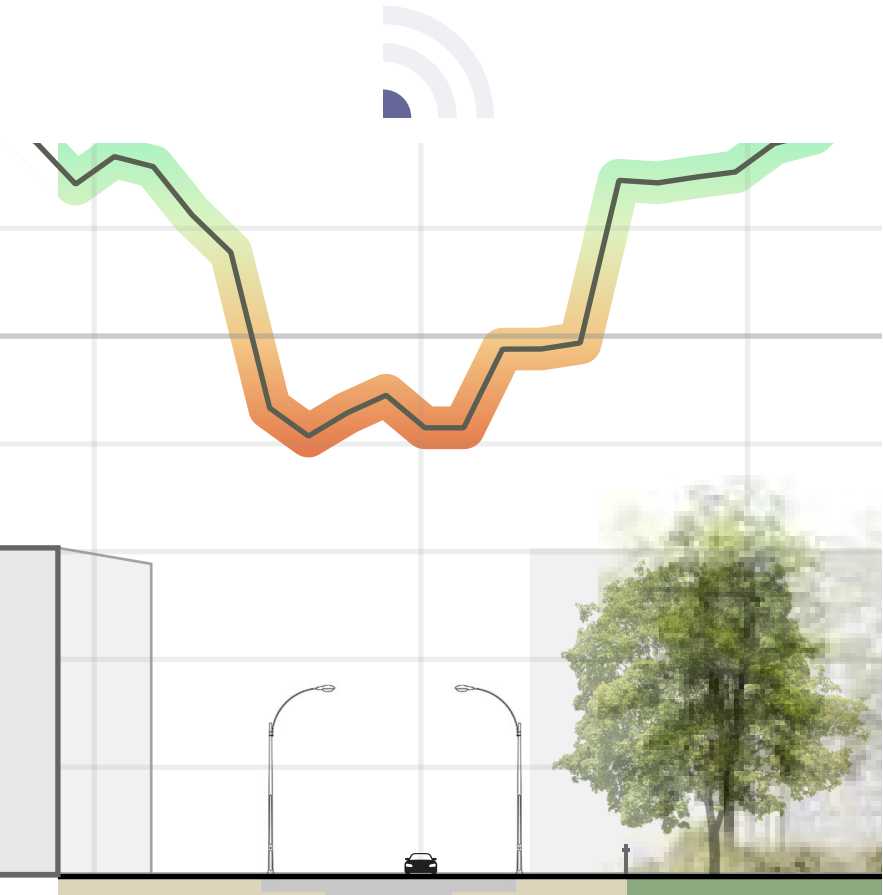
buildings London

pleasantness scale
Band 1 (Gray)
1
-1

Predictions on dataset locations

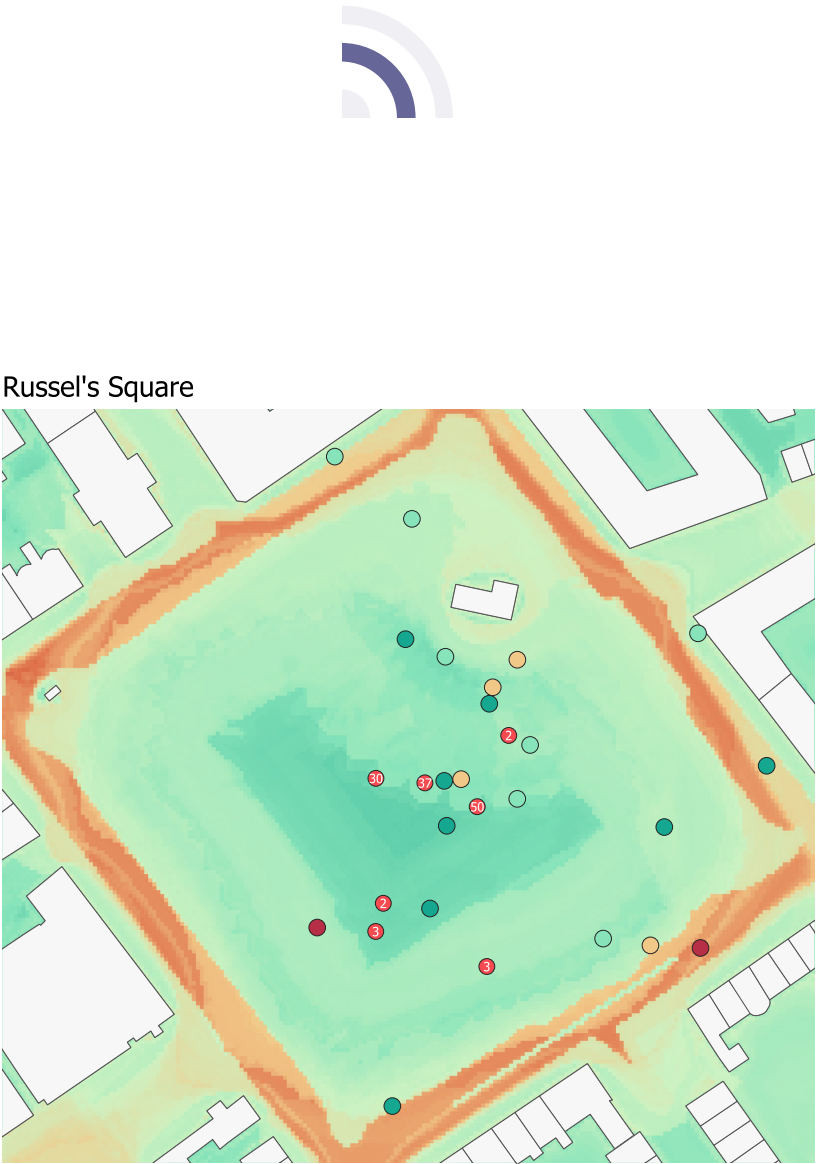
Appllication in design: Scales

Human Experience
(3-30m)



Link numbers to experiences

Building Block
(30-300m)



Contrast in Between Spaces

District
(300+m)



