INFLUENCE OF THE INTENSITY AND COMPOSITION OF TRAFFIC FLOW ON THE EQUIVALENT NOISE LEVEL

ABSTRACT

This article analyses the influence of two characteristics of the traffic flow (TF) - intensity and composition - on the equivalent noise level (LAeq). Acoustic measurements of the noise of the road traffic were taken in 1999 at 12 selected places on 4-lane urban roads in Bratislava. Through mathematical analysis, dependence of the LAeq from the TF and heavy traffic has been found out. The obtained relations can be used to determine the LAeq caused by road traffic on the urban roads with similar marginal conditions.

KEY WORDS

- intensity of traffic flow (TF)
- composition of TF
- road traffic noise
- equivalent noise level (LAeq)

1. INTRODUCTION

According to a type of roads, we distinguish the noise from the road traffic on motorways, roads, urban roads and special purpose roads. The most recent problem is the noise on the urban roads because the traffic causes the highest values of LAeq and crosses the highest number of residential areas.

According to [1], the dependency stated between the intensity of the TF and LAeq in Bratislava in 1983-1986 was as following

\[ LAeq = 69.1 + 0.0065 \times n \] (dB) (1)

where "n" is the intensity of the TF (vehicles/hour).

In the years 1983-1986, the share of heavy lorries was according to [1] around 35 % of the overall intensity on a weekday. At the present (1999), it is only around 10 %.

It is obvious that the above dependency was characteristic for a certain period, and this equation cannot therefore be applied today.

In the following parts of this article the applied method is specified in details - the preparation (the choice of places and time), the realisation, the processing, the analysing and at last the results of the acoustic measurements, i.e. the determined dependencies of LAeq from the intensity and the composition of the TF, as well as their importance.
2. METHODS

2.1 Preparation of the acoustic measuring

However simple the control of the sound level meter might be, the traffic noise measurement program and the processing of the obtained data have to be carefully planned.

From the viewpoint of acoustic situation research, the observed data can be divided into acoustic and non-acoustic (traffic, topographic and climatic).

Places of measuring

Based on the approximately equal marginal conditions (mostly concerning traffic features), 4-lane urban roads in Bratislava were selected. In these measuring point was no green.

It was necessary to examine the selected places visually and directly in situ, and determine the optimal location of the sound level meter in the horizontal direction based on these requirements:

- the even motion of vehicles in the TF
- the exclusion of the remaining noise sources
- the preference of direct sections with the minimal gradient.

The preference of direct sections with the minimal gradient of the vertical alignment.

When measuring L_{Aeq}, the preferred distance of the sound level meter is 7.5 m from the axis of the closest road lane. With regard to the fact that in an urbanized area this distance is not possible to keep on roads with buildings on one or both sides, the measuring places were selected at a distance of 1 m from the facade of the attached and coherent land coverage. The height of the measuring microphone is minimal according to [4] - 1.5 m above the ground, alternatively above the pavement. The measuring microphone is directed towards the road so that the axis of the microphone's highest sensitivity is vertical to the longitudinal axis of the road and parallel with surface of the ground (fig. 1).

Time of measuring

As continual noise measuring (24 hr) is impossible to realise, it is necessary to set the time of measuring. The time of measuring means when, how long and how many times noise is measured.

The noise measuring was performed in June and July in the year 1999. The measurements took place on Tuesdays, Wednesdays and Thursdays. On the basis of the daily course of traffic intensities in Trnavská Street (fig. 2) [5], in order to record the varying of the traffic and to keep approximately equal time distances, the following time intervals were selected:

- 7:00 - 8:00 morning intensity (traffic peak)
- 10:00 - 11:00 late morning intensity
- 15:00 - 16:00 afternoon intensity (traffic peak)
- 19:00 - 20:00 evening intensity
- 22:00 - 23:00 night intensity.

The decision "how long to measure" is made according to [4], which recommends the following minimal time of direct noise measuring depending on the intensity of the TF:

- up to 250 vph 60 minutes
- 250 - 500 vph 30 minutes
- more than 500 vph 15 minutes.

Only after these conditions have been fulfilled the measuring can be classified according to [10] as common accuracy measuring. In order to acquire accurate results and in order to exclude an error, it is necessary to perform the measuring twice in the same time interval. In the case of unfavourable weather conditions, the noise measurement should be interrupted or ended.

2.2 In situ acoustic measurements

The ground traffic noise measurements was taken according to current regulations [7], [8], [9], on the 12 selected places of the urban roads in Bratislava.

The subject of the measurements was the equivalent noise level L_{Aeq} (dB). The measuring was performed with the Brüel & Kjaer accurate module sound level meter type 2231 with added application module BZ 7110 (fig. 1). At the beginning and at the end of each measurement the sound level meter was examined by the acoustic calibrator 4230 Brüel & Kjaer.

