UNIVERSITY OF NIŠ
The scientific journal **FACTA UNIVERSITATIS**
Series: **Working and Living Environmental Protection** Vol. 1, No 2, 1997, pp. 73 - 81
Editor of series: Ljiljana Rašković, e-mail: ral@kalca.junis.ni.ac.yu
Address: Univerzitetski trg 2, 18000 Niš, YU, Tel. +381 18 547-095, Fax: +381 18 547-950
http:// ni.ac.yu/Facta

NAISS - MODEL FOR TRAFFIC NOISE PREDICTION

UDC:534.836

Dragan Cvetković[1], Momir Praščević[1], Violeta Stojanović[2]

[1] Department of Noise and Vibration, Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, 18000 Niš, Yugoslavia, e-mail: noise@znrfak.znrfak.ni.ac.yu
[2] Advanced Technical School, Beogradska 20, 18000 Niš, Yugoslavia

Abstract. *The traffic noise of motor vehicles, as main source in urban areas, makes up part of general environment problem which inflicts serious damage to the health of human beings and lowers their labor productivity. Therefore, the control of traffic noise has become a matter of major concern for communities trying to maintain a satisfactory environment in which to live and work. To ensure a high quality environment, methods for prediction the noise imission of motor vehicles are necessary tools. In order to modeling traffic noise and selecting corresponding noise control measures it is necessary to know functional relationships between noise emission and certain numbers of traffic parameters. In this paper, the results of traffic noise prediction based on NAISS-model obtained by trending of the experimental data collected by systematic noise measurement in urban areas of Nis as well as comparative analysis with other models will be shown.*

1. Introduction

The motor vehicles are in particular the passenger and utility vehicles. While the passenger vehicles are limited to the vehicles of a certain weight, the notion utility vehicles are a wide notion compassing all types of motor trucks, buses and off-road vehicles. Even today, the driving units of road vehicles are mainly the internal combustion engines. The petrol engines are mainly used for driving passenger vehicles and some small utility vehicles, while the diesel engines are used for driving the utility vehicles and a smaller number of passenger vehicles [1].

The traffic noise of motor vehicles is the most important type of noise to which people are exposed in their everyday life. Not only those who are in the vehicles, but particularly those who are in the vicinity of roads on which the vehicles move are exposed to that noise irrespective of the fact whether they are inside or outside rooms.

Received September 28, 1998

The spread of motor vehicles has led to serious problems in urban areas including, among other, noise pollution. Therefore, the control of traffic noise of motor vehicles has become a matter of major concern for communities trying maintaining a satisfactory environment in which to live and work. To ensure a high quality environment, methods for prediction of the noise imission of motor vehicles are necessary tools when:

- new dwellings in the vicinity of existing roads, airfields, railways are planned
- locations of new noisy activities are evaluated
- authorities specifies conditions for the approval of noise activities
- controlling if specified conditions are kept
- the effect of alternative noise reduction measures are considered
- treating complaints

In order to reduce traffic noise of motor vehicles on a scientific basis, it is necessary to know the functional relationship between noise emission and measurable parameters of traffic and roads. The classical functional relationships available in literature have been stated based on data measured through semi-empirical models, typically regression analysis. Although these correlations are nonlinear they do not provide very accurate approximation of the trend followed by sound pressure level according to a certain number of physical parameters because any models itself includes the flow and composition of the road traffic which may be different than examined urban areas. Because of that, the prediction model of traffic noise which to be valid for the flow and composition of the road traffic of Nis city is formed by Department of Noise and Vibration.

In this paper, the results of traffic noise prediction based on NAISS-model obtained by trending of the experimental data collected by systematic noise measurement in urban areas of Nis as well as comparative analysis with other models will be shown.

