An exploratory study on the association between noise pollution, urban forms and function, and the choice of transportation modes

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Summary

Noise pollution is problematic in highly urbanised areas, impacting adversely on active commuting experiences. The potential rippling effects of noise pollution on transportation choices inform the study's intent. Using London as a case study, the research explored the association between noise pollution, urban forms and functions and the mode of transportation to work. Results show cyclists are more vulnerable to high noise levels, whereas pedestrians are more exposed to mid-range noise levels, with urban density and diversity positively correlated with noise pollution.

KEYWORDS: urban, density, mode of transportation, noise pollution, active travel

1. Introduction

Noise pollution is a key environmental health issue in Europe, with road traffic as the second most harmful environmental stressor after fine particulate pollution (WHO, 2018; EEA, 2019). It is associated with not only physiological conditions such as hypertension and cardiovascular diseases (Andersson et al., 2020) but psychological (Díaz et al., 2016) and developmental conditions (Chetoni et al., 2016) However, the extent of investigation had not been comparable to similar research such as air pollution as identifying specific noise exposure was challenging (Sørensen et al., 2012; EEA, 2014; King and Murphy, 2016; Murphy and King, 2022), despite its importance to transitioning towards more sustainable cities.

Noise pollution may indeed be one mediating factor when it comes to choosing the transport mode, potentially discouraging active travel. Active travel is a key element for sustainable transportation systems, better land use planning (Liu et al., 2014), and physical health (Flint et al., 2014). Previous research identified various built environmental factors to increase the likelihood of non-motorised travel, including increased density, land use diversity and design oriented to pedestrians (Cervero and Kockelman, 1997). In particular, land use diversity, intersection density and destination accessibility are positively associated with walking (Ewing and Cervero, 2010). To inform policymaking, many studies examined the associations between built-environmental dimensions and odds of active travel (e.g. Aziz et al., 2018).

Although it is established that some built-environmental factors, such as density and land use diversity, have positive impacts on active travel (Mouratidis et al., 2019; De Vos, 2015), the relationship might be complicated by intermediate factors. Noise pollution could be one of them because of its positive relationship with higher urban density (Salomons et al.,2012) and has potentially deterred impact by making active transport journeys less appealing.

In response to these observations, the paper presents an initial exploration of the association between noise pollution with certain urban forms and functions, as well as commuters' mode of transport choices in London.

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2. Data

This work focuses on London for an initial exploration analysis. Table 1 contains information on the datasets employed for the study.

Table 1 Dataset employed for the study

Dataset Name	Description
Strategic noise mapping-2017 by DEFRA	Noise levels were simulated and presented according to the strategic noise mapping of road sources in areas with a population of at least 100,000 people and along major traffic routes. Noise levels were based on a 10m grid at a receptor height of 4m above ground. Data was ordinal in 6 classes (75.0+dB, 70.0-74.9dB, 65.0-69.9dB, 60.0-64.9dB, 55.0-59.9dB, <54.9dB). Noise-level examples are available in Figure 1. LAeq, 16h, which contained annual average noise levels for the 16-hour interval between 0700-2300, was employed.
UKBuilidngs – National Property Database by Verisk	Based on observation of aerial imagery, the dataset contained data including locations, 3D footprints, height, building use and residential type classifications for all buildings in the UK. The 26 categories for building use were condensed into 5 main categories for analysis: Retail, Residential Office, Public, Transport and Others.
Location of usual residence and place of work by method of travel to work (WU03UK) by Office for National Statistics	The dataset comprised employed residents in the UK aged 16 or above and classified residents' mode of travel between workplace and residence. The record was taken on census day on 27 March 2011.

Figure 1 Examples of noise level (Bhanap, 2013)

3. Methods [‡]

3.1 Data pre-processing

The study created a grid of 216,580 sqm hexagonal cells to integrate data having different geographies. Data retrieved from the databases listed in Table 1 were imported into QGIS3.26.3 as vector polygons and intersected with the hexagonal grid. For road noise information, the ordinal data class for each cell was determined based on the noise class that covered the largest cell's area.

