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A critical review of principal traffic noise models: Strategies and implications

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ABSTRACT

The paper presents an exhaustive comparison of principal traffic noise models adopted in recent years in developed nations. The comparison is drawn on the basis of technical attributes including source modelling and sound propagation algorithms. Although the characterization of source in terms of rolling and propulsion noise in conjunction with advanced numerical methods for sound propagation has significantly reduced the uncertainty in traffic noise predictions, the approach followed is quite complex and requires specialized mathematical skills for predictions which is sometimes quite cumbersome for town planners. Also, it is sometimes difficult to follow the best approach when a variety of solutions have been proposed. This paper critically reviews all these aspects pertaining to the recent models developed and adapted in some countries and also discusses the strategies followed and implications of these models.

Contents

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1. Introduction

Noise prediction is one of the vital tools for town planners for noise abatement and control. This technique got a special impetus after the European Directive about Environmental Noise 2002/49/EC, wherein noise maps have been recommended for transportation sources and urban agglomerations (EU Directive 2002/49/EC, 2002). Consequently, many scientific models have been developed in recent years focussing on this aspect and introducing exclusively source emission and sound propagation empirical formulations. These models have been developed and validated in respective countries and brought in regular usage and are integrated with GIS interface for generating noise maps. Apart from the source characterization, advanced numerical methods including wave equation and continuity equation are employed to solve the sound propagation effects. These models thus utilize high speed processing computers and skilled operators for achieving the end objectives. Thus, it is imperative to analyze scientifically and compare these models so as to ascertain their suitability in general and also to find out the best approach amongst them for traffic noise modelling. Steele (2001) did an exhaustive critical review of various traffic noise models. However, some of these models have been revised in recent years, and thus it is imperative to update this comparison done by Steele (2001) based on technical attributes. The present work describes the strategies and implications of these models developed in recent years. The various models discussed in the paper are FHWA of USA, ASJ RTN 2008 of Japan, CoRTN of UK, RLS 90 of Germany, Son Road of Switzerland, Harmonoise of Europe, Nord 2000 of Scandinavian countries and NMPB-Routes-2008 of France.

2. Principal traffic noise models

2.1. FHWA model

The Federal Highway Administration Traffic Noise model (Barry and Reagan, 1978; FHWA TNM) computes a predicted noise level through a series of adjustments to a reference sound level. The reference level is the vehicle noise emission level, which refers to the maximum sound level emitted by a vehicle pass-by at a reference distance of 15 m.

$$L_{Aeq,1\mathrm{h}} = EL_{\mathrm{i}} + A_{\mathrm{traffic(i)}} + A_{\mathrm{d}} + A_{\mathrm{s}} \quad (1)$$

where $A_{\mathrm{traffic\ (i)}}$ is adjustment for traffic flow, A_{d} represents the adjustment for distance between the roadway and receiver and for the length of the roadway and A_{s} represents the adjustment for all shielding and ground effects between the roadway and the receiver. TNM needs 17 constants (A, B, C, D_1 to J_1 & D_2 to J_2) for noise emissions of vehicles categorized as automobiles, medium trucks, heavy trucks, buses and motorcycles, depending upon vehicle type and pavement type. The empirical formulation used in computing A-weighted emissions in 1/3rd octave band in terms of speed s_{i} in km/h is:

$$E_A(s_{\mathrm{i}}) = (0.6214 s_{\mathrm{i}})^{A/10} 10^{B/10} + 10^{C/10} \quad (2)$$

$$\begin{aligned} L_{\mathrm{emis},\mathrm{i}}(s_{\mathrm{i}}, f) = {} & 10 \times \log_{10}(E_{\mathrm{A}}) + (D_1 + 0.6214 D_2 s_i) + (E_1 + 0.6214 E_2 s_i)[\mathrm{Log}_{10} f] \\ & (F_1 + 0.6214 F_2 s_i)[\mathrm{Log}_{10} f]^2 + (G_1 + 0.6214 G_2 s_i)[\mathrm{Log}_{10} f]^3 \\ & + (H_1 + 0.6214 H_2 s_i)[\mathrm{Log}_{10} f]^4 + (I_1 + 0.6214 I_2 s_i)[\mathrm{Log}_{10} f]^5 \\ & + (J_1 + 0.6214 J_2 s_i)[\mathrm{Log}_{10} f]^6 \end{aligned} \quad (3)$$

$$\mathrm{E}_{\mathrm{emis,i}}(s_{\mathrm{i}}, f) = 10^{(L\mathrm{emis,i}(\mathrm{si}, f)/10)} \quad (4)$$