2. MATHEMATICAL MODEL BACKGROUND

The ideal mathematical model of traffic noise should satisfy the following criteria:

- allow accurate determination of a unit that has shown good correlation with subjective response to the noise
- require only data that are readily available
- be as simple as possible to allow use by all who are involved with the planning and development of areas near roads

The most of mathematical models determine equivalent noise level, Leq, as the most representative physical variable quantifying noise emissions. The equivalent noise level corresponds to the sound pressure of a fictions stationary noise source emitting the same acoustic energy as the actual nonstationary source. The equivalent continuous noise level in A-weighted decibels (dBA) is a widely recognized as a stable descriptor of motor vehicle noise levels. It is recommended by many national and international regulatory agencies as a suitable index for use in motor vehicle noise assessments [2].

Leq is know to correlate well with know effects of the noise environment on the individual and the public. The physical parameters to which Leq is correlated are, among others, traffic intensity, type of road surface, type of urban area, height of buildings, width of road, etc.

Mathematical models for prediction of traffic noise usually extract the functional relationship between the parameter of noise emission, Leq, and measurable parameters of traffic and roads. The classical functional relationships available in literature have been stated based on data measured through semi-empirical models, typically regression analysis. Of all the mathematical models available in literature, the ones which present this feature are those proposed by Burgess [3], Josse [4], Fagoti [5], CEE [5]. These functional relationships are essentially based on statistical analysis (i.e. regression techniques) and are reported below:

$$Leq = 55.5 + 10.2\log Q + 0.3p - 19.3\log(L/2) \quad \text{(Burgess)} \quad (1)$$

$$Leq = 38.8 + 15\log Q - 10\log L \quad \text{(Josse)} \quad (2)$$

$$Leq = 10\log(N_c + N_m + 8N_{hv} + 88N_b) + 33.5 \quad \text{(Fagoti)} \quad (3)$$

$$Leq = 10\log(N_c) + p \quad \text{(CEE)} \quad (4)$$

Here p is the percentage of heavy vehicles, L is the road width, Q is the total number of vehicles per hour, N_c is the number of light vehicles per hour, N_m is the number of motorcycles per hour, N_{hv} is the number of heavy vehicles per hour, N_b is the number of buses per hour. The total number of vehicle per hour, Q, is expressed as the equivalent number of cars and obtained, as before, under hypothesis that one heavy vehicles is equivalent to 6 light vehicles and one motorcycle to 3 light vehicles.

Although these correlations are nonlinear they do not provide very accurate approximation of the trend followed by sound pressure level according to a certain number of physical parameters because any models itself includes the flow and composition of the road traffic which may be different than examined urban areas. Because of that, the prediction model of traffic noise which to be valid for the flow and composition of the road traffic of Niš city is formed by Department of Noise and Vibration [6]

Traffic noise on observed measurement points are mainly caused by the motor vehicle. In order to make it easier to appreciate the variability of three components of urban traffic, the total number of motor vehicles was decomposed into the number of light vehicles N_c, the number of heavy vehicles N_{hv} and the number of buses N_b. In such way, a model with three inputs - one output described was formed. The scheme of this model is shown in Figure1.

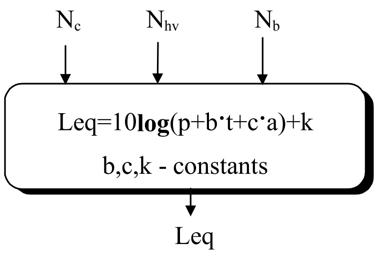

Fig. 1. Three-component NAISS - traffic noise prediction model

The equivalent noise level *Leq* is logarithmic function of total number of motor vehicles, where the constants *b* and *c* represent the relative acoustic weight of each class of vehicles respect to that of an "average" car. A constant *k* is the constant taking into consideration the property of sound propagation on the observed position. The model constants are determined by the experimental data fitting in the optimization process of mathematical model.

3. CHARACTERISTICS OF NAISS - NOISE PREDICTION METHOD

Starting from the measurement results collected by systematic traffic noise monitoring in urban areas of Niš, mathematical model for prediction of traffic noise of motor vehicle is formed by extracting function relation among the equivalent noise level and the traffic parameters.

