Interlaboratory and proficiency tests for building's sound insulation field measurements in Brazil - 6th Edition 2024

Eun Seon Jeong[1], Carolina Monteiro, Juan de Frias Pierrard
ProAcústica – Brazilian Association for Acoustical Quality
Av. Ibirapuera 3458, São Paulo - Brazil

ABSTRACT

Since the implementation of ABNT NBR 15.575, which establishes acoustic performance requirements for residential buildings, the demand for sound insulation testing has grown significantly in Brazil, leading to an increase in acoustic field measurement laboratories. To support this development, ProAcústica – Brazilian Association for Acoustical Quality, a non-profit organization, has been organizing the Interlaboratory and Proficiency Program of Field Measurements for Building Acoustics Laboratories – INTERLAB Program.
In 2024, the sixth edition of the INTERLAB Program was conducted in São Paulo, Brazil, with the participation of 34 laboratories. The program included tests on airborne sound insulation, facade sound insulation, impact sound level, sound pressure level from service equipment in buildings, reverberation time, sound pressure level in inhabited areas, and sound pressure level in indoor environments.
This paper presents the methodologies, procedures, and results of the 2024 edition of ProAcústica's Interlaboratory and Proficiency Program, as well as a comparison with previous editions. The main objectives were to evaluate the accuracy of field test methods in the Brazilian market, analyze the performance of participating laboratories, and reinforce quality control in building acoustics testing.

1. INTRODUCTION

An interlaboratory test is a collaborative test in which all the participant laboratories measure the same item, with their own methods, instrumentation, and staff. It aims to evaluate the acoustic measurement tests service quality provided by the acoustic laboratories through an instrument that allows evaluating the measurement procedure of the participating laboratories.

The main objectives of interlaboratory test are:

- Assess the precision and equivalence between different test methods;
- Assess the technical compliance of laboratories to carry on acoustic tests (proficiency tests) in a continuous follow-up of the performance;
- Detection of problems during the measuring process and developing corrective solutions;
- Provide confidence to clients who hire services from Building Acoustics laboratories.

[1] gerenciatecnica@proacustica.org.br

The Proficiency test is a specific case of interlaboratory test, that aims to assess the performance of the different participant laboratories. Regular participation in proficiency tests is a fundamental tool for the quality control of measurement services offered in each laboratory portfolio, as it is the most effective way of assessing if the tests are being carried out properly.

2. BACKGROUND

2.1. General

In Brazil, ProAcústica Association is the first institution to develop a program of interlaboratory and proficiency field tests for building acoustics. All the tests were carried out in the state of São Paulo joining laboratories from all over the country. The number of laboratories participating over the editions was: five laboratories in 2012; seven in 2014; nineteen in 2017; twenty-five in 2019/20 and thirty in 2022.

The first two interlaboratory programs took place in residential buildings provided by the construction company Tecnisa. In the third edition, the building under evaluation was lent by the company EZTec. For the fourth edition, the evaluated building was provided by company OWA Sonex. In the fifth edition, a warehouse was made available by company AtenuaSom. Finally, in the last edition, the program was conducted in a facility specially built by ProAcústica Association, in partnership with company Cerâmica City and the National Association of the Ceramic Industry (ANICER).

2.2. Sixth Edition (2024)

The 6th INTERLAB ProAcústica Edition was organized in the beginning of 2024, and the measurements were carried out from May 5th to August 28th by the 34 participant laboratories, listed in Table 1.

Table 1: Participant laboratories of the INTERLAB Program 6th Edition (2024).

