Transportation Research Part D 47 (2016) 149–161

Contents lists available at ScienceDirect

Transportation Research Part D

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

A traffic noise model for road intersections in the city of Cartagena de Indias, Colombia

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ARTICLE INFO

Article history:

Keywords:
Statistical modeling
Road traffic noise
Motorcycle noise
Noise pollution
Cartagena de indias
Colombia

ABSTRACT

Road traffic noise models are fundamental tools for designing and implementing appropriate prevention plans to minimize and control noise levels in urban areas. The objective of this study is to develop a traffic noise model to simulate the average equivalent sound pressure level at road intersections based on traffic flow and site characteristics, in the city of Cartagena de Indias (Cartagena), Colombia. Motorcycles are included as an additional vehicle category since they represent more than 30% of the total traffic flow and a distinctive source of noise that needs to be characterized. Noise measurements are collected using a sound level meter Type II. The data analysis leads to the development of noise maps and a general mathematical model for the city of Cartagena, Colombia, which correlates the sound levels as a function of vehicle flow within road intersections. The highest noise levels were 79.7 dB(A) for the road intersection *María Auxiliadora* during the week (business days) and 77.7 dB(A) for the road intersection *India Catalina* during weekends (non-business days). Although traffic and noise are naturally related, the intersections with higher vehicle flow did not have the highest noise levels. The roadway noise for these intersections in the city of Cartagena exceeds current limit standards. The roadway noise model is able to satisfactorily predict noise emissions for road intersections in the city of Cartagena, Colombia.

Introduction

Noise pollution sources in urban areas can be classified into two groups: stationary sources and mobile sources. Stationary sources include industrial, construction and demolition, commercial, domestic, and recreational. Mobile sources include ground and air transportation. In urban areas, the engine and the exhaust system of automobiles, light trucks, buses, and motorcycles are an important source of noise, which constitutes a major environmental impact (EPA Victoria, 2013). Thus, maximum permissible emission standards have been established. Table 1 shows the current noise emission limits for Colombia sanctioned by the Colombian Ministry of Environment, Housing and Territorial Development (MAVDT, for its acronym in Spanish) (MAVDT, 2006). Road traffic noise is one of the main sources of disturbance in urban environments. It represents over 70% of the complaints presented to environmental control agencies in developing countries (Brown et al., 2012; De Coensel et al., 2012; Kim et al., 2012; Quiñones-Bolaños et al., 2012; Banerjee, 2013; Dintrans and Préndez, 2013; Guarnaccia, 2013; Tiesler et al., 2013).

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http://dx.doi.org/10.1016/j.trd.2016.05.007
1361-9209/

Nomenclature

Δ_f	traffic flow adjustment
Δ_g	gradient adjustment
Δ_p	pavement type adjustment (road surface correction)
Δ_d	distance adjustment
Δ_s	shielding adjustment
Δ_a	angle of view adjustment
Δ_r	reflection adjustment
A	empirical intercept factor of the curve of measured values of $L_{Aeq,1h}$
a	automobiles weighting factor
B	slope of the curve of measured values of $L_{Aeq,1h}$
C	lumped parameters A and B
h	heavy vehicles weighting factor
m	motorcycles weighting factor
L	sound pressure level (dB(A))
p	heavy vehicle flow (rate of the number of heavy vehicles per total traffic flow)
Q	traffic flow (vehicles/h)
v	traffic velocity

Subscripts

90	sound pressure level that is overpassed by 90% of the data (dB(A))
10	sound pressure level exceeded for 10 percent of the time (dB(A))
eq	equivalent sound pressure level (dB(A))
1*h*	from the average of the total data obtained during one hour (dB(A))
measured	measured equivalent sound pressure level (dB(A))
predicted	predicted equivalent sound pressure level (dB(A))
autos	automobile traffic flow (vehicles/h)
motorcycle	motorcycle traffic flow (vehicles/h)
heavy	heavy vehicle traffic flow (vehicles/h)

Acronyms

CORTN	calculation of road traffic noise
GRG	generalized reduced gradient
ISO	International Organization for Standardization
MAVDT	Ministerio de Ambiente, Vivienda y Desarrollo Territorial
RMSE	root mean square error
UK	United Kingdom
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USEPA	United States Environmental Protection Agency

A wide variety of road traffic noise models has been proposed. However, traffic conditions in Europe, North America, Asia and most countries in South America are different than in Colombia (Sarmiento et al., 2013; Salvá et al., 2015). Motorcycles are one of the differences as there are fewer in developed countries. Givargis and Mahmoodi (2008) tested a modified version of the calculation of the road traffic noise (CORTN), developed by the Department of Transport in the United Kingdom (UK) (Department of Transport Welsh Office, 1988), with a trial and error based methodology converting the CORTN algorithm into heuristic equations capable of calculating $L_{Aeq,1h}$ for roads in the City of Tehran, Iran. Similar investigations have been conducted to develop road traffic noise models in developed and developing countries, including Brasil (Calixto et al., 2003), Chile (Dintrans and Préndez, 2013), China (Li et al., 2002), Croatia (Ahac et al., 2011), France (Bocquier et al., 2013), Hong Kong (To et al., 2002), India (Pradhan et al., 2012), Korea (Lee et al., 2014), Nigeria (Onuu, 2000), Spain (Barrigón Morillas et al., 2002), Taiwan (Chang et al., 2012), and Vietnam (Nguyen et al., 2012). In most of these studies, the CORTN model is used. Traffic composition is usually divided into light vehicles (<1525 kg unladen weight) and heavy vehicles (>1525 kg unladen weight), in which motorcycles are counted as light vehicles.

Therefore, an improved traffic noise model is needed to consider not only automobiles (passenger cars) and trucks as heavy vehicles but also motorcycles as a significant and distinctive category since in many cities in the Caribbean Region of Colombia, motorcycles occupy over 75% of the traffic on a number of roads (Quiñones-Bolaños et al., 2012). According to Hadad Lewis et al. (2013), 84.8% of motorcycle customers in Colombia have medium cylinder capacity motorcycles (between 125 and 200 cc). Furthermore, a recent study (Sheng et al., 2015), in which the CORTN model performance was