ASSESSING PEDESTIRANS' EXPOSURE TO TRAFFIC NOISE WITH SPATIAL ANALYSIS:

THE EFFECTS OF ROUTE CHOICE AND HOME LOCATION

–

Working title

20.3.2019

Research plan

Joose Helle

INTRODUCTION

- Active transport modes are considered healthier and more sustainable
  - Thus, they are being promoted in many cities
- Walking is evidently the most popular active transport mode
- However, potential health benefits of walking may get compromised due to the negative effects of vehicular traffic
- Vehicular traffic causes pollution which reduces **walkability**
  - Air pollution, noise and visual pollution
  - Walkability is a complex concept that aims to consider everything that affects the opportunities for walking
  - Safety, utility, comfort, ease, accessibility etc.

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Brief Original Report

Can air pollution negate the health benefits of cycling and walking?

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ABSTRACT

Active travel (cycling, walking) is beneficial for the health due to increased physical activity (PA). However, active travel may increase the intake of air pollution, leading to negative health consequences. We examined the risk–benefit balance between active travel related PA and exposure to air pollution across a range of air pollution and PA scenarios.

The health effects of active travel and air pollution were estimated through changes in all-cause mortality for different levels of active travel and air pollution. Air pollution exposure was estimated through changes in background concentrations of fine particulate matter ($PM_{2.5}$), ranging from 5 to 200 µg/m3. For active travel

Original article

Who owns the roads? How motorised traffic discourages walking and bicycling

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See Commentary, p 362

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Accepted 18 June 2009

ABSTRACT

Objective: To examine the impact of traffic on levels of walking and bicycling.

Method: Review of the literature of medical, public health, city planning, public administration and traffic engineering.

Results: The real and perceived danger and discomfort imposed by traffic discourage walking and bicycling. Accurately or not, pedestrians and bicyclists judge injury risk and respond accordingly. Although it can be difficult to measure these effects, observed behaviour provides good evidence for these effects, with the strongest association being an inverse correlation between volumes and speeds of traffic and levels of walking and cycling.

Conclusion: Interventions to reduce traffic speed and volume are likely to promote walking and bicycling and thus result in public health gains.

be walked or bicycled easily, thereby providing the recommended amount of daily physical activity.[7–9]

In addition, switching from driving to walking and cycling is important for reducing CO_2 emissions.[10] For example, it has been estimated that, if the US population aged 10–64 bicycled for 60 min a day and therefore reduced their car use by that distance bicycled, it could reduce US CO_2 emissions by almost 11%.[11]

How people perceive traffic is an important but poorly understood determinant of travel choices and consequent levels of physical activity through cycling and walking. In 2000, a report by the World Health Organization (WHO) noted that the impact of motorised traffic on people walking and bicycling remained unquantified, but speculated that it might be the greatest health impact of motorised traffic.[12] This paper describes these links and identifies possible entry points for corrective

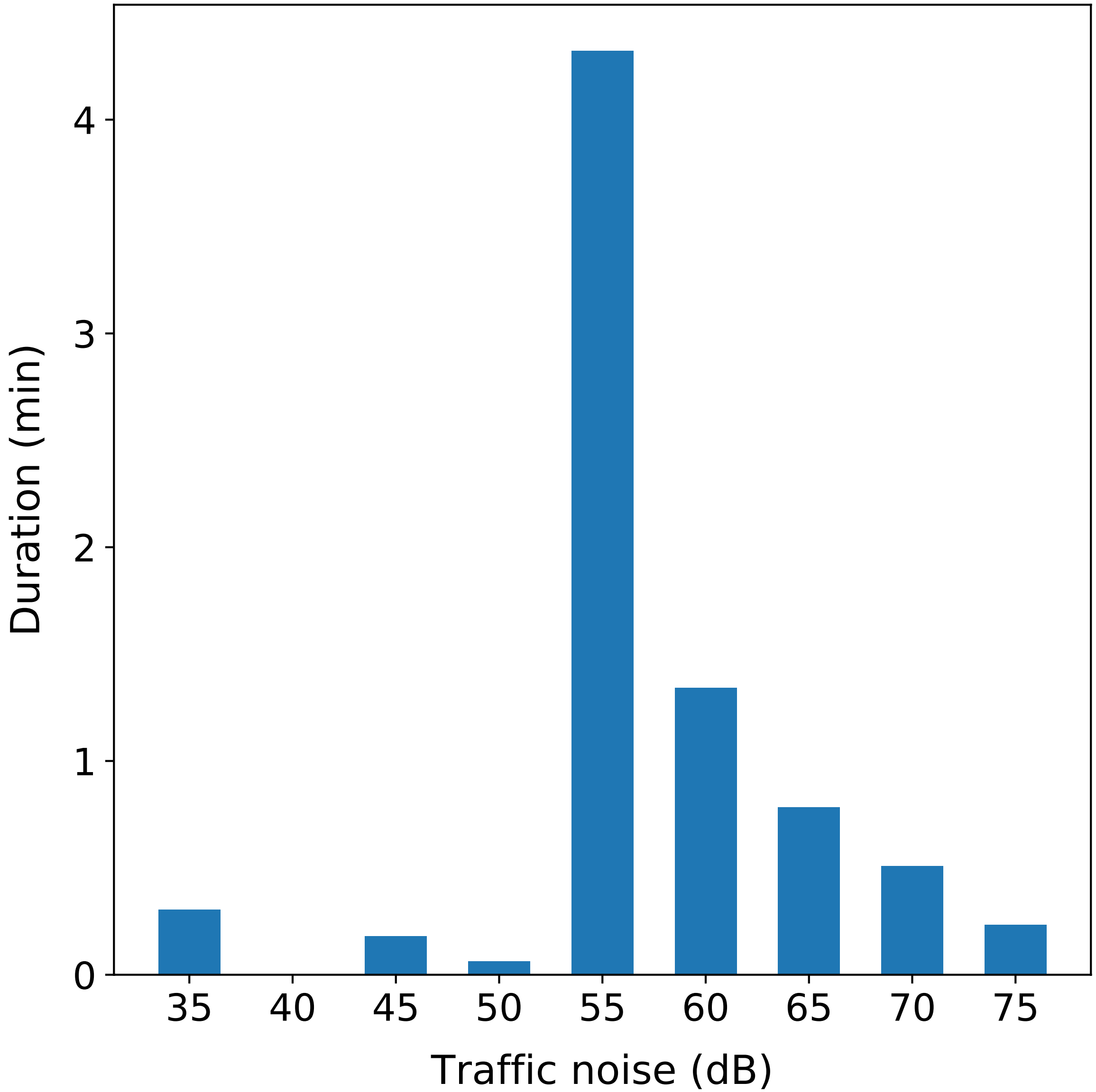
- There seem to be an apparent conflict of interests between road users…

BACKGROUND

- The concept of how different pollutants are experienced by citizens is called **exposure**
- Many of the previous studies on exposures to traffic noise have focused on counting the residents exposed to certain traffic noise levels based on their home location
    - Fixed thresholds (dB) have been defined as harmful traffic noise levels
    - Also some EU and national legislations require these assessments
    - Conceptually straightforward
    - Relatively easy to study via spatial analysis: overlay of census data and noise level surfaces
    - Static approach ignores the mobility of the residents

- However, true exposure is dynamic
  - Daily movements: home location, route selection, etc.
  - Used transport modes
- More realistic approaches to assess citizens' exposure to air/noise pollution consider mobility
  - Pedestrians & cyclists are most exposed -> emphasis on active transport
  - Most citizens are pedestrians every day -> emphasis on walking
- Pedestrians' exposure to pollutants can be quantified as distance or time spent (walking) in areas with different concentrations/levels (of pollutants)

Exposure as **durations** at different traffic noise levels along a walking route



- At least two approaches for assessing these exposures exist:
  1) Direct way: using measurement instruments attached to members of a study group and tracking them spatio-temporally
  2) Indirect way: using spatial analysis to extract modelled concentrations/levels of pollutants to either modelled or tracked paths of people

Health effects of traffic noise

- In many studies, health effects of traffic noise have been assessed
- The challenge has often been to separate the health effects caused by the noise from the effects of other environmental factors / pollutants
- Yet, it is evident that traffic noise affects citizens physical and mental health in many ways
    - Reduced quality of life
    - Stress
    - Problems in blood circulation (increased blood pressure etc.)

Int Arch Occup Environ Health 47, 179–190 (1980)

International Archives of Occupational and Environmental Health

Health Effects of Traffic Noise*

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Summary. In 57 test persons having worked 1 day under traffic noise (Leq = 85 dB(A) and 1 day without noise (Leq < 50 dB(A), blood pressure and pulse frequency were measured at 1 h intervals and total urine was collected during working hours. Additionally, blood was sampled at the end of each working day. Psychological parameters were assessed by means of questionnaires.

Statistically significant reactions to noise were found in the following fields:

1. Ergnomics—decrease of working quality;
2. Psychology—increase of psychical tension;
3. Blood circulation—increase of blood pressure and pulse frequency;
4. Biochemistry—increase of epinephrine, cAMP, urine and serum Mg, protein, cholesterol plus decrease of erythrocyte Na, and renin.

Research

Long-Term Exposure to Road Traffic Noise and Incident Diabetes: A Cohort Study

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Background: Road traffic noise at normal urban levels can lead to stress and sleep disturbances. Both excess of stress hormones and reduction in sleep quality and duration may lead to higher risk for type 2 diabetes.

Objective: We investigated whether long-term exposure to residential road traffic noise is associated with an increased risk of diabetes.

Methods: In the population-based Danish Diet, Cancer and Health cohort of 57,053 people 50–64 years of age at enrollment in 1993–1997, we identified 3,869 cases of incident diabetes in a national diabetes registry between enrollment and 2006. The mean follow-up time was 9.6 years. Present and historical residential addresses from 1988 through 2006 were identified using a national register, and exposure to road traffic noise was estimated for all addresses. Associations between exposure to road traffic noise and incident diabetes were analyzed in a Cox regression model

incidence of type 2 diabetes (Cappuccio et al. 2010). Their analysis of a total combined study sample of > 100,000 participants and 3,586 incident cases indicated that both the quality and quantity of sleep consistently and significantly predicted the risk of type 2 diabetes.

