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Research Paper

Relationship between traffic noise resistance and village form in China

Wen Luo Yu[a], Jian Kang[a,b,*]

[a] School of Architecture, Harbin Institute of Technology, No.66, Xidazhi Street, Nangang District, Harbin, China
[b] School of Architecture, University of Sheffield, Western Bank, Sheffield S10 2TN, United Kingdom

HIGHLIGHTS

- Noise problem in Chinese villages identified.
- Noise influence due to distances and angles between villages and the motorways revealed.
- Influence of village morphology on traffic noise demonstrated.

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ABSTRACT

The aim of this study is to determine methods to reduce traffic noise levels and to enlarge quiet areas in the rural residential areas in China by controlling relative locations and urban morphological parameters. Six urban morphological parameters, including complete aspect ratio (CAR), landscape shape index of buildings (LSI_B), patch density (PD), road length fraction (RLF), road intersections fraction (RIF), and landscape shape index of roads (LSI_R), are selected and developed. The relationships of the urban morphological parameters to the spatial noise level attenuation and the size of noisy areas were subsequently determined. The effects of motorway horizontal distances and orientations are considered based on spatial traffic noise attenuation. The results indicate that the effect of distance on traffic noise level attenuation is significant and varies widely among the 60 sites studied. A distance of more than 600 m can make the acoustic environment suitable as residential areas. Changing the orientation relationship between the village and the motorway is not always effective for increasing the traffic noise resistance of villages. The results highlight the importance of using urban morphology to improve the traffic noise resistance of rural residential areas; LSI_B and LSI_ R are the most important parameters that correlate to the traffic noise attenuation of motorways.

1. Introduction

A growing body of literature indicates that continued exposure to road traffic noise is detrimental to human health and well-being, including increased risk of ischaemic heart disease, sleep disturbance, cognitive impairment among children, annoyance, stress-related mental health risks, and tinnitus (Brink, 2011; Di, Liu, Lin, Zheng, & He, 2012; Fyhri & Aasvang, 2010; WHO, 2011). Studies also indicate that the significance of quietness and quiet areas benefit human health (Booi & Van den Berg, 2012; Shepherd, Welch, Dirks, & McBride, 2013). For many urban residents, a major source of environmental noise is road traffic noise. The main populations seriously affected by this noise are the residents of areas close to highways and large arterial roads.

To reduce the nuisance of traffic noise and to enlarge quiet areas in cities, solutions have been suggested, including improving/optimising roadway traffic loads, number of lines, road surface types and vehicle speed (Avsar & Gonullu, 2005); designing noise barriers for propagation outdoors (Renterghem et al., 2015), and designing buildings with higher noise reduction capabilities, such as building facades and balcony improvements (Kim & Kim, 2007; Lee et al., 2007); and designing buildings and courtyards with green plants (Gidlöf-Gunnarsson & Öhrström, 2010; Kim, Yang, & Kang, 2014; Renterghem & Botteldooren, 2009; Veisten et al., 2012; Wong, Tan, Tan, Chiang, & Wong, 2010; Yang, Kang, & Choi, 2012). Soundscape studies have recently focused on ecologically improving soundscapes as a method to reduce urban noises and enlarge quiet areas (Jeon, Lee, You, & Kang, 2010).

The effect of urban morphology on traffic noise propagation has been studied in terms of spatial structure (e.g., building layout) and certain urban morphological parameters (e.g., building density) to verify the method of simplifying noise mapping by examining the effects of building gaps. Kang compared the atten-

* Corresponding author.
E-mail address: j.kang@sheffield.ac.uk (J. Kang).

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uation of broadband sound among different street patterns with particular reference to three building configurations, simulating the typical UK housing types of detached, semidetached and terraced houses (Kang, 2007). The spatial distribution of traffic noise in a city is related to traffic volume, building density, shape of the building blocks and general urban form has been determined using numerical calculations of the data from Amsterdam and Rotterdam, for various idealized urban designs (Salomons & Pont, 2012), and from Greater Manchester in the UK and Wuhan in China, which have low and high average urban densities, respectively, for a number of typical urban areas (Wang & Kang, 2011). Three examples of studies focusing on how urban morphology influences the sound environment in low-density residential areas are the studies by Hao and Kang, who examined whether and how urban morphology influences the capability of attenuating traffic noise levels (Hao, Kang, Krijnders, & Wörtche, 2015), the influence of urban morphology on spatial noise level attenuation of flyover aircrafts (Hao & Kang, 2014), and how to increase birdsong loudness and the visibility of green areas by controlling urban morphological parameters (Hao, Kang, & Krijnders, 2015). In a wider context, urban morphology, which pertains to the spatial structure and characteristics of a metropolitan area, city, town, or village, has been widely studied regarding urban settings, particularly the characteristics of atmospheric environment (e.g., air quality and wind environment) (Borrego et al., 2006; Edussuriya, Chan & Ye, 2011; Golany, 1996; Ng, Yuan, Chen, Ren, & Fung, 2011; Oke, 1988; Soulhac, Mejean, & Perkins, 2001), renewable energy (solar energy) (Compagnon, 2004; Robinson, 2006; Sarralde, Quinn, Wiesmann, & Steemers, 2015), and the urban heat island effect (Brian, 2004; Brian & Michael, 2001; Touchaei & Wang, 2015). Other factors extensively examined using a series of quantitative urban morphological parameters include those on street layout and coverage as well as landscaping (Geoghegan, Wainger & Bockstael, 1997; Liu, Kang, Behm & Luo, 2014; Stephen, 2004, Chap. 4; Val, Atauri & Lucio, 2006).

