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Relationship between urban green spaces and other features of urban morphology with traffic noise distribution

Efstathios Margaritis, Jian Kang*

School of Architecture, University of Sheffield, Sheffield, UK

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ABSTRACT

The effect of greenery on traffic noise mitigation has been extensively studied on the level of single plants, green walls, berms and hedges, but not considering whole sample areas within the cities. Therefore, the aim of this paper is to investigate the relationship between features of urban morphology related to green spaces, roads or buildings and traffic noise distribution in urban areas. The analysis was applied in eight UK cities with different historical and architectural background, following two different settlement forms (radial, linear). In each city a 30 km^2 grid was defined and three different levels of approach were considered (macro-scale, meso-scale, micro-scale). The first level regarded the eight cities as single entities, while in the second one every single tile of the applied grid was investigated in two different cities. In the third level only the eight city centres were analyzed. Statistical analysis was used combined with GIS tools. In total 18 variables were constructed and tested for possible relationships with noise levels (L_{den}). It was found that in spite of the fact that each city has its own dynamic and form, features of urban morphology were related to traffic noise levels to a different extent at each scale. At the macro-scale, the green space pattern was related to the structure of the city as well as the traffic noise levels in combination with the rest of the morphological parameters. At the meso-scale, an increase in internal road connectivity contributed to higher traffic noise. Green space variables explained part of the variance in traffic prediction models. Finally, at the micro-scale, it was also proved that different areas can have the same building coverage but different noise levels. Therefore, these indexes could be profiled and used as an “a priori” tool for urban sound planning.

Introduction

Traffic noise is an increasing problem in the contemporary society and the prevalent noise source in the urban environment (Quis, 1999). About 210 million people, over 44% of the EU population, are regularly exposed to levels over 55 dB(A), a limit which has been recognized by the World Health Organization (WHO, 2011) to pose a serious risk to health. The Environmental Noise Directive (END) (2002/49/EC) and the supplementary noise action plans set the base for developing community measures for noise reduction emitted by major sources.

The generic structure of urban morphology, according to Kropf (2005), is a hierarchy of different characteristics at different interdependent scales involving (a) building elements, (b) road infrastructure and (c) land use components. In this network green spaces have a direct and dynamic relationship with the urban structure (Ståhle, 2010).

Previous studies have put emphasis on diverse building arrangements or formations (Oliveira and Silva, 2010; Guedes et al., 2011; Salomons and Berghauser Pont, 2012; Silva et al., 2014; Lee and Kang, 2015). Others focused more on a dwelling scale within the same or different cities (Wang and Kang, 2011; Hao and Kang, 2013; Lam et al., 2013; Hao et al., 2015a). However, in the urban scale, morphological parameters have been investigated to a lesser extent in connection with traffic noise (Tang and Wang, 2007; Salomons and Berghauser Pont, 2012) and more as part of the urban sprawl process (Galster et al., 2001; Knaap et al., 2005; Tsai, 2005) or land use attributes (Chakraborty, 2009; Kashem et al., 2009).

The accepted definition of urban green spaces by scientists of different backgrounds refers to public and private open spaces in urban areas covered by vegetation directly or indirectly available for the users (Haq, 2011). This broad category includes mainly parks, forests, public squares, recreational grounds and private front or backyard garden land. Ongoing interdisciplinary research is being carried out; either emphasizing the effect of vegetation on traffic noise in terms of trees, plants and hedges (Kragh, 1981;

* Corresponding author at: School of Architecture, University of Sheffield, Western Bank, Arts Tower, S10 2TN Sheffield, UK.
E-mail addresses: e.margaritis@sheffield.ac.uk (E. Margaritis), j.kang@sheffield.ac.uk (J. Kang).

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Huddart, 1990; Van Renterghem and Botteldooren, 2002; Fang and Ling, 2005; Kang, 2007; Wong et al., 2010; Pathak et al., 2011; Yang et al., 2011; Horoshenkov et al., 2013; Van Renterghem et al., 2014) or studying the acoustic properties of the ground in terms of porosity and other similar parameters (Attenborough, 2002; Gołębiewski, 2007; Attenborough et al., 2012; Bashir et al., 2015).

Previous work has put emphasis on individually assessing the effectiveness of parks on traffic noise reduction (González-Oreja et al., 2010; Cohen et al., 2014). However, in these cases the weight was put more on the contribution of greenery in soundscape perception (Nilsson and Berglund, 2006; Margaritis et al., 2015) and not in the distinction between rigid and porous ground as a land use element (European Commission, 2007). Similarly on the urban scale, green space patterns have previously been investigated using various spatial metrics (McGarical and Marks, 1994; Liu et al., 2014). Nevertheless, these indexes do not provide any statistical significance for the degree of clustering or dispersion of the pattern. The latter can be measured by two metrics: (a) the centroid-based Average Nearest Neighbour index (ANN) and the edge-based Connectivity index calculated by the Conefor software (Saura and Torné, 2009).

The street pattern, as a component of the urban morphology, gives a specific identity to each city. In particular, "settlement form" can be used as a term to describe the network structure of distinct units such as cities and towns (Marshall and Gong, 2009). For planning purposes at a city-scale level, Lynch and Hack (1962) proposed three simple systematic patterns/forms: radial, linear and grid. In radial patterns, a main ring road acts as the area constraint around built-up areas, while linear patterns refer to developments, laid out along a transportation 'spine' (Marshall and Gong, 2009). In the same level, Marshall (2005) recognized over 100 descriptors related to street patterns. Nevertheless, all the derivative patterns fall back into the neat sets of rudimentary typologies (radial, grid, linear).

