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E-COMPARISONS: A NEW APPROACH TO ROUND ROBIN TESTS FOR ENVIRONMENTAL NOISE ASSESSMENT IN TRANSPORT INFRASTRUCTURES

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The increasing importance of pollutant noise has led to the creation of many new noise testing laboratories in recent years. For this reason and due to the legal implications that noise reporting may have, it is necessary to create procedures intended to guarantee the quality of the testing and its results. For instance, the ISO/IEC standard 17025:2005 specifies general requirements for the competence of testing laboratories. In this standard, interlaboratory comparisons are one of the main measures that must be applied to guarantee the quality of laboratories when applying specific methodologies for testing. In the specific case of environmental noise, round robin tests are usually difficult to design, as it is difficult to find scenarios that can be available and controlled while the participants carry out the measurements. Monitoring and controlling the factors that can influence the measurements (source emissions, propagation, background noise…) is not usually affordable, so the most extended solution is to create very effortless scenarios, where most of the factors that can have an influence on the results are excluded (sampling, processing of results, background noise, source detection…)

The new approach described in this paper only requires the organizer to make actual measurements (or prepare virtual ones). Applying and interpreting a common reference document (standard, regulation…), the participants must analyze these input data independently to provide the results, which will be compared among the participants. The measurement costs are severely reduced for the participants, there is no need to monitor the scenario conditions, and almost any relevant factor can be included in this methodology.

1. Introduction

The increasing importance of pollutant noise has derived in the creation of regulations whose main objective is to reduce noise, and make different land-uses compatible. These regulations follow two different approaches. The first one is concerned with environmental noise protection, and the second one with the noise disturbance caused by activities [1-5]. The increasing demand on measurements and noise inspections has led to the creation of many new noise testing laboratories and inspection bodies in recent years. Due to the legal implications that noise reporting may have, it is necessary to guarantee the quality of the measurements and the independence and expertise of the noise inspectors and practitioners. For instance, ISO/IEC standard 17025:2005[6] specifies general requirements for the competence of testing laboratories. It establishes some general requisites regarding the instrumentation and its calibration, the expertise of the practitioners and the accordance of procedures with testing standards. Interlaboratory comparisons are one of the main measures intended to guarantee the quality, consistency and comparability of the results, tests and testing procedures. The development and operation of proficiency testing by interlaboratory comparisons is standardized in the ISO/IEC GUIDE 43-1[7], which defines the main concepts and managing procedures to be considered.

In the specific case of environmental noise, round robin tests are usually difficult to design, as it is difficult to find scenarios that can be available and controlled while the participants carry out their measurements. Monitoring the factors that can influence the measurements (source emissions, propagation, background noise…) is not usually affordable, therefore the most extended solution is to create very effortless scenarios, where most of the factors that can have an influence on the results are excluded (sampling, processing of results, background noise, source detection…). But this is not the best solution, as practically the only thing checked under these circumstances is the instrumentation, which is just an alternative to calibration. It would be required to create more complex scenarios to check the repeatability of the laboratories, and inter-laboratory reproducibility under more difficult and closer-to-reality scenarios. This is one way to achieve a continuous improvement in the quality of the methods and the laboratories.

According to the e-comparisons approach described in this paper, only the organizer of the comparison makes actual measurements. By applying and interpreting a common reference document (standard, regulation…), the participants will analyze real or virtual data and report the results, which will be compared among the participants. As long as the test scenario can be set up for any circumstance, and almost any relevant factor can be included in this methodology, this practice can be used to provide focused results, allowing fixing some of the factors and making them independent, as needed for every purpose. Measurement costs are severely reduced for the participants, as the physical process of measuring is avoided and data can be circulated using the Internet, and so, there is no need to control and monitor the scenario conditions.

2. Methodology

The design of an interlaboratory comparison starts by defining the precise objectives to be captured. It must set the focus on the capacities of the participating laboratories, and it needs to exclude any supplementary elements that are not important, or those that can be easily considered independently. This will only be possible if the organizer of the comparison is an expert in the field of application, and is very familiar with the reference documents and associated procedures.

E-comparisons spread huge potentials for many fields of acoustic testing. They can be used not only to estimate the uncertainty of the methods and rejection or acceptance of the results reported by the laboratories, but they also allow easily checking the compliance of the requirements in the standards, so that the results of non-compliant laboratories can be easily excluded from the statistical analysis. The following tables illustrate some of the possibilities of e-comparisons regarding the fields of environmental and building acoustics.

