Examining environmental exposure during travel – routing tool and population-level analysis

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Abstract

Urban dwellers are exposed to multiple environmental conditions when they move through the urban fabric. The environmental exposures depend on the dynamics of travel behavior as well as the spatiotemporal changes in the environment. We examine how environmental exposures during travel are analyzed in scientific literature and apply exposure-aware routing to examine exposures during travel at population level. We use Helsinki as our study area and explore exposures to noise, air pollution, and street-level greenery. The results show a significant spatial variation in exposure levels for people traveling in different parts of the city. Access to healthy travel environments is unequally distributed among the population of Helsinki. Exposure-aware routing shows a considerable improvement of exposures during walking and cycling when compared to the shortest routes. Further research with attention on different sociodemographic population groups and their access to healthy travel routes is needed. Understanding the associations of multiple environmental exposures and their effects on health and wellbeing supports evidence-based urban and transportation planning, and advances urban sustainability.

1. Introduction

In the era of urbanization, an increasing share of the global population is exposed to urban environmental conditions in their daily life. People are in instantaneous contact with the surrounding environment especially when moving through the urban fabric. While conventional environmental exposure assessment has focused on residential exposures, the emergence of spatiotemporally explicit data on both environmental conditions as well as human mobility has made it possible to assess the dynamic exposure during travel (Chaix, 2018; Helbich, 2018; Reis et al., 2015). This information enables to evaluate the accessibility of healthy travel environments for different urban population groups.

The current knowledge about environmental exposures during travel, their associations with travel behavior, and their social and health outcomes are limited (Poom et al., forthcoming). Existing research has predominantly focused on exposure to air pollution and its associations with travel mode (e.g., Boniardi et al., 2019; Mazaheri et al., 2018). Studying exposure to other environmental qualities during travel, such as noise or urban greenery, or multiple simultaneous exposures is only rising (e.g., Marquart et al., 2021; Ueberham et al., 2019; Zhang et al., 2021). While these studies represent personal exposure assessment, considerably fewer studies have examined environmental exposure during travel at the scale of populations (e.g., Mölter & Lindley, 2015; Park & Kwan, 2020; Shekarrizfard et al., 2020).

Examining exposure patterns and the equality of population groups in accessing healthy travel environments requires good understanding of the people in travel, their travel behavior and environmental conditions along the routes at the times of travel (Figure 1). Due to the limited availability of realized mobility data, population-level exposure assessment benefits from route modeling. Least-cost routing studies that compare the shortest and the least polluted routes in the street network have shown that reduced exposure to pollution tends to outweigh the increased distance cost of healthier routes (Alam et al., 2018; Mölter & Lindley, 2015).

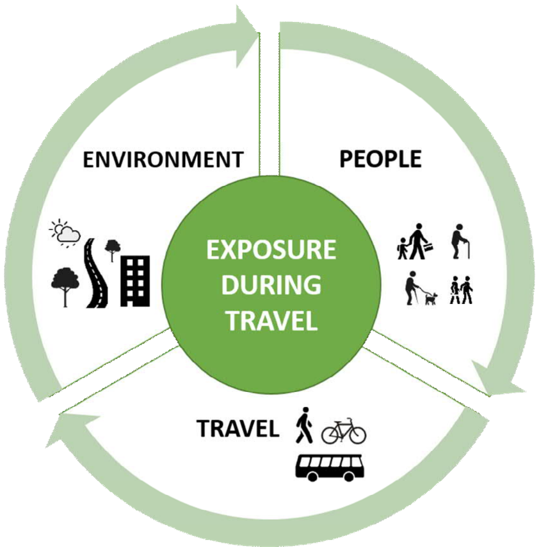

Figure 1. Environmental exposure during travel results from the spatial and temporal co-location of people on move and the environmental conditions of travel environments.

In this presentation, we 1) examine the state-of-the-art of analyzing environmental exposure during travel in scientific literature, 2) explore in practice how exposure during travel can be integrated to routing, and 3) use such exposure-aware routing to compare exposures during commuting at the population level. We use Helsinki as our study area and explore exposures to traffic noise, air pollution, and street-level greenery.

