



Master's thesis

Geoinformatics

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

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TABLE OF CONTENTS

1 Introduction.....	1
2 Background.....	3
2.1. Noise	3
2.2. Traffic noise in legislation	3
2.3. Alternative measures of pedestrian accessibility - Travel time is not enough.....	3
2.4. Approaches in assessing exposure to traffic noise.....	4
2.5. Route optimization in GIS	5
2.5.1. Graph theory	5
2.5.2. Least cost path.....	5
2.5.3. Optimizing short and green paths	5
2.5.4. Environmental impedance function	5
2.6. Web GIS.....	5
2.6.1. Concepts and recent developments	5
2.6.2. Interactive web map applications.....	5
3 Material & Methods	6
3.1. Overview of the methods	6
3.2. Materials.....	6
3.2.1. Modelled traffic noise data	7
3.2.2. OpenStreetMap data.....	7
3.2.3. Register based origin-destination (OD) data.....	7
3.2.4. Routing service of the local public transport authority.....	7
3.3. Route optimization application	7
3.3.1. Network acquisition and construction	7
3.3.1. Extraction of contaminated distances by noise levels to network edges	7
3.3.2. Environmental impedance function	7
3.3.3. Optimization of short and quiet paths	8
3.4. Assessment of pedestrians' exposure to traffic noise at neighborhood level	8

3.4.1. Extraction of commutes from aggregated OD data	8
3.4.2. Estimation of local PT stops' utilization rates by commutes.....	8
3.4.3. Least cost path calculations – short and quiet paths	8
3.4.4. Spatial aggregation of exposures to traffic noise along the paths.....	8
3.4.5. Assessment of potential to reduce exposure to traffic noise with route choices.....	8
3.5. Quiet path route planner web application	8
3.5.1. Technical architecture	8
3.5.2. Functions and features	8
3.5.3. Typical use cases.....	8
4 Results.....	8
4.1. Spatial patterns in pedestrians' exposures to traffic noise	8
4.2. Quiet path route planner web application	8
5 Discussion	9
5.1. Could traffic noise be used as a proxy for overall walkability?.....	9
5.2. Indirect large-scale assessment of pedestrians' exposures to traffic noise can reveal significant areal differences in walking conditions	9
5.3. Considerable share of the exposure to traffic noise can often be avoided by taking an alternative path.....	9
5.4. Definition of the environmental impedance function is critical yet somewhat arbitrary in quiet path optimization.....	9
5.5. Alternative quiet paths need to be calculated to suit different situations and users with varying preferences	9
5.6. Publishing a green path routing application online can facilitate citizens to choose healthier paths	9
6 Conclusions.....	9
7 References.....	9

1 Introduction

In the growing cities, active transport modes are getting increasing attention among policy makers and urban planners. The term active transport is usually used to refer to walking and cycling but also other active transport modes such as E-scooters and even city rowboats are emerging in urban context. Undoubtedly, walking remains 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 to others since they can help to reduce congestion. Hence, cities often have a strong willingness to promote and facilitate active transport modes for 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 fragmenting 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, since most of the traffic is 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 road surface. 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 health, namely stress levels and problems related to blood circulation (Babisch, Beule, Schust, Kersten, & Ising, 2005; Ising, Dienel, Günther, & Markert, 1980).

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.

It is anticipated, yet not explicitly verified in the study, that traffic noise levels have a strong spatial correlation with also other negative impacts of traffic such as air pollution and presence of large unwalkable (and unpleasant) infrastructures. With respect to this assumption, the methods developed in the study are suitable for identifying areas where improvements to walking conditions are most needed.

Given this context, the main objectives of the study were defined as follows:

- 1) Discover neighborhood-level spatial patterns in pedestrians' exposures to traffic noise with respect to citizens' daily pedestrian activities.
- 2) Develop and implement a "quiet path" routing application that optimizes more pedestrian-friendly walking routes by minimizing exposure to traffic noise pollution.
- 3) Publish the quiet path routing application as proof-of-concept (POC) quiet path planner web application.

In other words, the study aims to facilitate both 1) city planners to discover areas of problematic walking conditions (with respect to traffic noise) and 2) citizens to choose healthier (quieter) walking routes for their daily mobility (via the "quiet route planner" web application). Latter can be seen as a short-term and the first as long-term solution to the problem of minimizing pedestrians' exposure to traffic noise.

2 Background

2.1. Noise

Noise, in general, can be defined simply as undesirable sound. Other defining words unwanted, loud, unpleasant, disruptive and unintended aim to address the subjective nature of noise. The lack of explicit definition of noise derives from noise being indistinguishable from sound in physics; both are fundamentally just vibrations through air (or other transmission medium). Yet, the concept of noise is crucial in the research of negative health effects of high and unpleasant sounds. If a sound is described as noise, it implies that its assumed perception or health effect is negative as opposed to neutral or positive.

