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CNOSSOS-FR: are current road traffic noise emission coefficients still representative of today's vehicle fleet and roads?

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ABSTRACT

CNOSSOS-EU is the common noise prediction method for producing strategic noise maps in Europe, according to Directive 2002/49/EC. Its road vehicle noise emission model involves a propulsion noise component and a rolling noise component, with coefficients specific to each vehicle category. As currently applied in France, it relies on the original EU coefficients published in the 2015 CNOSSOS-EU version and the rolling noise contribution is detailed in road surface classes in agreement with the national NMPB2008 method. As provided in the European method, corrective coefficients in frequency bands were determined per road surface class. The objective was to minimise the overall difference between NMPB2008 and CNOSSOS-FR emission predictions under similar conditions, the former method being previously used for periodic mapping. Now considering the later release of new EU reference coefficients and the difficulty of making the two methods involving different expressions and assumptions coincide, as well as questioning the need to update emission values resulting from measurements of the vehicle fleet taken 20-25 years ago, the study MINOOS is being carried out to assess the noise emission of the current vehicle fleet and reconsider French prediction coefficients accordingly. The paper describes the procedure and presents the first results.

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1. INTRODUCTION

1.1. European context

CNOSSOS-EU is the European method for the production of strategic noise maps and the determination of exposure to environmental noise according to Directive 2002/49 CE [1]. It was published in Directive 2015/996 [2]. Concerning road traffic, the method provides a prediction model for vehicles' noise emission, those being separated in four categories, to be connected to a sound propagation model in the environment.

The noise emission model of road vehicles consists of a propulsion noise component and a rolling noise component, both expressed by equations that are functions of the driving speed and based on coefficients given by vehicle category and octave band. In each category, these coefficients describe the noise emission from an average European vehicle in specified reference conditions. Default coefficient values are given in the appendix of Directive 2015/996 (Table F-1), derived from measurements on traffic vehicles, controlled vehicles or bench testing, carried out in several European countries and resulting from the European projects HARMONOISE (2001-2005) [3] and IMAGINE (2003-2006) [4].

In order to adapt the emission values to different road surfaces and regional specificity, the method offers the possibility of introducing corrective coefficients affecting mainly the rolling noise component³. Default values of these correction coefficients are proposed for a list of road surfaces in use in the Netherlands (Table F-4 of the Directive). No regional adaptation is a priori planned for the propulsion noise component.

After 2015, technical adaptations were identified as necessary and a delegated Directive was published at the end of 2020 [5], introducing changes to the default coefficient values originally given in tables F-1 and F-4. This induced an increase of the predicted overall noise levels, relatively to the former version in the same reference conditions, of around 1.7 to 2.8 dB(A) over the speed range for light vehicles and 2.5 to 3.7 dB(A) for heavy vehicles.

1.2. French context

NMPB2008 is the French method for acoustic impact studies of road infrastructures [6]. Noise emission from road vehicles are described by an engine noise component and a road noise component. The engine noise component for the two categories of road vehicles (light vehicles and heavy goods vehicles) at constant speed results from measurements carried out on a sample of vehicles studied under controlled conditions, in 1997-2000 for light vehicles and in 2000 for heavy goods vehicles. The rolling noise component is based on the content of Cerema's "rolling noise" database at the time the method was developed, broken down into six classes of road surfaces.

The acoustic power of a vehicle's noise emission, for each of the two components, is given as an overall level. The frequency distribution in third octave bands applied to the total noise is identical for cars and trucks, at all speeds and without differentiating the noise component, the only parameter being whether the road surface is absorbant or not. The NMPB2008 method was used as an interim method for producing French strategic noise maps according to Directive 2002/49 EC before CNOSSOS-EU became available.