Table 1. E-comparisons applied to environmental noise measurements (ISO 1996)

Test procedure	Parameters to explore	Notes for e-comparison design
- Aircraft noise (ISO 20906) - Railway noise - Road traffic noise - Industrial noise	- Noise event detection techniques	The organizer has to provide noise level profiles and additional information for the identification task (recordings, notes…)
	- Time sampling	For a single location, the user has to report a single result from several measurements
	- Spatial sampling	The organizer has to provide measurements for several locations, allowing the user to choose the correct ones
	- Low frequency correction - Tone correction - Impulse correction	The measurements provided will include one or several of these factors, so that the expertise of the laboratories can be checked
	- Background noise correction	Background noise measurements must be provided
	- Uncertainty calculations	The user will be requested to report results and their related uncertainty. The organizer will provide information to allow the user to make the calculation for type A and type B contributions.
	- Instrumentation	Instrumentation could be also checked. It would be necessary to provide a recording of a reference signal for calibration purposes and the recordings of the noise to be measured. The recordings must be inserted into the measurement chain using a connection to the preamplifier. Only the microphone remains outside the comparison.
	- Other data processing	
- Noise inspection	- Compliance	To report compliance, the noise inspector will have to check almost all the parameters indicated above, including uncertainty.

Table 2. E-comparisons applied to noise insulation testing (ISO 140 series, field measurements)

Test procedure	Parameters to explore	Notes for e-comparison design
- Airborne sound insulation between rooms - Airborne sound insulation of façade and façade elements - Impact of sound insulation	- Positions of the source (facade and rooms) - Positions of the microphone in the emitting room - Positions of the microphone in the receiver room - Positions of the microphones in front of the façade	The organizer must provide results for many valid and non-valid positions so that the expertise of the laboratories and the influence of the location on the results can be checked. The virtual measurements can be created from random Gaussian variables, with known means and variances for each frequency band.
	- Background noise corrections	Background noise measurements must be provided
	- Rating according to ISO 717	This overall result is directly derived from the spectra results, but it could be also included in the comparison.
	- Uncertainty of the results	The user will be requested to report spectra and overall results and their related uncertainty. The organizer will provide information to allow the user to make the calculation for type A and type B contributions.

In order to clarify the description of the methodology throughout the paper, we will describe the steps followed for a comparison on airport noise measurements. For this specific case, it is very difficult to create a traditional interlaboratory comparison, as there are many factors involved that influence the results: instrumentation, the number and type of aircraft, the dispersion on the flight paths, airport operability, meteorological factors, source variation factors… But all of these factors were outside our scope. The aim of the comparison is to compare the specific methods that every laboratory implements from the bases described in ISO 20906[8]. Therefore, the reference document is ISO 20906, and we wished to compare the results obtained by the laboratories for the same meteorological conditions and the same source. The influence of the instrument was also excluded, as it can be quantified separately for every laboratory. The influence of residual noise, and how each laboratory manages it could also have been included in the comparison, but we decided to exclude it for simplicity. After excluding all those factors, the only remaining one is that derived from the processing of the measurements, which is the result of the methodology used for the marking of aircraft sound events (detection + classification + identification, according to ISO 20906, see Figure 1).