The aim of this paper is therefore to quantitatively investigate the relationship between features of urban morphology and traffic noise distribution with special emphasis on urban green spaces. The historical and architectural background of the cities was also investigated as a complementary element. However the main emphasis was to quantify the present conditions. A triple level analysis was conducted on a macro, meso and micro-scale. For the macro-scale, three targets can be identified: (a) the relationship between urban morphology and traffic noise, (b) the relationship between green space ratio, green space pattern and traffic noise with the settlement forms and (c) the effect of street typology on traffic noise distribution. In the meso and micro-scale the aim is to identify and assess the effectiveness of indicators related to urban morphology in traffic noise distribution.

As regards the scales of interest, the macro-scale refers to the consideration of the city as an entity where the entire sample area is represented by a single value per variable. In the meso-scale, each variable is calculated separately for each one of the 30 tiles of the grid. Finally, in the micro-scale, the analysis is conducted within a single tile from each city.

Materials and methods

Study sites

In the first part, a macro-scale analysis was conducted among eight cities of different settlement form according to the classification proposed by Marshall (2005). As shown in Fig. 1 the first

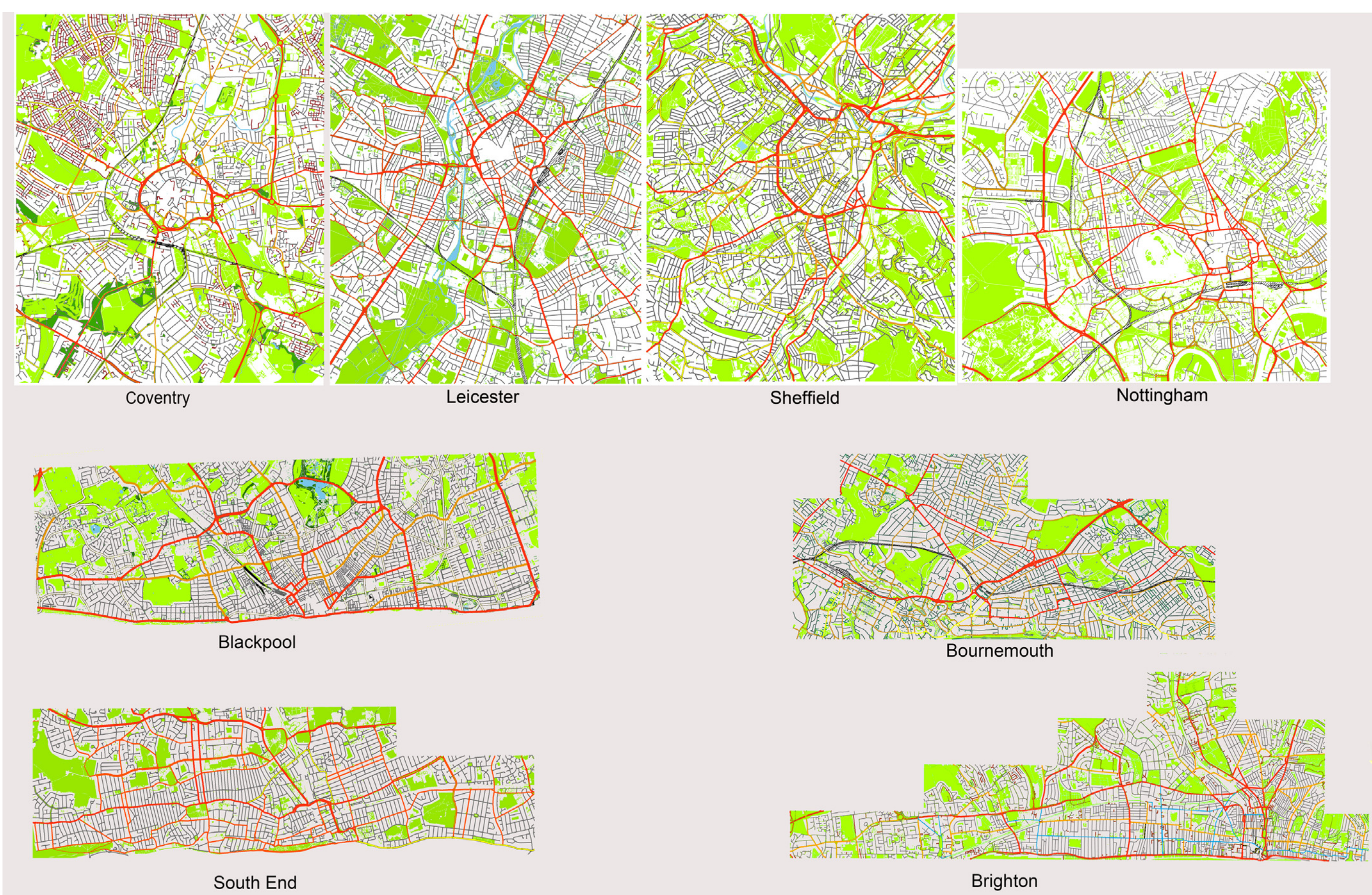

Fig. 1. Green space distribution in radial and linear settlement forms.