3.2 Noise, urban forms and functions

Building density was computed using the total building area divided by the area of each grid and is the only aspect of urban forms analysed in this initial study. To capture urban functions, we focused on building use types and diversity. Building use areas for each use type -- Retail, Residential Office, Public, Transport and Others, were aggregated for each grid's cell. As a proxy of diversity, the number of building use in each grid's cell was counted. To

[‡] Code available at link: https://github.com/aelissa/ActiveTravel_Noise

assess the relationship between road noise with urban density and functions, Kendall's rank correlations between these variables were computed. The correlation measures the extent of association for two or more ordinal variables nonparametrically.

3.3 Noise and active travel

Origin-Destination commuting data between MSOAs by mode of transport provided by the 2011 Census were employed to explore the relationship between noise and modal choices. Detailed itineraries, from MSOA's centroids as origins to MSOA's centroids as destinations, were computed with the r5r multimodal router (Pereira et al., 2021) accounting for the mode of transport. These itineraries were then intersected with the hexagonal grid to obtain a vector of cell's IDs with the related noise level for each OD pair. Figure 2 shows an exemplary itinerary intersecting the grid's cells containing road noise information.

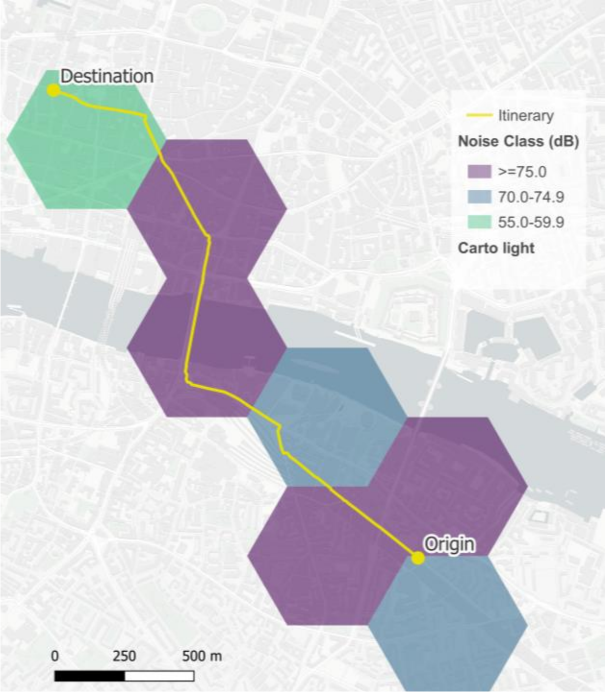

Figure 2 Example of OD pair itinerary and the intersecting cells containing information on the noise road class level.

We then computed the distance travelled through each noise class area by mode of transport based on the following equation:

$$d_{kj} = \sum_{1}^{N_j} \left(\frac{d_{ij}}{N_{ij}} \cdot N_{ijk} \right) \cdot c_i$$

where *i* is the OD pair itinerary index, *k* is the noise class, *j* is the travel mode spanning car, walk and bicycle, *d* is the distance in meters and *c* the number of commuters. Therefore, $\frac{d_{ij}}{N_{ij}}$ gave us an approximation of the distance travelled in each cell, dividing the distance travelled in itinerary *i* with mode of transport *j* by the total number of cells *N* intersected by that itinerary. This is then multiplied by the number of cells *N* corresponding to each noise class *k* and the number of commuters *c* travelling across that OD pair itinerary *i*, which gave us the distance travelled for each noise class *k* by commuters using mode of transport *j*. Finally, we summed those distances across all OD pairs for each transport mode.

As the distance travelled by car, bicycle or walking varies substantially, with commuting by car being the most popular mode and drivers reaching way farther distances than other modes, we obtained and visualised the percentage of distance travelled across each noise class.

4. Results and Discussion

4.1. Correlation Analysis

Table 2 provides a summary of the correlation analysis. A positive association between building density and road noise level was found, with $r_T = 0.21$, $p < 0.00$. Similar observations were obtained when assessing the relationship between the number of building use and road noise with $r_T = 0.31$, $p < 0.00$. The correlation persisted in its significance when noise levels were compared with building areas with a specific use. Regardless of building uses (retail/residential/office/public/transport/others), all building use resulted in a positive, significant correlation between building areas and noise levels. However, urban functions related to day-time activities such as retail and office yielded higher correlation coefficients.