The aim of the present study was to investigate the hypothesis that exposure to residential road traffic noise increases the risk of incident diabetes.

Methods

- Traffic noise is modelled in many cities with high spatial precision
  - Traffic count data & measured noise levels
  - Geometries and materials of structures of the environment
  - Mathematical equations to assess absorption and transmission of sound in 3D landscape (featuring varying textures, surfaces & geometries)
  - Modelled traffic noise data facilitates exposure analysis!
- How to minimize the exposure to traffic noise?
  - Pedestrian-friendly alternatives are needed to simple shortest paths
  - *Green/healthy/safe/clean/quiet path routing,* as a concepts, aim to take walkability into account in route optimization
    - Safety, air quality, noise levels
    - Presence of vegetation, green views
    - Other environmental variables that affect walkability

The Shortest Path to Happiness: Recommending Beautiful, Quiet, and Happy Routes in the City

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ABSTRACT

When providing directions to a place, web and mobile mapping services are all able to suggest the shortest route. The goal of this work is to automatically suggest routes that are not only short but also emotionally pleasant. To quantify the extent to which urban locations are pleasant, we use data from a crowd-sourcing platform that shows two street scenes in London (out of hundreds), and a user votes on which one looks more beautiful, quiet, and happy. We consider votes from more than 3.3K individuals and translate them into quantitative measures of location perceptions. We arrange those locations into a graph upon which we learn pleasant routes. Based on a quantitative validation, we find that, compared to the shortest routes, the recommended ones add just a few extra walking minutes and are indeed perceived to be more beautiful, quiet, and happy. To test the generality of our approach, we consider Flickr metadata of more than 3.7M pictures in London and 1.3M in Boston, com-

Keywords

Social Media; Urban Informatics; Derives

1. INTRODUCTION

At times, we do not take the fastest route but enjoy alternatives that offer beautiful sceneries. When walking, we generally prefer tiny streets with trees over large avenues with cars. However, Web and mobile mapping services currently fail to offer that experience as they are able to recommend only shortest routes.

To capture which routes people find interesting and enjoyable, researchers have started to analyze the digital traces left behind by users of online services like Flickr or Foursquare. Previous work has, however, not considered the role of emotions in the urban context when recommending routes. Yet, there exists the concept of psychogeography, which dates back to 1955. This was defined as "the study of the precise laws and specific effects of the geographical envi-

Route planning for soft modes of transport: healthy routes

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Abstract

The application of sustainability principles on the definition of policies and actions for urban mobility relies on the promotion of less pollutant, economic, and more equitable modes of transport, such as walking and cycling, also known as smooth modes of transport. In this paper, a methodology is presented and described under the concept of healthy route generation. This integrates the contamination of the smooth modes of transport network, according to the noise levels and air pollution indices of the urban environment in which it is located, with the main objective of reducing the exposure level and the risk of development of respiratory and cardiovascular diseases. Healthy routes can be applied to attract and promote the use of smooth modes of transport in a regular basis in urban environments.
Keywords: urban mobility, sustainability, walking, cycling, route planning, healthy routes, air pollution, noise.

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GGT 2017, 4 October 2017, Kuala Lumpur, Malaysia

OPTIMIZING PEDESTRIAN-FRIENDLY WALKING PATH FOR THE FIRST AND LAST MILE TRANSIT JOURNEY BY USING THE ANALYTICAL NETWORK PROCESS (ANP) DECISION MODEL AND GIS NETWORK ANALYSIS

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KEYWORDS: Pedestrian-Friendly, Path Selection, Geographical Information System, Analytical Network Process

Research Article

A Least-Cost Approach to Personal Exposure Reduction

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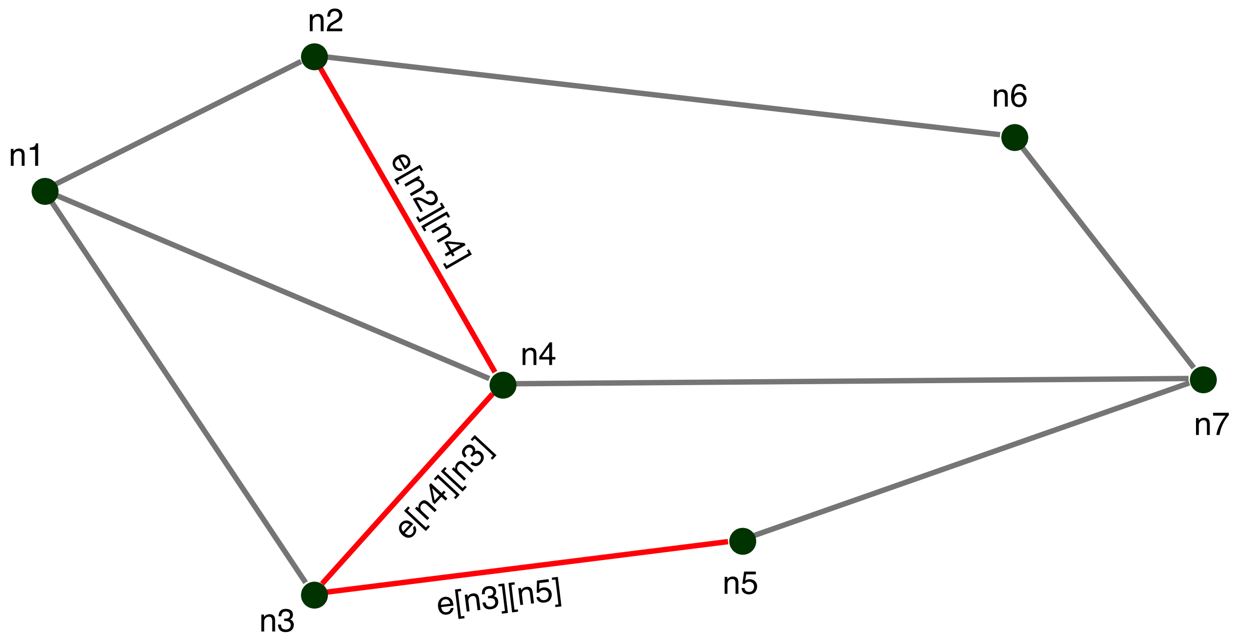
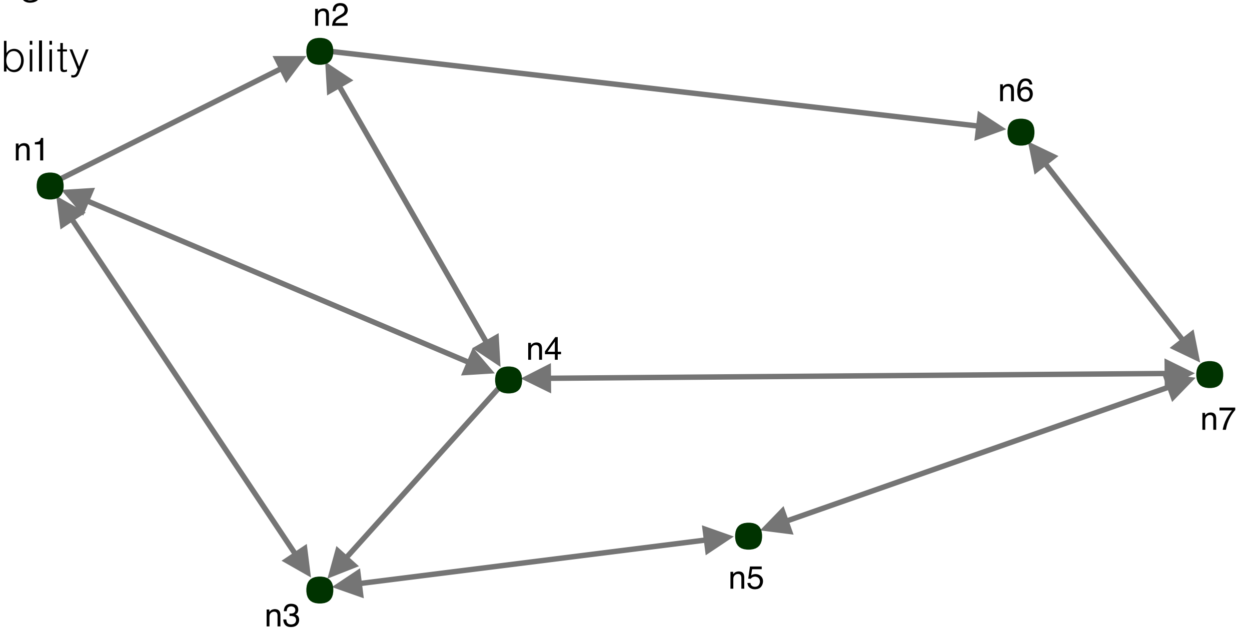
Abstract
Concerns over the potential negative health effects from exposure to air pollution have led to interest in assessing personal exposure and finding ways to reduce it. As journey-time exposure accounts for a disproportionately high amount of an individual's total exposure, this article assesses the potential to apply least-cost techniques within a GIS in order to identify paths of lower journey-time exposure. The methodology adopted uses pollution surfaces for PM_{10} and CO generated by the dispersion model ADMS, with an analysis mask derived from OS MasterMap to

- Route optimization algorithms can be used to find shortest paths in a network (graph)
  - Utilizes graph theory: navigable networks of nodes and segments (connections) (e.g. network of streets & intersections)
  - e.g. Dijkstra's algorithm finds the shortest path between nodes in a graph



- Usually lengths of the segments are used as the costs
- Real-world applications usually require more complex graphs
  - Directed graphs
  - Intersection costs
  - Speed limits
  - Custom weights
    - Walkability



- Exposures to pollutants at different parts of the network can be used as additional weights in the shortest path analysis
  - Noise levels (or air pollutions) are assigned to street segments of the network (spatial join)
    -> network of "contaminated distances"
  - *Environmental impedance function* is needed to convert the contaminated distances into weights usable by the route optimization algorithms
  - -> More pedestrian-friendly routes
  - Challenge is often the validation and definition of thresholds for different pollutants

AIMS OF THE STUDY

1. Develop a “quiet path” routing method/tool that optimizes more pedestrian-friendly walking routes by minimizing exposure to traffic noise pollution
2. Explore spatial patterns in pedestrians’ exposure to traffic noise on the walking legs of public transport itineraries to workplaces and to local grocery stores:
    1. Which residential areas accumulate the highest pedestrians’ exposures to traffic noise?
    2. How the opportunities to choose healthier (less noisy) walking routes are distributed spatially?

