DOI: 10.61782/fa.2023.0055

forum acusticum 2023

A SYNTHESIZED ROAD TRAFFIC NOISE SCENARIO FOR HEALTH IMPACT ASSESSMENT

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ABSTRACT

Within the Horizon 2020 project LEON-T (Low particle Emissions and lOw Noise Tyres), one of the aims is to investigate the effect on cardiovascular health from the effect on sleep of noise from heavy vehicle (EU class N2 and N3) tyres. Effects of noise on sleep are investigated by performing sleep experiments in a controlled lab environment where participants sleep several nights subjected to different traffic noise scenarios. The traffic noise scenarios have been constructed using synthesized tyre noise allowing for variation in parameters such as tyre tread pattern design, tyre air cavity resonance, traffic flow properties and distance between traffic noise source and receiver. The synthesized scenarios have been designed in close cooperation with experts on health effects from noise in order to expose the participants to such stimuli that provide relevant and valid responses. For the initial sleep experiment properties such as high or low traffc flow, individual vehicle noise level and level of perceptually salient tonal components in the synthesized tyre sound are investigated. This paper describes the synthesized vehicle sounds and the traffic noise scenario design process for the scenario used in the first sleep experiment.

Keywords: *noise, health, tyre, synthesis*

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1. INTRODUCTION

This research is part of the ongoing European project “Low particle Emissions and lOw Noise Tyres” (LEON-T) financed under the Horizon 2020 programme. The project aims to among other things address the issue concerning noise and health: “Evaluation of traffic noise effect on the cardiovascular system, assessing which type of noise (impulsive or background) has the most consequence on health [...].” The ”background” case is interpreted as corresponding to a relatively steady traffic flow - in this paper referred to as ”continuous”, and the ”impulsive” case is interpreted as several clearly separated vehicles passes with periods of silence between them.

Nighttime noise is of great importance for the impact on health which is correspondingly reflected in the european noise indicator L_{den} where noise occurring during night is given a 10dB penalty on top of calculated noise levels, in accordance with the European Environmental Noise Directive [3].

Noise exposure from road traffic is affected by many factors and can be very complex to determine precisely. The most common way to predict community noise exposure is by using some method for calculating the strength of the noise source from traffic intensity and combining that with a sound propagation model taking into account how sound is affected by reflection, refraction, diffraction and absorption. Several such methods have been developed that feature different levels of detail for describing the vehicle sources and the sound propagation between roads and nearby dwellings, most recently Common NOise aSSessment methOdS (Cnossos-EU) that is to be used in all noise exposure mappings according to the Environmental Noise Directive [4]. Most noise assessment calculation methods are based on statistical data of traffic flow to represent a yearly average day, most often denoted Annual Average Daily Traffic (AADT). Some calculation methods, Cnossos-EU among them, take into account variation in traffic flow during that average day in order to assess noise exposure during day (06.00 - 18.00), evening (18.00 - 22.00) and night (22.00 - 06.00) separately. Thus the traffic flow is described as number of vehicles per hour for each period of the day. Naturally, the traffic flow will differ from these conditions for a specific day, and the corresponding noise levels will be higher or lower than the predicted levels accordingly, but the overall average exposure should ideally be close to the predicted levels.

As an example, the non-profit environmental organization Brutiparif provide interactive maps visualising both calculated (https://carto.bruitparif.fr/) as well as measured (https://rumeur.bruitparif.fr/) noise levels from different sources such as road, rail and air traffic. Bruitparif issues reports of noise exposure from the calculations and these show that a little more than 700000 individuals are exposed to levels above 60 dB L_{night} [5]. The highest exposure likely occurs close to roads with a traffic flow of several thousand vehicles per hour at night even though traffic typically calms down compared to daytime. The calculated levels are given as outdoor levels at the façade, but the actual sleep disturbing exposure of course occurs indoors. Different countries apply different regulations for indoor noise levels and different standard values for facade reduction to translate between outdoor and indoor levels [6].

In addition to exposure level, there are other factors that may be of importance to the perception and annoyance or even health effects from noise. In the LEON-T project one such factor that is investigated is tonality. It is common knowledge that tonal sounds may be perceived more annoying than more stochastic sounds, something that is reflected in many national noise regulations which add a penalty of a few dB for tonal noise. There is also a connection to the design of vehicle tyres, since the design of the tread pattern may result in prominent tonal components in the tyre noise. The question is if tonality also affects sleep more than just level and impulsive/continuous character.

