Research Plan

ASSESSING PEDESTRIANS’ EXPOSURE TO TRAFFIC NOISE WITH SPATIAL ANALYSIS: THE EFFECTS OF HOME LOCATION AND ROUTE CHOICE

(Working title)

Master’s thesis  
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### Introduction

In the growing cities, active transport modes are getting increasing amount of attention among policy makers and urban planners. The term active transport is usually used to reference to walking and cycling but also other active transport modes such as E-scooters and even city rowboats are emerging. Undoubtedly, walking remains as the most popular mode of active transport since it doesn’t require any accessories and is essential part of all itineraries made by public transport.

It has been shown that active transport modes provide strong health benefits to their users (Pucher & Buehler, 2010) and also for others since they can help to reduce congestion. Hence, cities often have a strong willingness to facilitate active transport modes as urban mobility. In encouraging people to e.g. walking, it is essential for the cities to provide sufficient infrastructure and comfortable environments to make walking secure and easy.

Multiple factors affect the ease with which active transport is applicable in different urban environments. While infrastructure for cycling is predominantly defined by the more or less exclusive network of cycleways and bike lanes, the one for walking (footpaths, sidewalks etc.), in the other hand, is denser and more evenly distributed. However, not only the physical properties of the walking network define its applicability and desirability (walkability), but also multiple more or less subjective factors need to be considered (Maghelal & Capp, 2011). These include variables such as safety, building design, openness of spaces, proximity to opportunities, air quality and green spaces.

Many of the factors limiting walkability and other active transport modes are often caused by (or at least related to) other, “non-human”, users of the urban space. Evidently, one of the most significant of these is vehicular traffic and the infrastructures supporting it. Vehicular traffic affects walkability and bikeability by introducing large and typically unpleasant structures to urban spaces. From the active transport point of view, these structures act as barriers that fragment the active transportation networks and thus reduce the opportunities for walking and cycling.

Furthermore, vehicular traffic consumes the opportunities for active transport with at least two “invisible” ways. Firstly, due to most of the traffic being powered by gasoline engines, it has a strong negative impact on air quality due to the exhaust gases. According to numerous studies, these urban air pollutions can cause or worsen many lung diseases such as asthma or even cancer. Secondly, both the engines and the wheels of the vehicles cause noise. Amount of noise is related to the flow and speed of the traffic and to the type of the surface of the road. Increased but also varying traffic noise levels are typical to highways and other major roads. According to several studies, there seem to be some kind of relationship between pedestrians’ exposure to traffic noise and stress levels (Babisch, Beule, Schust, Kersten, & Ising, 2005; Ising, Dienel, Günther, & Markert, 1980).

**Background**

Since negative health impacts of vehicular traffic to pedestrians can compromise the potential health benefits of walking (Tainio et al., 2016), it is important to develop means for assessing pedestrians’ exposure to the negative effects of traffic. Clearly, two distinguishable approaches exist for addressing moving individuals’ exposures to traffic noise and air pollution:

1. Direct way: using measurement instruments attached to members of a study group and tracking them temporally and spatially (e.g. Apparicio, Carrier, Gelb, Séguin, & Kingham, 2016; Cole-Hunter, Morawska, Stewart, Jayaratne, & Solomon, 2012).
2. Indirect way: using spatial analysis combining modelled traffic noise or air pollution data and either tracked or modelled routes of people (e.g. Sheng & Tang, 2011; Whyatt et al., 2007).

While air pollution is often be challenging to quantify, measure and model (and tends to be highly dynamic with respect to weather conditions), traffic noise can be measured and modelled in a more straightforward manner. Also, the latter has the potential to offer spatially accurate information of urban traffic flows and their side-effects. Vehicular traffic noise levels have been spatially modelled in many cities with fairly high spatial resolution. The modeling has been done using mathematical models that consider traffic count data, noise measurements and data of materials and geometries of urban infrastructures (buildings, roads, walls etc.).