The French transposition CNOSSOS-FR of the European method adapted, as permitted by the directive, the CNOSSOS-EU noise emission model to national road surfaces by means of the corrective coefficients provided for this purpose (extension of Table F-4), with the essential concern that the change in calculation method from interim to the European method should not induce major differences in the noise maps produced, all other things being equal. These correction coefficients were determined relatively to the reference values given in Table F-1 of CNOSSOS-EU. In accordance with NMPB2008, the same road surface classification was used and

³and secondarily the propulsion noise for absorbing surfaces only.

the corrective coefficients minimising the differences between the sound power levels produced by CNOSSOS and NMPB2008 were determined for light and heavy vehicles [7].

The aforementioned European delegated directive, published at a later date, made the French corrective coefficients inconsistent with the updated references for vehicle noise emission. In the end, the current version CNOSSOS-FR refers to the basic CNOSSOS-EU tables of the 2015 version to preserve, as far as possible, numerical equivalence with NMPB2008 [8].

1.3. Motivation and outline

The time scale since the development of the French and European prediction methods as well as the recent sequence of versions, which has led to compromises, raise questions about the appropriateness and the potential for improving the current French model CNOSSOS-FR. This has motivated the project MINOOS.

This paper presents the objectives and the content of the MINOOS project in section 2. Then, in sections 3 and 4, the progress and some results are presented for propulsion noise and rolling noise respectively.

2. THE MINOOS PROJECT

A re-examination of the existing data relating to noise emissions from road vehicles in the CNOSSOS-FR method appeared necessary, considering that :

- Current data from road vehicle noise emission models, both in France and in Europe, are based on a fleet and road infrastructure situation that was established twenty or more years ago. During this period, vehicles have undergone significant technological development, in parallel with stricter regulatory requirements.
- Due to discrepancies in the respective emission models, the French adaptation of CNOSSOS-EU using the NMPB2008 method leads to physically questionable coefficients in several cases, which attempt to compensate numerically for the mismatches.

The aim of the MINOOS project is to assess the need for and, where appropriate, to define relevant road noise emission data for CNOSSOS-FR:

- in line with the current French road situation (vehicle fleet, road surfaces),
- scientifically satisfactory and consistent in terms of both frequency and speed.

The MINOOS approach consists of two phases:

1. Assessment and update of current knowledge on noise emissions from road vehicles, based on measurements carried out on samples of vehicles :
 - propulsion noise, with vehicles representative of categories 1 (light vehicle) and 3 (heavy vehicles) under controlled conditions ⁴,
 - rolling noise, obtained statistically from traffic vehicles of categories 1 to 3.
2. Determination of updated coefficients for the CNOSSOS-FR emission model, relevant to the objectives specified above and directly derived from the results obtained in phase 1:
 - Propulsion noise and rolling noise coefficients under reference conditions for vehicle categories 1 and 3 (Table F-1 of the Directive),

⁴The semi-heavy vehicles (cat. 2) have already been explored recently [9].

- Correction coefficients for French road surface classes differing from the reference conditions (Table F-4 of the Directive).

The direct determination of the coefficients is carried out without an intermediate use of the NMPB2008 method, thus bypassing the discrepancies between the models.

3. PROPULSION NOISE COMPONENT

This part of the study focuses on propulsion noise. Rolling noise, although taken into account, is not analysed specifically.

3.1. Approach

For the two vehicle categories considered, the approach is carried out similarly. A selection of recent vehicles in each category is studied in controlled pass-by (CPB) conditions at constant speed on test tracks, the setup being in accordance with standard ISO 11819-1:2002 [9]. For each vehicle, the noise received by microphones at roadside is recorded in conditions combining various speeds and gearbox ratios. Subsequently, the separation of the propulsion noise component from the rolling noise is achieved in octave bands, by considering that propulsion noise depends essentially on engine speeds while rolling noise depends on vehicle speed, with the gearbox disconnecting these two variables and creating two degrees of freedom. Finally, an average propulsion noise contribution from the vehicle category is determined in octave bands and the CNOSSOS-FR coefficients A_P and B_P are identified in accordance with the European prediction model. As a reminder, the same approach was already used previously for semi-heavy vehicles (CNOSSOS-EU category 2) [10].

