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Road and Rail Infrastructure III

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ISSUES RELATED TO THE IMPACT OF NOISE AT AT-GRADE INTERSECTIONS

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Abstract

The article addresses the issues of determining the impact of noise at at-grade intersections. While noise levels on open road sections may be determined relatively unambiguously, at intersections the noise pollution levels are relatively difficult to identify. It is, particularly, in urban areas where this becomes an essential problem that significantly affects the impact of designed transport solutions on their surroundings. At the same time, it is obvious that this type of noise pollution in the road network is one of the highest ever because of the vehicle movement characteristics. Therefore, a realistic evaluation of intersections is impossible without the identification of complex noise pollution and its distribution in the intersection area. This was done using the AIMSUN micro-simulation software environment. The generated result reflects both the traffic and layout characteristics of individual intersections. Traffic noise pollution levels were determined through the use of dot array.
Noise pollution is identified primarily with regard to the impact of its adverse effects on human health. This evaluation takes into account mainly the emergence or deterioration of some diseases. (also so-called lost years of life, the costs of hospital stays, etc.). The evaluation method of these effects is based on standards also used in EU countries; the methodology is also applied in the HDM-4 system. Thus, it allows determining a specific impact of individual noise levels on adjacent areas and the population. External costs of noise pollution may also be quantified. The paper gives a detailed account of the methodology for the determination of average noise pollution, its external costs and the dependence of these parameters on the shape of an intersection and its entry traffic volumes. It represents one of the basic criteria used for a complex assessment of intersections.

Keywords: noise emissions; intersection; HDM-4; traffic micro-simulation; external costs

1 Introduction

The impact of traffic noise is becoming one of the important aspects considered in the assessment and optimization of proposed traffic solutions, particularly in urban areas. The existing methodologies for detecting traffic noise are primarily designed to determine the noise level on open road sections. A problem, however, arises in urban areas where the main limiting factor of the road network are at-grade intersections where the possibilities of current methodologies are strictly limited. While the noise generated by car traffic may be identified without significant problems for existing design solutions, for newly built intersections or reconstructions of existing intersections this problem becomes far more complicated. The methodology described in the article uses an alternative procedure to identify the impact of traffic noise generated at at-grade intersections. However, the methodology is primarily designed to serve for comparative assessments of alternative designs of an intersection, not for a predictive identification of actual noise emissions. It is based on existing procedures exploiting the potential of the Aimsun micro simulation software from which the input data for the assessment of noise emissions are generated. The resulting data of traffic noise levels may then be used as part of a complex assessment of alternative designs of an at-grade intersection.

2 Traffic noise and its impacts

2.1 Basic parameters of noise emissions

The existing methodologies for the identification of noise effects on the human body use the values of L_{eq} (equivalent continuous sound pressure level). This is a fictitious level of steady noise pressure which has the same effects on the human organism during a reference time as variable noise. The total acoustic energy of variable noise for a reference time must be equal to steady noise with a constant level L_{eq}. Therefore, not a simple average, but mean energy applies in this case. The A-weighted filter, which represents the inverse sensitivity curve of the human ear, is used to measure noise from road traffic. This filter is built-in in measuring instruments, and the values corrected by this filter get the subscript "A". The value obtained is then called L_{Aeq} (equivalent continuous A-weighted sound pressure level).
Noise does not propagate linearly in space. The logarithmic scale is commonly used for the description of noise propagation. The effect of the noise source intensity and distance from the source is shown in Fig. 1.
Noise impacts are naturally regulated by the legislation. The legislation currently in force (Czech Republic) defines public health noise limits in protected outdoor spaces of structures. The $L_{Aeq,T}$ for noise from road traffic is detected for the whole day ($L_{Aeq,16}$) and night time ($L_{Aeq,8}$). Public health exposure limits are set as the arithmetic sum of the equivalent sound pressure level $L_{Aeq,T}$ = 50 dB and a correction considering the type of protected space and the day time or night-time. Table 1 presents public health exposure limits for the protected outdoor space of other structures in the day time, depending on the type of road.

Table 1 Public health exposure limits according to the type of road (CR)

Road Type	Public health exposure limit [dB]	
	Day (6-22 h)	**Night (22-6 h)**
Main roads	60	50
Minor roads	60	50
Other types of roads	55	45
Old noise values	70	60

For the usage in our methodology the value L_{Aeq} is not ideal. The methodology should be able to determine the complex traffic noise impact, nevertheless value L_{Aeq} defines the value for peak volumes mainly. For our purpose value L_{dvn} will be more suitable, because it takes into account volume distribution during the day.