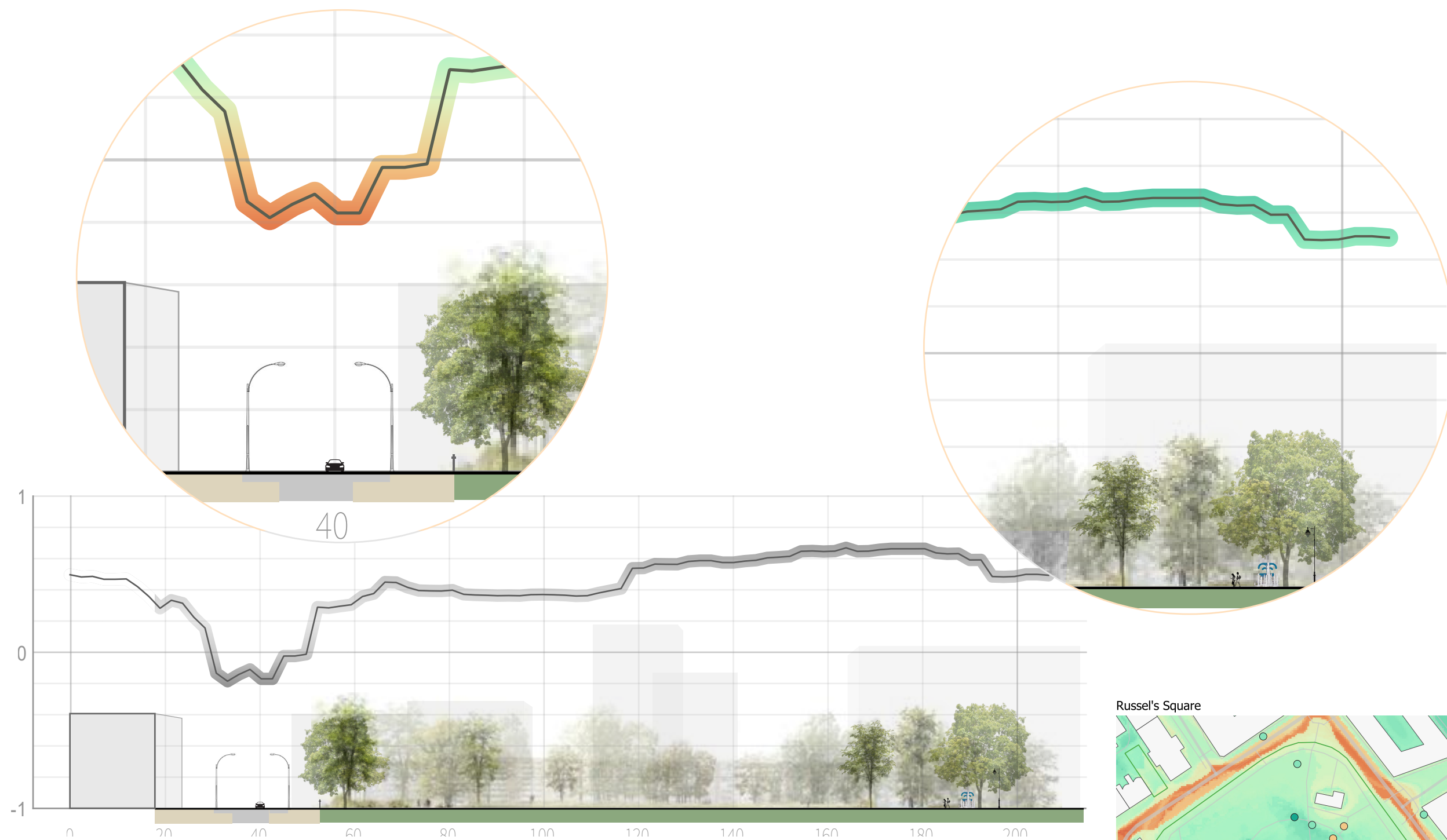
Take samples in multiple places, for comparison

Soundscape mapping / visualization

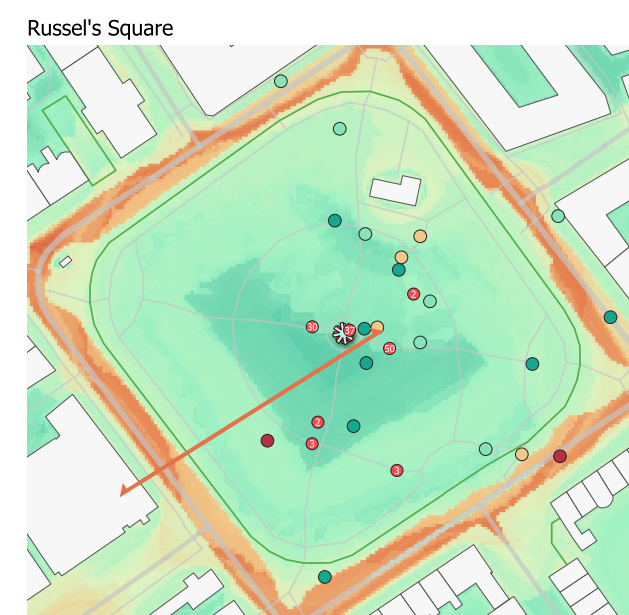
Legend & symbols

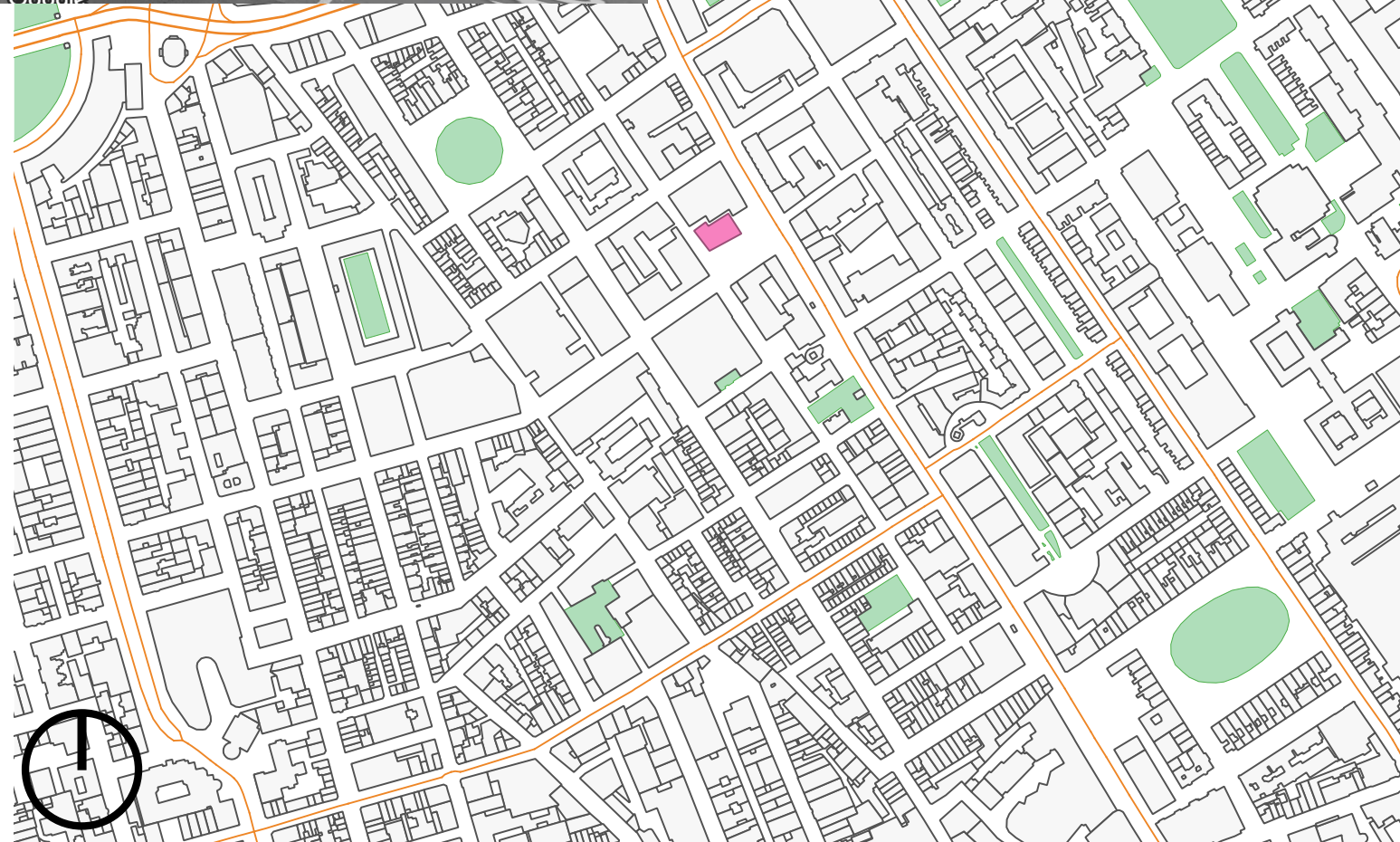


Urban soundscape maps modelled with geo-referenced data. Lavandier et al., 2016






Section from prediction map





Legenda

-  buildings London
-  Roads trunk
-  Parks London
-  Rivers, Canals
-  REDESIGN LOCATION