2. Methodology

2.1 Exposure-aware routing

We developed an open-source Green Paths routing software for environmental exposure assessment and identification of optional, environmentally better routes in the Helsinki Metropolitan Area (Poom et al., 2020). The tool optimizes walking or cycling routes by combining travel distance and environmental context data. It can be applied both to individual-level real-time route planning[1] as well as population-level exposure assessment. The tool may be used to compare environmental exposure on the shortest routes to those that are optimized in terms of exposure.

The routing tool uses environmental information on air quality, noise levels, and street-level greenery. The air quality information originates from the FMI-ENFUSER[2] air pollution model operational in the Helsinki Metropolitan Area (Karppinen & Johansson, 2018). The tool applies Air Quality Index 2.0, which is an hourly experimental composite index covering the concentrations of NO_2, O_3, $PM_{2.5}$, and PM_{10}. For noise, we use modeled data of the average day-evening-night noise levels from traffic, provided by the Finnish Environment Institute[3]. The greenery layer reflects the share of vegetation visible at the street level (Figure 2). We apply the green view index of the street and path network based on purchased street view panoramas and regional land cover data provided by Toikka et al. (2020). The tool uses street network data from OpenStreetMap and OpenTripPlanner[4]. The least-cost routing methods applied in this paper are available with permissive MIT license at GitHub repositories[5]. The routing service can be accessed via an API[6], and it returns a list of routes from the shortest to exposure-optimized ones in the GeoJSON FeatureCollection format.

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[1] green-paths.web.app/
[2] en.ilmatieteenlaitos.fi/environmental-information-fusion-service
[3] www.syke.fi/fi-FI/Avoin_tieto/Paikkatietoaineistot/Ladattavat_paikkatietoaineistot
[4] www.openstreetmap.org/, www.opentripplanner.org/
[5] github.com/DigitalGeographyLab/hope-green-path-server
[6] github.com/DigitalGeographyLab/hope-green-path-server/blob/master/docs/green_paths_api.md

Figure 2. Street-level greenery based on street view images and land cover data provided by Toikka et al. (2020). *Screenshot from the Green Paths user application.*

2.2 Population-level exposure assessments

We applied the Green Paths routing tool to examine the environmental exposure during everyday trips in Helsinki. We found the exposure to traffic noise, air quality, and street-level greenery for walking or biking travel modes. We studied city-wide exposure patterns by applying three data sets: (1) census-based commuting flow data provided by the Statistics Finland/SYKE[7] (2019) with 31,291 distinct origin-destination (OD) pairs (Helle, 2020), (2) realized trips from grid-based mobile phone data provided by Telia Crowd Insights[8] (2019) with 164,649 OD combinations, and station-based bike-share data from Helsinki[9] (2020) with 58,322 OD pairs. We weighted route-based exposure results by the traveler counts on respective OD pairs and aggregated results by the origin grid cell (census, mobile phone data) or origin Voronoi polygon (bike-share data) of the trip. We also tested the perspectives to improve environmental exposures during travel by route choice. We examined the results spatially without sociodemographic background data of people. Here we present the first results of the potential to apply exposure-aware routing for multiple environmental variables using city-wide mobility data sources, and get insights of the spatial disparities.

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[7] www.ymparisto.fi/fi-fi/elinymparisto_ja_kaavoitus/yhdyskuntarakenne/tietoa_yhdyskuntarakenteesta/yhdyskuntarakenteen_seurannan_aineistot

[8] www.telia.fi/yrityksille/palvelut/teknologiat/crowd-insights

[9] www.hsl.fi/en/hsl/open-data

3. Results and discussion

Our results show a positive correlation between exposure levels to traffic noise and air pollution, and a negative correlation between traffic noise and street-level greenery exposure. There is a significant spatial variation in exposure levels during everyday trips for people living in or starting their trips from different parts of the city. The variation in the levels of exposure on the shortest routes is the biggest for traffic noise and most modest for air pollution. For noise exposure for example (Figure 3), higher exposure occurs for trips starting in the city center or near major roads. At the same time, these areas tend to be poor from exposure to street-level greenery. People starting their trips in those areas have only little or no possibilities to improve their environmental exposures by exposure-aware route choice, particularly in case of initially short trips. The latter is characteristic to shared bike users, who tend to make short trips mostly in the city center.