The experimental data were collected near the main city traffic arteries with typical properties of commercial, residential, industrial and hospital areas, five times during daytime period (6^{00}-22^{00}) for all locations. All measurements were taken on working days of the week, excluding all atypical conditions. Each of the measurement points was to be determined from an acoustic point of view by the equivalent noise level. In addition, data relative to the urbanistic circumstances of each point were taken, as well as measurement of traffic density, according to the number of each type per hour. The standard apparatus based on the statistical noise level analyzer was used to determine the equivalent noise level.

In the optimization process of the models, the model constants were obtained by experimental data fitting by Nelder - Mead method using computer program. Three variants of model are formed. First, in order to form an unique model (one equation) for describing road traffic noise of motor vehicle it was carried out the fitting based on the experimental data for all measurement points grouped. Second, the measurement points were classified according to noise levels, so that the first group included measurement points with the levels between 65 and 75 dB(A) and second with the levels between 55 and 65 dB(A). For such data group were carried out fitting and the models with separate equation for both ranges of noise levels were obtained. Finally, the separate models for each measurement points were formed. In such way, obtained models include 11 equations for describing road traffic noise level according to the traffic parameters.

The constant values obtained by fitting experimental data are given in the Table 1 [7].

In order to examine validity of formed models, statistical analysis of differences of measured (*Leq,m*) and calculated noise levels (*Leq,c*) according to the model equations, the flow and composition of the road traffic was carried out. In addition, the correlation analysis of these noise levels has been carried out.

The average value of absolute differences of noise levels and standard deviation of differences (σ) as well as the correlation coefficient of noise levels (*r*) have been calculated. The parameters of analysis are given in the Table 2 [8,9].

Figure 2 shows trends for the equivalent noise levels measured and those predicted by different variants of model for one observed point in urban area of Nis where noise levels range from 55 to 65 dB(A). The comparison is shown for about 40 measurements quoted in the abscissa.

Table 1. The model constants

model variant	data group	model constants		
		b	c	k
I	all points	27.9	3.5	41.3
II	level range: 65 - 75 dB(A)	11.7	3.1	44.3
	level range: 55 - 65 dB(A)	3.7	-1.9	38.2
III	1	1.3	5	43.4
	2	2.4	11.8	42.0
	3	2	6.3	45.4
	4	0.5	5.2	46.6
	5	1.1	1.3	45.7
	6	1.6	3.3	47.2
	7	5.8	11.1	45.9
	8	-0.2	0.4	47.1
	9	4.1	2.3	44.6
	10	6.8	-3.1	38.4
	11	0.8	-0.2	37.9

Table 2. The parameters of analysis of different variants of model

model variant	parameters of analysis		
	$\overline{\Delta L}$	σ	r
I	2.46	1.19	0.70
II	1.12	0.79	0.80
III	0.70	0.51	0.86

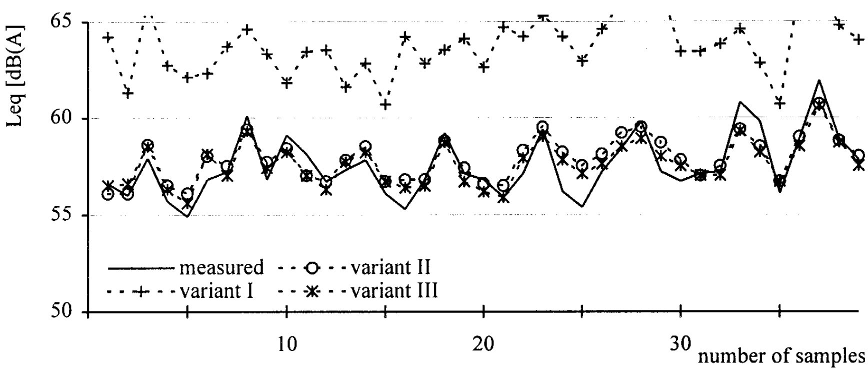

Fig. 2. A comparison between different variants of traffic noise prediction model

Based on above analysis of different variants of traffic noise prediction model it can be noted that prediction traffic noise of motor vehicles in urban areas of Niš by separate equations for two ranges of noise level, listed below,

$$Leq = 10\log(N_c + 3.7N_{hv} + 1.9N_b) + 38.2 \qquad 55dB(A) < Leq < 65dB(A) \qquad (5)$$

$$Leq = 10\log(N_c + 11.7N_{hv} + 3.1N_b) + 44.3 \qquad 65dB(A) < Leq < 75dB(A) \qquad (6)$$

is rather correctly with satisfactory precision. In addition, selected variant of model is very easy for use regard to its simplicity based on only two equations for describing traffic noise in urban areas of Niš.

