Journal of Environmental Management 196 (2017) 614–626

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

A modified 3D algorithm for road traffic noise attenuation calculations in large urban areas

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ARTICLE INFO

Article history:
Received 29 November 2016
Received in revised form
13 March 2017
Accepted 14 March 2017
Available online 27 March 2017

Keywords:
Traffic noise
3D noise attenuation simulation
Buildings volume ratio
Area ratio of buildings' projection
Scanning angle
Large urban area

ABSTRACT

The primary objective of this study is the development and application of a 3D road traffic noise attenuation calculation algorithm. First, the traditional empirical method does not address problems caused by non-direct occlusion by buildings and the different building heights. In contrast, this study considers the volume ratio of the buildings and the area ratio of the projection of buildings adjacent to the road. The influence of the ground affection is analyzed. The insertion loss due to barriers (infinite length and finite barriers) is also synthesized in the algorithm. Second, the impact of different road segmentation is analyzed. Through the case of Pearl River New Town, it is recommended that 5° is the most appropriate scanning angle as the computational time is acceptable and the average error is approximately 3.1 dB. In addition, the algorithm requires only 1/17 of the time that the beam tracking method requires at the cost of more imprecise calculation results. Finally, the noise calculation for a large urban area with a high density of buildings shows the feasibility of the 3D noise attenuation calculation algorithm. The algorithm is expected to be applied in projects requiring large area noise simulations.

1. Introduction

Currently, the number of vehicles is increasing rapidly with the developing economy, bringing more serious traffic noise pollution. The range of such pollution also becomes increasingly wider, disturbing residents along the roads (Pirrera et al., 2014; Douglas and Murphy, 2016; Baliatsas et al., 2016). Thus, traffic noise has caused wide public concern. One of the most important preceding works to reduce traffic noise pollution is the accurate simulation of the noise level distribution (Ouis, 2001; Steele, 2001; Guarnaccia, 2013). In the propagation of urban traffic noise, the influence of the 3D buildings in the road network is obvious. When a sound wave hits the surfaces of buildings, it experiences diffraction and reflection. Hence, it is essential to calculate the traffic noise among buildings in urban areas in 3D accurately and rapidly.

There are some studies (Dai et al., 2014; Licitra et al., 2016) about the validation of the traffic noise prediction method. And the frequency aspects, especially the very important low frequency, have been considered (Ascari et al., 2015; Torija and Flindell, 2015) when calculate the traffic noise. In reality, from the insight of surroundings, complicated roads and buildings make road traffic noise calculations more challenging. There are two common method types for computing the noise among obstacles. One type is the geometric acoustic method, which includes variations such as the image source method (ISM) (Gibbs and Jones, 1972; Hornikx and Forssen, 2009), the ray tracing method (RTM) (Jones and Bedard, 2015; Keranen et al., 2003), and the beam tracing method (BTM) (Wilson and Hopkins, 2015; Luo et al., 2012; Wang et al., 2017). These methods calculate the noise by simulating the micromesh sound propagation paths (Yousefzadeh and Hodgson, 2012; Chen et al., 2014; Funkhouser et al., 2004) Reflections, diffractions, and diffusion are considered in these methods. Thus, the geometric acoustic methods have a high accuracy. However, when the buildings are abundant in the urban area, these methods becomes computationally intensive because they simulate too much of the complex propagation process of sound waves (Yang and Shield, 2000; Sujira et al., 2012). Multiple reflections and diffractions among buildings make the calculations difficult. Although scholars have completed a series of studies on improving the efficiency of geometric acoustic methods (De Coensel et al., 2005; Hornikx and

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http://dx.doi.org/10.1016/j.jenvman.2017.03.039
0301-4797/

