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# Socio-economic and ethnic inequalities in transport-related outdoor noise at residence in London

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## ABSTRACT

Transport-related noise varies within cities but little is known about differential exposure across vulnerable subpopulations. We characterised inequalities in residential exposure to traffic-noise from roads, railways, and aircraft in relation to individual- and area-level socio-economic status (SES) and ethnicity in Greater London. We assigned road-traffic noise ($L_{Aeq,16hr}$, $L_{night}$, $L_{Den}$) to ~45,000 individuals, using the TRAffic Noise EXposure model and identified those within 50dB noise contours of over-ground railways and Heathrow and City airport. We used household income as an individual-level and the Index of Multiple Deprivation as an area-level marker of SES. Road-traffic noise increased slightly with decreasing area-level SES for all metrics. We observed a strong increasing trend in exposure from railways and City airport with deprivation (individual- and area-level); 10% and 0.3% of individuals in the highest tenth of household income were exposed to noise from railways and City airport, respectively, compared to 15% and 0.9% in the lowest tenth. For Heathrow airport the trend was opposite; 18% in the highest tenth of household income and 10% in the lowest. Differences by ethnicity were marginal.

## INTRODUCTION

Environmental inequality, the concept that more vulnerable subpopulations or communities are more likely to be exposed to higher levels of environmental pollution, is well establish for many pollutants, specially air pollutants. People of lower socioeconomic status (SES) and ethnic minorities have been identified as those living in areas of higher air pollution levels [1]. This inequality in air pollution exposure has been shown across many countries in North America and Europe, in particular for traffic-related air pollutants such as nitrogen dioxide [2, 3, 4]. Transport-related noise arises from similar local road, rail and aircraft sources as traffic-related air pollution and spatial patterns could therefore be assumed to be similar to those seen for air pollution. A recent study by Fecht et al. (2016) has, however, shown that correlations between noise and air pollution are moderate and vary considerably, depending on the geographical resolution of spatial units used for analysis (e.g. postcodes, neighbourhoods or districts) [5]. Patters of environmental inequality might, therefore, be very different from those previously identified for air pollution.

So far, only a few studies have explored environmental inequality in relation to transport-related noise, mainly in North America. A study from Minnesota, US, reported an association between transport-related noise (from road and aircraft sources) and household income as well as the percentage of non-white residents [6]. Others found similar associations between environmental noise and household income at the small area level [7].

Inequalities in noise exposure imply disadvantages in certain subpopulations because both increased levels of noise and socioeconomic deprivation may lead to impaired health. Social gradients in health are well-established, with more deprived people having higher disease rates and lower life expectancy compared to the less deprived [8]. In England, for example, between 1.3 and 2.5 million years of life are lost due to health inequalities [9]. Because of these higher baseline disease rates in the socially and economically deprived their susceptibility to the negative noise-related health effects such as myocardial infarction and stroke might be increased.

Understanding how noise levels differs between subpopulations is, therefore, important for environmental policy and public health; not only to reduce the average risk across the population but also to safeguard that no population subgroups such as deprived or ethnic minorities are more burdened than others. Here we quantify socioeconomic and ethnic inequalities in transport-related noise from road, over-ground railway and aircraft sources in Greater London, UK.

## METHODS

### Study population

The study population included members of households and individuals who responded to the London Travel Demand Survey (LTDS), conducted by Transport for London [10]. The survey samples approximately 8,000 households per year on a rolling basis and represents a random sample of households. Transport for London adjusts the samples for sampling weights and weights for non-response to generate a sample representative of London residents overall as well as for sub-regions of the city. Besides information on gender, age, ethnicity, and residential postcode, this data set also holds information on household income for each LTDS respondent; information which is not routinely collected in England. We used LTDS data from 49,537 individuals who responded to the survey between the years 2006 to 2010. After excluding individuals with missing residential postcode or demographic data (9%) or missing noise exposure (0.2%), 44,974 individuals were included in the analysis.

### Transport-related noise exposure

We assigned individuals with road-traffic noise exposure via their residential postcode (in England, on average 12 households per postcode). Annual road traffic noise for the years 2003-2010 was modelled using the TRAffic Noise EXposure (TRANEX) model [11]. TRANEX is an adaptation of the Calculation of Road Traffic Noise methods [12] for spatial assessment of noise levels in epidemiological studies. Details on model development and validation are described elsewhere [11]. Briefly, TRANEX uses detailed information on traffic flows, speeds and composition for each year, land cover, road geography and heights of individual buildings.

