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Low frequency noise impact from road traffic according to different noise prediction methods

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HIGHLIGHTS

- Low frequency noise (LFN) from road traffic is simulated with many mapping methods.
- The difference between C- and A-weighted levels is analyzed in several scenarios.
- Values are provided within virtual and real scenarios and for Pisa city center.
- LFN may increase in mitigated areas according to a new method and the Nord2000.
- Correct power spectra in methods are paramount in order to use the C–A indicator.

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ABSTRACT

The European Noise Directive 2002/49/EC requires to draw up noise action plans. Most of the implemented solutions consist in using barriers, even if some studies evidenced that annoyance could increase after their installation. This action dumps the high frequencies, decreasing the masking effect on low ones. Therefore, people annoyance and complaints may increase despite the mitigation. This can happen even in pedestrian zones near main roads due to the screening effect of first buildings row.
In this paper, the authors analyze the post-operam screening effects in terms of low frequency noise. The difference between C- and A-weighted levels is calculated as annoyance indicator (L_{C-A}). Different methods able to map noise with octave bands detail are tested in order to establish differences in the estimates of annoyance exposure. In particular, a comparison is carried out between data from interim method NMPB 96, its updated version 2008, NORD 2000 and those provided by a customized procedure through ISO 9613 propagation and Statistical Pass By measurements. Test sites are simulated in order to validate each model results through measurements. Results are discussed for real locations in Pisa city center and virtual scenarios in a rising scale of complexity.

1. Introduction

The need of a reliable noise prediction method has been pointed out after the two starting rounds of Noise Mapping according to the 2002/49/EC Directive. In addition to the difficulties in comparing results of different national methods, the inapplicability of interim method without calibration arises in local contexts. Thus, CNOSSOS-EU methodology has been set up by JRC (Kephalopoulos et al., 2012), on behalf of European Commission, to provide a common methodology. However, this methodology still lacks of implementation in commercial software and of application in legal terms due to the Member States resistance to change, though some software and validation tests were performed.

Apart from the potential developments that may come in the future from the EU commission, this paper analyzes mapping methods using also the outcomes of the local LEOPOLDO project (LEOPOLDO). This project was cofounded by Tuscany Region (Italy) and started in 2005 to develop a detailed knowledge of traffic noise and to implement actions including low emission pavements. Its specific goal was to evaluate absorbent and low emission asphalts as a mitigation action by means of different measurement techniques and to assess the most reliable method. One of the most relevant side outcomes of this project is a large database of vehicle emission, measured according to the Statistical Pass By (SPB) methodology (I. O. for Standardization, 1997). This database not only will constitute the base to eventually verify CNOSSOS implementation in Tuscany, but also is suitable at the moment to evaluate accordance between available models and measured noise emission.

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The previous comparisons (Licitra et al., 2011; Ascari et al., 2010) have shown a significant difference between interim method and spectra measured with SPB techniques, especially in low frequency bands.

Evaluating correctly the whole spectrum, especially the low frequency emission, is crucial because noise effects as annoyance or sleep disturbance increase with low frequency noise (LFN) predominance (Persson Waye and Rylander, 2001). Furthermore, LFN annoyance may arise at lower sound pressure levels than high frequency dominant noise (in rural areas not so far from highways, behind barriers, inside homes). This means that many mitigation measures, reducing noise energy, may not improve noise quality nor decrease annoyance (Nilsson et al., 2008).

In literature, LFN generally indicates a broadband noise with sound energy dominating at 10–250 Hz (Pawlaczyk-Luszczynska et al., 2003; Leventhall et al., 2003): potential sources of LFN are ventilation system, pumps, compressors, diesel engines and transportation vehicles too. In particular, the importance of evaluating the impact of low frequency noise from road traffic is confirmed in several studies and the Dutch study (Schreurs et al., 2008) L_{C-A} maps of the whole Dutch Highway network are presented. Road traffic is largely studied as low frequency source also by Nilsson et al. (Nilsson, 2007; Nilsson et al., 2008; Nilsson and Berglund, 2006). These studies not only underlined that LFN annoyance is reported in several contexts, but they also assert that it is more intensive than noises without dominant low frequency components (Persson Waye and Rylander, 2001). These studies reported how self-assessed annoyance increases also if a barrier is installed due to the turning up of low frequency noise predominance, since high frequencies are dumped by the barrier.

The L_{C-A} is the main indicator identified by Nilsson to relate the annoyance rate difference between barrier and non-barrier situations. It was previously used by different authors, particularly by Kjellberg et al. (1997) that also found a relation to correlate the annoyance perceived to this indicator.