In some papers, the term green path or route has been used to describe alternative, somehow more sustainable or comfortable, routes between two points on a road network (e.g. Lwin & Murayama, 2011, 2013; Ribeiro & Mendes, 2011). In the context of this study, “greener” would practically refer to routes of less noise exposure.

### Aim of the study

In this study, the broad and comprehensive definition of walkability is not trying to be addressed per se. Instead, from the perspective of walkability research, this study can be seen as an attempt to capture a narrow but important component of walkability; exposures to traffic noises have the potential to offer relevant spatial information of routes and areas of low walkability.

A method for assessing pedestrians’ cumulative exposure to traffic noise with spatial analysis will be developed in the study. The definition of pedestrian’s exposure to traffic will be based on the time spent at different noise levels (as in Apparicio et al., 2016). Similarly, pedestrians’ cumulative exposures to traffic noise will be calculated as the total amounts of times spent in different noise levels. However, since the sensitivity to different traffic noise levels is fundamentally subjective, no single indicator describing the total exposure (to noise) can be quantified, but the exposures to different noise level ranges have to be considered in the analysis and the results separately. Indeed, more literature needs to be gathered to find information about 1) quantifying total cumulative exposures to noise and 2) official and studied thresholds of tolerable levels of traffic noise.

It is anticipated, yet mostly left out of the scope of this study, that traffic noise levels have a strong spatial correlation with other negative impacts of traffic such as air pollution and presence of large unwalkable infrastructures. With respect to this assumption, the methods developed in the study will have the potential to contribute in finding better routes for walking. Hence, if it is feasible enough, also a method for calculating alternative, less noisy, walking routes will be developed in the study. The method will require constructing network where traffic noise information is assigned to every road segment. Adjusted shortest path algorithm could then be used to find routes off less noise exposure as alternatives to shortest paths.

The main objectives of the study are the following:

1. Develop a method for quantifying pedestrian’s cumulative exposure to traffic noise at given route.
2. If feasible, implement a type of green path routing algorithm that can be used to calculate better walking routes with respect to exposure to traffic noise as alternatives to shortest paths.
3. Demonstrate the use of the two methods with a case study in Helsinki about residents’ daily exposures to traffic noise on walking routes to local public transport hubs:
   1. Where are the least and highest residents’ (pedestrians’) exposures to traffic noise located in the city?
   2. What opportunities for choosing better (less noisy) walking routes exist in different areas of the city?

The methods and tools developed in this study will be conceptually straightforward yet highly applicable in assessing the spatial distribution of opportunities for walking with respect to vehicular traffic. Majority of the data acquisition, manipulation and analysis will be implemented with Python using exclusively open source tools and libraries. Thus, most, if not all, of the scripts and results of the study can be published in e.g. GitHub to facilitate future research on related themes.

### Materials

Table 1. Materials that will be used in the study.

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| Name | Source | Description | Use in the study |
| Traffic noise zones in Helsinki 2017 | Urban Environment Division of city of Helsinki  (Helsingin kaupunkiympäristön toimiala) | Modelled traffic noise zones as polygon layer covering the city of Helsinki. Minimum and maximum noise levels are stored as attribute information. | Traffic noise exposures will be based on traffic noise zones of this dataset. |
| Traffic noise zones in Helsinki metropolitan area 2012 | Urban Environment Divisions of cities of Helsinki, Vantaa and Espoo | Modelled traffic noise zones as polygon layers covering the Helsinki metropolitan area. Minimum and maximum noise levels are stored as attribute information. | If the analysis is done for the whole Helsinki metropolitan area (i.e. Greater Helsinki?), this dataset will be used as the traffic noise data. |
| 16 x POIs in Greater Helsinki | (Jäppinen, Toivonen, & Salonen, 2013) | Point coordinates and name. | Destinations to which the routing analysis is performed in determining the local PT hubs in the case study. |
| Grocery stores | Digital Geography Lab / Claudia Bergroth ? | Grocery stores in the Helsinki metropolitan area | In the case study, pedestrian walking routes could also be calculated to local grocery stores. |
| OpenStreetMap: highways | © OpenStreetMap contributors | All walkable highways and paths will be extracted from the data as vector lines. | Network construction for routing analysis. |
| Digitransit Routing API | Helsinki Region Transport (HRT) | Routing service for public transport provides routing results (geometries and itinerary information) as an application programming interface (API). | Identification of aerial transit hubs to which pedestrian walking routes are calculated from residential locations. |
| YKR population grid | Finnish Environment Institute (SYKE) | 250m \* 250m grid layer. | Center points of the grid layer are used as origins of the routing analysis. |