We applied the model to geometric centroids for all residential postcodes of LTDS respondents. Exposures for day- and night-time noise were estimated separately. Noise metrics were derived by averaging $L_{Aeq,1hr}$ as follows: i) $L_{Aeq,16hr}$, the hours 7:00 to 22:59; ii) $L_{night}$, the hours 23:00 to 6:59; and iii) $L_{DEN,}$ logarithmic composite of $L_{day}$ (7:00-18:59), $L_{eve}$ (19:00-22:59), and $L_{night}$ with 5 dB(A) added to $L_{eve}$ and 10 dB(A) added to $L_{night}$.

We also identified those individuals whose residential postcode was within the 50dB noise contours of over-ground railways and Heathrow and City airport. Information on noise contours comes from the strategic noise mapping results produced under the first round of the Environmental Noise Directive (END). Data for over-ground railways and aircraft noise from City airport (annual averages for 2006) were from Department for Environment, Food and Rural Affairs, supplied by Extrium Ltd. Data for aircraft noise from Heathrow airport were from annual average contours (2001) supplied by the Civil Aviation Authority.

### Deprivation and ethnicity

We analysed individual-level and area-level information on SES separately because they reflect different dimensions of deprivation. Individual-level SES influences individual lifestyle and behavioural choices, while area-level SES provides information on neighbourhood quality (e.g. housing conditions, crime levels, access to services).

We used self-reported household income from the LTDS as indicator of individual-level SES and the 2010 Index of Multiple Deprivation (IMD) as small-area level indicator of SES [13]. The IMD contains 7 different domains of deprivation reflecting i) income deprivation; ii) employment deprivation; iii) health deprivation and disability; iv) education training and skills deprivation; v) barriers to housing and services; vi) crime; and vii) living environment deprivation. These domains can be separated from the overall IMD. We included the income deprivation and the employment deprivation domains in our analysis, in addition to the overall IMD. These domains provide the proportion of people on income and employment support, respectively, within each small area. The IMD is available at the Lower layer Super Output Area (LSOA) level, on average 1500 residents per LSOA. We linked the LTDS respondents to LSOAs based on the residential postcode to assign the overall IMD and the two domains. Information on self-reported ethnicity was obtained for each individual from the LTDS.

### Statistical analysis

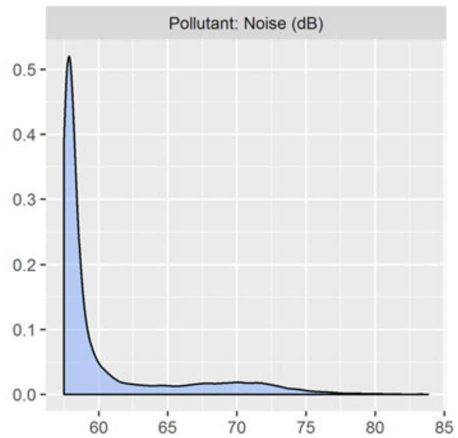
We used descriptive statistics to describe noise exposures for $L_{Aeq,16hr}$, $L_{night}$ and $L_{DEN}$, as well as a kernel density estimator to generate the distribution for $L_{DEN}$. We used Spearman's rho to measure the rank correlation of noise levels with household income and IMD scores. We categorised the IMD, income domain and employment domain into percentiles. We categorised LTDS respondents' self-reported ethnicity in White, Asian, Black and Other ethnic groups. All statistical analysis was performed with open-source software R version 3.3.2.

## RESULTS AND DISCUSSION

Summary statistics for modelled road-traffic noise levels at postcode location for all LTDS respondents included in the analysis are presented in Table 1. Figure 1 shows the exposure distribution for $L_{DEN}$ and corresponding number of individuals within 5dB bands of modelled noise exposure. As can be seen, road-traffic noise exposure is overall very high for LTDS respondents. Exposure levels are of similar magnitude to those reported previously across all postcodes in London [11], indicating that exposure levels for LTDS respondents are comparable to those of the general population in London.