Furthermore, LFN has objective effects on humans such as permanent hearing threshold shift, behavior, sleep period, task performances and social attitude as monitored in several studies (Alimohammadi et al., 2013; Kaczmarska and Luczak, 2007). Moreover, the participants surveyed within these works reported some concentration problems and annoyance if exposed to low frequency noises during working activities. At the same time these studies also reported improved mental performances due to the increased arousal of participants. All these studies evidenced that LFN could be a source of stress.

The importance of being able to predict low frequency is stated in the literature. Instead only few studies reported modeled values and to date there is not enough literature on low frequency mapping accuracy issues. This study identifies the most critical situations which are relevant to have a reliable method to estimate LFN. It also aims to assess in what extent noise maps are able to predict LFN exposure, comparing the outcomes of different methods and highlighting their pros & cons.

In addition to the interim method (NMPB 1996), other standard methods available have been calculated as the NMPB 2008 and the Nord 2000. Furthermore, authors developed a simple tool to obtain emission spectra of roads according to LEOPOLDO database using a modelization with ISO9613 linear sources. This experimental method is tested and compared with official methods results.

Tests are performed on virtual and real scenarios in a rising scale of complexity, ending with noise maps for Pisa city center (a Tuscany small city used as test case in previous studies). Results point out the LFN contribution according to the difference between C- and A-weighted levels (L_{C-A}), which is considered to be suitable to evaluate annoyance due to a low frequency content also for road noise (Schreurs et al., 2008; Yifan et al., 2008).

The aim of this paper is to evaluate the noise levels produced according to different methods in terms of L_{C-A}. A complete L_{C-A} map is reported for Pisa city center. Besides that, the final goal of the ongoing study is to provide a tool able to show a correlation between L_{C-A} hot spots, specific position of the building in the urban fabric, annoyance reported and health effects.

2. Methods

The comparison of different prediction methods is performed step by step, from simple to more elaborated and real contexts.

At first, a comparison of the methods estimates in a free field condition is needed. In this context, A-weighted levels, C-weighted levels and spectra are evaluated for light and heavy vehicles according to all the tested methods. The calibration is carried out for two measurement positions:

1. the first is positioned as the microphone of the measurements campaign of the Statistical Pass By (7.5 m far from central line, 3 m height, according to HARMONOISE methodology Jonasson, 2004), hereafter named R1;
2. the second is positioned at the reference distance of the NMPB interim method (30 m far from central line, 10 m height), hereafter named R2.

In order to verify the coherence of the methods to the measurements, a comparison with on site simple measurements is carried out. This test is performed both for measurements of direct noise and in screened situations (behind noise barriers) to verify the accordance of screening formulas provided by methods, i.e. the reliability of mapping models.

Then, the differences in screened and more complex urban configurations are tested on ad hoc scenarios, established by JRC for method equivalence check (Paviotti and Kephalopoulos, 2008). Through those simulations, principal differences of methods in terms of LFN will be highlighted. Within JRC proposed scenarios, the *city flat* scenario has been chosen because it includes several configurations of buildings and barriers, providing enough complexity and, at the same time, having no altitude variations which are beyond the aims of this paper. Finally, noise maps for Pisa city center are analyzed in terms of LFN impact in specific areas.

The similarities and differences between methods on these maps are going to underline the challenges of estimating LFN for road traffic.

2.1. Calculation methods

All the simulations presented in this paper have been carried out with the software SoundPLAN 7.1. Differences could be found with other noise mapping software (Marsico et al., 2010).

All calculations have been done at fixed temperature (10 °C) and humidity (70%), assuming no correction for favorable propagation. Only the first reflection has been taken into account and, if not specified further, a ground absorbing factor of 0.5 and building absorbing coefficient of 0.2 have been considered.

The asphalt type depends on the applied method: we have generally chosen the type of asphalt within each method that does not apply correction to the source power level. This solution is in accordance with the local procedure that actually does not implement asphalt correction. Implemented methods with their settings are briefly described in the following.

2.1.1. NMPB 1996

The “Nouvelle Method de Prevision du Bruit” (NMPB 1996 Cetur, NMPB-Routes-96, 2000) is based upon Guide de Bruit (CETUR, 1980) database and it is the official interim method for the implementation of the 2002/49/EC (to be used by those countries which do not have their own standard). It has been chosen by EU commission because it has the advantage of taking into account both frequency propagation and tested meteorological corrections, requirements fulfilled by few other methods. However, the sound power level database is quite obsolete and weighted traffic flows have to be used in many applications to