The synthesis of traffic noise for health impact assessment within the LEON-T project has been previously described in [7]. Using this synthesis technique, stimuli for the first sleep study within the project was developed based on traffic flows and levels prevalent inthe EU member states, and is presented in detail in this paper.

2. METHOD

Two traffic flow scenarios where developed to represent the two traffic flow situations corresponding to ”impulsive” and ”background”, or ”continuous”, traffic noise cases specified in the call.

2.1 Noise levels

Indoor noise level limits at night vary between countries, and in order to cover a couple of different situations it was decided that either of two different overall indoor noise levels should be set for each night. The levels chosen were L_{night} = 35 dB(A) and L_{night} = 40(A) dB. In addition to the overall level, each individual vehicle pass for the impulsive scenario was given one of four levels for each over all level Tab. 1.

Table 1. Levels of individual vehicle passes used in the impulsive scenario.

L_{night} = 35 dB(A)	L_{night} = 35 dB(A)
53.4	58.4
54.9	59.9
56.4	61.4
57.9	62.9

The slightly varying levels of the continuous scenario were determined by slight randomisation in the individual vehicle speed and in the Poisson distribution of individual vehicle passes. The overall level was calibrated to either L_{night} = 35 dB or L_{night} = 40 dB. The L_{night} levels for the sleep study are indoor values. A façade filter was applied to all sounds in order to achieve a correct indoor spectrum as well as indoor overall noise level. The level reduction of the filter was 25dB(A) which is a common standard value when calculating indoor noise exposure from outdoor noise levels, e.g. according to the Swedish National Board of Housing, Building and Planning [8]. The corresponding outdoor levels would thus be L_{night} = 60 dB and L_{night} = 65 dB respectively which is not uncommon in larger urban areas in the EU such as in central Paris.

2.2 Tonal components

Tab. 2 shows the tonal component frequencies and relative levels. Tones where added to one synthesized tyre sound with low tonality, so as to keep everything fixed apart from the tonality. Here, the term "tonality" is only used to refer to the added tonal components of specific frequency and level. The tonal components were added so that the level of the fundamental frequency (208Hz as given in Tab. 2) was set to either 1.5dB or 3dB above the synthesized tyre sound at the corresponding frequency, resulting in three tonality levels when combined with the original synthesized tyre sound used as "low tonality" stimulus. Adding tonal sound of course adds to the overall level of the sound, so the most tonal sounds were louder than the less tonal sounds. This is a common problem when designing auditory stimuli - it is very difficult to vary different aspects or characters of a sound without varying level, which will then influence the outcome as it is hard to know if it was the level or some sound character that caused the response. On the other hand, keeping overall level constant and varying character by e.g. adding tonal components will affect the levels of the non-tonal part of the sound and thus affecting perceived level of the entire sound. In this study we chose to simply add tonal components and thus increase level, but as we also included varying level for non-tonal sound we hope to have covered both dimensions separately.

Table 2. Tonal component frequencies and relative levels.

Frequency [Hz]	Relative level [dB]
208	0
392	-7
588	-9
802	-12

The resulting sounds have not been submitted to any tonality calculation such as defined in DIN 45681 or ECMA-74, but have rather been designed according to physical properties such as tonal componen frequency and level.

2.3 Traffic flow

A really busy highway can have several thousand vehicles passing each hour, even at night. For the continuous scenario we aimed at 1000 vehicles per hour, giving a stimuli that through informal listening was decided to give a realistic impression of a high traffic flow and also representing a large number of highways around Europe. If we assume that about 10% of the traffic flows during the night, the 1000 vehicles per hour corresponds to about 80000 vehicles per 24h which is not extremely high, but also not extremely low, and thus reasonably representative. Using a very simplified noise prediction calculation the 1000 vehicles per hour would result in outdoor L_{night} = 65 dB at a distance of a few hundred meters depending on propagation conditions, and even further for L_{night} = 60 dB. The synthesized continuous traffic flow scenario was based on a mix of 80% passenger cars (EU category M1) and 20% heavy vehicles (EU category N3), in order to achieve a realistic impression of a busy highway traffic flow.

The impulsive scenario was aimed at representing a urban or suburban street very close (10-20 meters) to the façade of the nearby dwelling, as is common i e.g. so-called city street canyons. For the impulsive scenario only heavy vehicles (EU category N3) were used, as they are part of the main focus of the LEON-T project. It was decided to limit the traffic flow to just 12 vehicles per hour, corresponding to combinations of the four levels and three tonality levels chosen. Calibrating to the same overall indoor L_{night} levels as for the continuous scenario, the combined variations in level and tonality resulted in individual vehicle pass maximum levels, L_{AFmax}, between 53.4 and 67.4 dB. Of course, an indoor level of L_{AFmax}=67.4dB with a façade reduction of 25dB(A) would mean a corresponding outdoor level of 92.4dB(A) and it is unlikely that a single vehicle would reach such high levels even passing just outside the dwelling, but this was intentionally done to provoke biomarker responses which are often relatively faint.