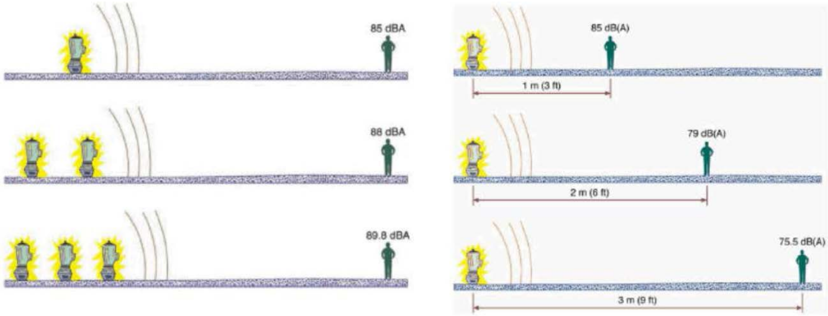


Figure 1 The effect of noise source intensity and distance from the source

2.2 Noise from car traffic

The basic sources of noise from car traffic are the following:
- noise of the engine (drive unit)
- noise arising during the contact of wheels with the pavement (rolling), or also rolling noise
- aerodynamic noise (bypassing)
- noise of transmission and distributor gear
- noise of the exhaust system
- noise of brakes
- noise of impacts and shocks of the load.

Engine noise is the primary source of noise prevailing particularly at lower vehicle speeds. For passenger cars, it dominates at speeds of up to 30 km/h, while for heavy vehicles at speeds of up to 50 km/h. "Total noise emissions from vehicles" are currently regulated by the EU limit of 74 dB for passenger cars and 80 dB for heavy vehicles.
Noise levels are further affected by other factors (i.e. traffic volumes, traffic flow composition, vehicle speed, pavement surface etc.) The resulting noise level at a given site is affected by numerous factors, some of which are under our control while others are steady and invariable.

3 Noise emission model in intersection areas

3.1 Usability of existing methods at intersections

It is obvious from the above facts (2.2) that the noise generated in the area of intersections is mainly generated by the vehicle drive unit due to the expected lower driving speed of vehicles. For this reason, while considering noise emissions we must also take into account other factors than just the vehicles driving speed. This may be mainly apparent at intersections with traffic lights where a traffic flow starts moving all at once in accordance with a signal plan. The noise generated by the engine during the start depends on the engine rpm, not on the driving speed. From this perspective, the application of existing static methodologies at intersections without their major modifications is practically useless. Another problem of intersections is the identification of the factor that can be measured, or at what point is can be measured. Complex assessment based on micro-simulations would have to take into account information on the movement of individual vehicles and, applying the principle of the detection of the sound pressure level generated by these vehicles, establish equivalent sound pressure levels.
The above described methodology would set extreme computational demands and would be unnecessary for our purposes. Therefore, our starting point is the current applicable met-

hodology for calculating noise levels from car traffic, which was calibrated and modified for our needs. In other words, proposed methodology combines current static calculations with technical information of vehicles used in evaluated micro-simulation model, i.e. on evaluated intersection. The calibration of the microscopic model itself was based on the output of a classical noise assessment of this model intersection performed in the HLUK+ specialized programme as well on the comparison of measured in-situ values with the values from existing micro-simulation model.

3.2 Design of a methodology of area detection of noise emissions

The designed methodology is based on the fact that the noise level detection at a specific point of intersections is not a relevant value indicating the overall area noise emissions generated by traffic in the intersection area. Thanks to the possibilities of the Aimsun micro simulation software, however, we are able to express the sound pressure value at each point in the vicinity of an intersection. With a view to noise characteristics, valid limit values are detected at a distance of 7.5 m from the axis of the adjacent lane. The values were detected up to the distance of the branches (100 m) from the intersection boundary (Fig. 2). The area delimited by these boundaries is relevant for the detection of average noise emissions generated by the intersection in the form of the $L_{dvn,int}$ value (equivalent continuous sound pressure level in the intersection area).
For the purposes of computations limitation, the delimited area was subdivided by a square grid with squares 2x2 m. While a 2 m difference would have a significant impact on the accuracy of the result in point detection of noise levels, interpolation methods may be used to identify the values with sufficient accuracy in area detection. The accurate $L_{dvm,i}$ value is detected at each intersection of the axes of the square grid to be used as an input value for the identification of the resulting value $L_{dvn,int}$. The distribution of individual $L_{dvn,i}$ values also defines the range of respective equivalent sound pressure levels. Due to the nature of noise, however, it is also necessary to take into account the negative impact of individual noise levels on the surroundings, namely on the health of the population influenced with traffic noise.

