FIFTH INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
DECEMBER 15-18, 1997
ADELAIDE, SOUTH AUSTRALIA

# MODELING OF URBAN TRAFFIC NOISE

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**Abstract** - The traffic noise, 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. With little or no noise abatement legislation and by disregarding eventual noise control measures in sound source themselves and in urban environments, the traffic noise in cities may grow up alarmingly due to continued development of transportation infrastructure, to higher unit capacities and speeds of motor vehicles. 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. 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. The noise levels can be predicted by a mathematical model while designing planning and developments schemes for new transportation routes and re-development of existing ones or when the flow and composition of traffic are changed. In this paper, the results of modeling road traffic noise level by trending of the experimental data collected by systematic noise measurement at 11 measurement points in urban areas of Nis will be shown.

## 1. INTRODUCTION

The traffic noise, 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. With little or no noise abatement legislation and by disregarding eventual noise control measures in sound source themselves and in urban environments, the traffic noise in cities may grow up alarmingly due to continued development of transportation infrastructure, to higher unit capacities and speeds of motor vehicles.

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. 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. The noise levels can be predicted by a mathematical model while designing planning and developments schemes for new transportation routes and re-development of existing ones or when the flow and composition of traffic are changed. Also, modeling traffic noise allow zoning of the areas with respect to the ambient noise.

In this paper, the results of modeling road traffic noise level by trending of the experimental data collected by systematic noise measurement at 11 measurement points in urban areas of Nis will be shown. The models describing the noise level by unique equation for all measurement points, by two separate equations for two noise level ranges (55-65 dB(A) and 65-75 dB(A)) and by separate equations for all points were formed and they will be presented.

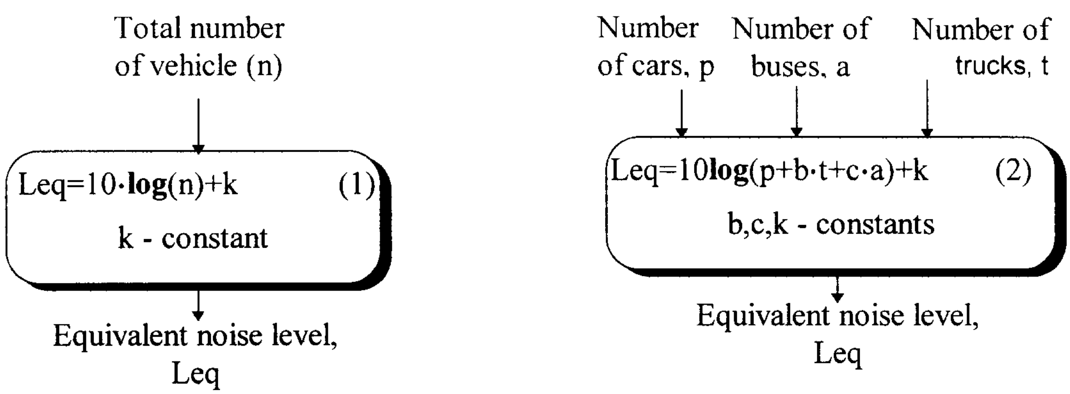
## 2. CHOICE OF MATHEMATICAL MODEL OF ROAD TRAFFIC NOISE

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

- allow accurate determination of a unit which has shown good correlation with subjective response to the noise
- require only data which 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

Using the available models for modeling road traffic noise in the urban areas of Nis was not give valid results, because any models itself includes the flow and composition of the road traffic which may be different than examined urban areas [1-3]. Because of that, the paper's authors tried to form the traffic noise models which to be valid for the flow and composition of the road traffic of Nis city.

With regard to traffic noise on observed measurement points are mainly caused by the road traffic flow, first it was formed a model with one input - one output described by the equation (1). The scheme of this model is shown on the Fig.1.(a).




**a) model with one input** **b) model with three inputs**

Fig. 1. The traffic road noise models

The model output (equivalent noise level, Leq) is a logarithmic function of total flux of motor vehicles near the measurement position (1), where (k) is the constant taking into consideration the property of sound propagation on the observed position. This constant is determined by the experimental data fitting in the optimization process of mathematical model.