4. COMPARATIVE ANALYSIS

The good results shown in the previous section need to be completed by a comparison with the performance obtainable using classical prediction methods available in literature. Only in this way can be validity of prediction method of traffic noise in urban areas of Nis proposed be really highlighted. In order to give as satisfying and complete results as possible, it is necessary to confine the comparison to those classical solutions, which show the greatest possible number of analogies with the hypotheses underlying the proposed method. These analogies essentially consist of the number of parameters on which the equivalent noise level is made to depend.

The comparison between NAISS - traffic noise prediction model in urban areas of Niš discussed in section 3 and selected prediction model available in literature given in section 2 was made on data referring to urban areas of Nis where noise levels range from 55 to 65 dB(A) and on data where noise levels range from 65 to 75 dB(A).

In order to compare different models, statistical analysis of differences of measured noise levels referring to urban areas of Niš and calculated noise levels according to the model equations and the flow and composition of the road traffic in urban areas of Niš was carried out. The average value of absolute differences of noise levels and standard deviation of differences (σ) have been calculated. The parameters of comparative analysis of different models are given in the Table 3.

Table 3. The parameters of comparative analysis of different models

data group	parameter	Burgess	Josse	Fagoti	CEE	DNV
55 - 65	$\overline{\Delta L}$	7.94	3.53	6.04	4.36	1.07
dB(A)	σ	2.10	1.23	2.25	2.52	0.75
65 - 75	$\overline{\Delta L}$	2.46	1.61	3.18	4.60	1.29
dB(A)	σ	1.63	1.29	1.31	3.13	0.92

The results of the comparison of different models for data group referring to urban areas of Niš where noise levels range from 55 to 65 dB(A) are graph presented in Figure 3 and for data group where noise levels range from 65 to 75 dB(A) in Figure 4.

The results of comparative analysis for data group 55 - 65 dB(A) and Figure 3 clearly show that the NAISS - model based on equation (5) allows better prediction of noise pollution of motor vehicles in urban areas of Niš than any other empirical relationship. The equation (4) underestimation the data whereas the equations (1)–(3) overestimation, with worst performance of equation (1).

Also, and in case data group of 65 - 75 dB(A), the results of comparative analysis and Figure 4 clearly show that the NAISS - model based on equation (6) allows better prediction of noise pollution of motor vehicles than any other empirical relationship. The equations (2)-(4) underestimation the data whereas the equations (1) overestimation, with worst performance of equation (4), whereas equation (2) provides good results for this group data but poor predictions for the levels under 65 dB(A).