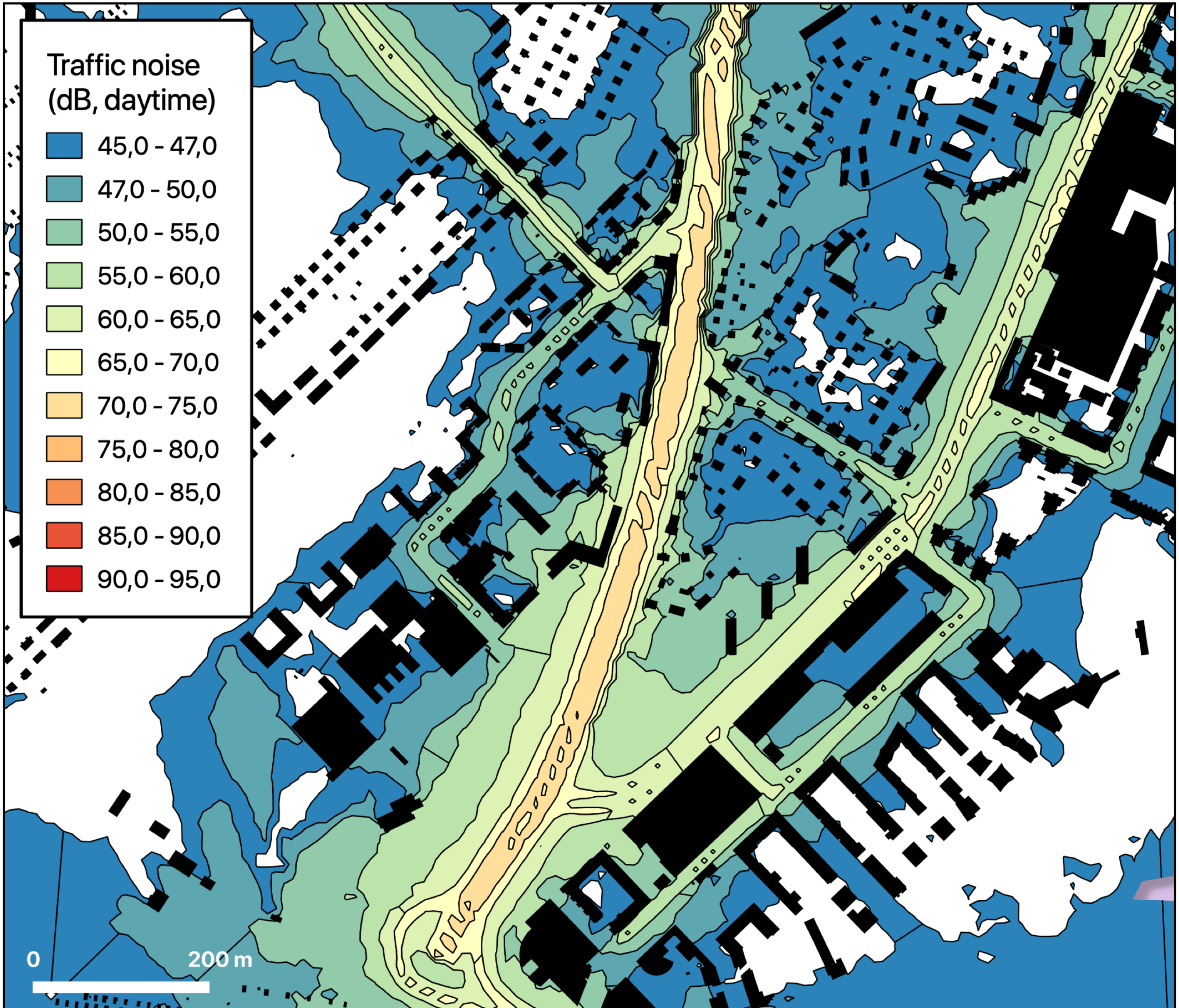
AIMS OF THE STUDY

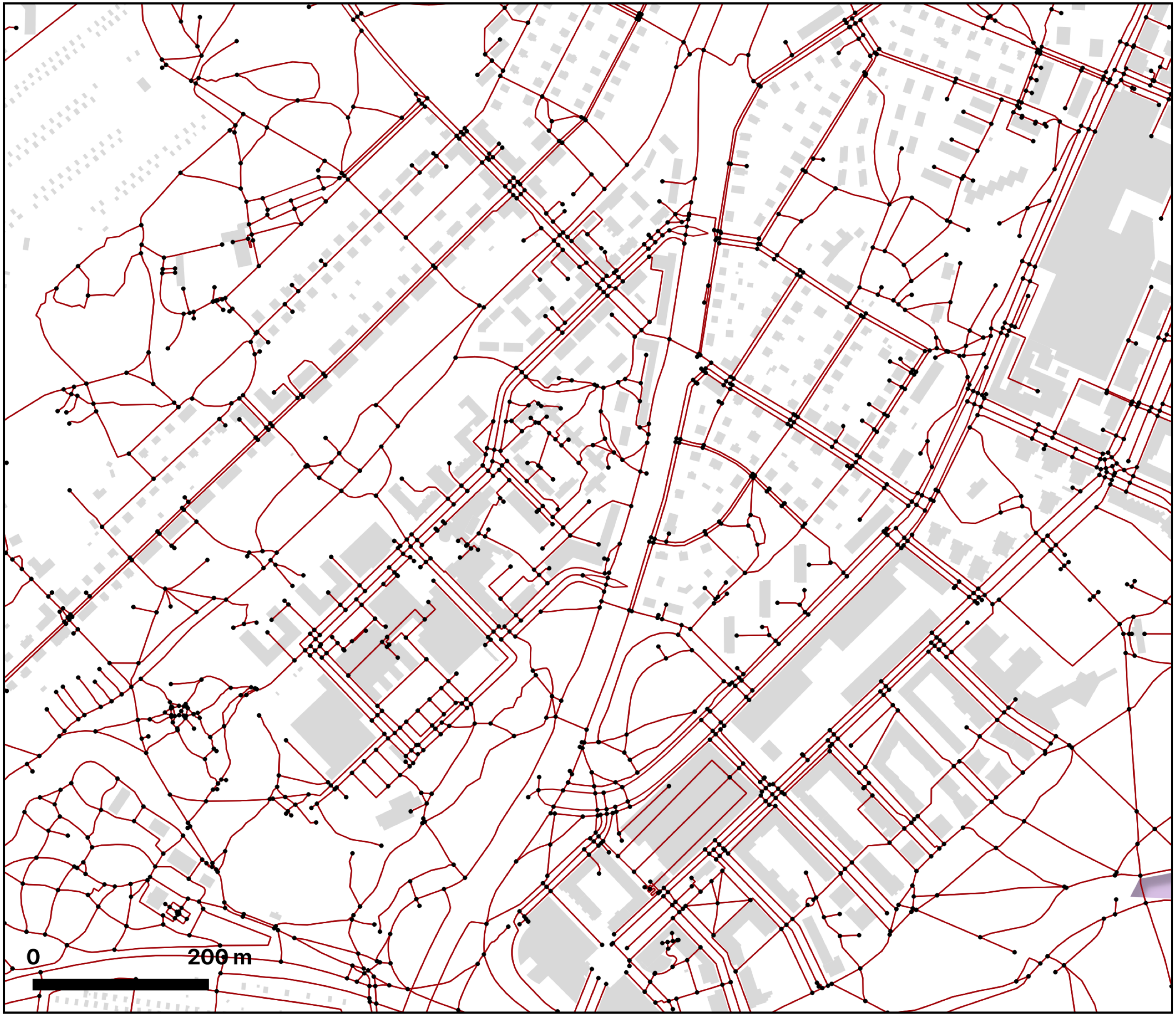
3. Publish the developed methods as a stand-alone proof-of-concept (POC) quiet path planner app with web user interface
   - User can plan more pedestrian-friendly walking routes
   - Web map application: client-side interactive web map + server-side routing service
   - For each routing query, several alternative routes are returned from the server and visualized on the map
     - Information of route length and exposures to different noise levels along the route are also shown

4. Explore opportunities to implement the quiet path routing in HRT's route planner
   - It's open source and uses OpenTripPlanner (OTP)

MATERIALS

- Modelled Traffic noise zones in Helsinki 2017
  - Urban Environment Division of city of Helsinki
  - WFS Service: spatial data in surface/polygon format
  - Noise range information as attributes (45-50, 50-55 dB etc.)
- OpenStreetMap (OSM)
  - Data will be acquired programmatically using Overpass API
  - Tag 'highway' is used to get all road segments
  - Walkable street segments are filtered from the data (based on tag-key -value pairs) and used in the network construction


Traffic noise
(dB, daytime)
45,0 - 47,0
47,0 - 50,0
50,0 - 55,0
55,0 - 60,0
60,0 - 65,0
65,0 - 70,0
70,0 - 75,0
75,0 - 80,0
80,0 - 85,0
85,0 - 90,0
90,0 - 95,0
0
200 m


