Considerations about the Road Traffic Noise in a Roundabout versus a Signalized Intersection

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Abstract: - This paper presents a study made on a hypothetic intersection, for two configurations: signalized cross intersection and roundabout, in order to find the differences in noise which may affect the environment and the population nearby. The traffic flow data were detailed near and inside the intersection and an 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 noise reduction measures that can be undertaken by the local authorities. In some cases even the changes in the road network should be preceded by such analysis.

Keywords: - road traffic, noise, roundabout, intersection

1. Introduction
The main sources of noise in urban areas are: road traffic, railways, industrial facilities and airports. From these, the road traffic noise is the most annoying and difficult to control, since it is always present and are many individuals involved. There are many traffic noise models developed, based mainly on empirical and approximated approach [6].

Reducing the noise caused by road traffic in urban areas is not an easy task, since usually a single mean of abatement is not enough to reduce the noise sufficiently to achieve the desired levels. Many measures to reduce the noise level will result in small abatements, so the accuracy is very important. It is generally known that the road traffic noise is influences by the number of vehicles (the traffic flow volume) and the traffic speed. In urban areas, the influence of the speed on the noise is determined by two main factors [10]: the interaction between tires and road and the powertrain noise (influenced mainly by the engine speed). At higher speeds (highways) the interaction between air and vehicle body has also an important effect.

The relation of tyre-road noise versus vehicle speed follows a logarithmic law [10]. This means that there is a range of speeds where the noise is much affected by the tyre-road interaction. The influence of the powertrain is important when the vehicle accelerates. When shifting to an upper gear, the noise will decrease for a while, until the engine speed rise again. On the other hand, when down shifting 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 [1].

2. The traffic flow speed and the noise
The individual speed on urban routes follows basically a driving cycle that characterizes that area [3]. An example is given in Figure 1, showing the evolution of the vehicle speed versus time.

The diagram is composed by driving pulses, each pulse starting with an accelerating phase, then a short period of approximative constant speed, and is closing by braking (decelerating). This can be better seen in a speed versus distance diagram, like the example shown in
Figure 2. Obviously, the traffic flow in the city is not continuous.

Figure 1. Example of urban driving cycle [3]

Figure 2. Driving pulses on a speed/distance diagram

The Good Practice Guide for Strategic Noise Mapping, released by WG-AEN [12] recommends splitting the traffic noise sources close to the junctions, so that the accelerating and decelerating phases can be highlighted.

The method used in Romania for road traffic noise mapping is NMPB Routes-96 [11], the so-called “french method”. This method assumes a dependancy of the noise by the vehicle speed as in the diagram shown in Figure 3.

Figure 3. The noise generated by individual vehicles as function of speed [11]

As can be seen in Figure 3, the french model gives a high importance to the accelerations at low speeds (lower than 40 km/h), unlike other models [10]. So, considering a pulsating traffic flow, on horizontal roads, there will be a decrease of the noise level when increasing the flow speed from 20 to 40 km/h (here increasing speed means that the average speed of the traffic flow is higher, it is not an acceleration process).

In literature [1], [2], [7], [9] is generally considered that the road traffic in a roundabout generates less noise than in a cross intersection, because of the lower speed of the vehicles passing through. But the effect of the vehicles speed on the generated noise depends by the traffic noise model adopted.

3. Data acquisition and processing

3.1. Data acquisition

The traffic flow speed can be ascertained using various methods [10], and each method has a different accuracy. One of the recommended methods is to use a radar device and to ascertain the median speed V50 for the traffic flow. However, the V50 value in this case will characterize the flow in a single point, where the radar is located, and in most cases the speed will be measured on the middle of a road segment and will not be affected by the speed fluctuation on junctions. A better, more accurate method is to use an instrumented vehicle that follows the main traffic flow. The measuring device used for this study is a GPS receiver, with a sampling rate of 1 Hz.

The instrumented car was driven across main arterial roads in the entire city, in order to obtain traffic data that are representative for all the main urban roads. Then the area close junctions were detailed, for signalized cross intersections and for roundabouts.

3.2. Data processing

The global results are represented in Figure 4, as the diagram of frequency distribution and diagram of cumulative frequency distribution. The average speed can be calculated from the diagram of frequency distribution using the formula (1) below

\[ \bar{V} = \frac{\sum N_i v_i}{N} \]  

where \( \bar{V} \) is the average speed, \( N_i \) is the absolute frequency of observations in the speed group \( i \), \( v_i \) is the middle value of speed in the group \( i \) and \( N \) is the total number of observations.
The median speed $V_{50}$ can be obtained directly from the diagram of the cumulative frequency distribution [5].

**Figure 4.** Frequency distribution and cumulative frequency distribution for speed values measured on the major urban roads [5]

For junctions, it is important how large is the area considered, or which is the distance from the junction point. In Figure 5 is presented the speed-distance diagram in an intersection that was initially signalized with traffic lights and was converted to roundabout. The intersection area starts with a braking sequence and is closed after accelerating, when the speed tends to stabilize (in this example at 40-50 km/h).

**Figure 5.** Example of speed versus distance diagram over an intersection

The diagrams of speed frequency distribution and cumulative frequency distribution in intersection are shown in Figure 6 and Figure 7, for a signalized and roundabout intersection.