The speed of the simulated vehicle passes was set to around 90 kph for both scenarios, with a slight random variation for each individual vehicle in the continuous traffic flow. The reason for keeping the speed constant is that the rise time for a sound event is an important factor in triggering detection and eventually awakening. Having heavy vehicles passing close to a façade in 90 kph is likely not very common. Such urban streets mostly have a speed limit of 70 kph or even 50 kph. However, due to the fact that the rise time should be kept constant and also because the individual vehicle levels was intentionally set very high for the impulsive scenarion, it was decided to set the speed accordingly.

3. RESULTS

Fig. 1 shows the resulting traffic scenarios as level vs time. As can be seen, and indeed as expected, the continuous scenario varies relatively little in level, whereas the impulsive scenario is virtually silent with occational high level peaks.

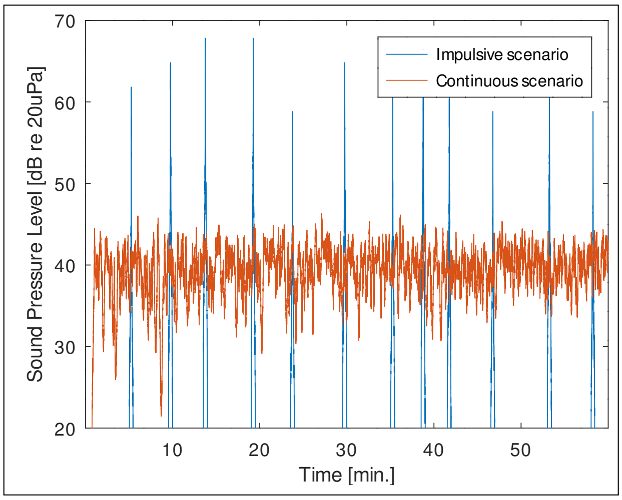

Figure 1. Impulsive versus continuous traffic flow scenarios at the same 40 dB(A) equivalent level.

Fig. 2 show spectra for the continuous traffic flow scenario, and for the loudest and the softest single vehicle pass in the impulsive scenario respectively. The absolute levels are of less importance as for the impulsive scenario the depend on the size of the time window applied around each peak, but the spectra give information about the differences in spectral content between the different individual synthesized vehicle passes. The continuous scenario did not contain any added tonal components, but each individual vehicle pass included in the continuous scenario was given a small random difference in velocity, resulting in both a spectral and a level variation. The stimuli were used in the first sleep study within the LEON-T project where participants were subjected to the two different scenarios on different nights while sleeping in the Sound Environment Laboratory at the University of Gotheburg [2]. Data collection from the sleep study seems to have been successful and indicates that the stimuli were suitable for their purpose. Statistical analysis of the different biomarkers collected is currently ongoing and some preliminary results will be discussed during the presentation at Forum Acusticum in Turin.

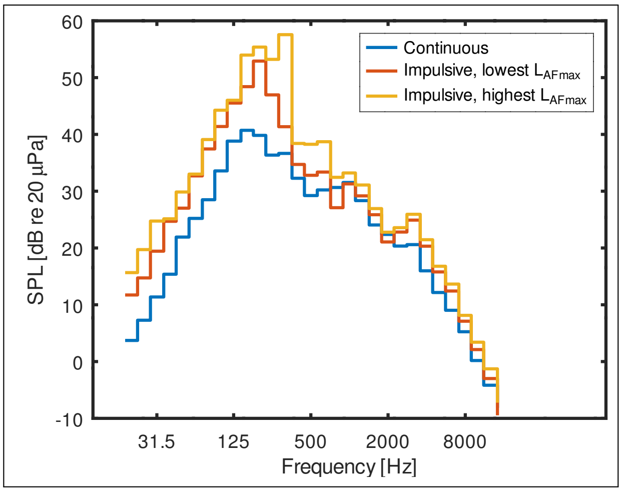

Figure 2. Spectra for the continuous traffic flow scenario, and for the loudest and the quietest single vehicle pass in the impulsive scenario respectively.

4. ACKNOWLEDGMENTS

This research has been funded by the EU Horizon 2020 SOCIETAL CHALLENGES - Smart, Green and Integrated Transport research program, grant agreement ID: 955387..

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