



## EXPERIMENTAL ESTIMATION OF ECOLOGICAL CAPACITY OF A ROAD FROM THE NOISE POINT OF VIEW

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### Abstract

Ecological capacity of a road from the point of view of noise is the maximum traffic volume at which allowed noise levels are not exceeded in a road neighbourhood. Ecological capacity can be calculated using model equations which include a large number of factors influencing noise levels in a road neighbourhood – number of vehicles, their velocity, slope of a road, road surface, surface of a road neighbourhood, distance from the road, etc. In the article a simple experimental method is proposed which makes possible to estimate ecological capacity of a specific road. It is based on the calculation of the average values of a noise level produced by a passenger car and a heavy vehicle in the location of interest from two measurements of noise levels for two different compositions of traffic flow (different ratio of passenger cars and heavy vehicles). The resulting values are influenced by all factors mentioned above and therefore the noise level produced by the traffic flow of arbitrary composition (arbitrary ratio of passenger cars and heavy vehicles) can be calculated and for the estimation of ecological capacity of a road in the location of interest only the allowed values of noise levels are needed. In case that the measures for reduction of traffic volume are considered (e.g. exclusion of heavy vehicle from traffic flow) the expected decrease of noise level can be calculated and this can be helpful in the decision-making process.

*Keywords: noise, noise level, road, ecological capacity*

### 1 Introduction

The difference between the capacity of a road and its environmental capacity was for the first time determined in the 1960th by C. D. Buchanan [1] who also pointed out the importance of these concept in urban planning. Environmental capacity of a road has a broader meaning than the capacity of road because it takes into account not only transportation but also ecological goals in urban planning. Each urban unit should have the maximum traffic volume estimated – maximum road capacity – which if not exceeded makes the specific road acceptable from the environmental point of view – from the point of view of noise, vibrations, pollution, visual disturbances, pedestrians while the motion of vehicles and their parking is taken into account. This capacity can be called environmental capacity of a road. This concept is also used in relation with sustainability of airports [4]. This concept has been introduced also in the Slovak road design standards [2] but as the ecological road capacity and it is defined as the maximum traffic volume under given geometrical and traffic conditions at which the limit values of negative impacts on environment from traffic (noise, emissions, vibrations) are not exceeded. Ecological capacity from the point of view of noise can be called acoustical road

capacity. It is the maximum traffic volume at which the allowed noise levels specified in [3] are still not exceeded. This quantity for a given road can be determined by the model calculation [5],[6],[7],[8], in which a large number of factors is included which influence the noise level in a road neighbourhood (number of vehicles, their velocity, slope and road surface, surface of road neighbourhood, the distance from a road, etc.) by the procedure reported in [9]. The accuracy of the results depends on the accuracy of particular calculation model and the estimate of model input parameters.

The ecological road capacity can be determined also in experimental way. In this paper a simple experimental method is proposed which makes possible to determine ecological capacity for a given road from the noise point of view. It is based on the estimation of an average noise level of one vehicle in the location of interest in the road neighbourhood. This quantity includes all above mentioned factors except the number of vehicles and the ratio of passenger cars and heavy vehicles.

## 2 Quantification of the levels of noise from traffic

The equivalent noise level  $L_{Aeq}$  in the location of interest at a certain distance from the road is usually measured over 1 hour interval and it is calculated using the following formula

$$L_{Aeq} = 10 \log \frac{I}{I_0} \tag{1}$$

where  $I$  is the mean value of physical intensity of noise over a given time interval and  $I_0$  is the threshold sound intensity  $I_0 = 10^{-12} \text{Wm}^{-2}$ .

The vehicles moving on the road are the sources of noise and from the point of view of noise which they produce they can be divided into passenger cars and heavy vehicles. The equivalent level of noise from traffic on the road can be then expressed by the following formula

$$L_{Aeq} = 10 \log \frac{N_n I_n + N_{os} I_{os}}{I_0} \tag{2}$$

where  $N_n$  is the number of heavy vehicles and  $I_n$  is physical intensity of noise from one heavy vehicle,  $N_{os}$  is the number of passenger cars and  $I_{os}$  is physical intensity of noise from one passenger car which move on the road over a defined time interval.

Eqn (2) can be rearranged and have the form

$$L_{Aeq} = 10 \log (N_n 10^{0,1L_n} + N_{os} 10^{0,1L_{os}}) \tag{3}$$

where  $L_n$  is the level of noise produced by one heavy vehicle and  $L_{os}$  is the noise level produced by one passenger car. If these quantities are known then the noise level of any traffic volume can be calculated.

Using eqn (3) it is possible to determine e.g. the level of noise from one passenger car (heavy vehicle) in case that there no heave vehicles (passenger cars) moving on the road, since then it holds

$$L_{os} = L_{Aeq} - 10 \log N_{os} \tag{4}$$

$$L_n = L_{Aeq} - 10 \log N_n \tag{5}$$

Analogical formula for the average level of noise from one vehicle  $L_v$  can be derived in case that the traffic volume is characterized by the total number of vehicles  $N$  [5]:

$$L_v = L_{Aeq} - 10 \log N \tag{6}$$

In case that traffic flow includes passenger cars and heavy vehicles eqn (2) contains two unknown quantities  $I_{os}$  a  $I_n$ . If the noise levels for two different traffic volumes are measured, i.e.,

we measure the noise levels for two different traffic flow compositions with different numbers of passenger cars ( $N_{os1}, N_{os2}$ ) and heavy vehicles ( $N_{n1}, N_{n2}$ ), the following equations hold

$$L_{Aeq1} = 10 \log \frac{N_{n1} I_n + N_{os1} I_{os}}{I_0} \quad (7)$$

$$L_{Aeq2} = 10 \log \frac{N_{n2} I_n + N_{os2} I_{os}}{I_0} \quad (8)$$

from which the following expressions can be obtained for the equivalent noise levels for one passenger car  $L_{os}$  and one heavy vehicle  $L_n$ :

$$L_{os} = 10 \log \frac{N_{n1} 10^{0,1L_{Aeq2}} - N_{n2} 10^{0,1L_{Aeq1}}}{N_{n1} N_{os2} - N_{n2} N_{os1}} \quad (9)$$

$$L_n = 10 \log \frac{N_{os1} 10^{0,1L_{Aeq2}} - N_{os2} 10^{0,1L_{Aeq1}}}{N_{os1} N_{n2} - N_{os2} N_{n1}} \quad (10)$$