While there are major differences in how different people experience sound and which of all sounds are regarded as noise, some loud sounds are generally regarded as noise. Moreover, all sounds can be coarsely divided into three classes based on the general perception of them:

- 1) Sounds which most people perceive as desirable, pleasant or harmless (e.g. the sounds of flowing water and light wind)
- 2) Sounds which some people perceive as pleasant and some as noise depending on the individual, sound level, other sounds and circumstances (e.g. the sounds of dishwasher, quiet background chat and calm bird singing).
- 3) Sounds that most people regard as noise (e.g. the sounds of vehicular and aerial traffic, construction sites, babies crying and people yelling).

Previous research on health impacts of noise is usually focused on the sounds that most people perceive as noise (3).

2.2. Traffic noise in legislation

2.3. Alternative measures of pedestrian accessibility - Travel time is not enough

In accessibility research, travel time is often used as the main measure of accessibility; how many minutes it takes to get from origin to destination? The advantages of such approach are obvious: it is, by definition, simple and enables comparison of accessibility between different travel modes and study areas. In previous research, it has been pointed out that travel time has strong impact on route and travel mode choices.

However, several weaknesses in using only travel time as a measure of accessibility have been identified.

Pedestrian, as an individual who moves in space and time, is of all the road users most exposed to the environmental conditions surrounding the taken path. The perception of these conditions can be classified by the human senses to at least three major categories:

- 1) Touch: how does the environment feel like? Is the air cold, humid, hot or dry?
- 2) Taste and smell: how is the air to breathe; does it smell clean?
- 3) Visual: how does the environment look like? How many sights are visible throughout the path? What is the ratio between natural and artificial sights (e.g. green vs. built)?
- 4) Hearing; how does the environment sound like? Are there more sounds or noises, or is it mostly quiet?

When considering pedestrian's perceptions with respect to these five senses, it becomes clear that only the travel time is rather fuzzy measure of the perceived impedance of a given walk.

2.4. Approaches in assessing exposure to traffic noise

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 3D data of materials and geometries of urban infrastructures (buildings, roads, walls etc.).

Since negative health impacts of vehicular traffic (to pedestrians) can compromise the potential health benefits of walking (Tainio et al., 2016), means for assessing pedestrians' exposure to the negative effects of traffic have been developed in the previous literature. Clearly, two distinguishable approaches exist for addressing mobile 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).

2.5. Route optimization in GIS

2.5.1. Graph theory

2.5.2. Least cost path

2.5.3. Optimizing short and green paths

In the previous literature, the concepts green, healthy, sustainable, safe and quiet paths have been introduced to address the problem of finding alternative walking routes. Taking environmental factors into account in solving route optimization problems clearly seem to have the potential to generate healthier or in other ways better walking routes (e.g. Lwin & Murayama, 2011, 2013; Quercia, Schifanella, & Aiello, 2014; Ribeiro & Mendes, 2011). In the context of this study, the concept quiet path is used to refer to routes of less noise exposure.

2.5.4. Environmental impedance function

2.6. Web GIS

2.6.1. Concepts and recent developments

2.6.2. Interactive web map applications

3 Material & Methods

3.1. Overview of the methods

- Flowchart of methodology/methods (Figure 1)