The traffic data were obtained in the cross section of the measurement, alternatively on the section of the road around the measuring place. The following traffic characteristics were noted:

Fig. 1 Traffic noise measuring by means of the module accurate sound level meter Brüel & Kjaer type 2231
• the description of the road (its cross section, directional and altitudinal conduit, road surface, the closest junction)
• the intensity of the TF at the time of the measuring (separately for both directions)
• the composition of the TF at the time of the measuring (PV - personal vehicles, LL - light lorries (to 3.5 tons), HL - heavy lorries (over 3.5 tons), A- BUS - buses, T- BUS- trolley-buses)
• the average velocity of the TF (manually).

The surroundings of the measuring places were examined for the following topographic data:
• the situation at the measuring place with the microphone location
• the height of the surrounding land coverage
• the photography.

The climatic data were gathered as macroclimatic from the SHMÚ station. The following climatic data were recorded:
• the weather
• the air temperature
• the velocity and direction of wind
• the atmospheric (barometric) pressure.

2.3 Processing of acoustic measurements

The term statistic processing means the data transfer from the original form of counting paper sheets to the electronic form. The results of the statistic processing are records of noise level measuring. These protocols serve as the source of data for the regression analysis in the correlation matrix (table 1).

Average values in 1-hour intervals of measuring were calculated from each pair of the recorded data obtained from 15 or 30 minute long measuring as a logarithmic mean according to the equation 2

\[ L_{\text{Aeq,1-2}} = 10 \log \left( \frac{1}{4.15} \cdot \left( 2 \cdot 10^{LA_{\text{eq,1}}/10} + 2.15 \cdot 10^{LA_{\text{eq,2}}/10} \right) \right) \text{ (dB) } \]  

where

- \( L_{\text{Aeq,1}} \) is the first 15-minute long traffic noise measuring (dB),
- \( L_{\text{Aeq,2}} \) is the second 15-minute long traffic noise measuring (dB).

The average values of time interval - day, were calculated as the logarithmic mean according to the equation 3 (fig. 2) in the next step

\[ LA_{\text{eq,d}} = 10 \log \left( \frac{1}{16} \cdot \left( 2 \cdot 10^{LA_{\text{eq,7-8}}/10} + 6 \cdot 10^{LA_{\text{eq,10-11}}/10} + 2 \cdot 10^{LA_{\text{eq,15-16}}/10} + 6 \cdot 10^{LA_{\text{eq,19-20}}/10} \right) \right) \text{ (dB) } \]  

where

- \( LA_{\text{eq,d}} \) is the average daily equivalent noise level (dB)
- \( LA_{\text{eq,7-8}} \), \( LA_{\text{eq,10-11}} \), \( LA_{\text{eq,15-16}} \), \( LA_{\text{eq,19-20}} \) are the average values of \( LA_{\text{eq}} \) in the corresponding intervals.

Since the values of \( LA_{\text{eq,d}} \) had been measured in different distances from the closest drive lane axis (according to the land coverage), they had to be converted to the unified distance of 7.5 m according to equation 4

\[ L_2 = L_1 - 10 \cdot \log \left( \frac{r_2}{r_1} \right) \text{ (dB) } \]  

where

- \( L_1 \) is the value of \( LA_{\text{eq}} \) (dB) in the distance \( r_1 \) (m)
- \( r_2 \) is the distance, in which the \( L_2 \) is calculated, i.e. 7.5 m.

The recorded values of the intensity of the TF in 15 or 30-minute long traffic research were converted to 1-hour values of intensity in both directions. These data were then used to calculate the average intensity in the relevant 1-hour interval according to the type of vehicles. At the end, the average daily intensity was calculated in both directions as the weight mean, the length of the relevant time interval being the weight according to equation 5

\[ n_d = \frac{1}{16} \cdot \left( 2 \cdot n_{7-8} + 6 \cdot n_{10-11} + 2 \cdot n_{15-16} + 6 \cdot n_{19-20} \right) \text{ (vph) } \]  

where \( n_{7-8}, n_{10-11}, n_{15-16}, n_{19-20} \) are the average values of the intensity of the TF (vph) in the relevant time intervals.
2.4 Statistical analysis. Regression analysis

Pair linear regression
The intention is to find a regression straight line by means of the smallest square method which equation has the form

\[ Y = a + b \cdot X \]  (6)

and to show this on the value graph.