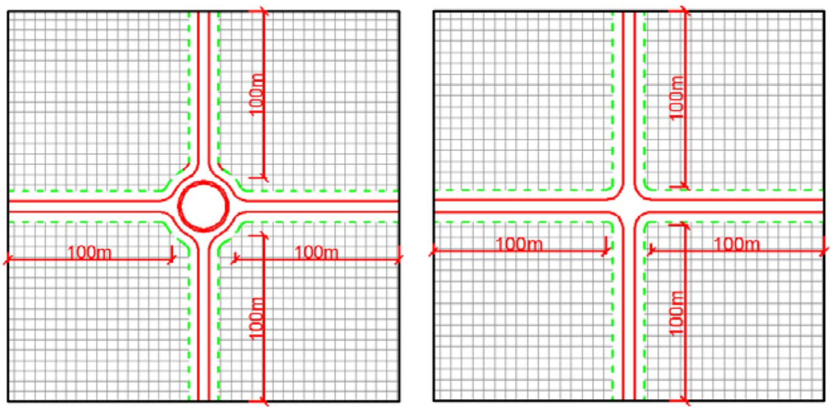


Figure 2 Area detection of sound pressure levels at a roundabout and a four-way intersection

The existing HDM-4 methodology, which determines the prices of external costs of noise exposure, was used to identify these impacts (Table 2). The essential figure in the context of our assessment is not the real quoted price, but the ratio between individual noise levels.
The $L_{Aeq,int}$ value is calculated from the following formula (1):

$$L_{dvn,int} = \frac{\sum_{i=1}^{n} L_{dvn,i} * A_i * C_i}{\sum_{i=1}^{n} A_i * C_i} \quad (1)$$

where:

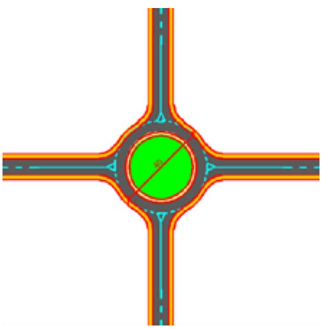
$L_{dvn,i}$ the L_{dvn} value at the i-th point of a square grid [dB];
A_i specific area corresponding to the $L_{dvn,i}$ value [2×2 m $= 4$ m^2];
C_i price of external costs of noise exposure [€].

Table 2 External costs of noise exposure (2010 – per person and year)

L_{dvn} [dB]	Cost [€]	L_{dvn} [dB]	Cost [€]	L_{dvn} [dB]	Cost [€]
53	30.6	62	126.2	71	277.3
54	42.1	63	135.8	72	294.6
55	51.6	64	147.3	73	313.7
56	63.1	65	156.9	74	330.9
57	72.7	66	168.3	75	348.1
58	84.1	67	177.9	76	382.5
59	93.7	68	187.4	77	399.7
60	105.2	69	198.9	78	417.0
61	114.7	70	208.5	79	436.1

3.3 Methodology application to a model example

The selected model example was a single-lane roundabout with four perpendicular branches formed by a two-way two-lane road. The assessment involved overall traffic volumes carried by the intersection ranging between 600 – 2800 veh/h, with a symmetrical distribution of traffic volumes into individual branches (i.e. in the ratio 1:1:1:1), intersection movements in the ratio 1:2:1 (left/through/right), the percentage of heavy vehicles being 4% in all branches. The terrain is considered as non-reflective, the longitudinal slope being 0%. The assessed intersection and individual traffic volumes are displayed in Fig. 4.



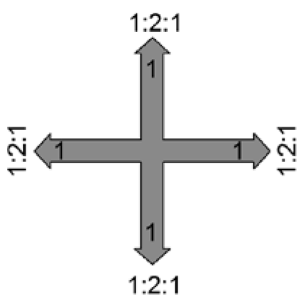


Figure 3 Assessed intersection and distribution of approach traffic volumes

The resulting values for individual approach traffic volumes are presented in the text and graphic format in Figure 5. An assessment of a four-leg four-way intersection with traffic lights was performed for comparison.