**Table 1:** Summary statistics for road-traffic noise exposure in dB for LTDS sample (n = 44,974)

| | N | Mean | Std. Dev. | Min | 25th PCT | Median | 75th PCT | Max |
|---|---|---|---|---|---|---|---|---|
| $L_{Aeq,16hr}$ | 44,974 | 57.6 | 4.6 | 54.8 | 55.0 | 55.4 | 57.3 | 80.7 |
| $L_{night}$ | 44,974 | 52.3 | 4.9 | 49.2 | 49.5 | 50.0 | 52.1 | 76.2 |
| $L_{DEN}$ | 44,974 | 60.5 | 4.8 | 57.5 | 57.8 | 58.2 | 60.3 | 83.8 |




| dB | $L_{Aeq,16hr}$ | $L_{night}$ | $L_{DEN}$ |
|---|---|---|---|
| 49 – 54 | - | 35,785 (79.57) | - |
| >54 - 59 | 35,791 (79.58) | 38,967 (86.64) | 30,185 (67.12) |
| >59 - 64 | 38,910 (86.52) | 42,686 (94.91) | 37,100 (82.49) |
| >64 - 69 | 42,948 (95.50) | 44,633 (99.24) | 40,426 (89.89) |
| >69 - 74 | 44,689 (99.37) | 44,945 (99.94) | 43,941 (97.73) |
| >74 - 79 | 44,955 (99.96) | 44,974 (100) | 44,838 (99.70) |
| >79 - 84 | 44,974 (100) | - | 44,974 (100) |

**Figure 1:** Exposure to road-traffic noise distribution ($L_{DEN}$) at residential postcode for LTDS respondents. Left: Probability density of $L_{DEN}$ (extreme values removed for purpose of visualisation); Right: Cumulative counts of LTDS respondents (percentage in brackets) for 5dB increments in modelled $L_{DEN}$ road-traffic noise exposures

We could not detect any consistent correlation of noise levels with individual- and area-level measures of deprivation; for example, correlation of $L_{DEN}$ and household income $r = -0.03$, and $L_{DEN}$ and IMD score $r = 0.07$. These correlations are slightly lower than those reported by Dale et al. (2015) in Montreal, who found Pearson correlation coefficients for $L_{Aeq,24hr}$ with indicators of SES at the small area level of $r = 0.23$ [7].

Table 2 lists the mean road-traffic noise levels by IMD quintiles and Table 3 by ethnicity. Patterns for income and employment domain were similar (data not shown). We observed the highest mean road-traffic noise levels for $L_{Aeq,16hr}$, $L_{night}$ and $L_{DEN}$ for residents in the most deprived areas. Differences were small but we saw a consistent increase in noise levels by deprivation. For $L_{night}$, for example, differences between the least compared to the most deprived quintile were 0.55 dB. Exposure differences for road-traffic noise by ethnicity were small. We observed highest noise levels for Asian LTDS respondents, followed by Blacks respondents. Results for other ethnicities were inconclusive but lower than those for Whites respondents (data not shown).

**Table 2:** Mean road-traffic noise levels (dB) by Index of Multiple Deprivation quintile

| IMD quintile (Q) | $L_{Aeq,16hr}$ | $L_{night}$ | $L_{DEN}$ |
|---|---|---|---|
| Q1: least deprived | 55.22 | 49.64 | 57.96 |
| Q2 | 55.36 | 49.84 | 58.13 |
| Q3 | 55.39 | 49.92 | 58.19 |
| Q4 | 55.40 | 49.95 | 58.20 |
| Q5: most deprived | 55.56 | 50.19 | 58.39 |

**Table 3:** Mean road-traffic noise levels (dB) by ethnicity

| Ethnic groups | $L_{Aeq,16hr}$ | $L_{night}$ | $L_{DEN}$ |
|---|---|---|---|
| White | 55.35 | 49.86 | 58.13 |
| Black | 55.38 | 49.92 | 58.17 |
| Asian | 55.46 | 50.00 | 58.26 |

Table 4 shows the percentage of LTDS respondents living within 50dB noise contours of over-ground railways, Heathrow airport and City airport by individual-level (household income) and area-level (IMD) socioeconomic status. There were clear gradients in noise exposure from both over-ground railway and City airport by deprivation, such that a higher percentage of respondents in the lowest tenth of household income live in proximity of these sources (15% within 50dB contour for railways, 1% for City airport) compared to the highest tenth of household income (10% within 50dB contour for railways, 0.3% for City airport. The socioeconomic gradients for aircraft noise from Heathrow airport were in the opposite direction: 10% of respondents in the lowest tenth of household income love within 50dB contour compared to 18% in highest tenth). Patterns for area-level SES (i.e. IMD) are similar. (Please note the reverse order of least versus most deprived for household income and IMD deciles in table 4.)