0
200 m

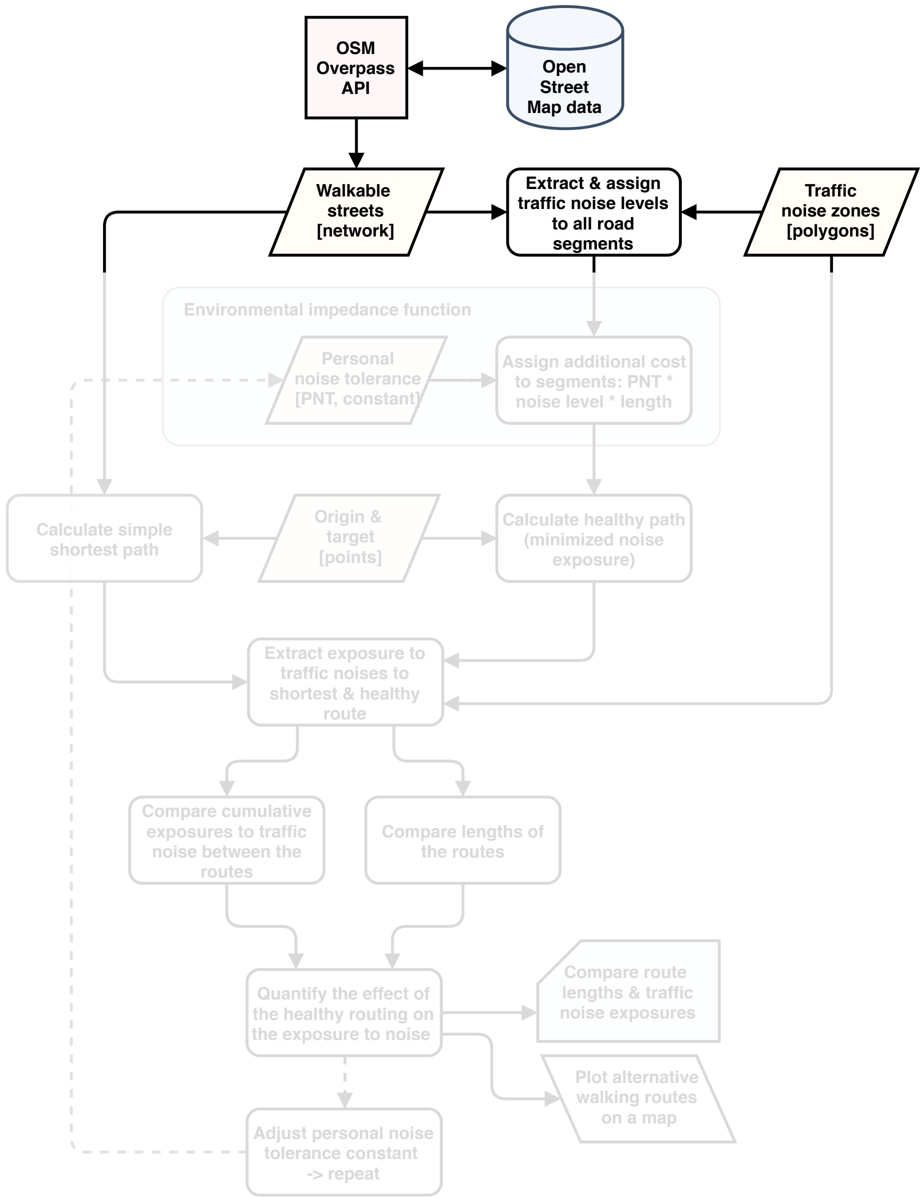
- Digitransit Routing API
  - Used to query the routes from residential areas to workplaces
  - Walking legs of the planned itineraries (routes) are used in the exposure analysis
- YKR Population grid
  - 250m x 250m polygon grid layer
  - Centers of the grid cells are used as origins in the routing analysis
  - Cumulative exposures are aggregated by the origin grid cells
- YKR Workplace grid
  - Centers of the grid cells are used as destinations in the routing analysis
- Grocery stores
  - Walking routes are also calculated from each origin cell to the closest grocery store for exposure analysis

METHODS

Acquiring and processing walkable street network

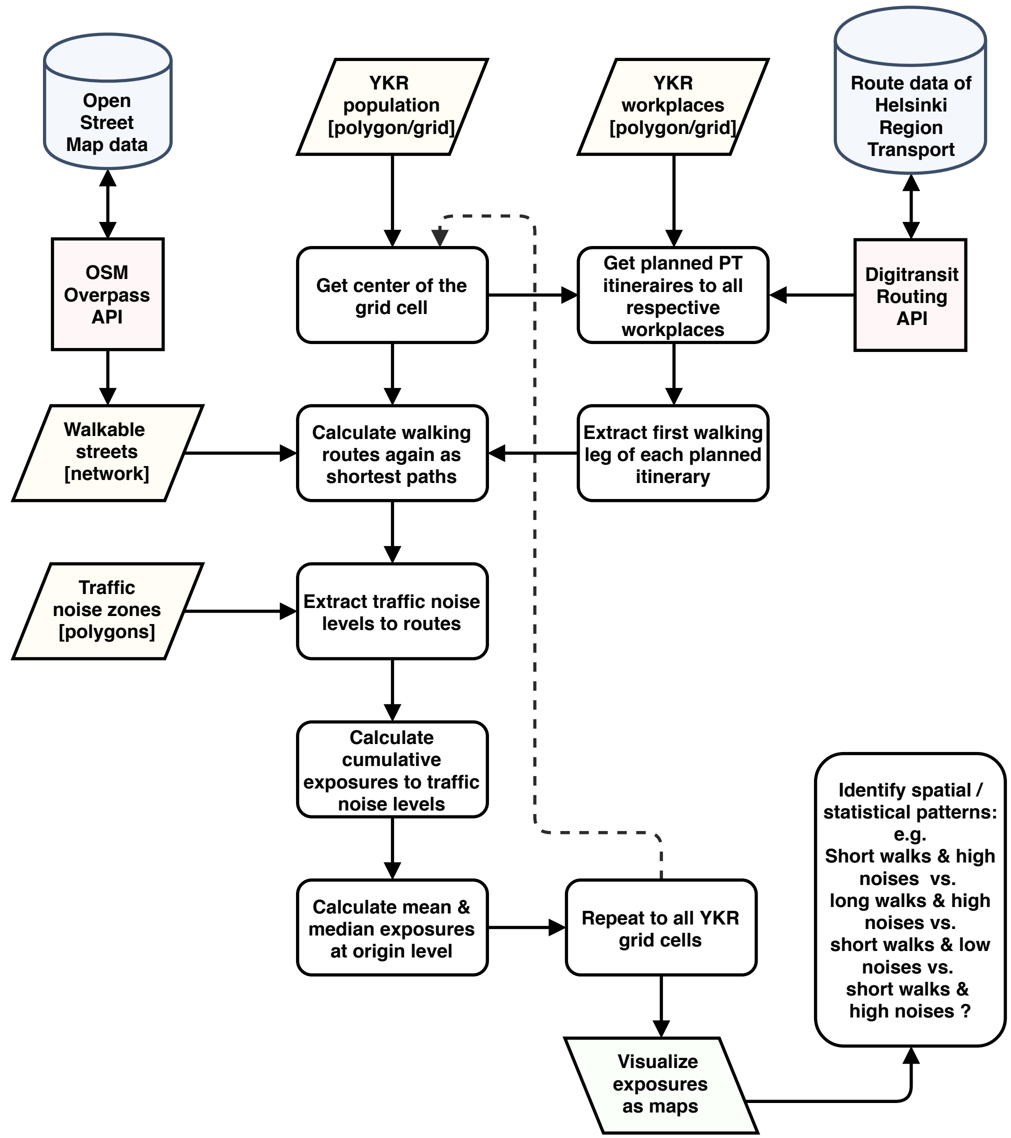
1) Query walkable OSM edges from Overpass API
2) Use OSMnx* to convert OSM data into (NetworkX*) graph
3) Extract & assign traffic noise levels to all segments of the network as attributes

* Python library



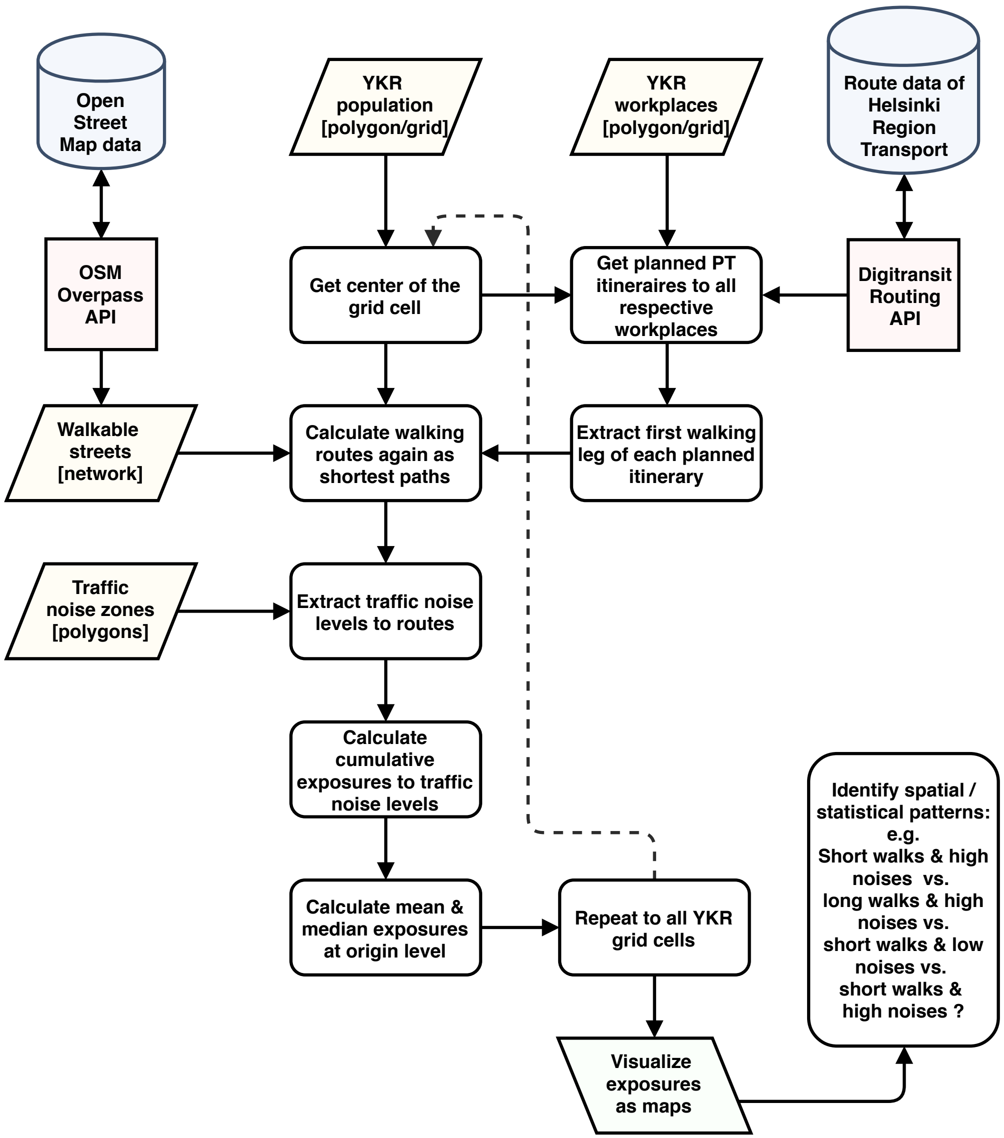
Itinerary planning from all origins to their respective workplaces

