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The impacts of environmental noise on the academic achievements of secondary school students in Greater London

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ABSTRACT

Previous studies on the detrimental impact of chronic external noise upon the academic performance of school children were normally based on sampled school sites, and the results were often limited to a specific range of areas. The aim of this paper is to investigate the relationships between environmental noise levels of secondary schools in Greater London and a set of academic achievement factors, and also, to determine the noise exposure of secondary schools. Four academic achievement indicators were considered and five noise indicators were obtained after processing noise map data. It has been shown that the environmental noise levels of secondary schools in Greater London have almost no significant relationships with those academic achievement indicators. As expected, the secondary schools in Inner London are noisier than those in Outer London. The average difference is calculated as 2 dBA.

1. Introduction

Noise pollution is a major environmental problem, and some estimated 10 millions of people in Europe are exposed to the excessive traffic noise, which may cause stress, illness and even fatal impact. At a conservative estimate, the social costs of traffic noise amount to 0.4% of total GDP [1]. In the UK, according to the national noise survey, people indicated that the road traffic noise around their home had got worse over the last 5 years, and the majority of the UK population were affected by the noise levels above those suggested by the WHO Guidelines for Community Noise [2].

There have been some studies on the detrimental influence of chronic external noise upon the academic performance and attainments of school children. A number of findings have indicated that chronic noise exposure would impair concentration, general cognitive functioning, and particularly reading skills [3–9]. However, previous evidence was normally based on subjective or field surveys with sampled school sites, and the results were often limited to a restricted range of areas and in particular, the research on the secondary schools has been limited. A key study relating to this research was conducted by Shield and Dockrell [3], to examine the impact of external and internal noise on the academic attainments of London primary school children, although it only considered a number of schools situated in 3 London boroughs. It was found that external noise has a significant negative impact upon performance, the effect being greater for the older children.

Recently large-scale urban strategic noise mapping has become an essential requirement, particularly in European countries [10–12], and corresponding techniques have been widely adopted in practice for the establishment of noise strategies and planning policies [13–16]. A noise map, typically in a form of interpolated iso-contours, is a way of presenting the geographical distribution of noise exposure, either in terms of calculated or measured levels [17]. Whilst there have been varied attempts to improve the accuracy [18–20], computing-based noise mapping techniques are certainly useful for relative comparisons, especially for large scale areas [21].

The socio-acoustic research approach has been widely applied in similar research questions, for instance the relationship between human reactions to noise and non-acoustic variables, like income and occupational status [17,22–27].

The aim of this study is to investigate the relationships between environmental noise levels of secondary schools from noise mapping calculations and a set of academic achievement factors, as well as to determine the noise exposure of secondary schools. For this the Greater London is considered as a case study city.

2. Methodology

2.1. Academic achievement indicators

Every year the Department of Children, Schools and Families (DCSF) publishes the Achievement and Attainment Tables for all

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the secondary schools in England. These tables give information on the overall performance of each school, which is helpful for parents when choosing secondary schools for their children. As previous research suggests that environmental noise has a negative impact upon pupils' performance [3,7,9], four major achievement indicators were considered for this study, including the average total point score per pupil of Key Stage 4, CVA score, overall and persistent absence.

A Key Stage is a part of the British state educational system for students at various ages. Pupils aged 14–16 years old normally enrol in Key Stage 4 and at the end of this stage there is a range of exams typically of the GCSE level (General Certificate of Secondary Education). The average total point score provides a fuller picture of the achievements of pupils of all abilities at Key Stage 4.

Contextual Value Added (CVA) score measures the progress made by pupils from the end of Key Stage 2 (KS2) to the end of Key Stage 4 (KS4), using their test and exam results. CVA takes into account the varying starting point of each pupil's KS2 test results, therefore provides a fairer indication of a school's overall effectiveness [28]. The overall absence is the percentage of possible half-days recorded under any combination of the authorised and unauthorised absences for schools which do not report absence by reason, while persistent absence is the percentage of pupil enrolments equalling or exceeding the threshold number of half-day absences over the autumn and spring terms combined [28].

Due to the lack of appropriate income and occupational data, this study did not take into account the effect of social variables on the correlation results.

2.2. Selection of secondary schools

As the capital of both England and the UK, Greater London covers 1572 km^2 and had a most recent (mid-2007) estimated population of 7.56 million accounting for 14% of the England and Wales total [29]. Noise levels in Greater London were measured to be significantly higher than those over the whole of England and Wales. Road traffic noise was heard and reported as causes of annoyance by a greater proportion of respondents in Greater London than nationally [30].