For light vehicles, 16 vehicle models with internal combustion engines have been tested, from French or foreign carmakers, including 14 passenger cars with segments A to E (including SUV and MPV versions ⁵) and using either diesel or petrol engines, according to a breakdown based on statistics available on the French car fleet and car market in 2020-2022. In this category, two light duty vehicles were also tested. Electric vehicles are excluded as they have their own category in the prediction method. Concerning heavy vehicles, seven road tractors from distinct manufacturers and coupled to trailers loaded with 10 T were tested. Some articulated buses (i.e. equipped with 3 axles) were also used to gain an insight into the urban context.

3.2. Controlled pass-by experiment

The first step consists in measuring pass-by noise at roadside, over a wide range of constant speeds from around 20 km/h to at least 80 km/h for light vehicles and 70 km/h for heavy ones. For each pass-by, the engine operating conditions correspond to the gearbox ratio best adapted to the speed tested, according to the vehicle's specifications on the dashboard or the automatic gear selection in the case of a robotised gearbox. These 'adapted' pass-bys are complemented by pass-bys imposed to a lower gear ratio, so as to widen the range of rpm encountered, which will make it easier to separate the propulsion noise from the total noise. All light and heavy vehicles (except buses) were tested on the same straight track with a dense asphalt concrete (DAC) 0/10 road surface at the Transpolis facility near Lyon (France). Six microphones (3 on either side) were used and occasionally three on only one side, with vehicles driving in both directions. Microphones are at a distance of 7.5 m from the track centre and a height of 1.2 m (Figure 1). The experiment is completed by measurements at standstill at various engine speeds.

⁵SUV: Sport Utility Vehicle; MPV: Multi-Purpose Vehicle.



Figure 1: Controlled pass-by experiment with a light vehicle (left) and an heavy vehicle (right)

3.3. Comparison with the French and European noise prediction models

The acoustic indicator used is the A-weighted maximum noise level (L_{Amax}) at vehicle pass-by and the corresponding spectrum in octave bands at the time of L_{Amax} . For the purposes of this paper, in order to assess the adequacy or otherwise of the current CNOSSOS-FR model in relation to the MINOOS measurements, the maximum noise levels measured at roadside are compared with the predicted sound pressure levels at the microphone position considering the vehicle as a point source close to the road in accordance with CNOSSOS-EU assumptions. Plots are given in overall levels for greater clarity and conciseness, while frequency comments are included in the text.

In Figure 2, the maximum noise levels measured with the 16 light vehicles at the ‘adapted’ gear ratio over the speed range are represented by grey dots. The noise value extent exceeds 10 dB(A) from the quietest to the noisiest vehicle at low speeds, where propulsion noise predominates, and reaches 6-7 dB(A) at high speeds, where rolling noise prevails. In this latter case, the tyre characteristics and the shape of the vehicle body are the key parameters for this behaviour. The noise prediction by CNOSSOS-FR is also plotted for the class of road surface R2 (non drainage) to which DAC 0/10 belongs. It is clear that the Transpolis track is not very noisy within this class, which derives from statistics, but this is a secondary issue here. The main point concerns the propulsion noise component, which alone exceeds most noise levels measured at low speed and gives a biased and overestimated prediction. The plot on the right-hand side of Figure 2 shows that this effect would be even more pronounced with the 2020 version of CNOSSOS-EU. The same observations can be made generally by octave band, although this is less significant at medium frequencies. In any case, a downward reevaluation of the propulsion noise component from French light vehicles (Cat. 1) would be relevant.

