inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 1.0

RAILWAY NOISE IN GREECE: MEASUREMENT AND PREDICTION

Y. Bamnios*, A. Trochides**

* Dept. of Electronics, Faculty of Technological Applications, TEI of Thessaloniki, P.O. Box 14561, GR-541 01, Thessaloniki, Greece

** General Department of Physics and Mathematics, School of Engineering, Á.U.Th, P.O. Box 500, GR-540 06, Thessaloniki, Greece

Tel.: ++30 31 835 038 / Fax: ++30 31 853 400 / Email: bamnios@el.teithe.gr

Keywords:
RAILWAY NOISE, TRANSPORTATION NOISE, NOISE MEASUREMENT, NOISE PREDICTION

ABSTRACT
This study describes a method of predicting railway noise in Greece. A series of measurements were conducted for the first time in Greece in order to investigate the specific characteristics of railway noise in the Greek network of railways. Based on the results of these measurements, a prediction model has been formulated and a measurement methodology has been proposed. Finally, a legislation with higher acceptable railway noise limits is proposed.

1 - INTRODUCTION

Many social surveys on the environmental effects of railway noise have been conducted in various countries [1−5]. The results of these studies show that railway noise can cause annoyance to the neighborhood. In particular, telephone conversation and listening to TV, radio or listening to music are reported as the most affected activities. Thus, the prediction of railway noise becomes very important, particularly in the case of planning new railways. In addition, prediction can be also used to estimate the noise level from existing railways.
Because of the specific characteristics of railway noise in every country, due to different vehicle used and to track types and conditions, prediction models designed in various countries [6−10] could not be applied in Greece, unlike the models for road traffic noise and aircraft noise. Thus, in order to determine the acoustical characteristics of railway noise in Greece, for the first time, a series of noise measurements emitted by the vehicles used in the Greek railway lines were conducted.

2 - MEASUREMENTS

From the social surveys mentioned above, acoustic index L_{Aeq} (A-weighted equivalent noise level) measured outside, in front of the facade, proved to be the most suitable to determine general annoyance caused by railway noise. The current study uses $L_{Aeq,12h}$, i.e. L_{Aeq} measured between 08.00 and 20.00 hours. Also, $L_{A\max}$ (maximum A-weighted noise level) measured at a distance of 25m from the track centerline and at a height of 1.2m above the tracks is used to describe the pass-by noise level for a single train. This level which is called basic reference level is necessary in the case of railway noise prediction and depends mainly on speed and the specific characteristics of vehicles and tracks.
Four categories of trains are in current use in Greece, i.e. Intercities (IC), Self-propelled cars, Diesel passenger trains (DI-passenger), and Diesel fright trains (DI-fright). For each of these categories the basic reference level was estimated from measurements as a function of speed V. For that reason the time history of noise during pass-by was recorded in open field at a distance of 25m from the track centerline and at a height of 1.2m above the track level. From these recordings $L_{A\max}$ was calculated.
Measurements took place at four different locations for all four categories of trains and different speed velocities. A sample of 20 intercities, 25 self-propelled cars, 14 diesel passenger trains and 10 diesel fright trains was measured. In Fig. 1 measured values of $L_{A\max}$ and the corresponding regression curves are shown. Applying regression analysis to the measurement results, analytical expressions of $L_{A\max}$ as a function of speed V were obtained (table 1).