Existing situation




Legenda

 buildings London

roads

 0,6 - 1,2

 1,8 - 2,4

 2,4 - 3

pleasantness scale

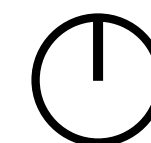
Band 1 (Gray)

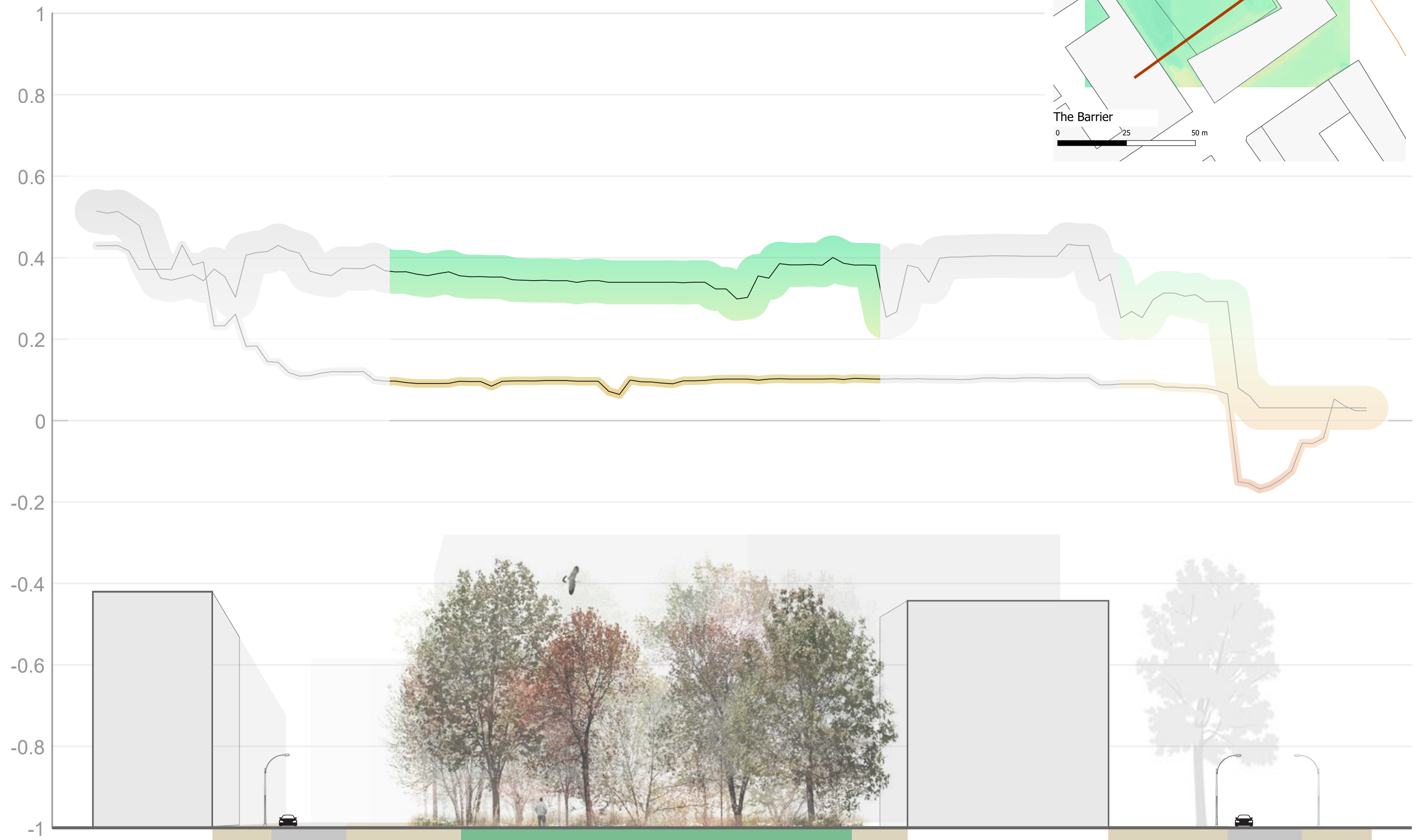
 1
-1

The Barrier

0 25 50 m

Soundscape evaluation







average increase
in predicted
pleasantness = 0.25