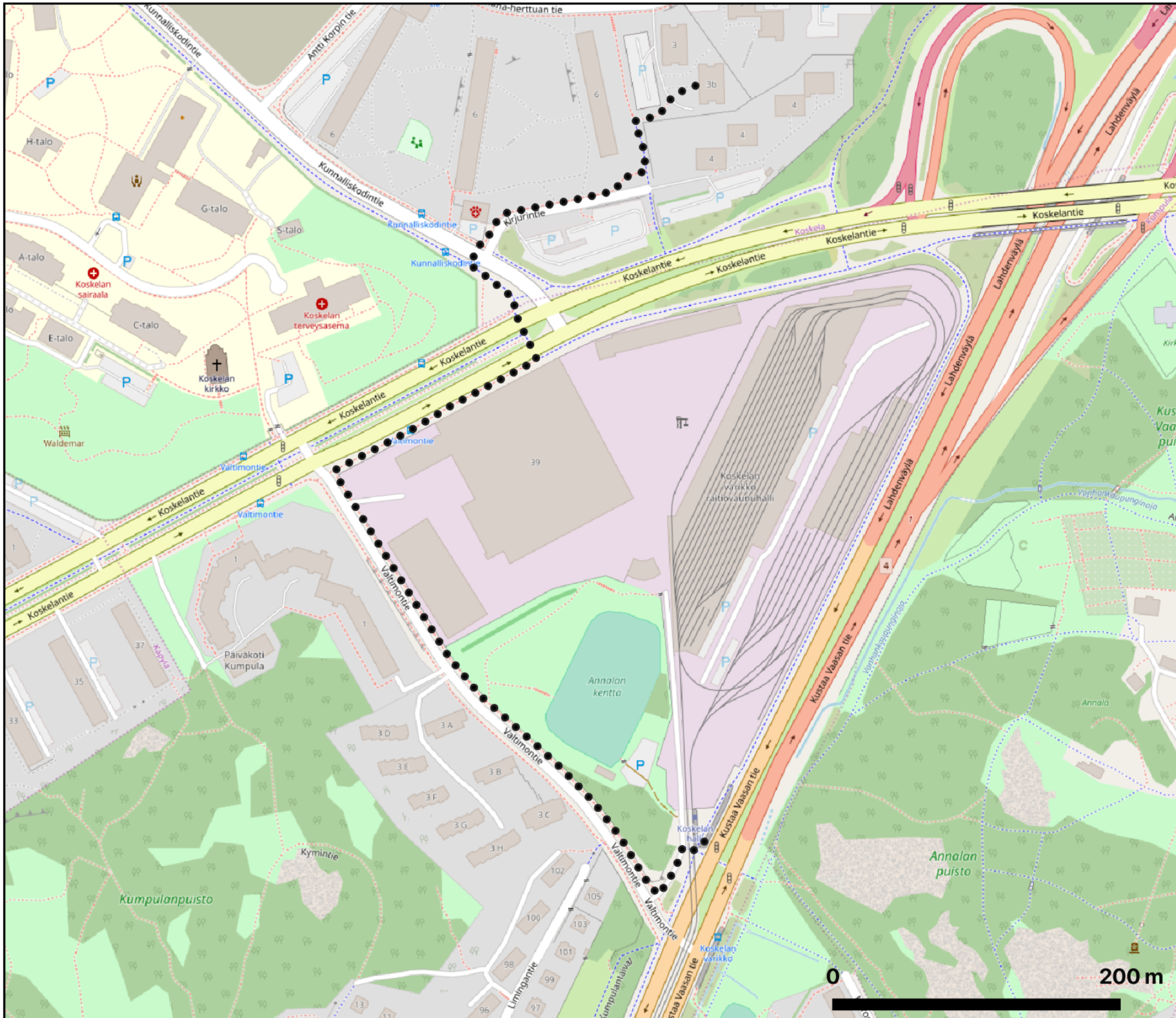
1) Query planned itineraries from Digitransit Routing API
2) Extract first walking leg of each planned itinerary (origin – PT station/destination)
3) Aggregate origin–PT station/destination pairs



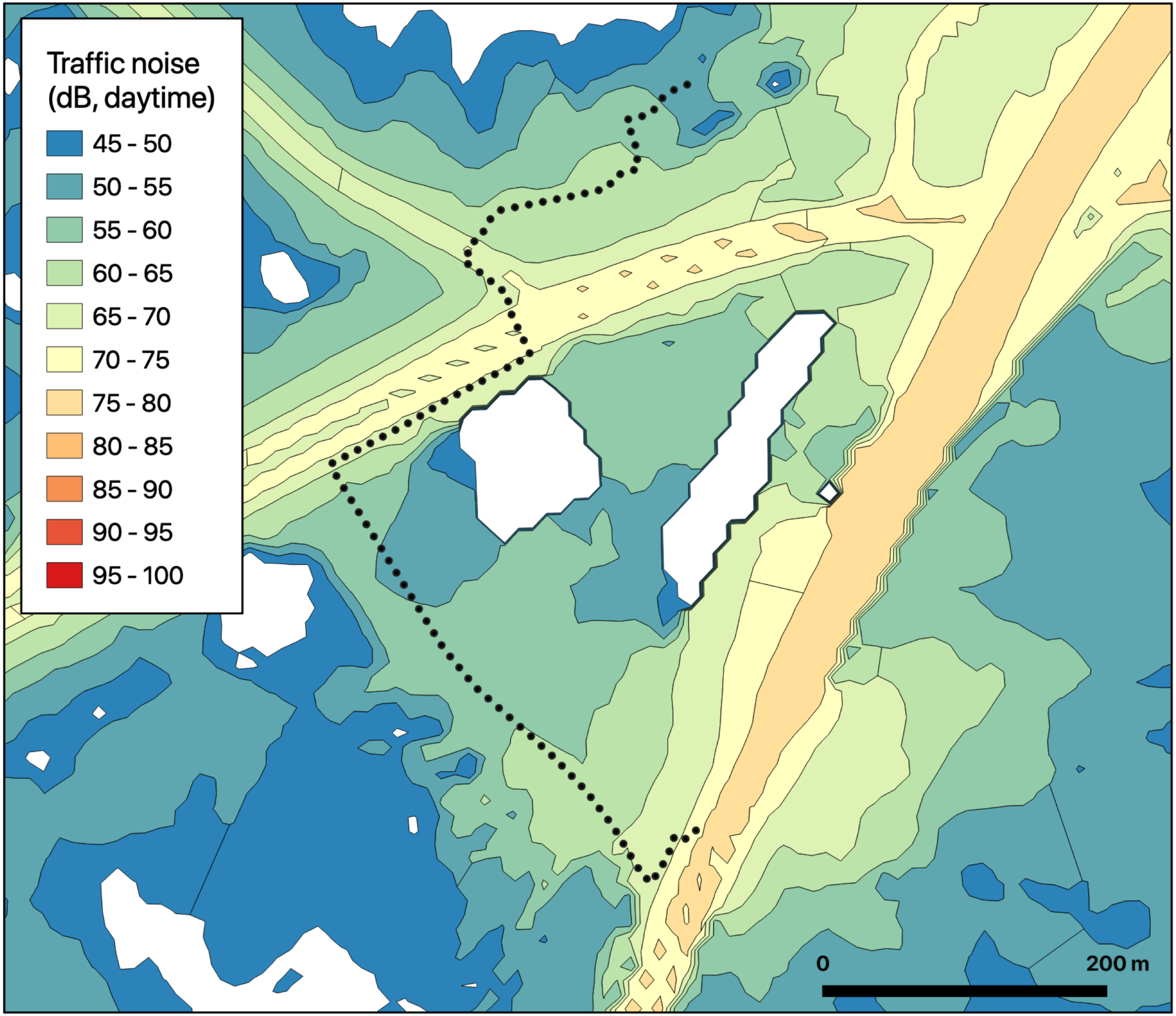
Shortest paths and exposures to traffic noises

1) Calculate shortest paths for each origin–PT station pair
2) Calculate shortest paths for each origin– closest grocery store pair
3) Extract & join exposure to traffic noise to each walk
4) Aggregate exposures to traffic noise at origin level (mean, median etc.)
5) Visualize results (maps & figures)