Figure 3 is the counterpart for heavy vehicles (category 3). The left-hand side shows the A-weighted maximum noise levels for the 7 coupled heavy goods vehicles at the ‘adapted’ gear ratio, grouping both driving directions and vehicle sides. The range of noise values is about 5 dB(A) in all cases, though perhaps a little less at higher speeds. The noise prediction by CNOSSOS-FR is also plotted for the class of road surface R2. Once again, we can see that the test track road surface is not very noisy in its category. However, the main point to note here is that the propulsion noise component of CNOSSOS-FR is very high. On its own it exceeds the noise levels measured at urban speeds and thus contributes to an overprediction of noise over a wide speed range. A comparison with the propulsion noise component from other prediction methods or versions plotted on the right-hand side shows that the use of the recent CNOSSOS-EU 2020 version would worsen this discrepancy. That of NMPB2008 is closer to the measurement, but still at the upper limit, showing that propulsion-related noise emissions from heavy vehicles have decreased over the last 20 years.

Therefore, in the light of changes in the vehicle fleet, a more realistic prediction in the French

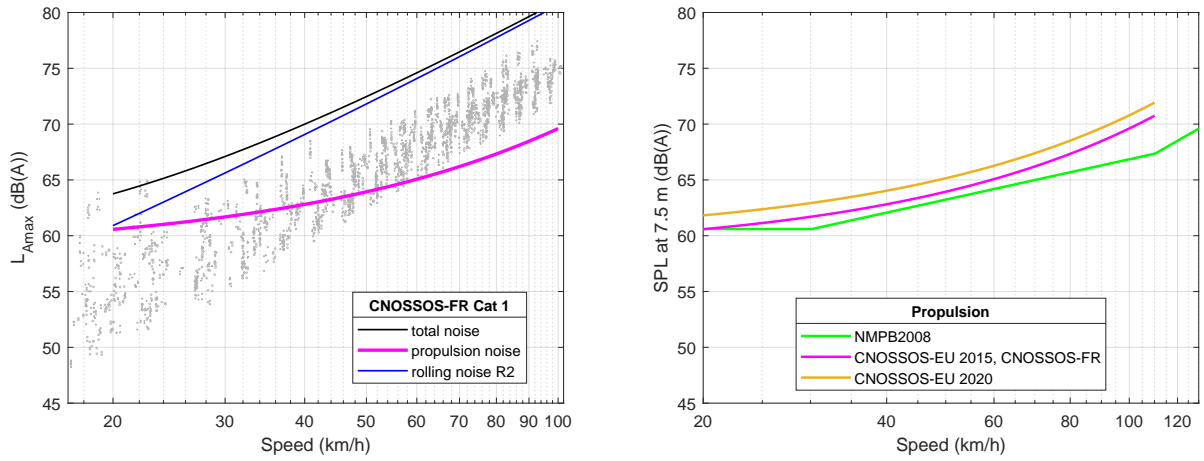


Figure 2: Noise emission from vehicles of Cat. 1 driving at the ‘adapted’ gear – Left: L_{Amax} at road side for the 16 vehicles tested (grey dots) and CNOSSOS-FR prediction for road class R2 – Right: Propulsion noise prediction by NMPB2008 and the different CNOSSOS versions.