More than 500 secondary schools are listed in Greater London in the DCSF Achievement and Attainment Table. Regarding the initial selection, the schools without applicable academic achievement factors were automatically excluded from the selection. There are two large and busy airports in Greater London, namely London Heathrow Airport and London City Airport. The impact of aircraft noise on the school children have been studied by a number of researchers [9,31,32], and in this study the schools in the areas where aircrafts are dominant noise sources were excluded due to their special features. According to the official airport noise maps [33], the schools located within 60 dB zone were deleted from the above list.

Based on random number generation, 96 secondary schools in Greater London were identified and verified in accordance with relevant noise maps. Data in both academic achievement and noise aspects were then obtained from corresponding databases.

The administrative area of Greater London is generally divided into Inner and Outer London. Inner London forms the interior part of Greater London with a land area of 319 km^2 and the population is 3 million. Occupying 1253 km^2 for 4.57 million residents, Outer London forms a ring around Inner London [29]. Inner London is considered as one of the richest areas in Europe.

2.3. Processing of noise map data

The original data calculated for the noise levels of secondary schools in Greater London were obtained from an open database called London Noise Maps, produced and hosted by Atkins from 2004 to 2008 on behalf of DEFRA [14]. It considers road traffic as the predominant noise source in London. The maps represent the average noise levels at a height of 4 m above the local ground level, according to the EU regulations [10–12]. It is assumed that the roads are dry but the wind is adverse, namely blowing from the road to the receiving position. The published colour noise maps were processed to obtain a series of digital numbers for the following analysis. The average noise levels of London Noise Maps are expressed in L_{den}, which is a logarithmic composite of the day, evening and night levels [21]. After being smoothed for display, each pixel in the noise map indicates a 1 m $\times$ 1 m square in reality.

Every house and business in the UK has been given a postal address to sort and deliver mail quickly and accurately. The postcodes have been widely adopted for many other purposes such as the important geographic references to pinpoint the UK locations automatically on a map. The approximate boundary of a sampled school was firstly approached from the noise map database in accordance with its unique postcode. As the initially obtained noise maps may contain other unwanted buildings or areas surrounding the schools that are actually not a part of the selected schools, essential boundary information was double checked through GoogleMap and StreetMap to ensure every building of the studied school was not excluded.

A MATLAB program was developed for the further processing of the identified noise map data. Fig. 1a illustrates a typical noise map of a secondary school in Greater London, where each colour represents a 5 dBA scale, which is the highest available resolution from the published noise maps. Since the noise levels range from 35 to 85 dBA, this resolution is acceptable for this study. Firstly a noise map is loaded into MATLAB program, and all the colours of that map will be automatically transformed to corresponding noise values in a 2D grid system. Two sets of matrix are subsequently generated, as illustrated in Fig. 1b and c. In Matrix A (see Fig. 1b), 0 represents the location of building blocks and other values refer to the actual noise levels in dBA at grid points where applicable. Based on Matrix A, Matrix B (see Fig. 1c) is produced to demonstrate the noise environment around the school buildings, where only the noise levels at the grid points indicating the 1 m external locations outside the facades of selected school buildings are retained, while all the other values are assigned to 0. It is noted that Fig. 1b and c corresponds to the area highlighted with dotted lines in Fig. 1a.

The next step was to decide the appropriate noise level indicators for a specific school, after identifying the relevant noise values for all the buildings of a secondary school. Five noise indicators were introduced to this research, including the average spatial noise level $L_{s\text{-}ave}$ (dBA), maximum spatial noise level $L_{s\text{-}max}$ (dBA), minimum spatial noise level $L_{s\text{-}min}$ (dBA), intrusive spatial noise level $L_{s\text{-}10}$ (dBA) and background spatial noise level $L_{s\text{-}90}$ (dBA), respectively. It is noted that L_n generally represents the level of noise exceeded for n% of the specified measurement period, whereas in this study they were to represent spatial rather than temporal distribution. In other words, if N noise levels are obtained for a school from Matrix B and they are sorted in an descending order, then L_n is the $(100n/N)$th noise levels in the order.

2.4. Data analysis

Software SPSS was used for the statistical analysis. One-sample Kolmogorov–Smirnov normality tests were firstly conducted for both academic and noise indicators. Normality hypothesis is to be rejected if 2-tailed asymptotic significance value p is less than 0.05. The averaged Key Stage 4 score ($p = 0.226$), overall absence ($p = 0.574$), persistent absence ($p = 0.291$), as well as $L_{s\text{-}ave}$