However, despite these research efforts, noise reduction in rural residential areas is still primarily achieved using noise barriers. The relationship between road traffic noise and the characteristics of village form planning still needs to be analysed in detail. Few studies have considered how to improve the traffic noise resistance of villages by systematically controlling a set of urban morphological parameters, especially considering the rural residential areas in less developed regions such as those in China. At the end of 2014, the Chinese expressway with a total mileage of 112000 kilometres opened to traffic, becoming the world's largest motorway system. Moreover, China has a large rural population with high density; thus, many villages are located on or near a well-travelled motorway. These villages are no longer quiet places, and new villages have expanded in locations adjacent to the motorway for economic or other reasons.

Therefore, this study aims to examine the influence of different effects of location, such as distance and orientation between a village and the motorway, and to explore methods to integrate the effects of urban morphological parameters to improve the traffic noise resistance of rural residential areas in China. To analyse these parameters, a series of noise mapping was performed for selected typical villages.

2. Methodology

2.1. Case study sites

Since the "Eleventh Five-year" Plan for Developing Socialism New Rural Areas was proposed, village development has received unprecedented attention in China. Over the past several decades, the living standards of villages have improved rapidly. It is important to note that the village classifications in this study refer to homes for living and various productions of the villagers according to the "Environmental Quality Standard for Noise" (GB3096-2008).

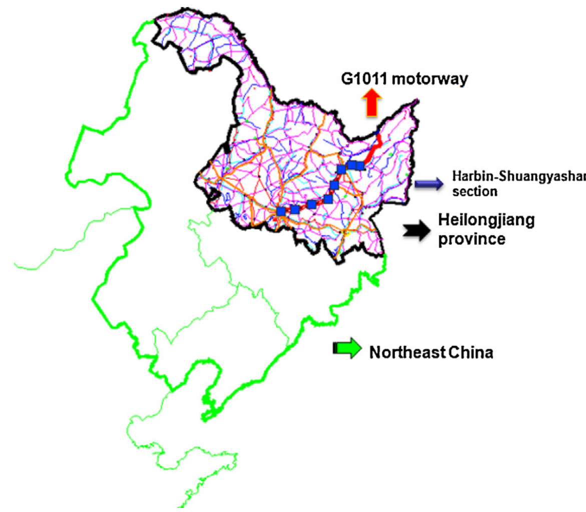

Fig. 1. Locations of the study sites.

The village sites in this study were chosen in Heilongjiang because it is the major grain-producing area in the flat terrain with a planting area that accounts for 83.5% of the province's total and a rural population that accounts for 43.1% of the province's total, according to the Heilongjiang Statistical Yearbook (2014, Chap. 11). Heilongjiang has a transportation network composed of a motorway and hierarchical traffic roads throughout the province, as shown in Fig. 1, which generate widespread traffic noise.

Due to the cold climate and lagging economic situation in the villages of Heilongjiang, there are very diverse village forms with low-rise and low-density residential zoning plans. Therefore, 60 villages sites located along the Harbin-Tongjiang section of the G1011 motorway in Heilongjiang were chosen for site samplings as typical villages in the cold region of China. These sample villages that were each located along one kilometre of G1011 from Harbin, Jiamusi and Shuangyashan were numbered H1-H30, J1-J16, and S1-S14, respectively. The conditions of the building façades and of the ground were obtained from in situ investigations and Google Maps. CAD software was used to describe the spatial morphology of the villages and their relationship with the surrounding G1011motorway, as shown in Fig. 2.

2.2. Selection and calculation of urban morphological parameters

To obtain a comprehensive description of the village form in cold regions, this study used 18 quantitative morphological parameters from previous studies that explored, developed, and studied diverse urban morphology. The parameters include all of the factors that are likely related to traffic noise resistance based on the potential effects of urban morphology on outdoor sound propagation, such as distance from the source to the receiver, ground effects, the barrier effect, and the canyon effect (ISO 9613-2; Kang, 2007). The 18 quantitative parameters include the following: Landscape shape index of roads (LSI_R), Building Plan Area Fraction (BPAF), Road length Fraction (RLF), Road Area Fraction (RAF), Road intersections fraction (RIF), and Distance of First-row Building to Road (DFBR). These six parameters chiefly concern geometrical divergence and ground effects. Landscape shape index of buildings (LSI_B), Complete Aspect Ratio (CAR), Building Surface Area to Plan Area Ratio (BSAPAR), Patch density (PD), Height-to-Width Ratio which vertical to the road direction (HWR_V) and Height-to-Width Ratio which