Baseline, existing situation



Half Open



Courtyard



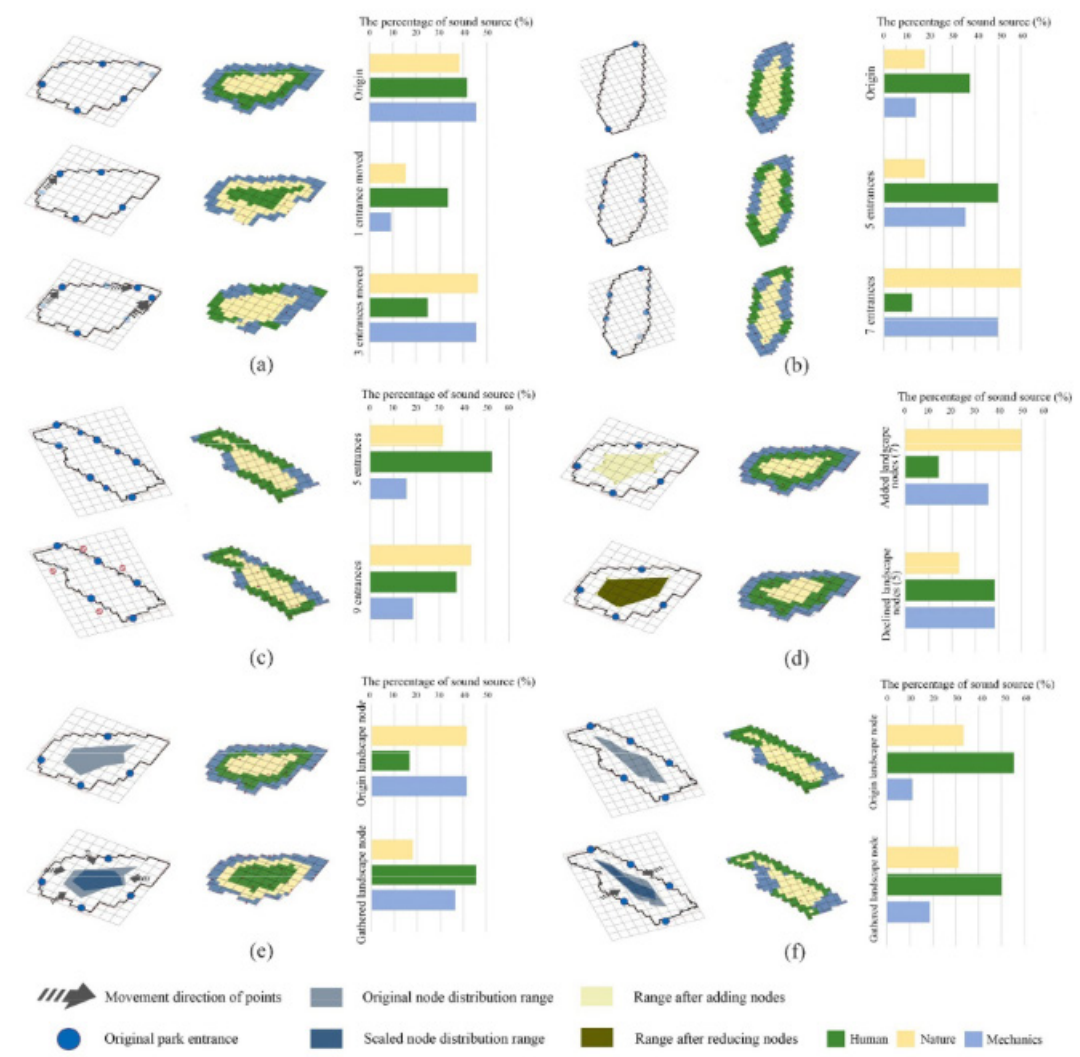
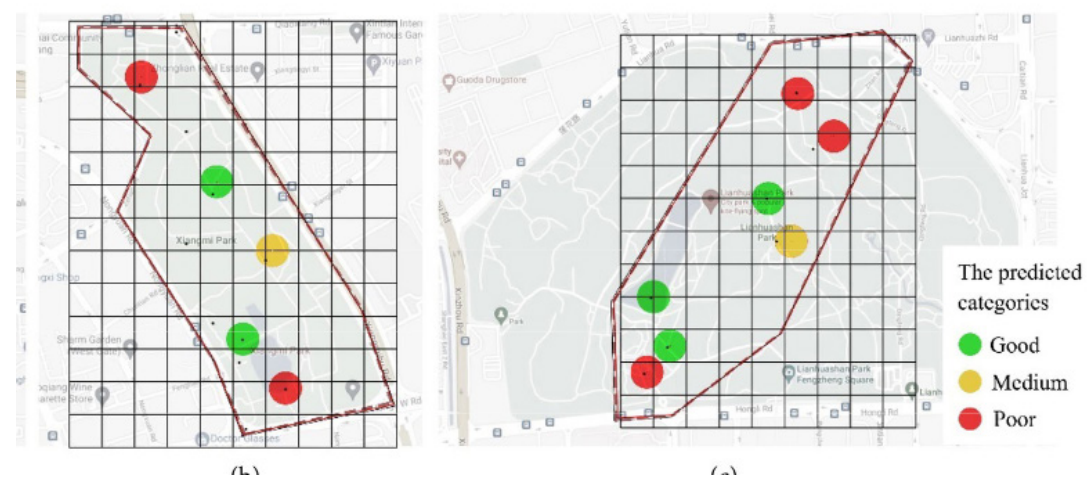
Enclosed green



The Green Courtyard

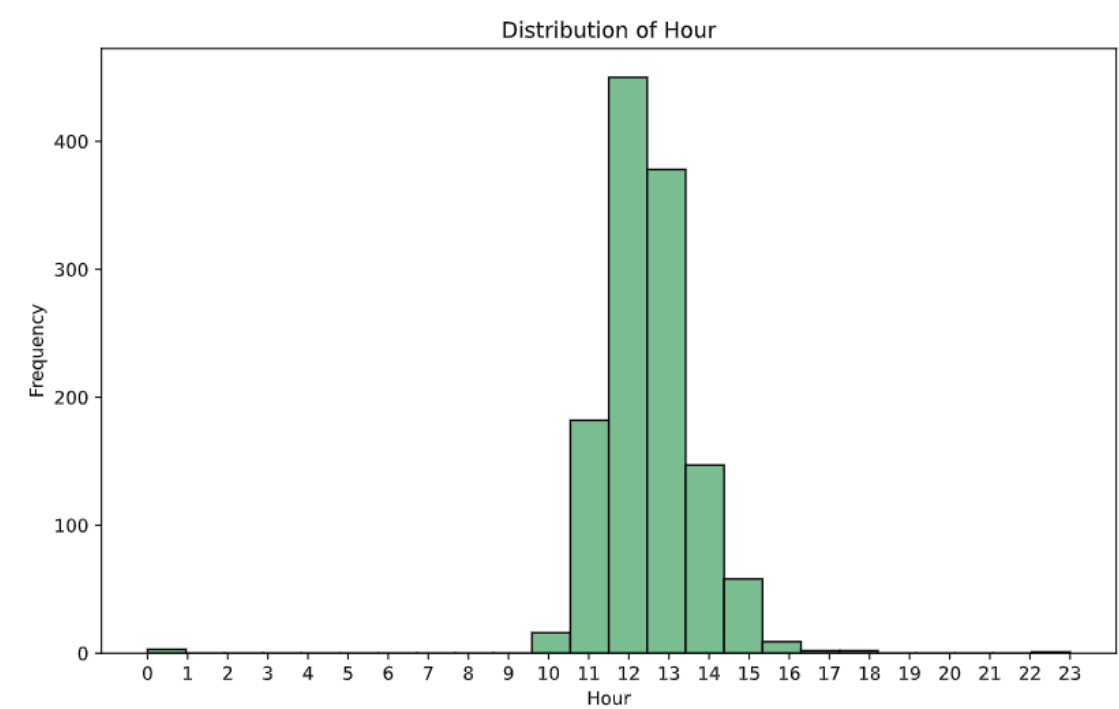
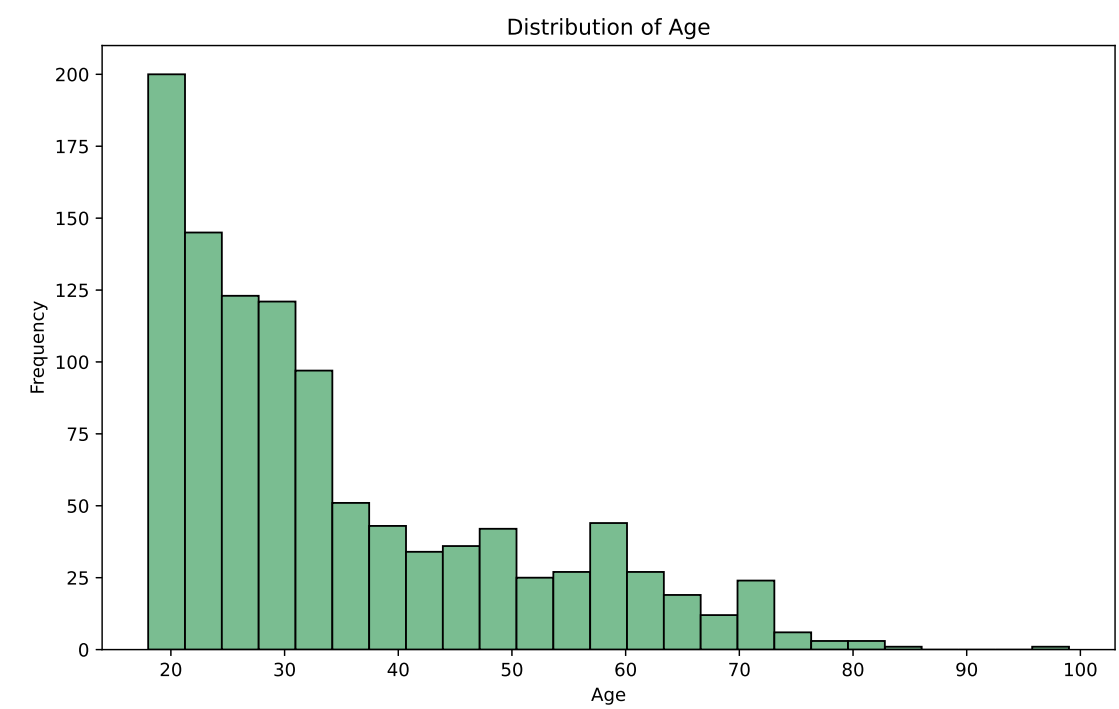
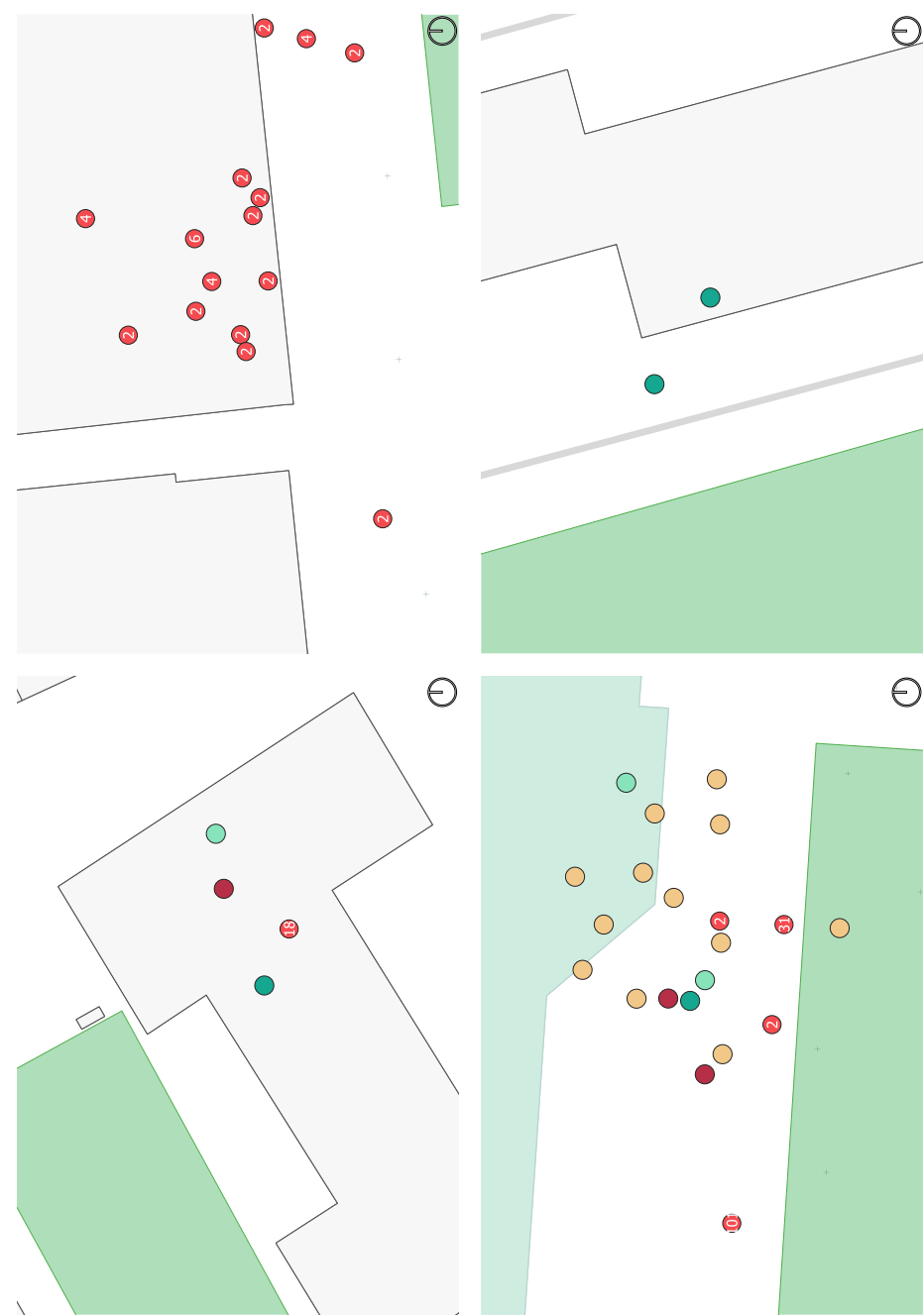