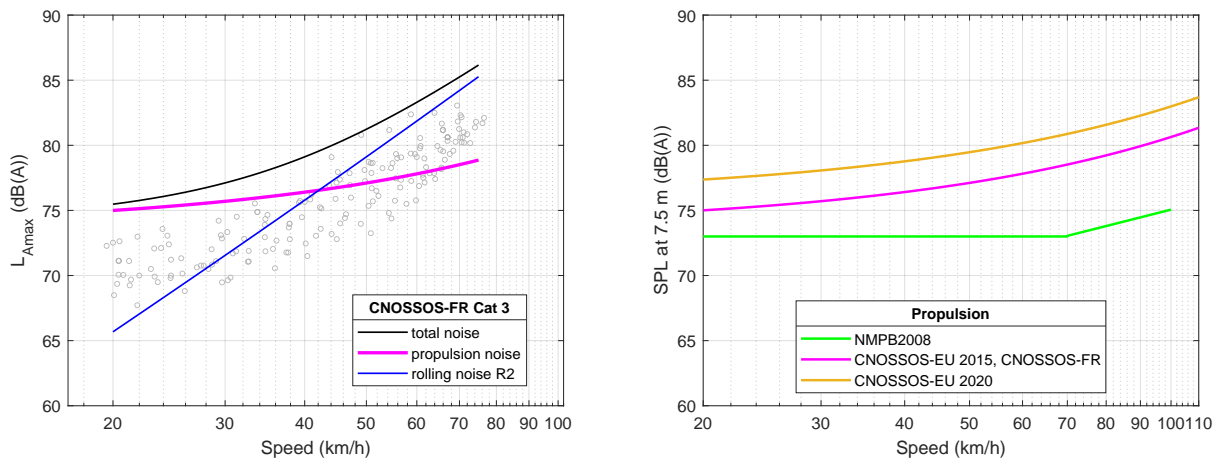


Figure 3: Noise emission from vehicles of Cat. 3 driving at the ‘adapted’ gear – Left: L_{Amax} at road side for the 7 coupled truck tested (grey dots) and CNOSSOS-FR prediction for road class R2 – Right: Propulsion noise prediction by NMPB2008 and the different CNOSSOS versions.

context would require a reconsideration of the propulsion noise component for light (Cat. 1) and heavy (Cat. 3) vehicles.

4. ROLLING NOISE COMPONENT

4.1. Approach

Several measurement campaigns have been done in order to get rolling noise information. The aim of these campaigns is double: the first one is to get information about rolling noise of category 2 vehicles, for which no information is available for French vehicles and road surfaces, the second one is to update the rolling noise database of French road surfaces in vehicle categories 1 and 3 as most data available was collected for the NMPB2008 method and predates 2008.

4.2. Pass-by experiments

Ten measurements campaigns were carried out on separate sites. Five sites dealt with BBTM 0/10-type 1 road surface, three sites with BBSG 0/10, one site with BBM 0/10 and one with SMA road

surface⁶. The ages of road surfaces ranged from 1 year to 20 years. Those road surfaces are all included in the "R2 non-drainage" category of NMPB2008 road surface categories and are very common in France. Pass-by rolling noise measurements procedure is described in standard ISO 11819-1:2002 [9]. The method consists in recording sound levels of noise emitted by passing-by vehicles using a microphone positioned at 1.2 m high and 7.5 m from the centre of the lane being tested (Figure 4). The maximum noise levels at each pass-by are correlated with the speed of the vehicle. The standard describes three vehicle categories. Light vehicles correspond to category 1 of the standard, and a minimum of 100 passes is required. Heavy vehicles (HV) with 2 axles correspond to category 2a of the standard, requiring a minimum of 30 passes. Those with 3 axles or more correspond to category 2b of the standard, with a minimum of 30 passes required. In practice, as there are relatively few 2-axle HVs on the road this minimum condition is not always fulfilled. The road surface must be dry during the measurements and the wind speed less than 5 m/s. The air temperature is taken in order to correct the results to 20°C [9]. For each category of vehicle, a linear regression is then used to obtain the $L_{A,max}$ sound level as a function of speed (Figure 4), such as :

$$L_{A,max}(V) = L_{veh} + a \cdot \log(V/V_{ref}) \quad (1)$$

where a is the slope coefficient and V is the speed. L_{veh} is the emission level of the vehicle category at the reference speed V_{ref} .