In order to make it easier to appreciate the variability of three components of urban traffic, the number of vehicles was decomposed into the number of cars, the number of trucks and the number of buses. In such way, a model with three input - one output described by the equation (2) was formed. The scheme of this model is shown on the Fig.1.(b). Now, the equivalent noise level (Leq) is logarithmic function of equivalent flux 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. The constant (k) has the same meaning as the previous model and the model constants are determined by same procedure.

## 3. FORMING TRAFFIC NOISE MODELS

Starting from the measurement results collected by systematic traffic noise monitoring in urban areas of Nis, it has been carried out an optimization of suggested mathematical models by extracting function relation among the equivalent noise level and the traffic parameters.

The experimental data were collected at 11 different measurement points, near the main city traffic arteries with typical properties of commercial, residential, industrial and hospital areas, five times during day-time period ($6^{00}$-$22^{00}$) for all locations [4,5]. All measurement were taken on working days of the week during 1995, excluding all atypical conditions. Each of the measurement points was to be determined from the 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. In order to form an unique model (one equation) for describing road traffic noise, first it was carried out the fitting based on the experimental data for all measurement points grouped. Afterwards, 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.

Table 1. The model constants

| data | model with one input | model with three inputs | | |
|---|---|---|---|---|
| group | k | b | c | k |
| 1 | 44.5 | 1.3 | 5 | 43.4 |
| 2 | 44.2 | 2.4 | 11.8 | 42.0 |
| 3 | 47.5 | 2 | 6.3 | 45.4 |
| 4 | 46.5 | 0.5 | 5.2 | 46..6 |
| 5 | 45.7 | 1.1 | 1.3 | 45.7 |
| 6 | 47.9 | 1.6 | 3.3 | 47.2 |
| 7 | 49.0 | 5.8 | 11.1 | 45.9 |
| 8 | 46.5 | -0.2 | 0.4 | 47.1 |
| 9 | 45.3 | 4.1 | 2.3 | 44.6 |
| 10 | 38.4 | 6.8 | -3.1 | 38.4 |
| 11 | 37.6 | 0.8 | -0.2 | 37.9 |
| all points | 44.9 | 27.9 | 3.5 | 41.3 |
| level range: 65 - 75 dB(A) | 46.4 | 11.7 | 3.1 | 44.3 |
| level range: 55 - 65 dB(A) | 38.0 | 3.7 | -1.9 | 38.2 |

## 4. ANALYSIS OF FORMED MODELS

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. Also, the correlation analysis of these noise levels has been carried out.

The average value of absolute differences of noise levels ( $\Delta L = |Leq,c - Leq,m|$ ) and standard deviation of differences ($\sigma$) as well as the correlation coefficient of noise levels (r) have been calculated.

It was analyzed the following variants of models describing traffic noise:

variant 1: by the unique equation for all measurement points

model with one input: $Leq = 10\log n + 44.9$

model with three inputs: $Leq = 10\log(p + 27.9t + 3.5a) + 41.3$ (3,4)

variant 2: by separate equations for two noise level ranges

model with one input

$Leq = 10\log n + 38.0 \quad 55 < Leq < 65$

$Leq = 10\log n + 46.4 \quad 65 < Leq < 75$ (5,6)

model with three inputs

$Leq = 10\log(p + 3.7t - 1.9a) + 38.2 \quad 55 < Leq < 65$

$Leq = 10\log(p + 11.7t + 3.1a) + 44.3 \quad 65 < Leq < 75$ (7,8)

variant 3: by separate equations for each measurement points; the model constants are given in rows of Table 1. from 1 to 11.

The parameters of analysis are given in the Table 2 for mofel with one input and in the Table 3 for model with three inputs.