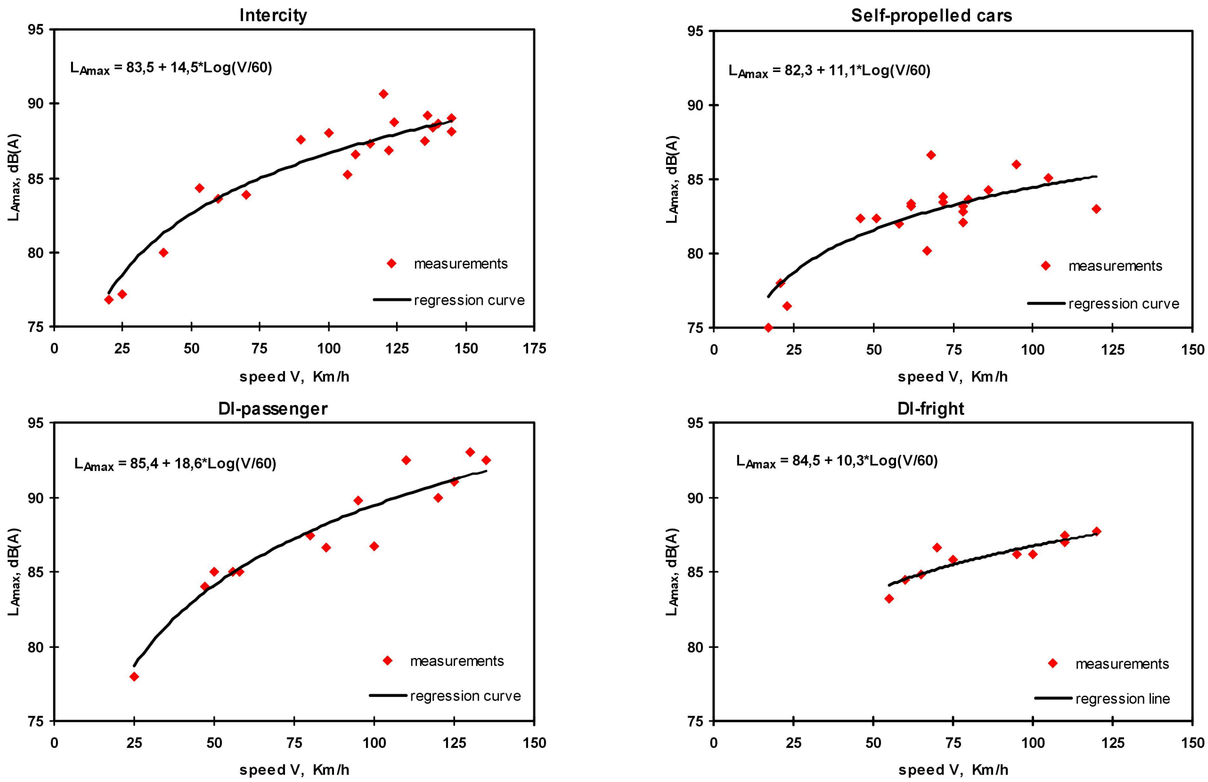

Figure 1: Measured values of L_{Amax} and regression curves for all train categories.

Train category	L_{Amax} (dB(A)) at a distance of 25m and height of 1.2m
Intercity	$L_{\text{Amax}} = 83.5 + 14.5 * \log (V/60)$
Self-propelled cars	$L_{\text{Amax}} = 82.3 + 11.1 * \log (V/60)$
D-passenger	$L_{\text{Amax}} = 85.4 + 18.6 * \log (V/60)$
D-freight	$L_{\text{Amax}} = 84.5 + 10.3\log (V/60)$

Table 1: Reference level L_{Amax} as a function of speed.

3 - RAILWAY NOISE PREDICTION

The railway noise prediction method presented below requires the knowledge of area topology, speed and traffic load characteristics. The prediction process starts with the noise level L_{Amax} at the prediction location due to the pass-by of a single train. The same procedure is applied for all train categories passing from the area. The calculation is based on the basic reference levels given in table 1, which are then corrected for transmission loss due to the distance, the air, the ground and meteorological conditions [11], [12].

$$(L_{AX})_i = (L'_{\text{Amax}})_i + 10\log\left(3.6\frac{L}{V} + \frac{6d}{100}\right) \quad (1)$$

$$(L_{AX})_i = (L'_{\text{Amax}})_i + 10\log\left(\frac{d}{V}\right) + 8.6 \quad (2)$$

$$(L_{Aeq})_i = (L_{AX})_i - 10\log T \quad (3)$$

$$(L_{Aeq})_j = (L_{Aeq})_i + 10\log N_i \quad (4)$$

$$L_{Aeq} = 10\log\left(\sum_{j=1}^{M} 10^{(L_{eq})_j/10}\right) \quad (5)$$

After the corrected basic reference levels $L'_{A\max}$ have been calculated, one can calculate $(L_{AX})_i$ (single event exposure level) using equations 1 or 2 in case of Diesel hauled trains. Equation 3 gives $(L_{Aeq})_i$ (A-weighted equivalent noise level) for a single train pass-by, while equation 4 gives $(L_{Aeq})_j$ which is the total noise level produced by all trains of the same category. Finally, from equation 5 the overall noise level L_{Aeq} due to all trains passing from the area between 08.00 and 20.00 hours is obtained. Following this process a software has been developed to predict railway noise level at a specific location.