Table 2 Correlation between noise level and three variables (building area, no. of building use and building uses)

	Noise level	
	Kendall's Rank Correlation Coefficient (r_T)	p-value
Building area	**0.21**	0.00***
No. of building use	**0.31**	0.00***
Specific building use		
Retail	**0.33**	0.00***
Residential	0.09	0.00***
Office	**0.30**	0.00***
Public	0.18	0.00***
Transport	0.16	0.00***
Other uses	0.13	0.00***

p<0.05*, p<0.02**, p<0.01***
Coefficients in **bold** indicate moderate to strong correlation

4.2. Exploring road noise and commuting

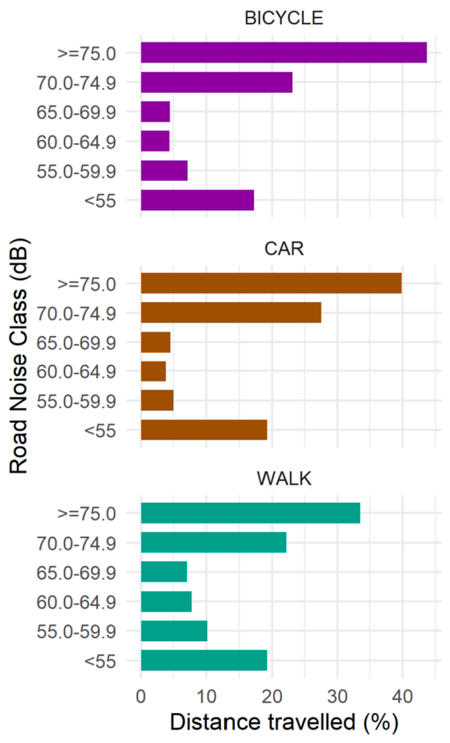

Figure 3 Percentage of distance travelled by different modes of transportation across each road noise classes.

Figure 3 shows the level of noise commuters are mostly exposed to depending on the transport mode they choose. We note that more than half of the distance travelled crosses the two highest classes of noise for all transport modes, 66% for commutes by car or bicycle and 55% by walking. This demonstrates that noise affects most of people's travels, independently from the transport mode, with the important difference that cars contribute to increasing noise, while car drivers are slightly less affected as travelling within a vehicle. Walking is the transport mode that exposes people more directly to noise, which likely motivates why these commuters have the highest percentage of distance travelled in areas with less than 60dB - 30% in the two lowest classes – when compared with cyclists and car drivers – 23% and 24% respectively.

Comparing active travels modes, we see that cycling and walking diverge quite considerably in how the distance travelled distribute across noise classes, with cyclists following routes broadly more similar to cars than people walking, who likely tend to avoid big, more trafficked roads. This highlights that while commuting by bicycle puts cyclists on similar routes to car drivers, travelling with a bike exposes them to a higher risk of being affected by the noise.

5. Conclusions

To summarise, exploring the relationship between noise pollution, urban forms and functions and commuters' travel choices provides initial evidence of key aspects for the planning of sustainable cities.

While urban density remains fundamental to making cities more walkable or bikeable, its relationship with noise pollution has to be carefully considered. Mobility justice considerations can also be made as this initial evidence shows the extremely high exposure of cyclists to noise pollution, despite them not contributing to noise.

A key limitation of the current analysis was that OD itineraries were based only on commuting and computed by the shortest path, while people might opt for different routes based on preferences. Future works can leverage new forms of data on human mobility to gain information on movements to a wider variety of destinations and preferred paths.

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Biographies

Ki is a PhD candidate at the Advanced Care Research Centre of the University of Edinburgh. She is a chartered landscape architect by profession and was a research psychologist. Combining her background in landscape and psychology, her research focused on the facilitators and barriers to accessing urban green space and the well-being benefits of nature.

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