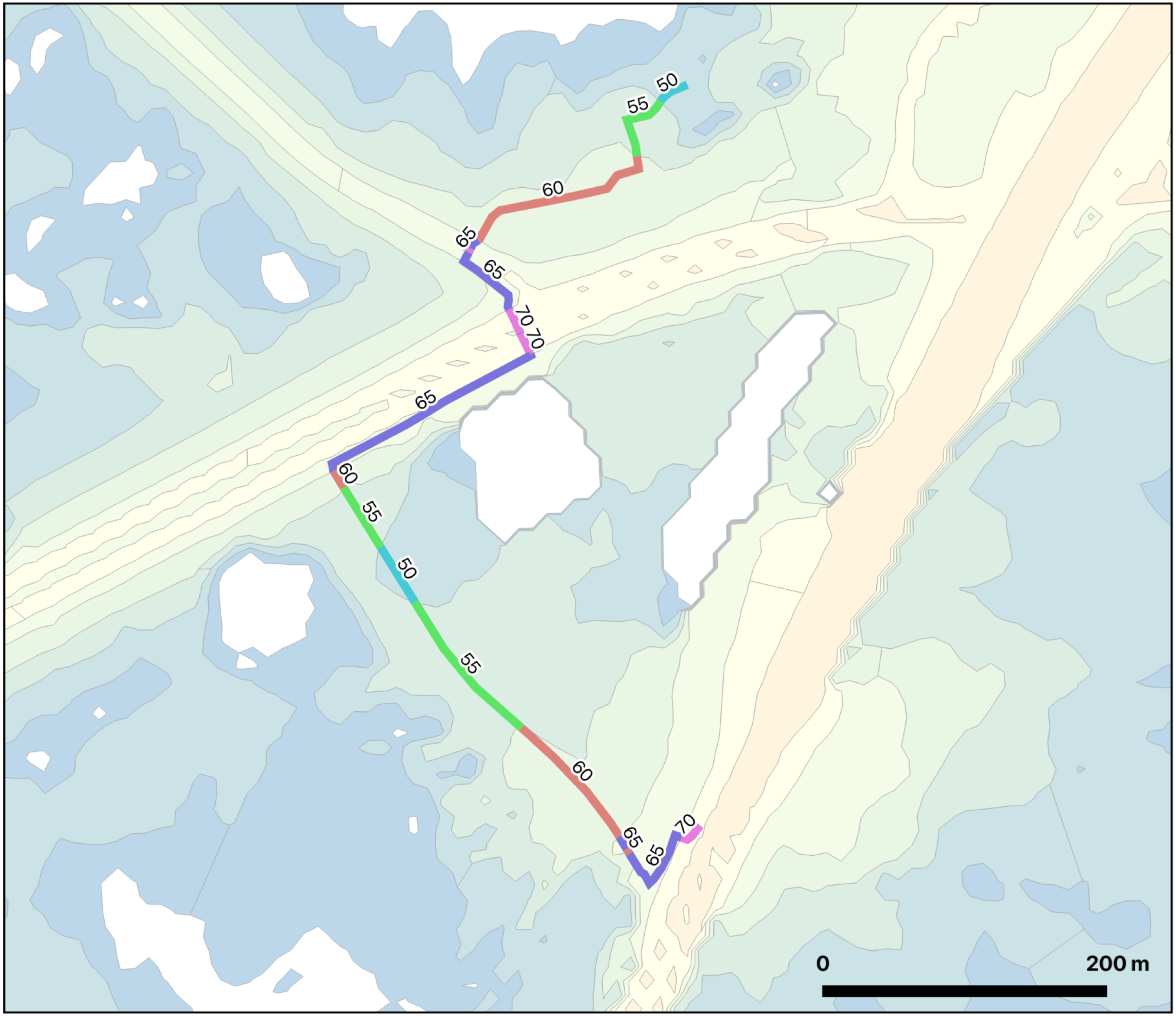




Kunnalliskodintie
Antti Korpin tie
H-talo
G-talo
S-talo
A-talo
C-talo
E-talo
Koskelan sairaala
Koskelan terveysasema
Koskelan kirkko
Waldemar
Kunnalliskodintie
Nirjurintie
Koskelantie
Koskela
Lahdenväylä
Valtimontie
Koskelan varikko raitiovaunuhalli
Annalan kenttä
Päiväkoti Kumpula
Kymintie
Kumpulanpuisto
Kustaa Vaasan tie
Annalan puisto
Annala
Koskelan halli
Koskelan varikko
Limingantie
Kumpulantaival
Vanhankaupunginoja
0
200 m

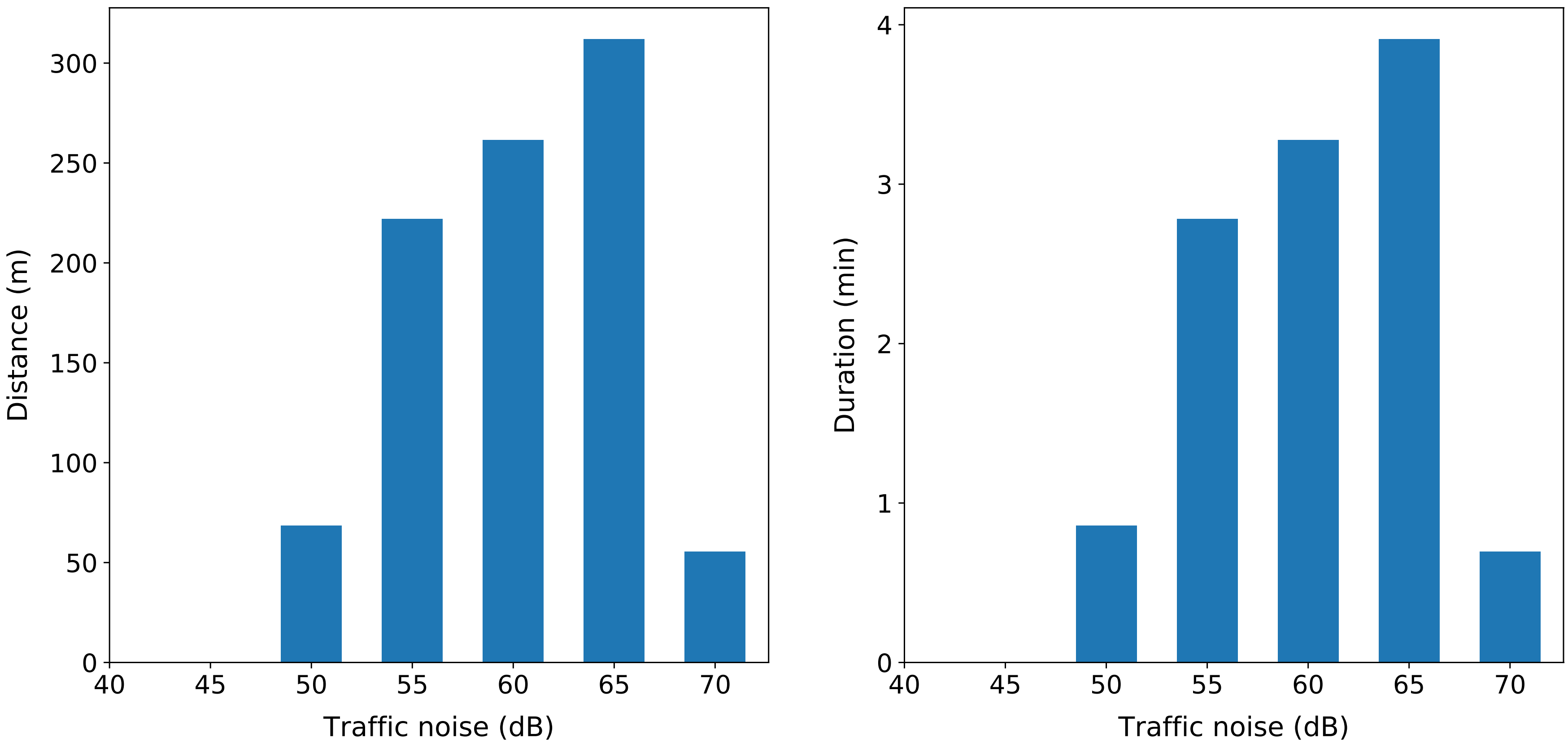


Traffic noise (dB, daytime)
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100
0
200 m



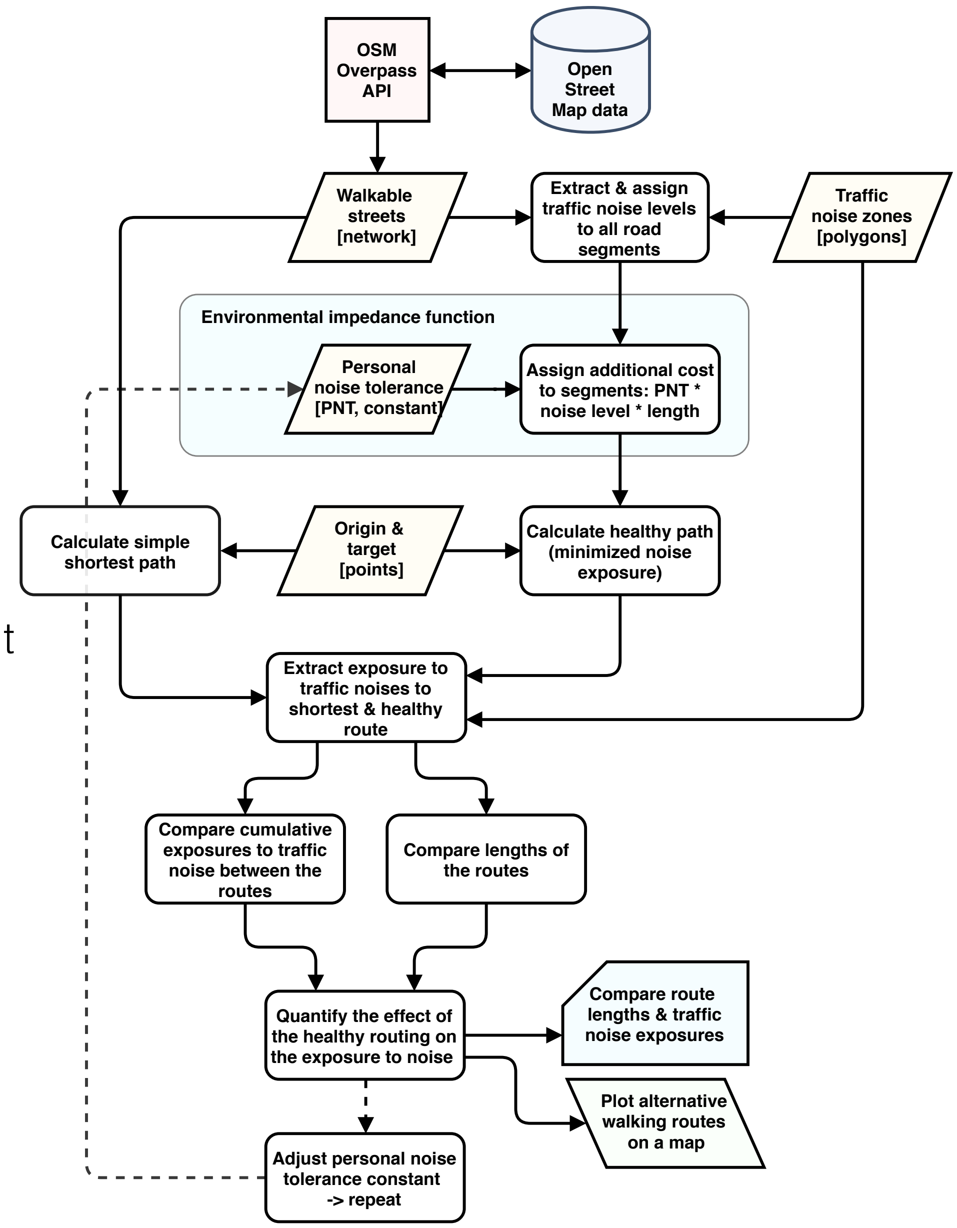
50
55
60
65
65
70
70
65
60
55
50
55
60
65
65
70
0
200 m