Table 2. The parameters of analysis of model with one input

| data group | variant 1 | | | variant 2 | | | variant 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\overline{\Delta L}$ | $\sigma$ | r | $\overline{\Delta L}$ | $\sigma$ | r | $\overline{\Delta L}$ | $\sigma$ | r |
| 1 | 0.79 | 0.68 | 0.72 | 1.91 | 0.95 | 0.72 | 0.71 | 0.66 | 0.72 |
| 2 | 1.05 | 0.81 | 0.84 | 2.25 | 1.09 | 0.84 | 0.83 | 0.73 | 0.84 |
| 3 | 2.59 | 1.03 | 0.75 | 1.23 | 0.85 | 0.75 | 0.86 | 0.55 | 0.75 |
| 4 | 1.64 | 0.96 | 0.75 | 0.82 | 0.50 | 0.75 | 0.81 | 0.49 | 0.75 |
| 5 | 0.97 | 0.71 | 0.83 | 0.92 | 0.54 | 0.83 | 0.60 | 0.60 | 0.83 |
| 6 | 3.02 | 0.93 | 0.91 | 1.55 | 0.89 | 0.91 | 0.77 | 0.51 | 0.91 |
| 7 | 4.12 | 1.06 | 0.82 | 2.62 | 1.06 | 0.82 | 0.85 | 0.62 | 0.81 |
| 8 | 1.65 | 0.55 | 0.93 | 0.46 | 0.32 | 0.93 | 0.44 | 0.32 | 0.93 |
| 9 | 1.00 | 0.71 | 0.92 | 1.29 | 0.95 | 0.92 | 0.99 | 0.60 | 0.92 |
| 10 | 6.45 | 1.19 | 0.93 | 1.07 | 0.66 | 0.93 | 0.95 | 0.67 | 0.93 |
| 11 | 7.30 | 0.82 | 0.88 | 0.75 | 0.54 | 0.88 | 0.67 | 0.45 | 0.88 |
| mean value | 2.78 | 0.86 | 0.64 | 1.35 | 0.76 | 0.84 | 0.77 | 0.56 | 0.84 |

Table 3. The parameters of analysis of model with three inputs

| data group | variant 1 | | | variant 2 | | | variant 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\overline{\Delta L}$ | σ | r | $\overline{\Delta L}$ | σ | r | $\overline{\Delta L}$ | σ | r |
| 1 | 1.09 | 0.86 | 0.72 | 1.47 | 0.87 | 0.75 | 0.61 | 0.58 | 0.77 |
| 2 | 1.24 | 0.80 | 0.78 | 1.40 | 1.00 | 0.85 | 0.67 | 0.48 | 0.91 |
| 3 | 2.22 | 1.24 | 0.78 | 1.00 | 0.83 | 0.80 | 0.69 | 0.47 | 0.84 |
| 4 | 2.53 | 1.27 | 0.47 | 1.35 | 0.74 | 0.55 | 0.81 | 0.50 | 0.76 |
| 5 | 1.77 | 1.30 | 0.59 | 0.94 | 0.78 | 0.66 | 0.60 | 0.60 | 0.82 |
| 6 | 1.80 | 1.32 | 0.88 | 1.06 | 0.84 | 0.91 | 0.74 | 0.47 | 0.92 |
| 7 | 2.00 | 1.16 | 0.84 | 1.34 | 0.92 | 0.85 | 0.70 | 0.55 | 0.87 |
| 8 | 1.34 | 0.99 | 0.70 | 0.88 | 0.73 | 0.77 | 0.41 | 0.29 | 0.94 |
| 9 | 1.44 | 0.99 | 0.75 | 1.14 | 0.75 | 0.84 | 0.98 | 0.57 | 0.91 |
| 10 | 5.41 | 1.57 | 0.66 | 1.01 | 0.63 | 0.91 | 0.86 | 0.70 | 0.88 |
| 11 | 6.25 | 1.58 | 0.54 | 0.72 | 0.55 | 0.86 | 0.67 | 0.45 | 0.88 |
| mean value | 2.46 | 1.19 | 0.70 | 1.12 | 0.79 | 0.80 | 0.70 | 0.51 | 0.86 |

Figure 2. shows trends for the equivalent noise levels measured and those predicted by different variants of model with one input for one selected measurement point and Figure 3 shows trends for model with three inputs. The comparison is shown for about 40 measurements quoted in the abscissa.