**Planned methods**

In this chapter, the method for assessing pedestrians’ exposure to traffic noise is explained within the planned workflow of the case study (Figure 1). In the last paragraphs of the chapter, some considerations of the green path routing tool are discussed.



Figure 1. Planned workflow of the analysis.

In order to find the most used walking routes of local daily mobility, walking itineraries are calculated (planned) to local public transport hubs (PT hubs). PT hubs are determined by executing an extensive routing analysis from all origin points (centers of YKR grid cells) to at least 16 important destinations (defined by Jäppinen et al., 2013). Importance of each hub with respect to the origin can be defined as the count of itineraries using the same PT hub.

Routing analysis is implemented as a batch of routing requests to Digitransit Routing API (application programming interface), that is run by Helsinki Region Transport (HSL / HRT). The routing API is utilized by the most popular route planner applications in Helsinki and fine-tuned to consider many aspects of public transport itineraries. Thus, it will provide realistic routing results from a user perspective.

### Subsequently, walking routes to local PT hubs are calculated from each origin (grid cell). The routing analysis requires acquisition of road data from OpenStreetMap and constructing network from it. Shortest paths are calculated with Dijkstra’s algorithm using NetworkX Python library.

### Traffic noise information is extracted from the modelled traffic noise data (Table 1) and added to the walking legs of each origin-PT-hub pair with a spatial join based on line-polygon intersections. Total cumulative times spent at different traffic noise levels are aggregated to each walk route. Statistics of origin-level routes and exposures to traffic noises are aggregated from the individual walk routes to PT hubs and weighted by the local (origin-level) importance of each PT hub.

### Local (grid cell level) pedestrians’ cumulative exposures to traffic noises are visualized as a choropleth map. It is yet to be decided how the cumulative exposures to different traffic noise level ranges could be converted into a single metric describing the total exposure to traffic noise during a walk.

Furthermore, a type of green path routing method for finding less noisy walking routes will be developed in the study. The workflow and structure of the green path modeling is illustrated in Figure 2. It is yet to be decided what (if any) will be the role of the green path routing method in the study. At least two potential applications for it exist within the context (and the case study):

1. Routing alternative walking routes from each YKR grid cell to local PT hubs and quantifying the level of opportunities to choose less noisy routes at neighborhood (YKR grid cell) level. Avoided exposure to traffic noise and differences in route lengths needs to be considered.
2. Setting up a server-side application that calculates walking routes of less noise exposure on demand. Developing a client-side web map application that user can use to plan walking itineraries of less noise exposure. The application would show user several optional walking routes with different lengths and different exposures to traffic noise to choose from.

However, a critical challenge is posed to green path routing by highly subjective definition of tolerable level of traffic noise. Thus, special attention has to be paid to also assessing the sensitivity of the routing model to varying tolerances to different noise levels. In Figure 2, the constant ‘Personal noise tolerance’ (PNT) is introduced to the workflow to conceptualize this subjectivity. Here, an important question is: can the personal noise tolerance be compressed into one constant, or should it be defined separately for different noise level ranges? Nevertheless, the sensitivity of the green path routing to noise tolerance could be quantified to some extent with systematically altering the PNT and comparing the routing results and their cumulative noise exposures.



Figure 2. Potential workflow & structure of the "green" path analysis.

**Schedule**

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| --- | --- |
| February | Gathering literature and preparing the analysis. |
| March | Building the analysis by writing & running Python scripts. |
| April | Adjusting & finishing the analysis and writing the thesis. |
| May | Writing the thesis and preparing the scripts and tools for publication. |
| June | Mostly done? |

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