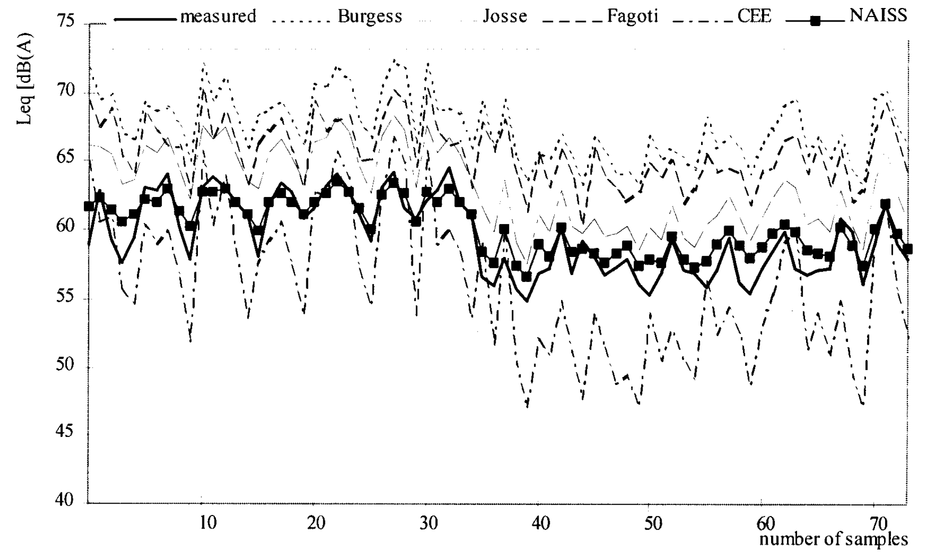

Fig. 3. A comparison between different models - data group 55 - 65 dB(A)

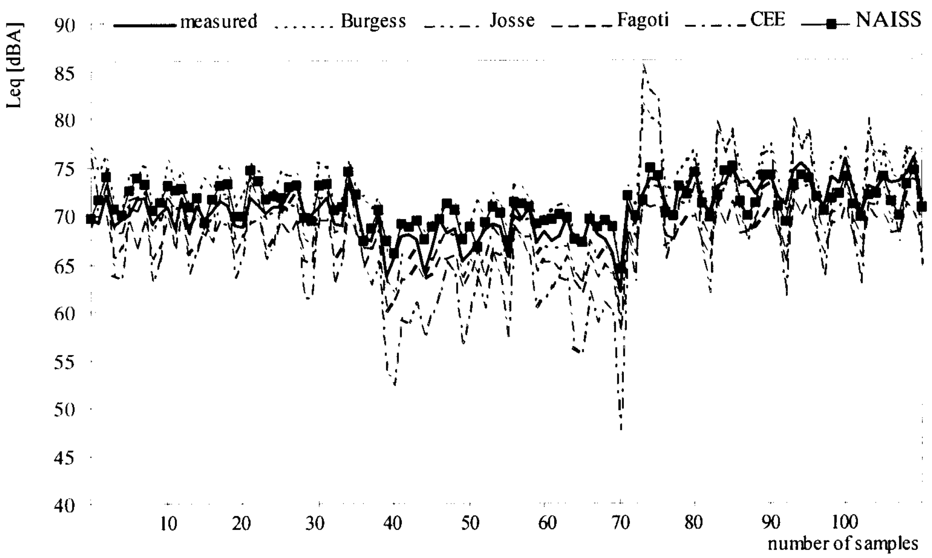

Fig. 4. A comparison between different models - data group 65 - 75 dB(A)

The success of NAISS- model can without doubt be attributed to performance of model formed on the basis of experimental data obtained in urban areas of Niš that itself includes the characteristics of flow and composition of the road traffic on observed points. In addition, it includes the number of light vehicles, heavy vehicles and buses as independent variables instead of using the previous mentioned equivalence, with consistent increase in accuracy.

5. Conclusion

Using the available models for traffic noise prediction in the urban areas of Niš was not give valid results. Because of that, the prediction model of motor vehicle noise which to be valid for the flow and composition of the road traffic of Niš city is formed by Department of Noise and Vibration. Based on analysis of different variants of traffic noise prediction model it can be noted that prediction traffic noise of motor vehicles in urban areas of Niš by separate equations (5,6) for two ranges of noise level is rather correctly with satisfactory precision. In addition, selected variant of model is very easy for use regard to its simplicity based on only two equations for describing traffic noise in urban areas of Niš.

The good results are completed by a comparison with the performance obtainable using classical prediction methods available in literature. The results of comparative analysis clearly show that the NAISS - model allows better prediction of noise pollution of motor vehicles in urban areas of Niš than any other empirical relationship. The equation (4) underestimation the data whereas the equations (1)–(3) overestimation, with worst performance of equation (1).

The success of NAISS - model can without doubt be attributed to performance of model formed on the basis of experimental data obtained in urban areas of Niš that itself includes the characteristics of flow and composition of the road traffic on observed points. In addition, it includes the number of light vehicles, heavy vehicles and buses as independent variables instead of using the previous mentioned equivalence, with consistent increase in accuracy.