2.2. CoRTN model

The CoRTN (Calculation of Road Traffic Noise) has been developed by the Transport and Road Research Laboratory and Department of Transport of United Kingdom. It estimates the basic noise level L_{10} both on 1 h and 18 h reference times at a reference distance of 10 m from the nearest carriageway edge of a highway. The CoRTN model is represented as (Department of Transport, U.K, 1998; Givargis and Mahmoodi, 2008):

$$L_{\mathrm{A}10} = 42.2 + 10 \ \log_{10} q + \Delta_{\mathrm{f}} + \Delta_{\mathrm{g}} + \Delta_{\mathrm{p}} + \Delta_{\mathrm{d}} + \Delta_{\mathrm{s}} + \Delta_{\mathrm{a}} + \Delta_{\mathrm{r}} \quad (5)$$

where q is the total hourly flow calculated at a reference distance of 10 m from the nearside carriageway edge at a reference hourly mean traffic speed of 75 km/h, Δ_{f} is traffic flow adjustment, Δ_{g} is gradient adjustment, Δ_{p} is pavement type adjustment, Δ_{d} is distance adjustment, Δ_{s} is the shielding adjustment, Δ_{a} is angle of view adjustment and Δ_{r} is the reflection adjustment. The corrections for heavy vehicles and speed are determined using the expression:

$$\Delta_{\mathrm{f}} = 33 \ \log\left(v + 40 + \frac{500}{v}\right) + 10 \log\left(1 + \frac{5P}{v}\right) - 68.8 \quad (6)$$

where v is hourly mean traffic speed in km/h and P is percentage of heavy vehicles calculated as $P = \frac{100f}{q}$ where f is hourly flow of heavy vehicles and q is total hourly flow.

2.3. RLS 90 model

The RLS 90 (*Richtlinien für den Lärmschutz an Straben*) is German model that calculates noise emission level L_{mE} at a distance of 25 m from the centre of a road lane. The parameter L_{mE} is a function of the amount of vehicles per hour Q and of percentage of heavy trucks P (weight >2.8 tons) under idealized conditions i.e. speed of 100 km/h, a road gradient below 5% and a special road surface expressed analytically as (Quartieri et al., 2009)

$$L_{\mathrm{m,E}} = 37.3 + 10 \ \mathrm{Log}\{\mathrm{Q}.(1 + 0.082p)\} \quad (8)$$

where L_{m} is A-weighted mean level, Q is the standardized traffic flow according to whether the road is a Federal autobahn; a Federal road; State, District or Municipal connecting roads; Municipal roads and p is corresponding percent heavies (over 2.8 t).The next step is to quantify the various deviations from these idealized conditions for the real speed, the actual road gradient or the actual surface etc. The mean level L_{m} in dB(A) is calculated as:

$$L_{\mathrm{m}} = L_{\mathrm{m,E}} + R_{\mathrm{SL}} + R_{\mathrm{RS}} + R_{\mathrm{RF}} + R_{\mathrm{E}} + R_{\mathrm{DA}} + R_{\mathrm{GA}} + R_{\mathrm{TB}} \quad (9)$$

where R_{SL} is correction for speed limit, R_{RS} is correction for road surfaces, R_{RF} is correction for rises and falls along the streets, R_{E} is correction for the absorption characteristics of building surfaces, R_{DA} is attenuation's coefficient that takes into account the distance from receiver and air absorption, R_{GA} is attenuation's coefficient due to ground and atmospheric conditions and R_{TB} is attenuation coefficient due to