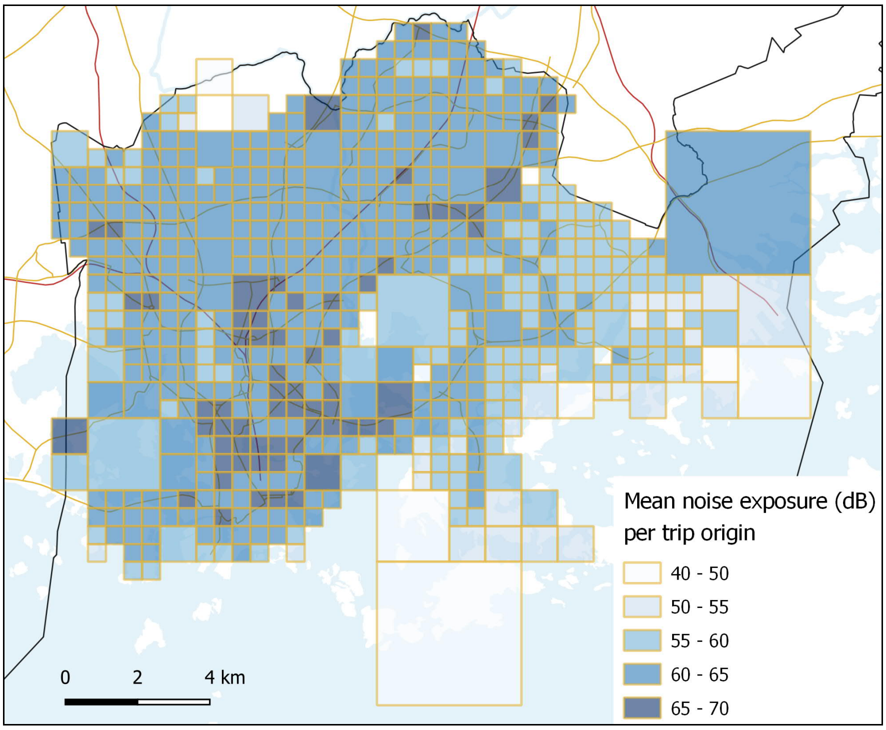

Figure 3. Example of mean noise exposure (dB) on the shortest paths aggregated per trip origin in Helsinki, based on Telia Crowd Insights mobile phone OD data. *Base map: the City of Helsinki.*

In general, most significant exposure reduction is achievable for traffic noise, followed by air pollution. Being aware of the effect of route choice enables people to make informed decisions on travel route and time. More importantly, access to healthy travel environments should be made available for people in all parts of the urban area.

Environmental exposures during travel are context-specific and depend strongly on land use patterns or traffic intensity in the region, among others. Human travel choices and route selection, however, have an effect on the realized exposures. We acknowledge the future need to explore the consistency of route choice effects for improving exposures to multiple environmental variables at a time. In our next analysis, we combine travel-time exposure results with the socioeconomic background data of population groups to get insights on the socio-spatial variation in access to healthy travel routes.

4. Conclusions

Population-level environmental exposure assessment during daily travel is achievable with the help of contemporary data and modeling tools. Our study indicated that access to healthy commuting routes is unequally distributed among the population of Helsinki. At the same time, the spatial variability of exposures during travel depends on the environmental variable under examination. More research is needed on the associations between multiple exposures and their health and wellbeing effects. Urban and transport planning can benefit from the knowledge on the accessibility of healthy urban travel environments to develop fair, healthy, and sustainable cities.

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