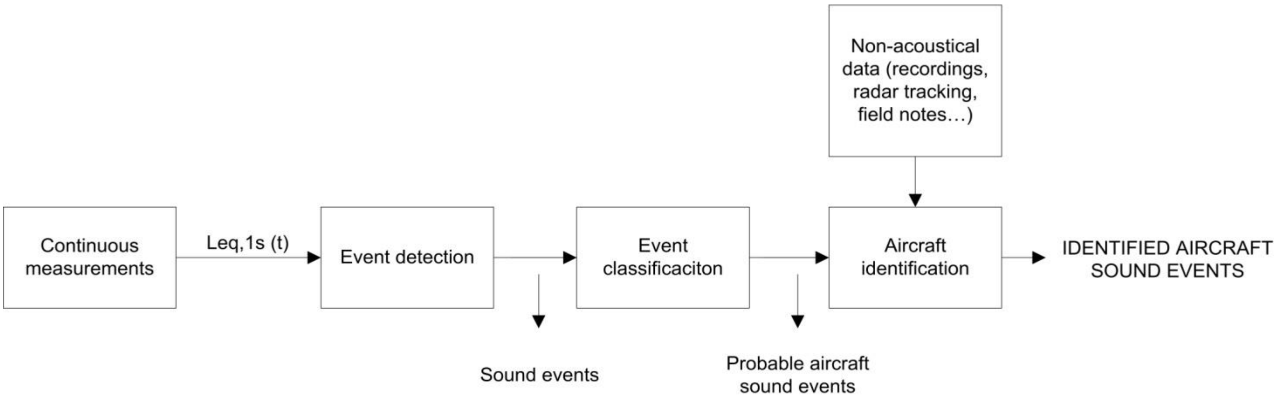

Figure 1. Aircraft events identification scheme according to ISO 20906

Once the objectives have been defined, we must find a way to meet them. In our example, we can achieve the objectives by just using a measurement file that can be processed by all the laboratories. The organizer made measurements and recordings, and selected the appropriate profile for the experiment. Then, this reference material (measurements + recordings) was circulated among the participants. As established by ISO 5725[9], the test items remain identical for all of them. The organizer decided to set three different scenarios for the comparison according to the dynamic range of the aircraft noise events considered. Consequently, three different reference materials were tested by each laboratory in this e-comparison:

- ENV1: Aircraft sound events easily detectable (from measurements and audio files)
- ENV2: Aircraft sound events hard to detect in the measurement files, but clearly audible
- ENV3: Aircraft sound events very difficult to detect, and the presence of other sound events.

It was decided not to use files longer than 1 hour, as this duration was considered long enough to analyze the competence of the laboratory and validity of its procedures. Every test set consisted of an audio file and a measurement file, with a duration T (seconds).

Every measurement file contained T one-second continuous equivalent sound pressure level measurements ($L_{Aeq,1s}$) that comprised the noise profile (see, Figure 2). In general, this profile will be used for event detection and classification tasks, while the recordings will be used for identification.

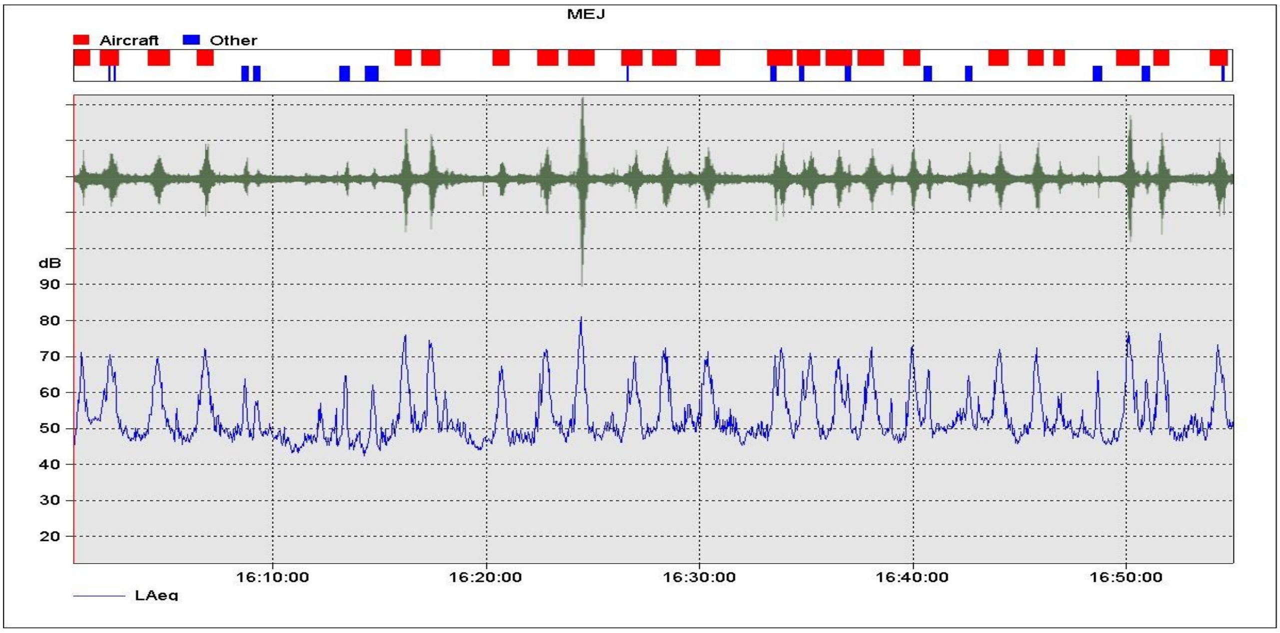

Figure 2. Example of measurements time history (blue) and recordings (green)

The participants were asked to report results according to ISO 20906, in terms of equivalent noise level referred to the reference time interval T (which is also the duration of the measurements). The requested results must be calculated according to equation 1, but this equation was not provided:

$$L_{aircraft} = L_{Aeq,T(aircraft)} = 10\log\left[\frac{1}{T}\cdot\sum_{i=1}^{T_a}10^{0.1\cdot L_i}\right] \tag{1}$$

where L_i refers to the T_a measurements ($L_{Aeq,1s}$) marked as aircraft noise.