References

1. V. Tandara: *Noise of Utility Vehicles and Passanger Cars and Influence of Transmission*. In: Proc. of 14th International Congreess on Acoustic, paper E2-5, Bejeing, China, 1992
2. C. G. Balachandran: *Urban Traffic Noise in Environmental Impact Assesssments*. In: Proceedings of 14th International Congreess on Acoustic, paper E1-4, Bejeing, China, 1992,
3. M. A Burgess: Noise Prediction for Urban Traffic Conditions - Related to Measurements in the Sydney Metropolitan Area. Appllied Acoustics, Vol. 10, pp. 1-7, England, 1977,
4. R. Josse: *Notions d'acoustique Paris*. France: Ed. Eyrolles, 1972
5. C. Fagotti and A. Poggi: *Traffic Noise Abatment Strategies. The Analysis of Real Case not Really Effective.* In: Proc. of 18th International Congress for Noise Abatment, pp. 223-233, Bologna, Italy, 1995
6. D. Cvetkovic, A. Deljanin and M. Prascevic: *Community Noise Levels Survey of Nis*. In: Proc. of the 1997 Internationala Congress on Noise Control Engineering, pp. 815-819, Budampest, Hungary, Vol. II, 1997
7. M. Prascevic, D. Cvetkovic and V. Stojanovic: *Mathematical Models for Describing Road Traffic Noise*. In: Proc. of the 1997 Internationala Congress on Noise Control Engineering, pp. 895-899, Budampest, Hungary, Vol. II, 1997
8. M. Prascevic, D. Cvetkovic, and V. Stojanovic: *Traffic Noise Modeling in Urban Areas.* In: Proc. of XLI Yugoslav Conferece ETRAN (in Serbian), pp. 629-633, Beograd, Vol. II, 1997

9. M. Prascevic, D. Cvetkovic, A. Deljanin and V. Stojanovic: *Modeling of Urban Traffic Noise*. In: Proc. of the Fifth International Congress on Sound and Vibration, Adelaide, South Australia, 1997
10. L. Ercoli and all: *Recent Studies on Community Noise in Bahia Blanca City (Argentina).* In. Proc. of the Fifth International Congress on Sound and Vibration, Adelaide, South Australia, 1997
11. M. Recuero, C. Gil, and J. Grundman: *Effects of Traffic Noise Within the Madrid Region*. In: Proc. of the Fifth International Congress on Sound and Vibration, Adelaide, South Australia, 1997
12. M. Arana and A. Garcia: *A Comparasion Between the Noise Surveys Carried Out in Two Spanish Cities (Valencia and Pampalona).* In: Proc. of the 1997 Internationala Congress on Noise Control Engineering, pp. 819-823, Budampest, Hungary, Vol. II, 1997,

NAISS - MODEL ZA PREDIKCIJU SAOBRAĆAJNE BUKE

Dragan Cvetković, Momir Praščevic, Violeta Stojanović

Saobraćajna buka motornih vozila, kao glavni izvor buke u urbanim sredinama, predstavlja opšti ekološki problem koji ozbiljno ugrožava zdravlje čoveka i smanjuje njegovu radnu produktivnost. U cilju održavanja visokog kvaliteta životne sredine u kojoj čovek živi i radi, kontrola saobraćajne buke, koja podrazumeva poznavanje metoda za predikciju imisije buke motornih vozila, postaje jedna od glavnih mera koju treba preduzeti. U cilju modeliranja saobraćajne buke i izbora odgovarajućih mera za kontrolu buke neophodno je poznavati funkcionalni odnos između emisije buke i određenih parametara saobraćaja. U ovom radu biće prikazani rezultati predikcije saobraćajne buke NAISS-modelom koji je formiran trendovanjem eksperimentalnih podataka, dobijenih sistematskim merenjem nivoa buke u urbanim zonama grada Niša. Takođe prikazani su i rezultati komparativne analize predloženog modela sa modelima uzetih iz literature.