### 3 Calculation of ecological capacity of a road

As was mentioned above ecological capacity of a road from the noise point of view is the maximum traffic volume which produces noise with levels in the location of interest not exceeding maximum allowed noise level  $L_p$  [3]. The maximum allowed noise levels are different for different urban areas and time of the day (day, evening, night).

If we do not take into account the composition of traffic flow, i.e., the ratio of passenger cars and heavy vehicles and we know the average value of noise level of one vehicle  $L_v$ , the ecological capacity from the noise point of view  $N_{EK}$  can be calculated using eqn (6):

$$N_{EK} = 10^{0,1(L_p - L_v)} \quad (11)$$

For illustration the calculation of ecological capacity of a local road in urban area is shown. The measurements of noise levels were carried out in front of a house at distance of 2m from the façade of the house and 26m from the nearest lane of a four-lane road. The measurements were done during the day (measurement 1), evening (measurement 2) and night (measurement 3). The results of measurements and maximum allowed noise levels are listed in Table 1.

**Table 1** The numbers of passenger cars, heavy vehicles  $N_n$ , the total number of vehicles  $N_n$ , measured values of noise level  $L_{Aeq}$  and maximum allowed noise levels  $L_p$ .

Measurement	$N_{os}$ (veh/h)	$N_n$ (veh/h)	$N$ (veh/h)	$L_{Aeq}$ (dB)	$L_p$ (dB)
1	1108	64	1172	62,8	60
2	268	36	304	57,5	60
3	132	28	160	56,1	50

In order to obtain the maximum value of traffic volume at which the maximum allowed noise levels are not exceeded, i.e., to determine ecological capacity of the road, it is necessary to calculate the average value of the noise level  $\bar{L}_v$  of one vehicle. The noise level  $L_v$  for each measurement was calculated using eqn (6). The average value of noise level  $\bar{L}_v$  for one vehicle was calculated using weighted average value of physical intensity of noise:

$$\bar{L}_v = 10 \log \frac{I}{I_0} = 10 \log \frac{1}{I_0} \left( \frac{N_1 I_1 + N_2 I_2 + N_3 I_3}{N_1 + N_2 + N_3} \right) = 10 \log \frac{N_1 10^{0,1L_{v1}} + N_2 10^{0,1L_{v2}} + N_3 10^{0,1L_{v3}}}{N_1 + N_2 + N_3} \quad (12)$$

The results of calculations are listed in Table 2.

**Table 2** The calculated values of noise levels  $L_v$ ,  $L_{os}$ ,  $L_n$  for each measurement and average values  $\bar{L}_v$ ,  $\bar{L}_{os}$ ,  $\bar{L}_n$ . The values  $L_{os}$ ,  $L_n$  were calculated for all possible combinations of measurements indicated in brackets.

Measurement	$L_v$ (dB)	$L_{os}$ (dB) (combination)	$L_n$ (dB) (combination)
1	32,1	31,6 (1-2)	36,9 (1-2)
2	32,7	25,9 (2-3)	41,0 (2-3)
3	34,1	30,8 (1-3)	39,5 (1-3)
	$\bar{L}_v = 32,5$ dB	$\bar{L}_{os} = 30,8$ dB	$\bar{L}_n = 39,2$ dB

Ecological capacity of the given road  $N_{ek}$  was calculated using eqn (11) taking into account maximum allowed noise level for this time of the day. If we take into account the average value of noise level of one vehicle  $\bar{L}_v$ , the ecological capacity of the road in question is 562 veh/h during the day and evening and 56 veh/h during the night. These values are considerably lower than measured ones. This fact is also reflected in higher measured values of noise levels  $L_{Aeq}$  for the day and night in comparison with the allowed ones. It is therefore necessary to take measures to reduce the noise from traffic. The most simple measure is to decrease the traffic volume.

In order to quantify the influence of exclusion e.g. heavy vehicles from traffic flow, it is necessary to determine the average values of noise levels  $\bar{L}_n$ ,  $\bar{L}_{os}$ , for one heavy vehicle and one passenger car, respectively. For this purpose at least two measurements are needed. We did three measurements in the location of interest. Using all possible combinations and eqns (9) and (10) we obtained three pairs of values. The average values  $\bar{L}_{os}$  and  $\bar{L}_n$  were calculated using modified eqn (12). If heavy vehicles are excluded from traffic flow, ecological capacity of the road will be 832 veh/h during the day and evening and 83 veh/h during the night.

## 4 Conclusion

The proposed method for the determination of noise levels of one passenger car and heavy vehicle makes possible to calculate the noise level from traffic flow of any composition, i.e., any ratio of passenger cars and heavy vehicles, as well as to determine ecological capacity of a road from the noise point of view. If the measures for the decrease of noise levels are considered it makes possible to quantify e.g. the decrease of noise levels due to the exclusion of heavy vehicles from traffic flow.

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