Communicating with the participants, circulating the reference material and reporting the results or any other details, can be carried out using a collaborative Internet website, or simply by email. Confidentiality must be assured whatever method is used for communication.

The statistical analysis of the reported results does not change for e-comparisons. One of the main issues refers to the detection of outliers and the rejection criteria for the laboratory's results.

3. Results

The idea of e-comparisons was conceived while carrying out the Aircomp Project, intended to describe the influence of the human factor on the results of aircraft noise monitoring. Five European universities were involved in this project (Politecnico di Milano, Universidad Politécnica de Madrid, University of Zagreb, Universidad Politécnica de Cataluña and the University of Sheffield). The results reported by the 64 participants on this project have been used to check the validity of this methodology for the production of e-comparisons. Most of the participants were engineering or master's students, with a certain background regarding acoustics. But some professors, researchers and experts in environmental acoustics were also involved in the comparison. Figure 3 shows the box plot of the results reported, where some outliers can be clearly identified. A simple analysis of the data shows that the methodology used by the participants has an influence on the reported results, which means variability. If we exclude the outlier participants from this analysis, the variability in the results increases as the acoustic environment becomes more difficult, and the dynamic range of the noise events is lower.

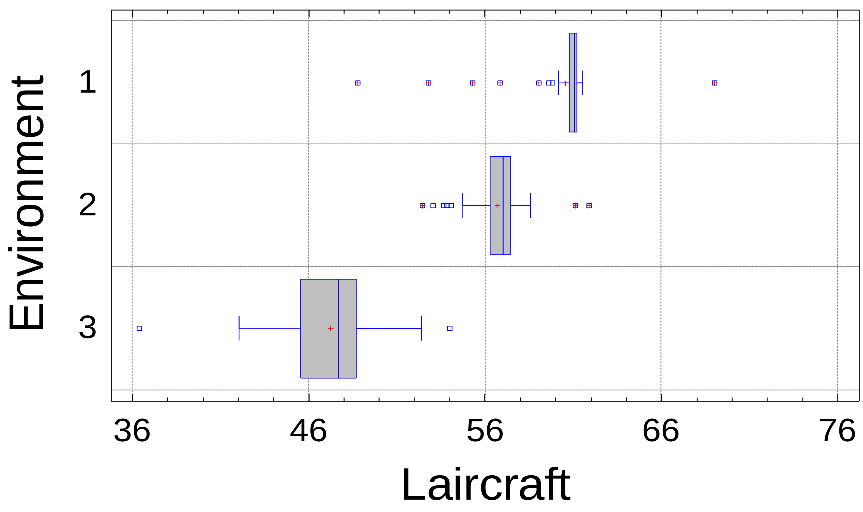

Figure 3. Box plot of the results reported by the participants for the three acoustic environments

The results would allow the outlier participants to reject their results, and revise their procedures. The rest of the participants reported comparable data within a coverage interval, which is evidence of the quality in their results. Furthermore, they could be used for estimating the uncertainty of the method.

4. Conclusions

In this paper, we have presented a new approach to round robin tests for environmental noise assessment in transport infrastructures through e-comparisons. By using e-comparisons, it is possible to make an in-depth evaluation of the methodology, performance and expertise of laboratories, and set specific targets that can be configured in as complex a way as required. The reference material used for the tests can be measured just by the organizer, but it is also possible to create virtual reference material artificially in the laboratory, so that comparisons can be made beyond the limits of real world acoustics.

It has been demonstrated that the use of the new technologies can be very useful to simplify the process and reduce the costs of interlaboratory comparisons. E-comparisons have currently shown to be a boundless and technologically suitable concept.

Following this approach, it becomes possible to include in the round robin tests aspects as difficult to evaluate as sampling methodology (spatial and temporal), the analysis of noise characteristics (presence of tones, low frequency noise, impulse…), and the detection of noise sources…

E-comparisons can be carried out from any part of the world, they can cover almost every aspect of testing procedures, and they can be reused with slight changes for periodic interlaboratory comparison exercises.

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