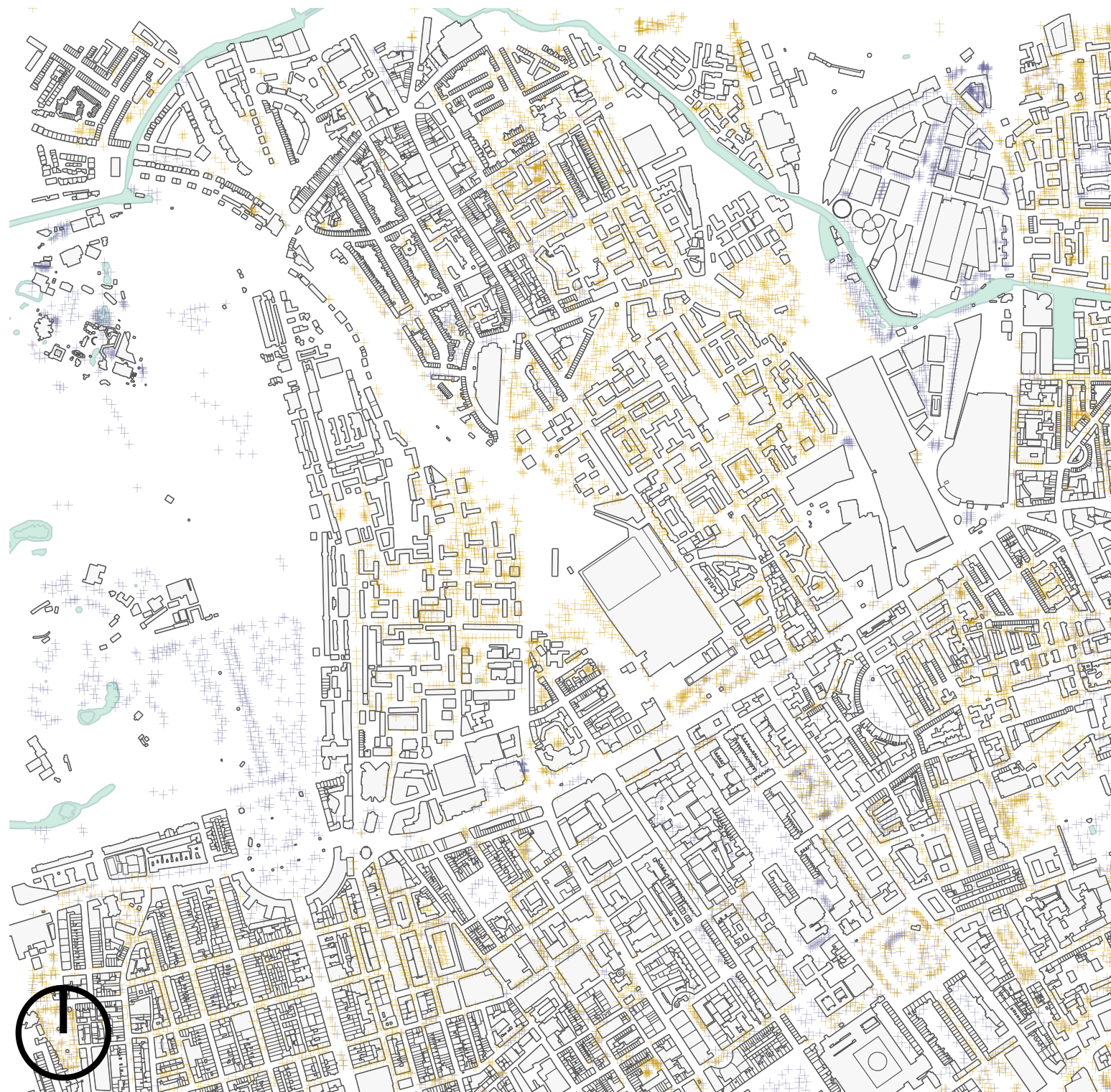
Predictive Soundscape Design Sound Source Types