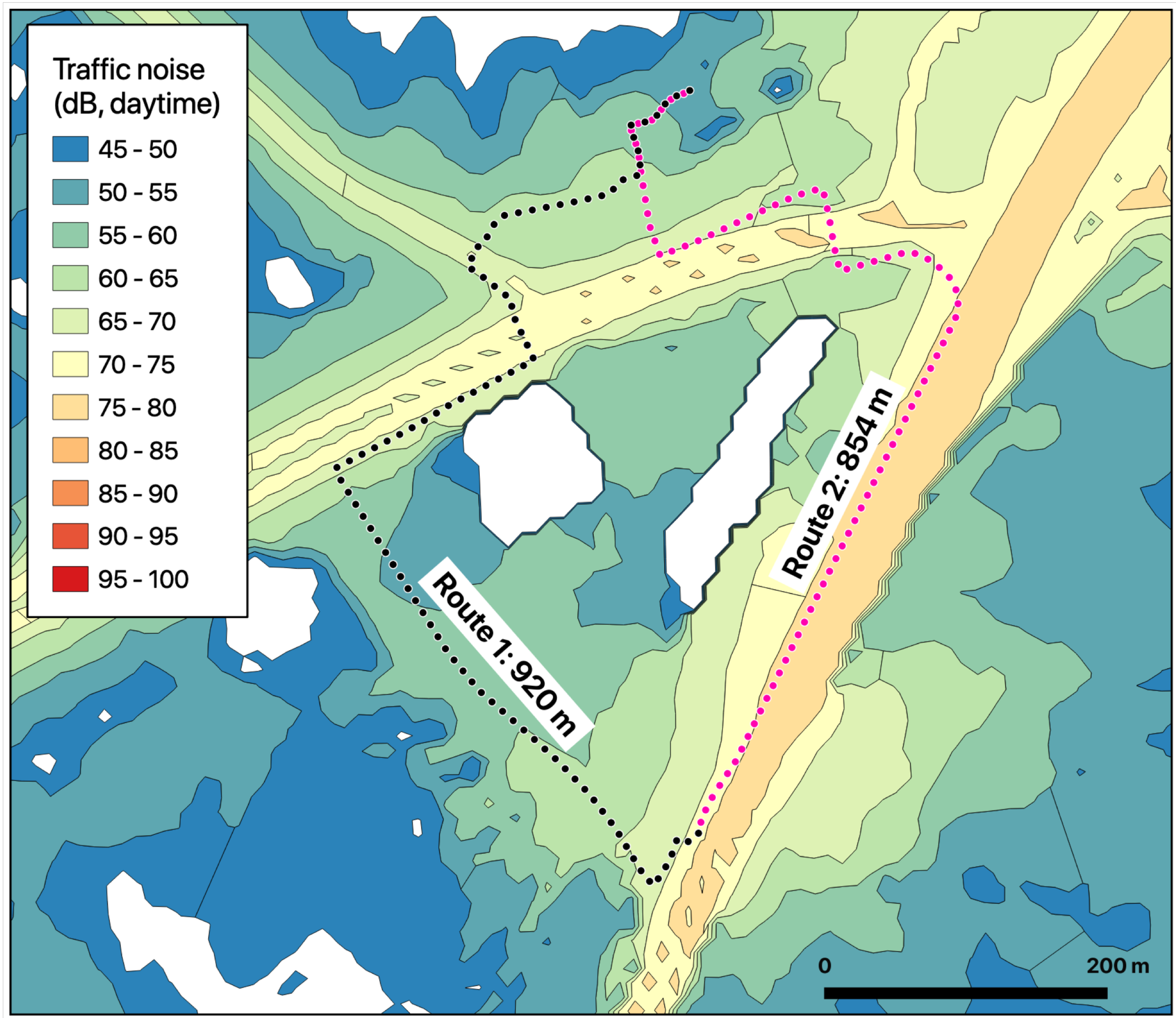
Exposure to traffic noise as **distances** and **durations** at different traffic noise levels along the walking route



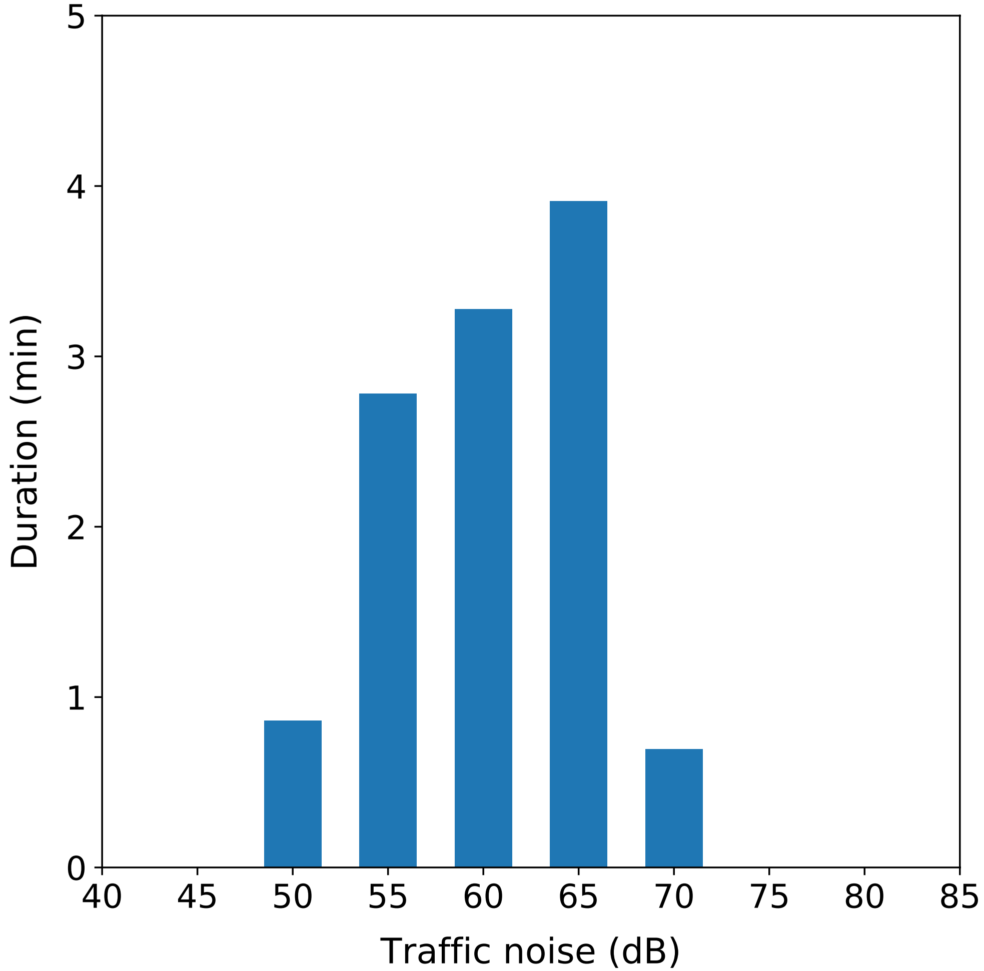
Calculating “quiet paths” by minimizing noise exposure

1) Assign additional cost to network segments with environmental impedance function:
Personal noise tolerance (PNT) * traffic noise levels * length
2) Calculate shortest paths with respect to additional noise impedances
3) Compare paths to shortest path (distance & noise exposure)
4) Adjust PNT and repeat…
5) Visualize results (maps & figures)