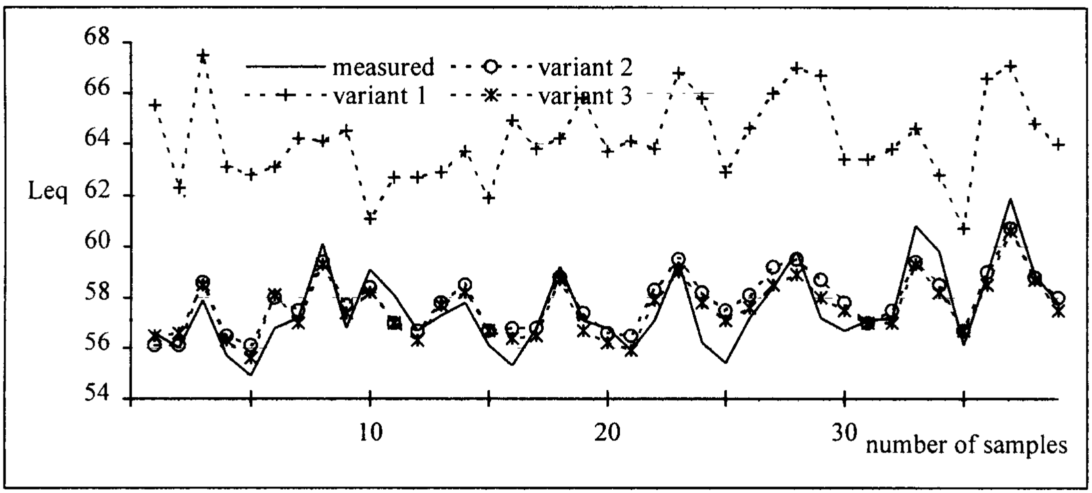



Fig.2. A comparison between different variants of model with one input

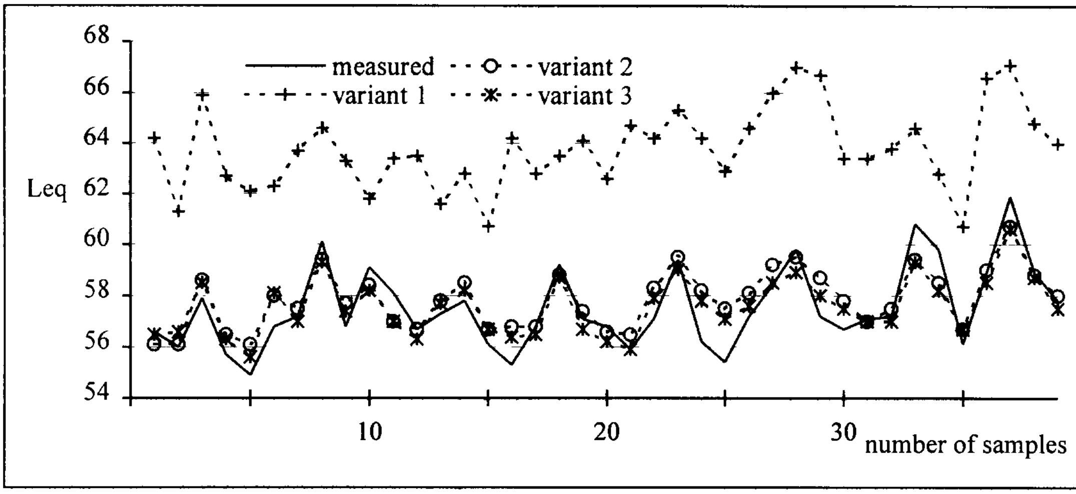



Fig.3. A comparison between different variants of model with three input

## 5. CONCLUSION

In this paper, the results of modeling road traffic noise level by trending the experimental data collected at 11 measurement points in urban areas of Nis are shown. The paper's authors decided for two types of models described by equations (1) and (2). Three groups of models were formed and statistical and correlation analysis were carried out.

Based on analysis of suggested models it is noted following:

- with regard to wide range of measured traffic noise levels, practically it is impossible modeling traffic noise by unique equation correctly (differences lower than 2.5 dB)
- modeling traffic noise by separate equations for two ranges of noise level is rather correctly and these models are very easy for use
- models forming for each measurement points separately are the most precision, although with regard to number of equations they are relatively complex
- model 2 is more precision than model 1, although with regard to its simplicity that fact do not excluded using model 1 for modeling traffic noise

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This paper is part of Project No. 04M03 supported by Ministry of Science and Technology of Republic Serbia.