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Estimation of the noise level produced by road traffic in roundabouts

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ABSTRACT

Many studies of the environmental impact in urban areas are related to road traffic noise. The noise generated by road traffic is more disturbing near junctions, where multiple flows are intersecting. It is largely accepted that converting a cross intersection into a roundabout the noise level will decrease. This article presents a study made on a hypothetic intersection, for two different configurations: signalized cross intersection and roundabout. The traffic flow data were detailed near and inside the intersection, using traffic flow speeds measured in real conditions, for passenger cars. The analysis was made using the noise mapping software LimA. The results show that there are differences in the resulted noise levels when the intersection is detailed and these differences may affect the measures that can be undertaken by the local authorities for noise abatement. In most cases even the changes in the road network should be preceded by such analysis.

1. Introduction

Road traffic is one of the major sources of noise pollution in urban areas. In order to reduce the impact of the traffic noise, the local authorities should adopt action plans based on the strategic noise maps [1]. In the last decade, noise mapping has become an important tool for predicting and control the environmental noise. How to obtain the noise maps, particulary for the noise generated by the road traffic, is described in the Good Practice Guide of WG-AEN [1], the Guide of CERTU [2], the Methodologic Guide for Road Noise Prediction [3], as well as in many articles and technical papers ([5,6]).

Road traffic noise may depend by several parameters. As described in literature (see for example [7]), some of these parameters are: the traffic volume, the traffic flow typology, the vehicles typology, the road and pavement features, the speed. These parameters are influenced by other parameters, like the speed limits, the amount and typologies of road intersections, the vehicles maintenance duties, the skills and behavior of the drivers. The influence of the speed on the noise is determined by two main factors [8]: the interaction between tires and road and the powertrain noise, influenced by the engine speed. The effect of the powertrain noise is much significant at low speeds, and this is the case in urban areas, where the vehicle accelerates more. When shifting to an upper gear, the noise will decrease for a while, until the engine speed rise again. On the other hand, when downshifting the transmission, the noise will be increased. This means that the noise generated by an individual vehicle is influenced by the driving pattern. A detailed description of the driving pattern influence on the generated noise is presented in the SILENCE project report [9].

The effect of noise on the environment is described using an energetic indicator that take into account both the noise level and the exposure duration. This indicator is the *equivalent sound level*, *LAeq*. Since the noise on a road vary from a time to another, *LAeq* is a conventional measure that represents the sound level which, if should be constant for the entire reference duration, will give the same acoustic energy like the fluctuating noise of the road. The equivalent sound level is expressed in dB(A), unit that consider the sensitivity of the human ear.

The measurable parameter that is at the base of the equivalent sound level estimation is the sound pressure level. This is calculated using the equation below:

$$P_a = 20 \cdot \log_{10} \frac{P_{meas}}{P_{ref}} \tag{1}$$

where P_a is the sound pressure level (in dB), P_{mas} is the measured sound pressure and P_{ref} is the reference sound pressure.

When the noise is generated by multiple sources, like many vehicles on the same road segment, the effect of summation of all sources is calculated using the relation:

$$P_{atot} = 10 \cdot \log_{10} \sum_{i=1}^{n} 10^{\frac{P_{ai}}{10}} \tag{2}$$

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The estimation of the noise generated by the road traffic can be made using statistical Traffic Noise Models, based on analyses performed on experimental data collected in some defined places. The models are usually implemented in noise mapping software.

1.1. Traffic noise predictive model

The noise map is realized by numerical simulation, based on input data that include the location and properties of noise sources, and also the obstacles that obstruct the noise propagation. To date, there are more calculation methods used in different countries. A review of the main traffic noise models is presented by Quartieri et al. in [10]. The European directive 2002/49/CE [1] suggest to use the official interim French standard model NMPB-Routes-96 [2] for the traffic noise prevision model.

The acoustic emitter in case of the road traffic is the street segment. The equivalent noise level can be calculated based on the nomogram shown in Fig. 1 and on the equations presented above (a logarithmic summation).