**Figure 6.** Speed frequency and cumulative frequency distributions for an intersection signalized with traffic lights [4]

**Figure 7.** Speed frequency and cumulative frequency distributions for a roundabout [4]

The average speed ascertained using the formula (1) is 37.7 km/h, and the $V_{50}$ value for the same data is 37.5 km/h.

For the junction area, the values are:

- traffic lights: average speed=33.3 km/h, $V_{50}$=35.2 km/h;
- roundabout: average speed=27.5 km/h, $V_{50}$=27 km/h.

In case of a cross intersection signalized with traffic lights, $V_{50}$ is close to $V_{50}$ ascertained for the entire route (35.2 km/h versus 37.5 km/h).

In case of a roundabout, the difference between the two $V_{50}$ values is significant (27 km/h versus 37.5 km/h). In this case, the diagram in Figure 3 indicates a difference of about 1.5 dB in the equivalent noise produced by a single light vehicle for an hour. For more vehicles, the total equivalent noise is obtained by logarithmic summation.

The long term sound level at the receiver in dB(A) is calculated using the formula (2):

$$L_{Aeq,LT} = 10 \log \left( \sum_{j} 10^{0.1L_{eq,LT}(j)} \right)$$  \hspace{1cm} (2),

where suffix $j$ denotes the six octave bands.
from 125 to 4000 Hz. This sound level, $L_{Aeq,LT}$, is the wanted final result that is the long term sound level at the receiver point.

According to the report of the UK Noise Association (Mitchell) [8], for a single vehicle 1 dB change in loudness is only perceptible under laboratory conditions, but on a busy road, with a mix of traffic, a reduction of 1 dB can be noticeable because it signals a reduction in the number of disturbing noise events.

4. Simulation

The intersection considered for this study has the configuration in Figure 8. All the entries are considered identical, with the same traffic volumes (1800 vehicles/hour) and the same speed. The goal is to compare the noise generated in this intersection with the noise generated after the intersection is transformed into a roundabout, like in Figure 9. It is considered that the overall width of each road segment is less than 15 m (two lanes per each direction), so it is used a single emission line for each road segment.

The emission lines for roundabout (Figure 9) are approximated to straight lines. The traffic flow median speed ($V_{50}$) is 37.5 km/h for the first case, the value ascertained for all the major roads in the city. Many experts who develop strategic noise maps don’t use to detail the roads near junctions. This approach is right for simple cross intersections, for which the median speed ascertained was close to the median speed for the other road segments.

In case of roundabout the median speed used is 27 km/h, as presented above.

The software used for noise mapping was LimA and it was configured to use the NMPB Routes-96 noise model.

For the first case, the noise level obtained in the intersection and in surrounding area is shown in Figure 10. As can be seen, the highest noise level (over 75 dB) is obtained in the center of intersection, where the emission lines are intersecting.

For the second case, the noise level is shown in Figure 11. The highest noise level (over 75 dB) obtained in roundabout is obtained along the emission lines that approximate the roundabout; this maximum value is not the effect of...
summing the emissions of two intersecting lines, but the effect of the multiple accelerations and brakings (resulting in a lower value for V50). So the results obtained with LimA software is in concordance with the diagrams in Figure 3.

The differences in noise emissions between the two versions of the intersection are better shown on a difference map. The noise maps presented here (Figure 10 and Figure 11) consist in a raster with the cell size of 1 m. The difference map represents the difference in noise level for each point in the raster, with a step of 1 dB (Figure 12).

![Figure 12. Difference map for Lden in both cases, detail](image)

The differences in the junction area depend mainly by the position of emission lines. Obviously the noise is higher where the emission lines are intersecting each other and along the emission lines simulating the roundabout (+/-3dB). A 3dB change in loudness is very noticeable, but when this is exactly on the road, it is not relevant. Most important is the effect of the noise on the surrounding area, including the buildings.

In this study the buildings were not taken into account nor as reflecting obstacles, nor as receivers. However, there is a significant area around where the equivalent noise level is 1 dB higher in case of roundabout.

5. Conclusions

Speed plays a significant role in causing road traffic noise. Many studies indicate that a higher speed means higher noise level. The acceleration is also important, especially at low speeds. The speed records made with an instrumented vehicle along all major roads in a city show many variations in speed when the vehicle passes through road junctions. These variations mean higher acceleration values. In the urban traffic where the average speed is low (30-40 km/h), the noise is influenced both by speed and acceleration.

This research shows that is false to consider that a roundabout means lower noise than in case of a cross intersection. However, other traffic noise models may give different results. But when the intersection is located inside an urban agglomeration, transformation of the existing cross intersection into roundabout will move the emission lines closer to the buildings (and inhabitants) located nearby.

On the other hand, the differences between noises levels in the two cases analyzed here are lower than the maximum difference admissible between the estimated noise level and the measured noise level, which is 3 dB. This doesn’t mean the difference is too low and the intersections can be neglected in the strategic noise maps. This difference demonstrates that the accuracy of traffic data collected is very important. Inaccurate data will give inaccurate results.

Future studies may consider also the buildings near intersection, since the buildings affect the noise as reflecting obstacles, and the buildings facades are the supports of the receivers used to estimate the population exposure to various noise levels.

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