Volumes [veh/h]	Ldvn,int RA [dB]	Ldvn,int 4W [dB]
600	59.78	60.10
1000	61.02	61.31
1200	61.67	61.96
1400	62.26	62.52
1600	62.85	63.14
1800	63.30	63.70
2000	63.85	64.80
2200	64.29	-
2400	64.72	-
2600	65.24	-
2800	66.04	-

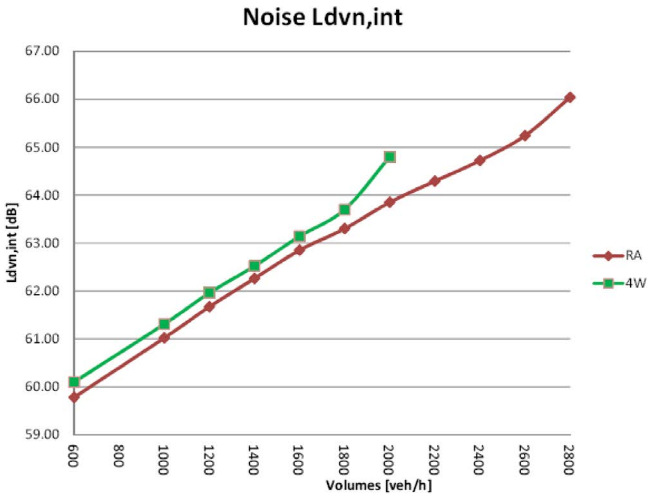


Figure 4 Assessed intersection and distribution of approach traffic volumes

Figure 5 also clearly shows the rapid growth in noise emissions after the intersection capacity was exceeded (for RA over 2600 veh/h, for 4W over 1800 veh/h). The assessment of the values once the intersection capacity was exceeded is pointless as computational methods operate with a free traffic flow and, therefore, congestion generated noise is subject to a considerable error. The difference in the distribution of individual noise levels is evident from Figure 6 showing a noise map for a model intersection at the overall traffic volumes carried of 1000 veh/ h (left) and 2400 veh/h (right).

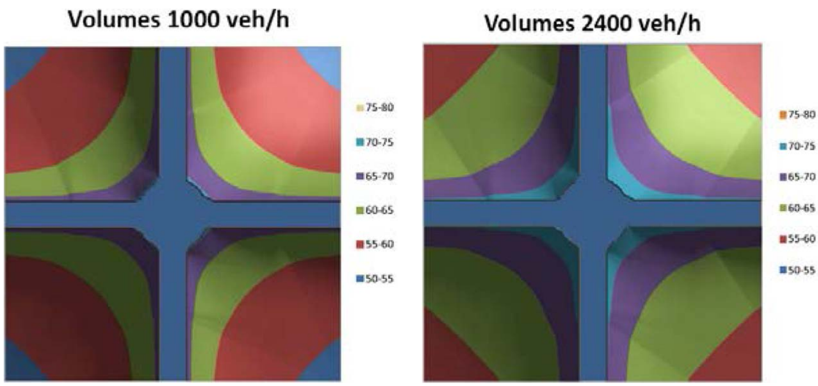


Figure 5 RA noise maps for 1000 veh/h and 2400 veh/h

4 Future application potential

The above procedure provides sufficiently valid data for the assessment of alternative design solutions of intersections under identical conditions. The application options are offered primarily to designers, traffic engineers and municipalities. No matter what the resulting data are used for: as input data for multi-criteria analysis or for a separate assessment in terms of noise emissions, we may say that the final evaluation will be valid and will identify the differences between individual design solutions considered. This methodology may appear more problematic in the determination of the actual impact of traffic on the surroundings. Here, a relatively large number of factors that can significantly affect the result enter the assessment (such as terrain reflectance, type and configuration of surrounding developments, density of population, etc.). Despite the fact that the calibration procedures verifying model results provided results within acceptable tolerance limits (ca up to 0.6 dB), sufficient accuracy of the model cannot be unambiguously confirmed. On the other hand, it must be added that this calculation model is sufficiently accurate and more suitable for the assessment of the impacts of car traffic in the area of intersections than the design methodology without any corrections. An even more accurate model results would be achieved only in the case of its interconnection with traffic engineering micro- and nano-simulation software where the movement of individual vehicles would have to be continually tracked and their impact on noise emissions defined in surrounding area.

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