**Table 4:** Percentage of LTDS respondents living within 50 dB noise contours for over-ground railways, Heathrow airport and City airport by individual-level (household income) and area-level (Index of Multiple Deprivation) socioeconomic status.

| | Household Income | | | Index of Multiple Deprivation | | |
|---|---|---|---|---|---|---|
| | Railways (%) | Heathrow (%) | City (%) | Railways (%) | Heathrow (%) | City (%) |
| **Q1*** | 15 | 10 | 0.9 | 11 | 16 | 0.0 |
| **Q2** | 12 | 12 | 0.9 | 12 | 14 | 0.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Q3** | 13 | 12 | 1.3 | 10 | 15 | 0.0 |
| **Q4** | 12 | 13 | 1.0 | 12 | 15 | 0.0 |
| **Q5** | 12 | 11 | 1.0 | 13 | 17 | 0.3 |
| **Q6** | 14 | 12 | 0.9 | 12 | 16 | 0.4 |
| **Q7** | 12 | 13 | 0.7 | 12 | 14 | 0.2 |
| **Q8** | 11 | 13 | 0.3 | 12 | 9 | 0.5 |
| **Q9** | 13 | 15 | 0.5 | 14 | 9 | 0.8 |
| **Q10*** | 10 | 18 | 0.3 | 15 | 5 | 4.0 |
| **ALL** | 12 | 13 | 1 | 12 | 13 | 0.6 |

* Q1: for household income = most deprived, for IMD least deprived; Q10 for household income = least deprived, for IMD most deprived

Figure 2 shows the percentage of LTDS respondents living within 50dB noise contours of over-ground railways, Heathrow airport and City airport by ethnicity. 14% of White respondents lived within the 50dB noise contour of Heathrow airport and 12% of over-ground railways, a reverse pattern than for Black respondents (12% within 50dB noise contour of Heathrow airport, 14% of over-ground railways).

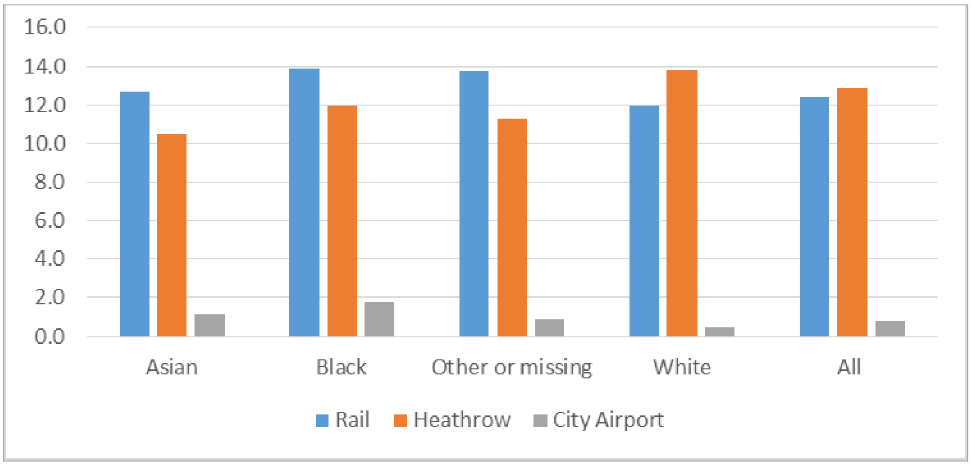



**Figure 2:** Percentage of LTDS respondents within 50dB noise contours for over-ground railways, Heathrow airport and City airport by ethnicity

## CONCLUSION

We analysed socioeconomic and ethnic characteristics in relation to transport-related noise from road, over-ground railway and aircraft sources in London. Using a large dataset (~45,000 individuals) including individual-level data on household income and ethnicity, we observe a complex pattern of socioeconomic and ethnic inequalities in exposure to transport-related noise pollution.

Our study is one of the first in England to explore inequalities in noise exposure across different subpopulations. Our study benefitted from a very large study population for which we were able to obtain individual-level household income, which is not routinely collected in England, and self-reported ethnicity. We were also able to assign road-traffic noise exposure using a high-resolution noise model developed for epidemiological analysis at the near individual level (i.e. postcode level). By including analyses using an area-level measure of deprivation such as the IMD we were able to compare our study results to the few other studies on noise inequality which have been published so far. Results at the small-area level reported by Dale et al (2015), for example, showed similar patterns than those observed here for road-traffic noise [7].

Our study contributes to the growing evidence on inequalities in exposure to transport-related noise. Such knowledge is important to target environmental inequalities and the consequent health inequalities experienced by vulnerable subpopulations. Our work takes a step towards this goal.

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