A visualized soundscape prediction model for design processes in urban parks. Yue et al., 2023.

Limitations of the dataset





Legenda

- + trees_database_GLA [16891]
- + trees_OpenStreetMap
- buildings London
- Rivers, Canals

0 250 500 m

Limitations of added data quality

Camden Town



Legenda

datapoints from ssid [1332]

- 1 - -0,07 [275]
- 0,07 - 0,24 [260]
- 0,24 - 0,46 [269]
- 0,46 - 0,7 [261]

buildings London

pleasantness scale
Band 1 (Gray)

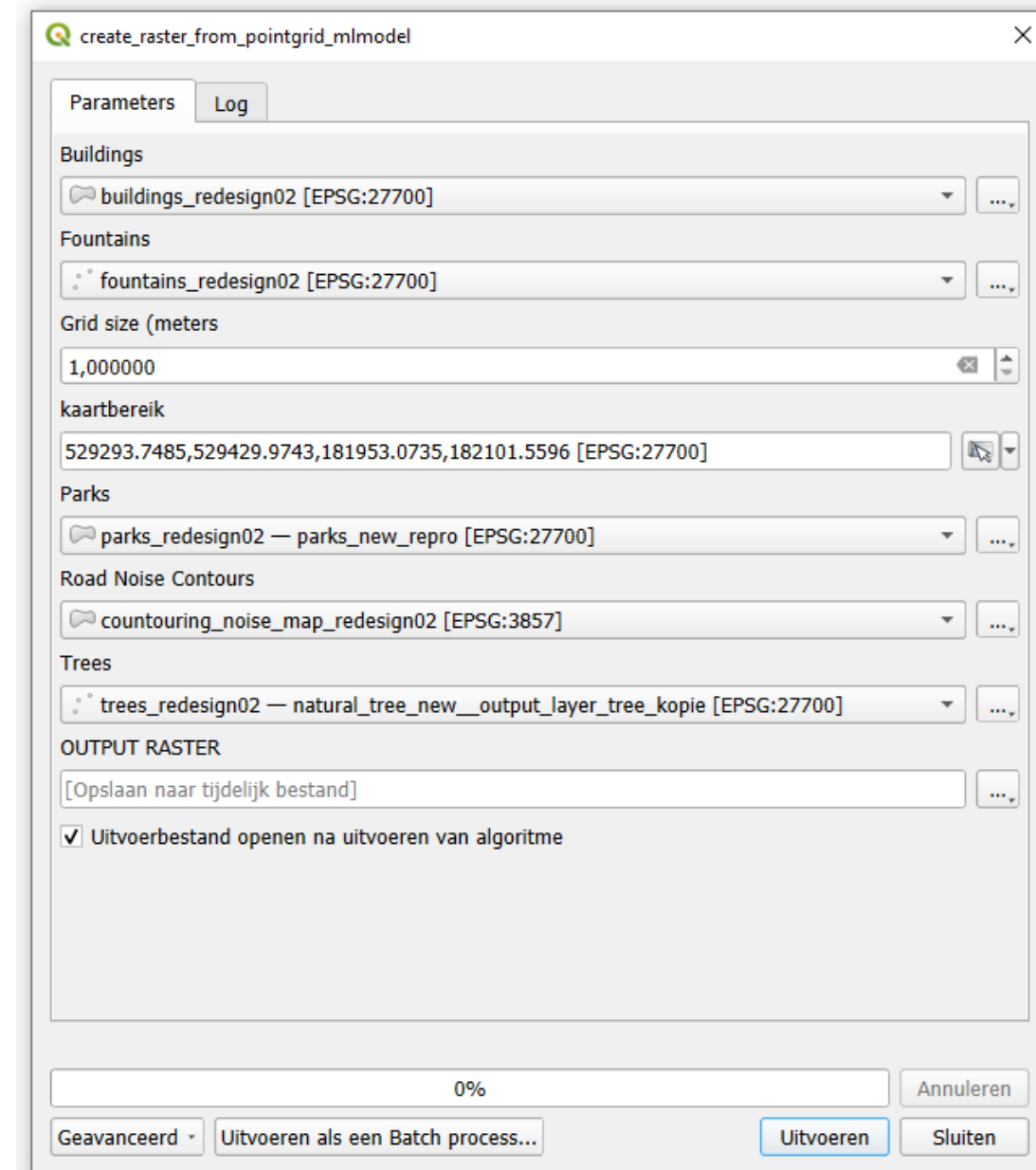
- 1
- 1

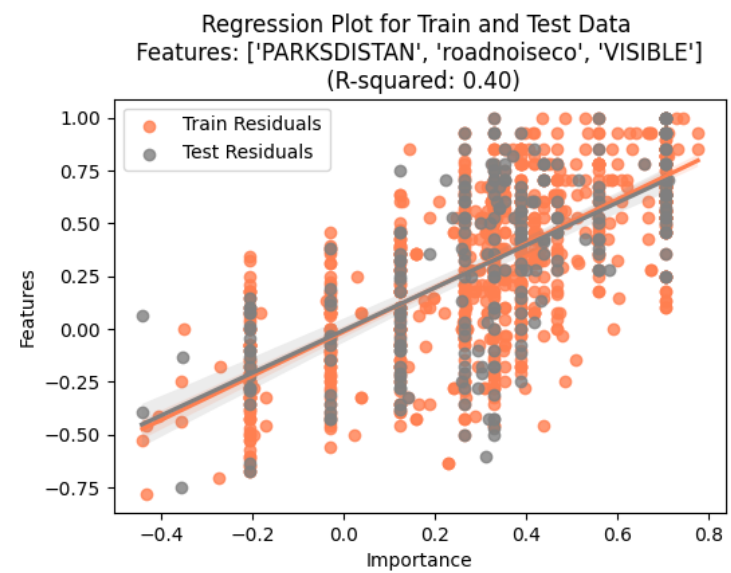
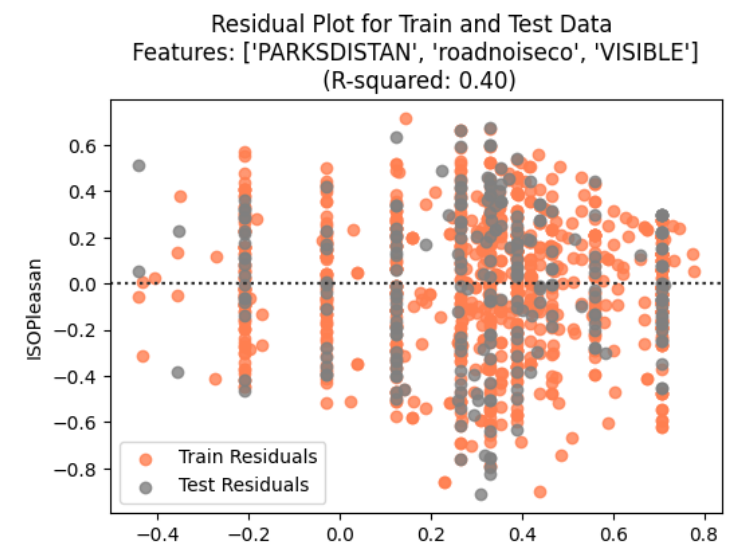
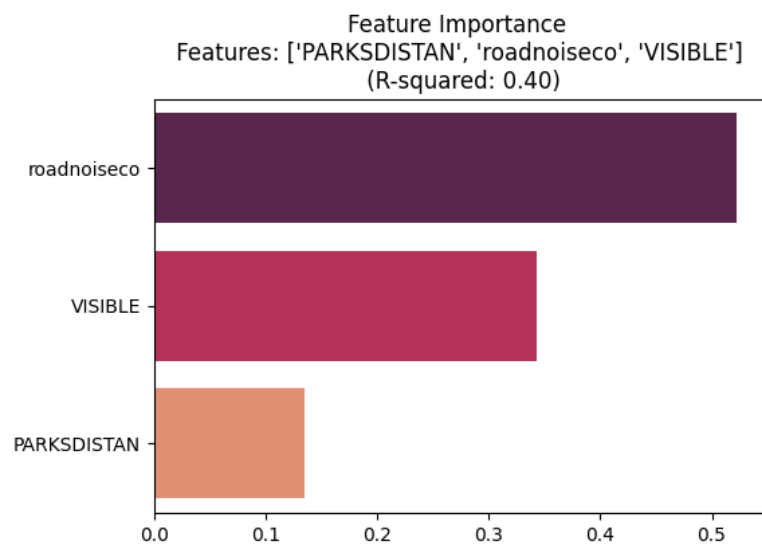


Machine learning model inaccuracy
 L_{den} and Average view Distance

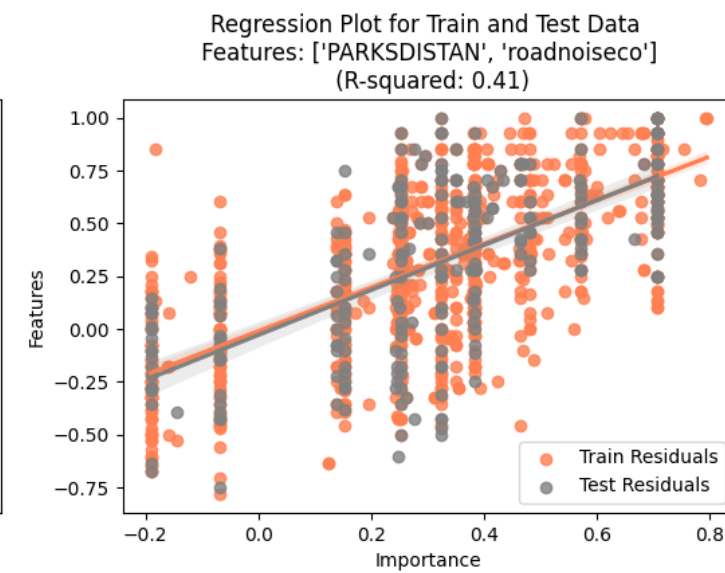
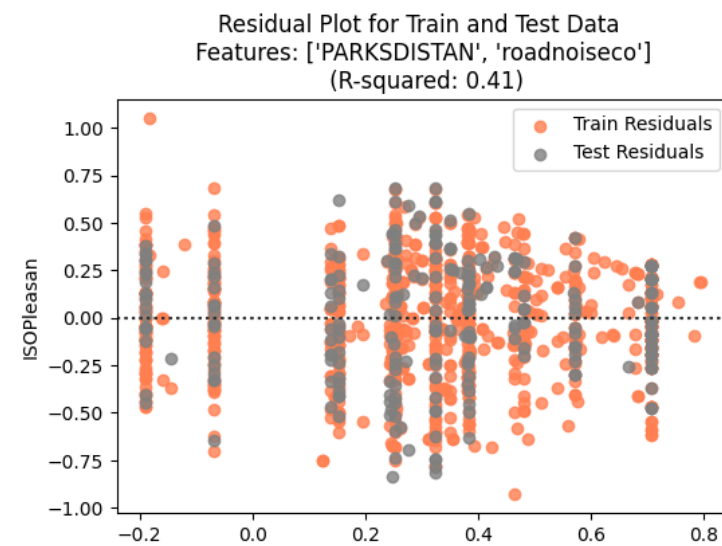
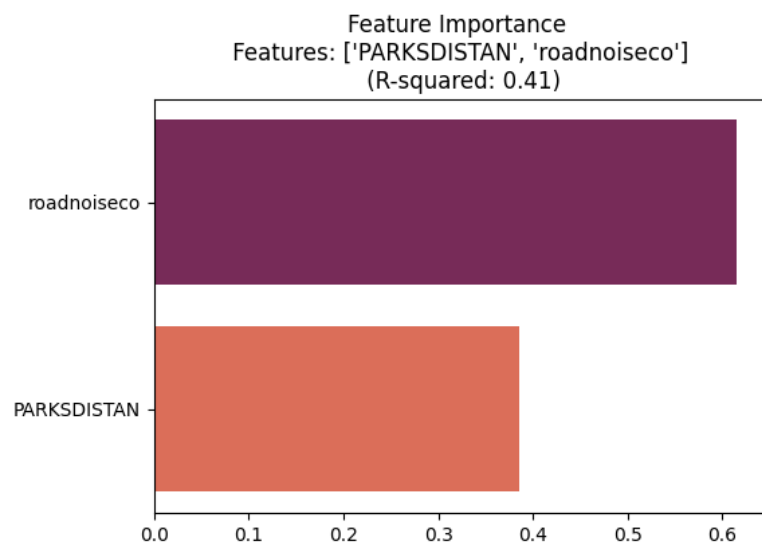
Application as Design Tool