Multidimensional regression
This is an extension of the simple regression when taking into account more than one independent variable \( X \). Its equation has the form

\[ Y = b_0 + b_1 \cdot X_1 + b_2 \cdot X_2 + \ldots + b_k \cdot X_k \]  (7)

Non-linear regression
The task is to determine the function given by the equation

\[ Y = A + B \cdot \log(X) \]  (8)

Similarly as in the linear regression we look for the coefficients \( \beta_k \) by means of the smallest square method. As long as the relevant coefficient \( \beta_k \) is not nearly equal to 0, the relevant factor \( X_i \) cannot be excluded from the regression equation.

3. RESULTS

After having completed the correlation matrix (table 1), the calculation of the selective correlation coefficients, the correlation and regress analysis, the calculation of residues and graphs showing the obtained equations (fig. 3-5), the results are:

- the researched equation between \( L_{Aeq} \) and the intensity of the TF "n" with the coefficient of correlation \( r = 0.7265 \) can be expressed with the regressive line with equation:

\[ L_{Aeq} = 0.00255 \cdot n + 67.1 \text{ (dB)} \]  (9)

- the non-linear dependency between \( L_{Aeq} \) and the intensity of the TF "n" with the correlation coefficient \( r = 0.8198 \) in the form of the logarithmic function

\[ L_{Aeq} = 8.8295 \cdot \log(n) + 43.6 \text{ (dB)} \]  (10)

- the positive correlation coefficient \( r = 0.5600 \) interprets a direct dependency between \( L_{Aeq} \) and the intensity of heavy vehicles "N" according to the equation 11

\[ L_{Aeq} = 0.0335 \cdot N + 68.5 \text{ (dB)} \]  (11)

- the dependency between \( L_{Aeq} \) from the intensity of the TF "n" and the intensity of heavy traffic "N" is determined by means of multidimensional non-linear regression with a relatively high determination coefficient \( R^2 = 71\% \) and decisive divergence 2.4 dB according to the equation 12

\[ L_{Aeq} = \text{function} \]  (12)

Tab. 1 The correlation matrix acoustic and traffic data

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Nr.place</th>
<th>( L_{Aeq} ) (dB)</th>
<th>( n ) (vph)</th>
<th>( N ) (vph)</th>
<th>( N_p ) (%)</th>
<th>( v ) (km/h)</th>
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<tbody>
<tr>
<td>6:00-22:00</td>
<td>1</td>
<td>73.1</td>
<td>1485</td>
<td>49</td>
<td>3.2</td>
<td>45</td>
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<td>2857</td>
<td>155</td>
<td>5.4</td>
<td>50</td>
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<tr>
<td>3</td>
<td>71.8</td>
<td>1937</td>
<td>75</td>
<td>3.8</td>
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</tr>
<tr>
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<td>1378</td>
<td>53</td>
<td>3.8</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>5</td>
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<td>1043</td>
<td>48</td>
<td>4.6</td>
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</tr>
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<td>2610</td>
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<tr>
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<td>171</td>
<td>6.2</td>
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<td>594</td>
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<tr>
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<td>68.4</td>
<td>876</td>
<td>90</td>
<td>10.3</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

1) \( N = \) - heavy lorries (HL) + buses (A-BUS)

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\[
L_{Aeq} = 11,639 \cdot \log(n) - 0,019 \cdot N + 36,3 \quad (dB) \quad (12)
\]

showed on picture 5 - thick line.

- the mentioned equations can serve as assistance in calculating the equivalent noise level \(L_{Aeq}\) under equal marginal conditions, i.e.:
  - the 4-lane urban road without any tram lanes
  - the intensity of about 250-4000 vph
  - the intensity of heavy traffic (HL and A-BUS) around 200 vph
  - the velocity of TF about 40-70 km/h
  - the approximately 0 per cent gradient of the road
  - the asphalt concrete is cover of pavement
  - the fluency of the TF is not interrupted (by junctions, crossings)
  - calculated for a point 7,5 m distant from the axis of the nearest traffic lane and 1,5 m above the surface of pavement.

4. CONCLUSIONS

With regard to the fact that the situation in the field of road traffic is constantly changing (the number of vehicles is increasing, the share of different types of vehicles is changing significantly, the rolling stock is being renewed, the velocity of vehicles is increasing etc.), it is necessary to continuously specify the dependency of noise level from these varying traffic parameters.

Its determination has great application in determining \(L_{Aeq}\) from road traffic simply and quickly. \(L_{Aeq}\) can then be determined approximately through the graph or calculation of the stated dependencies (fig. 3-5).

The stated dependencies confirm the generally known fact - when the intensity is doubled (line acoustic source) \(L_{Aeq}\) gains 3 dB. The following research in this field can be oriented towards determining the dependency between traffic parameters and \(L_{Aeq}\) on other types of urban roads, roads, and motorways.
REFERENCES