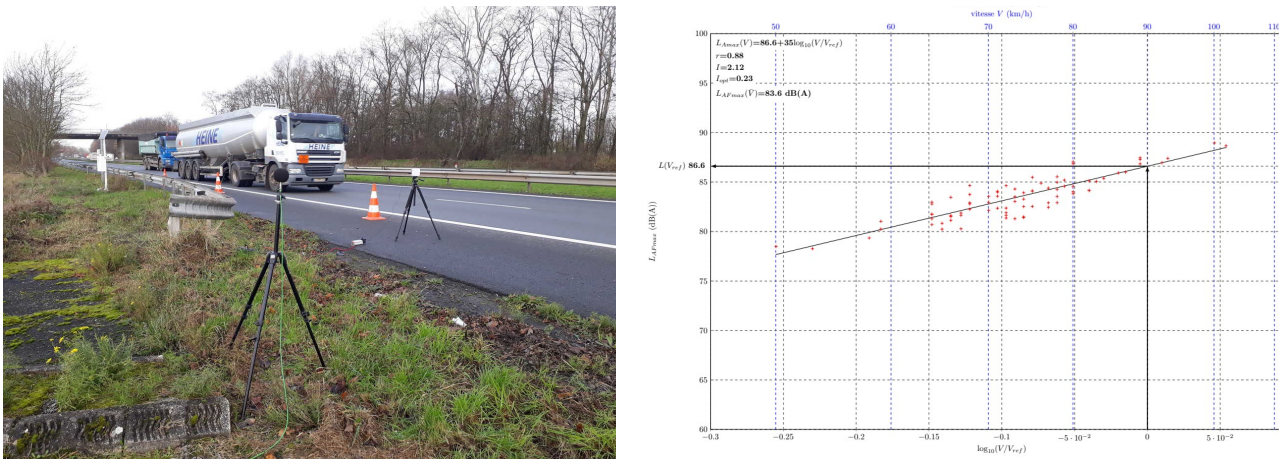


Figure 4: Left: Pass-by set up according to ISO 11819-1:2002 procedure. Right: Example of regression analysis between $L_{A,max}$ and passing-by vehicles speeds

The results of these measurements were added to those already available in the French rolling noise database managed by Cerema since 1988 [11].

4.3. Comparison with former rolling noise database

Data from the rolling noise database, including the new measurements, will be reprocessed in order to estimate CNOSSOS coefficients for rolling noise adapted to French road surface and vehicles. Nevertheless, as more than 75% of data from this base are prior to 2001, it is necessary to check if oldest data are still available for current road surfaces, or if any time evolution in the rolling noise behaviour of road surfaces can be noticed.

Figure 5 gives a comparison between rolling noise of light vehicles from data before and after 2007 for two road surfaces measured in this study. In order to exclude the ageing effect of road surfaces on the rolling noise, those data represent $L_{A,max}$ corrected by formulas given in [12].

⁶BBTM: Very Thin Asphalt Concrete; BBSG: Dense Asphalt Concrete; BBM: Thin Asphalt Concrete; SMA: Stone Mastic Asphalt.

A statistical significant difference ($pvalue < 0.05$, Student t-test) of about +2 dBA is noticed for the BBTM surface, whereas this is not the case for the BBSG surface ($pvalue > 0.05$).

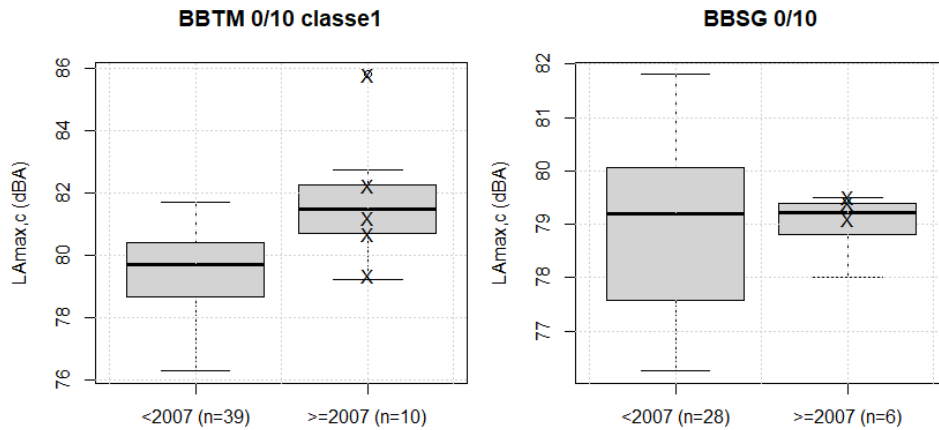


Figure 5: Light vehicles: comparison of age corrected $L_{A,max,c}$ boxplots for two periods of the database and two road surfaces (left: BBTM 0/10 type 1, right: BBSG 0/10). Cross are results of the new MINOOS measurements.