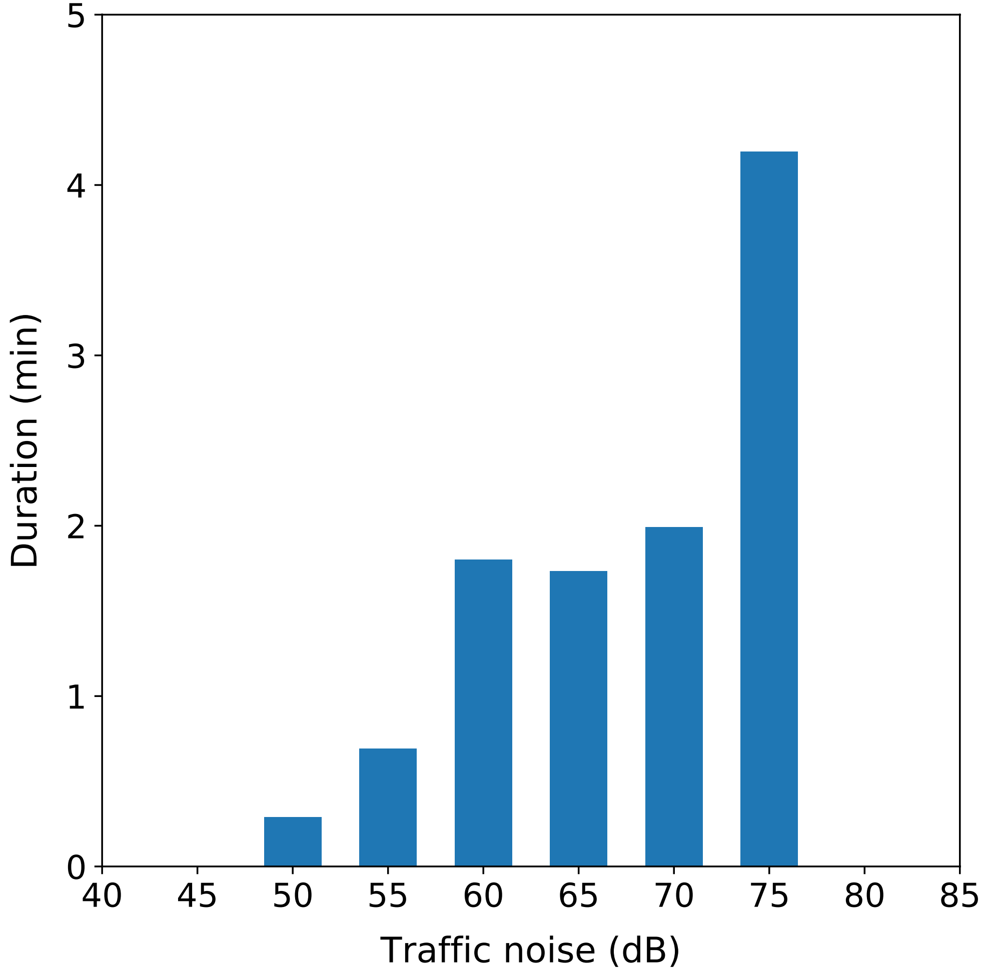



Traffic noise (dB, daytime)
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100
Route 1: 920 m
Route 2: 854 m
0
200 m

Exposure to traffic noise along walking **route 1**
(920 m / 11.5 min)



Exposure to traffic noise along walking **route 2** (854 m / 10.7 min)



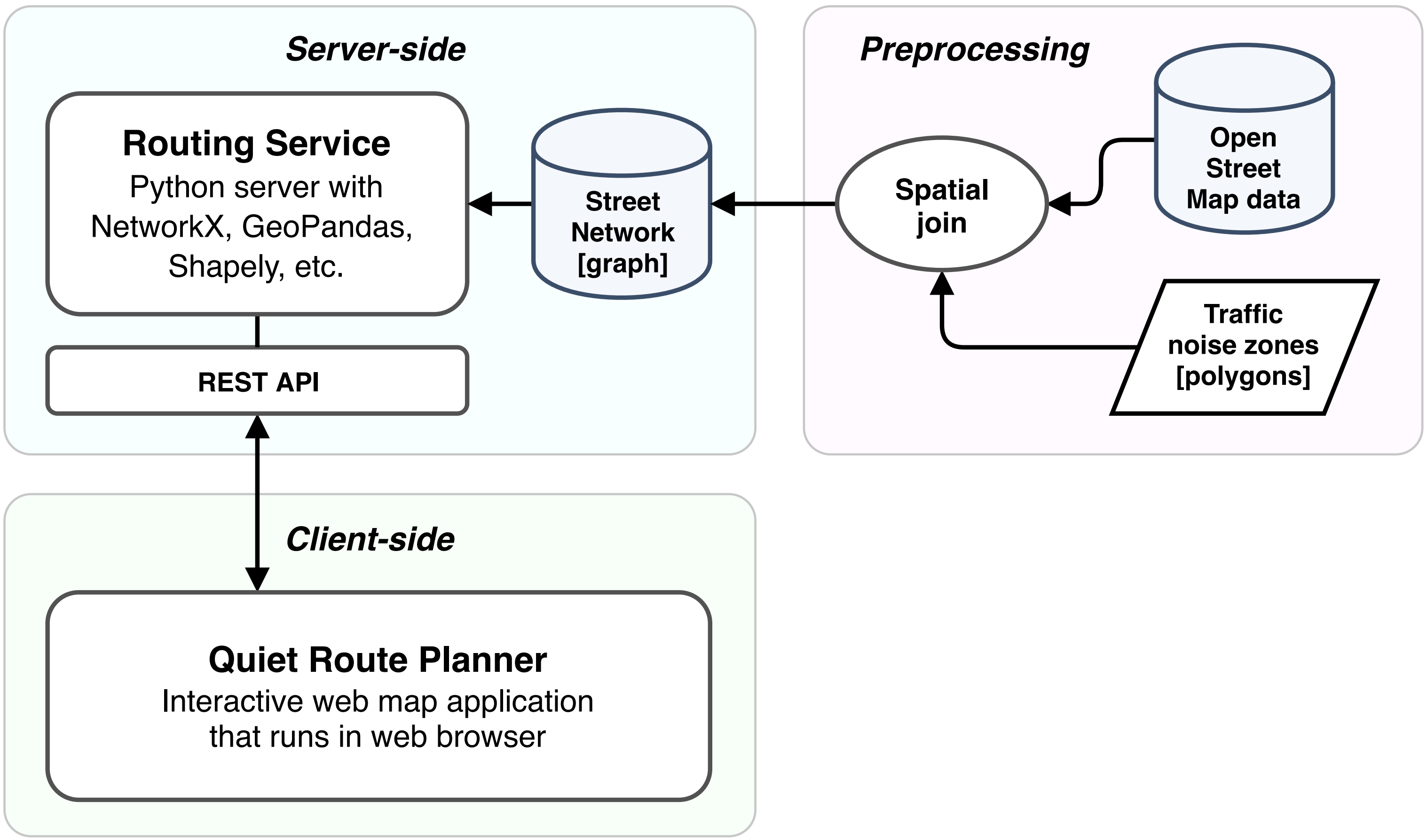
TECH

- Only open source tools & libraries will be used
  - Python development environment managed with Conda
  - Geopandas, Shapely, OSMnx, NetworkX for spatial analysis and network construction
  - igraph Python library would be a lot faster, but not as convenient as OSMnx + NetworkX
  - QGIS for the visualizations
- Computing power & memory from CSC's Taito supercluster
  - Parallel processing with Python
  - At least for network construction, noise data extractions for segments and route optimizations (shortest paths)

- Static files for storing data and results
  - GeoPackages might outperform Shapefiles when handling large files with Geopandas and QGIS
  - Probably no need to use databases for performance or due to very large datasets
- Reproducibility and quality assurance
  - No manual/undocumented steps in the analysis
  - Unit tests for most important functions
  - All codes shared in GitHub (already now: github.com/hellej/gradu-pocs)
  - Simple "one line" setup for identical Python environment as used in the study (with Conda)
- Functions should be modularized to be useful also in assessing exposures to other pollutants
  - Highly modularized and well documented codebase (not yet)

- The “quiet path” routing as a proof of concept (POC) web app
    - Route optimization service as a server-side application featuring REST API built with Python + Flask/Django (?)
    - User interface as a front-end web map application built with ReactJS & Mapbox GL (?)
    - Minimum viable product

Architecture of the quiet path routing web app:



EXPECTED RESULTS

- Higher exposures to traffic noise in some areas
  - Massive road infrastructure, high (vehicular) traffic flows
  - Long distances from residential areas to PT stations / grocery stores
  - Exposed walkways near big highways
  - Low walkability?
- Lower exposures to traffic noise in other areas
  - Good walkable street network: sheltered and functional walkways
  - Short distances to PT hubs
  - Low traffic flows
  - Residential streets as opposed to big highways
  - Better walkability?

- Opportunities for choosing healthier (less noisy) walking routes are distributed unequally:
- More / better opportunities are found in areas where
  - Noise exposures along the shortest paths are high (also the potential to reduce them is higher)
  - Sheltered walkways exist and are well connected to the rest of the street network
  - The walkable street network is dense and hence total number of route options is greater
- Less opportunities are found for areas where:
  - Noise exposures along the shortest paths are already low
  - No sheltered walkways exist or they are not well connected to the rest of the street network
  - Sparser network doesn’t provide many route options in the first place

DISCUSSION

- More realistic approach to assess citizens' exposure to air/noise pollution is to also consider their mobility
- Spatial analysis can provide estimates of pedestrians' exposures to traffic noise with limited accuracy
  - Real "taken" paths are likely to differ from the modelled (shortest) ones
  - Real traffic noise levels vary in time
- "Quiet path" routing is sensitive to definition of the environmental impedance function
  - Weighting of varying exposures to different traffic noise levels is subjective and hence tricky
  - Hence, the sensitivity of the quiet route optimization needs to be evaluated by systematically altering the environmental impedance function

- Both exposure to traffic noise and the presence of alternative (better) walking routes need to be known in order to support spatial planning
  - Exposure to noise along only the shortest path is not enough
  - Exposure to noise along the alternative (short) paths is essential
  - If exposures to noise are high both along the shortest **and** the alternative paths (if any), actions should be crafted to improve opportunities for walking in the area
- Quiet path routing method needs to be published in order to improve citizens quality of life
  - Nothing but a static python script collecting dust in a GitHub repository doesn’t help anyone to choose better walking routes
  - Hopefully the implementation of the interactive web map route planner application is feasible enough
  - …Or that HRT implements something similar in their route planner

SCHEDULE

- Gathering literature
  - January – March
- Data processing and analysis
  - March – April
- Visualizations and writing
  - April – May
- Done?
  - June