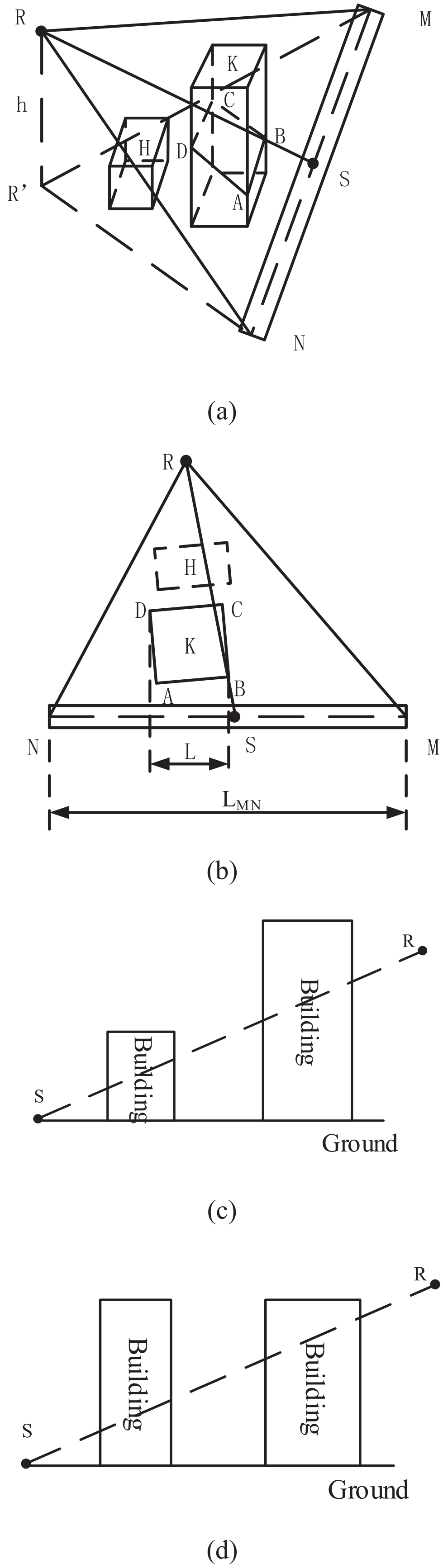

Fig. 1. Geometrical features of traditional ISO methods.

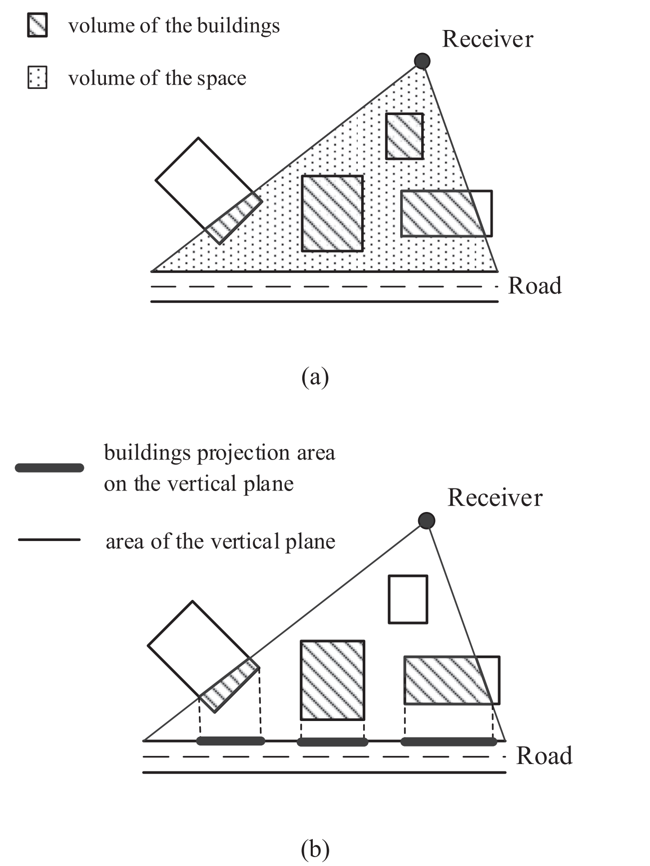

Fig. 2. Geometrical features of modified 3D noise attenuation calculation method: (a) Diagram of the first attenuation term; (b) Diagram of the second attenuation term.

Forssen, 2007), including central line tracing target (Lewers, 1993), binary space partitioning (Pamanikabud and Tansatcha, 2009), 3D space subdivision (Wang et al., 2016) and others, the efficiency is only moderately improved. Applying the geometric acoustic methods in a large urban area noise simulation is still difficult, especially in a 3D scene. The second type of method to calculate the noise affected by obstacles and buildings is the empirical method, such as the International Standardization Organization (ISO) model (ISO 9613-2, 1996; Morillas et al., 2016), the Road Traffic Noise in Acoustical Society of Japan (ASR) model (Research Committee of Road Traffic Noise in Acoustical Society of Japan (2004); Yamamoto, 2010), the Chinese model (JTGB03, 2006) and others. These methods and their applications (Cai et al., 2015, 2016) consider the density of building groups and the roads nearby buildings and avoid the simulation of complex noise propagation paths. Although they have a high efficiency, these methods

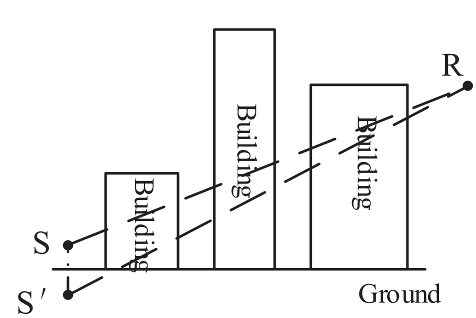

Fig. 3. Impact of ground to noise attenuation.