The nomogram (Fig. 1) is defined in CERTU Guide [2] as part of the traffic noise model, and represents the equivalent noise level Leq (1 h) in dB(A), in other words the noise emission. The model is implemented in the software used for simulation (LimA 7812). From the same nomogram it results that the noise emission depends by vehicle speed, traffic flow and the longitudinal profile of the road. This means that by doubling the number of vehicles that travel the same road section in one hour, means also doubling the power of the noise sources, which leads to an increase with 3 dB(A). In the figure are shown only the diagrams that corresponds to light vehicles, because the traffic flow inside cities is composed mainly by light vehicles, and also because the real data used for this study were collected with light vehicles. The speed in the diagram designates the average speed of a vehicle category on the analyzed road segment.

The traffic flow types include the steady-speed, where the speed of the vehicle or stream of vehicles is significantly constant, acceleration and deceleration. Inside cities the traffic flow can be generally considered to be pulsating and horizontal – this is the curve 2.1 in the nomogram. The reason is the high number of intersections, where the speed profile includes accelerating and decelerating phases. The noise generated by this type of traffic has a higher level at lower speeds because it involves many accelerations and decelerations (caused by a higher contribution of the power-train), and the effect of tyre-road interactions is not so important at low speeds. The decrease of the equivalent noise with the average speed, at low speed values, is also included and explained in the updated Methodologic Guide for Road Noise Prediction [3]. More detailed information about the influence of the acceleration on the noise emission of the vehicle can be found in the *Deliverable 11* of the IMAGINE project [4].

1.2. Noise in intersections

The intersection design may have a significant influence over the traffic noise. This influence should be included in the models of road noise implemented by different software. The modification of a crossroads (establishment of a crossroads, light signals or roundabout) can modify the noise emissions. Several studies, like those presented in [11–13] or [14], dealt with the influence of intersections on the traffic generated noise. More articles, mentioned in [12], concluded the following:

(a) A supplement of 2–3 dB(A) may be allotted to the noise level average of the two adjacent segments taking into account the transverse traffic. The improvement of the traffic fluidity (for example by roundabouts) can reduce noise with 2–4 dB(A).
(b) Some models or standards gives a 0–3 dB penalty near signal-controlled junctions, according to distance, others recommends a penalty of up to 7 dB for crossroads with traffic lights.
(c) The noise level close to a signal controlled junction was 2.4 dB(A) higher than a continuous equivalent traffic (a japanese report).
(d) The active adaptation of traffic lights according to vehicles speed (favouring the vehicles rolling near the speed limit) will reduce the noise level; the optimization of the traffic fluidity by traffic lights control can gain up to 2 dB(A).
(e) The transition from a fluid to a pulsated traffic mode (stop-go-stop) increases noise by about 2 dB(A), while judiciously installed traffic light decreases noise up to 2 dB(A).
(f) Compared to a continuous traffic (without intersection) the acceleration of the vehicles at the exit of roundabouts has a noise increase of 1–2 dB(A).
(g) The transformation of an intersection regulated by traffic lights or stops into roundabout makes possible a reduction of 1 dB(A).

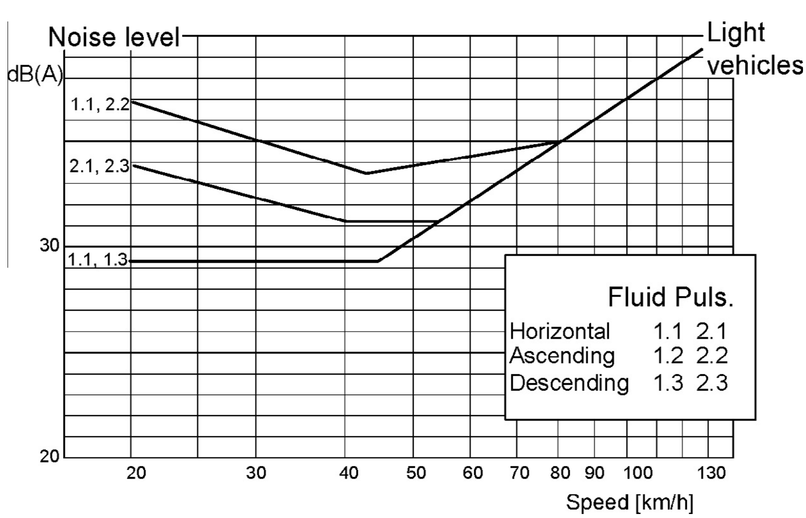

Fig. 1. Equivalent noise level as function of speed, according to [2].