4 - RAILWAY NOISE MEASUREMENT

Measuring railway noise is a complex and time consuming process, due to the fact that it requires a great number of simultaneous measurements covering all train passages in a wide area for at least 12 hours. For that reason a combined method of measurement and calculation is used. At fixed points the noise produced by passing trains is measured, and further noise levels are then calculated taking into account the number of trains, type of trains, etc.

$$L_{Aeq} = 10\log\left(\frac{t_{10}}{T}10^{\frac{L_{pA,\max}}{10}}\right) \tag{6}$$

$$L_{Aeq}\left(N \text{ trains}\right) = L_{Aeq}\left(1 \text{ train}\right) + 10\log N \tag{7}$$

The quantities which can be derived directly from measurements are the time history of sound pressure level L_{pA}, the maximum sound pressure level $L_{pA,\max}$ during the measurement and the exposure time t_{10}. Then one can calculate L_{Aeq} due to a single train passage using equation 6, where T is the calculation time in s. Next, applying equation 7, L_{Aeq} due to N trains of the same category can be derived. Finally, by adding the different levels corresponding to different train categories, the overall L_{Aeq} (08.00-20.00) is obtained.

5 - CONCLUSIONS

A railway noise prediction model has been developed based on the analytical expressions of table 1 which relate the basic reference level $L_{A\max}$ with speed V. These expressions were obtained from measurements in the Greek railway network. Using this model one can predict noise level at a fixed point assuming that area topology, speed and traffic load characteristics are known. As for the railway noise measurement, a combined process of measurement and calculation, that determines L_{Aeq} (08.00-20.00) has been proposed. Finally, in agreement with traffic noise, it is proposed to adopt the level of 67dB(A) as the higher acceptable railway noise limit for L_{Aeq} measured at a distance of 2m from the building's facade.

ACKNOWLEDGEMENTS

Part of this study is based upon the results of the Research Program "Protection measures from railway noise", 1997, founded by the Hellenic Ministry for the Environment, Physical Planning and Public Works.

REFERENCES

1. **J. M. Fields, J. G. Walker**, The response to railway noise in residential areas in Great Britain, *Journal of Sound and Vibration*, Vol. 85(2), pp. 177-255, 1982

2. **T. V. Andersen, K. Kuhl, E. Relster**, Reaction to railway noise in Denmark, *Journal of Sound and Vibration*, Vol. 87(2), pp. 311-314, 1988

3. **U. Moelher**, Community response to railway noise: a review of social surveys, *Journal of Sound and Vibration*, Vol. 120(2), pp. 321-332, 1988

4. **J. Kaku**, Community response to railway noise - comparison of social survey results between Japan and other countries, In *Proc. INTER-NOISE 94*, pp. 121-124, 1994

5. **J. Lambert et al.**, Community response to high speed train noise in France, In *Proc. INTER-NOISE 94*, pp. 125-128, 1994

6. **M. Mogilevsky, Y. Berman, Y. Kadman**, Experimental investigation of acoustical characteristics of trains, In *Proc. INTER-NOISE 94*, pp. 97-100, 1994

7. **M. Ringeim**, Sound propagation and the prediction of railway noise, *Journal of Sound and Vibration*, Vol. 120(2), pp. 363-370, 1988

8. **B. Hemsworth**, Railway noise prediction - Data base requirements, *Journal of Sound and Vibration*, Vol. 87(2), pp. 275-283, 1988
9. **C. J. M. van Ruiten**, Dutch railway noise prediction schemes, *Journal of Sound and Vibration*, Vol. 120(2), pp. 371-379, 1988
10. **U. J. Kurze**, Prediction scheme for railroad noise emission in Germany, In *Proc. INTER-NOISE 90*, pp. 391-394, 1990
11. **Deutsche Bundesbahn, Schall 03**, *Richtlinie zur Berechnung von Schallimissionen von Schienenwegen*, 1990
12. **E. J. Rathe**, Railway noise propagation, *J. of Sound and Vibration*, Vol. 51, pp. 371-388, 1977