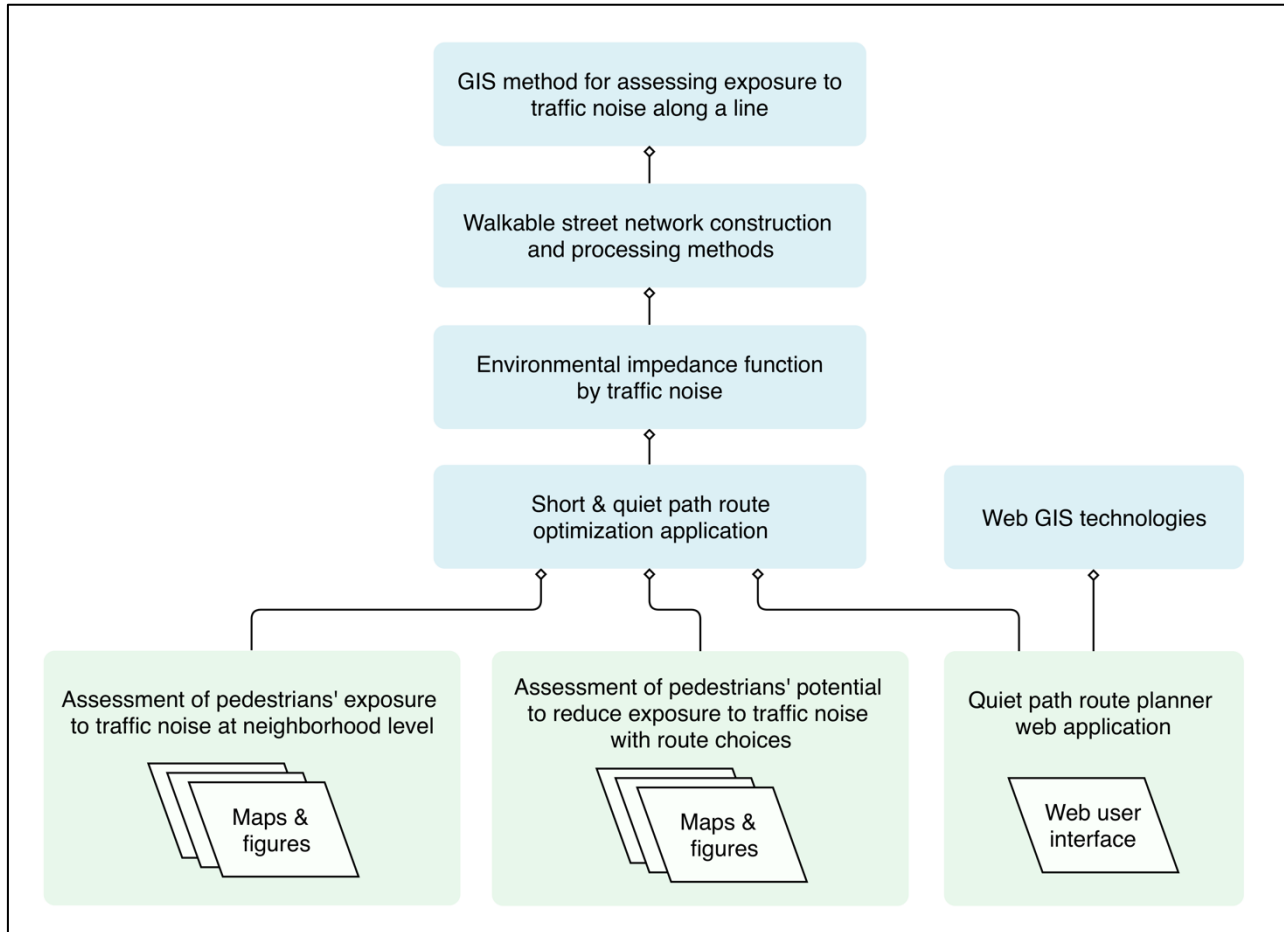


Figure 1. Overview of the quantitative methodology.

3.2. Materials

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

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	Traffic noise exposures will be based on traffic noise zones of this dataset.

		noise levels are stored as attribute information.	
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.
YKR workplaces grid	Finnish Environment Institute (SYKE)	250m * 250m grid layer. Commutes to work from homes to workplaces aggregated to the grid cells.	Public transport itineraries will be planned for all commutes to work and the walks extracted from those itineraries for exposure analysis.
OpenStreetMap: highways	© OpenStreetMap contributors	All walkable highways and paths will be extracted from the data as vector lines.	A graph suitable for solving route optimization problems will be constructed from the data.
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 areal transit hubs to which pedestrian walking routes are calculated from residential locations.

3.2.1. Modelled traffic noise data

3.2.2. OpenStreetMap data

3.2.3. Register based origin-destination (OD) data

3.2.4. Routing service of the local public transport authority

3.3. Route optimization application

3.3.1. Network acquisition and construction

Network of walkable streets was obtained from OpenStreetMap via Overpass API.

3.3.1. Extraction of contaminated distances by noise levels to network edges

3.3.2. Environmental impedance function

3.3.3. Optimization of short and quiet paths

3.4. Assessment of pedestrians' exposure to traffic noise at neighborhood level

3.4.1. Extraction of commutes from aggregated OD data

3.4.2. Estimation of local PT stops' utilization rates by commutes

3.4.3. Least cost path calculations – short and quiet paths

3.4.4. Spatial aggregation of exposures to traffic noise along the paths

3.4.5. Assessment of potential to reduce exposure to traffic noise with route choices

3.5. Quiet path route planner web application

3.5.1. Technical architecture

3.5.2. Functions and features

3.5.3. Typical use cases

4 Results

4.1. Spatial patterns in pedestrians' exposures to traffic noise

4.2. Quiet path route planner web application

5 Discussion

5.1. Could traffic noise be used as a proxy for overall walkability?

5.2. Indirect large-scale assessment of pedestrians' exposures to traffic noise can reveal significant areal differences in walking conditions

5.3. Considerable share of the exposure to traffic noise can often be avoided by taking an alternative path

5.4. Definition of the environmental impedance function is critical yet somewhat arbitrary in quiet path optimization

5.5. Alternative quiet paths need to be calculated to suit different situations and users with varying preferences

5.6. Publishing a green path routing application online can facilitate citizens to choose healthier paths

6 Conclusions

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