User-friendliness
Computation time
Generalisable





PARKSDISTAN & roadnoiseco & VISIBLE	MAE	0.26
	MSE	0.1
	RMSE	0.32
	R ²	0.40



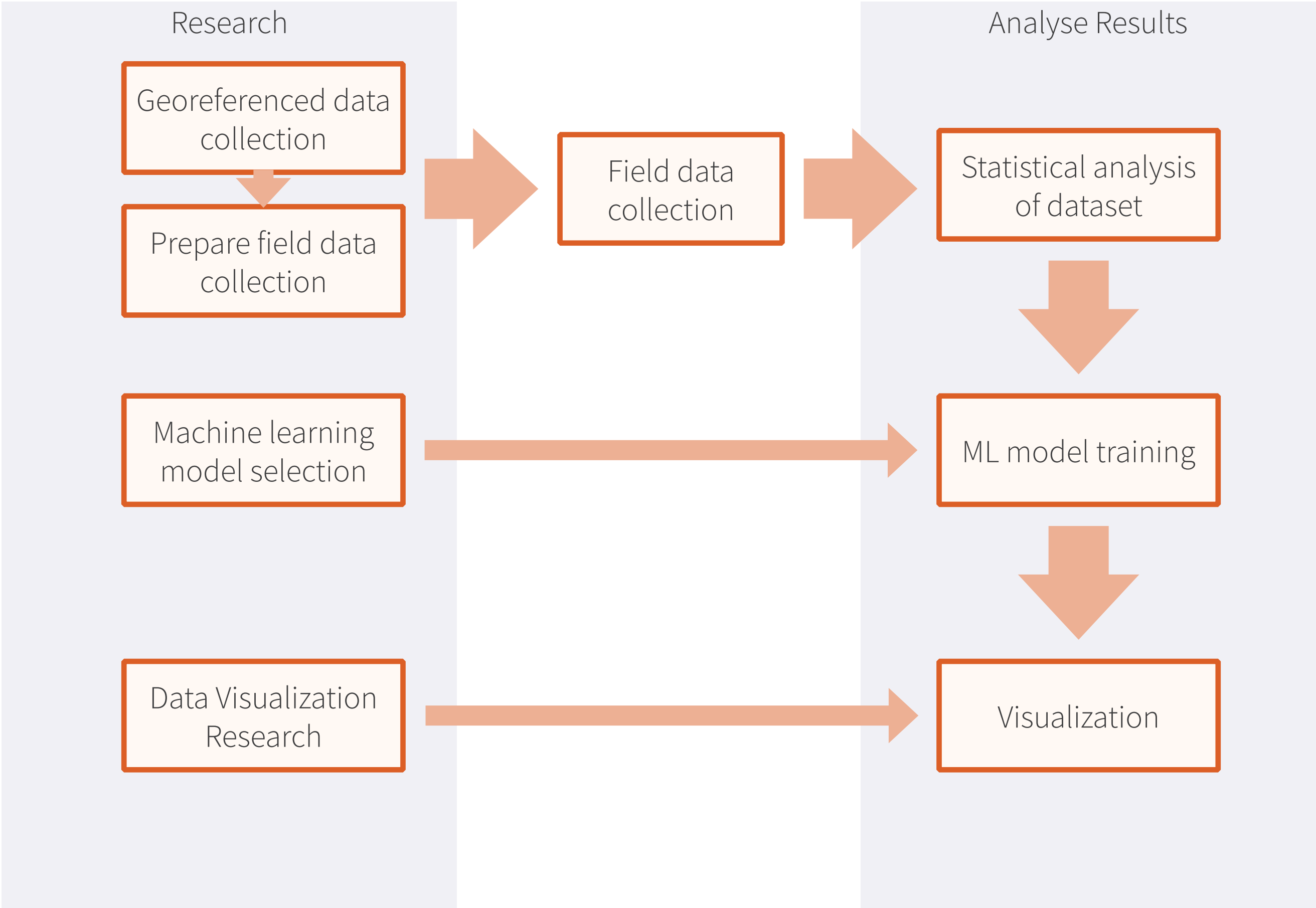
PARKSDISTAN & roadnoiseco		
	MAE	0.26
	MSE	0.1
	RMSE	0.32
	R²	0.41

Further Research Steps

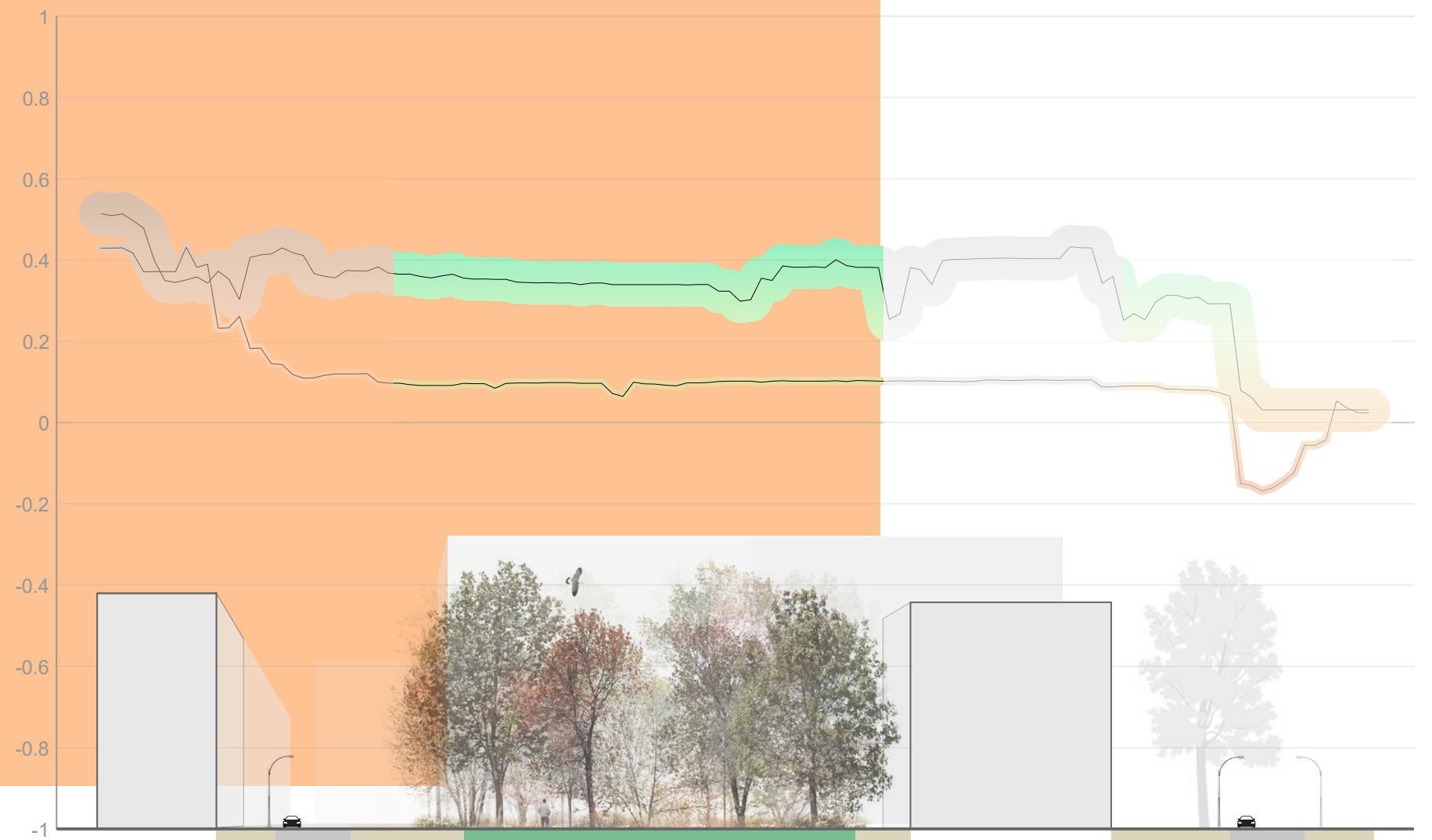
Collect new data:

- focusing on new designs
- includes a wider variety of urban settings.

Road Map new research



Beyond Noise



Niroda Vitusha Smit

18-06-2024

Msc. Building Techonolgy

First mentor: Martin Tenpierik

Second mentor: Michella Turrin