A similar comparison is made for the three road surface NMPB2008 categories (Figure 6). The less noiser category R1 does not exhibit a significant evolution with time ($pvalue > 0.05$), whereas the two other categories do ($pvalue < 0.05$), with an increase with time of about +1.4 dB(A) for R2 and +2 dB(A) for the R3 category. It should be noted that the conclusion for R3 must be interpreted carefully, as the number of samples available is fairly low for the period after 2007.

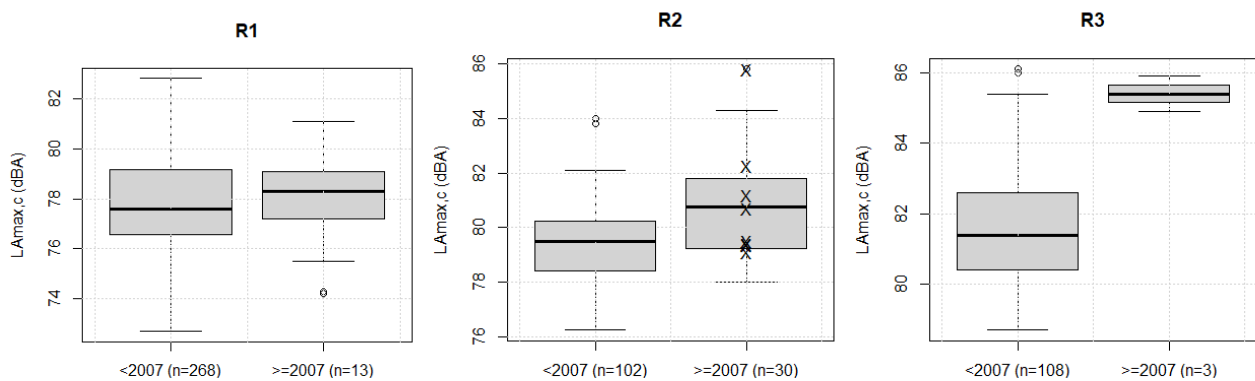


Figure 6: Light vehicles: comparison of age corrected $L_{A,max,c}$ boxplots for two periods of the database and the three road surfaces categories of NMPB2008 (from left to right: R1, R2, R3 categories). Cross are results of the new MINOOS measurements.

These results are preliminary but tend to show that, except for the least noisy road surfaces, a slight increase in light vehicle rolling noise can be observed over time, independently of the effect of the ageing of the road surface. One explanation could be the evolution of tyre widths or the increase in vehicle weight, both of which have tended to increase over the last 30 years. The trend towards an increase in rolling noise over time indicates that for the next stage in the estimation of the CNOSSOS-FR rolling noise coefficients, it will be necessary not to use the oldest data in the database and also to supplement it with other more recent data.

5. SUMMARY AND FUTURE OUTLOOK

The project MINOOS reconsiders the CNOSSOS-FR coefficients in the light of updated knowledge on road noise emission, so as to address some inconsistencies and better reflect today's reality in France. First findings show that the current propulsion noise component, respectively for light and heavy vehicles (Cat. 1 and 3), overestimates the noise emission from the existing vehicle fleet, a likely indication of a reduction in noise emission over time linked to technological developments. On the contrary for the rolling noise component, preliminary results based on the French 35-year 'rolling-noise database' tend to show that, except for the least noisy road surface class, a slight increase in light vehicle rolling noise can be observed over time, independently of the effect of the ageing of the road surface. As a consequence, by the end of MINOOS project scheduled for January 2025, updated coefficients for CNOSSOS-FR will be proposed.

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