PARTICIPANT LABORATORIES	
2 KTM Engenharia de Segurança e Saúde Ocupacional Ltda.	Grom Equipamentos Eletromecânicos Ltda.
Acoem Brasil Ltda.	Harmonia Acústica SS
Acústica Engenharia SS	Inovatech Engenharia Ltda.
Aluvial Engenharia e Meio Ambiente Ltda.	Isoteste Ensaios Técnicos Ltda.
Anima Acústica Tecnologia e Conhecimento Ltda.	KR3 Laudos Técnicos Ltda.
Associação Antônio Vieira – UNISINOS	LGS Gestão Empresarial Ltda.
Aven Engenharia Ltda.	MMC Lab Controle Tecnológico Ltda.
Bracústica Consultoria Ltda.	Modal Acústica e Engenharia Ltda.
Centro Cerâmico do Brasil	MS Engenharia e Consultoria Ltda.
CM2 Engenharia e Tecnologia Ltda.	Scala Acústica Ltda.
Consultare Engenharia de Desempenho Sociedade Simples Ltda.	Serviço Nacional de Aprendizagem Industrial – SENAI RJ
dB Laboratório de Engenharia Acústica Ltda.	Silentium Engenharia Acústica Ltda.
Echo Projetos Acústicos Ltda.	Síntese Arquitetura e Construção Ltda.
Élcio José de Oliveira Terron Consultoria	Sonar Engenharia Ltda.
Engesul Projetos e Laudos Ltda.	Tecomat Engenharia Ltda.
Environmental Solutions Consultoria S/S Ltda.	TG Consultoria e Engenharia de Segurança do Trabalho Ltda.
Fundação Universidade de Caxias do Sul	Trional Ensaios, Tecnologia e Inovações Ltda.

Table 2 shows the number of participants that had attend each available test of the INTERLAB program, as not all laboratories participated in all tests, totalizing 200 measurements.

Table 2: Tests of the INTERLAB program and number of participant laboratories.

Nº	TEST	STANDARD	NUMBER OF LABORATORIES
1	Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation	ABNT NBR ISO 16283-1:2018 ISO 16283-1:2014/Amd 1:2017	28
2	Acoustics - Field measurements of airborne and impact sound insulation and of service equipment sound - Survey method: airborne sound insulation between rooms	ABNT NBR ISO 10052:2022 ISO 10052:2021	6
3	Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 2: Impact sound insulation	ABNT NBR ISO 16283-2:2021 ISO 16283-2:2020	27
4	Acoustics - Field measurements of airborne and impact sound insulation and of service equipment sound - Survey method: impact sound insulation of floors	ABNT NBR ISO 10052:2022 ISO 10052:2021	7
5	Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation	ABNT NBR ISO 16283-3:2021 ISO 16283-3:2016	28
6	Acoustics - Field measurements of airborne and impact sound insulation and of service equipment sound - Survey method: airborne sound insulation of facades	ABNT NBR ISO 10052:2022 ISO 10052:2021	7
7	Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms	ABNT NBR ISO 3382-2:2017 ISO 3382-2:2008/Cor 1:2009	26
8	Acoustics - Measurement of sound pressure level from service equipment in buildings - Engineering method	ABNT NBR ISO 16032:2020 ISO 16032:2004	18
9	Sound pressure levels in inhabited areas - Detailed method	ABNT NBR 10151:2020	29
10	Sound pressure levels indoors - Detailed method	ABNT NBR 10152:2020	24

For each test, the participants carried out five complete repetitions of the measurement, with procedures that should comply with the corresponding ISO measurement standard, as well as the equivalent Brazilian standards (ABNT NBR). It is important to highlight that each participant laboratory was allowed to decide certain aspects, such as the number of measurement points, the location of the source/microphone, and the measurement time.

3. RESULTS

3.1. Presented quantities

The results of the performed field measurements of each laboratory were assessed accordingly ISO 17043:2023 [1], with the following indicator as output data:

a) True value (X) and proficiency standard deviation (σ_p), obtained respectively from the robust mean value (x*) and robust standard deviation (s*), regarding Annex C of the standard ISO 13528:2022 [2].
b) Z'-Score, for assessment of the performance of the participant laboratories, calculated with the following equation:

$$Z' = \frac{x - X}{\sqrt{\sigma_p^2 + u_x^2}}, \quad (1)$$

Where x is the result obtained by each laboratory, X is the true value of the result and σ_p is the proficiency test standard deviation.

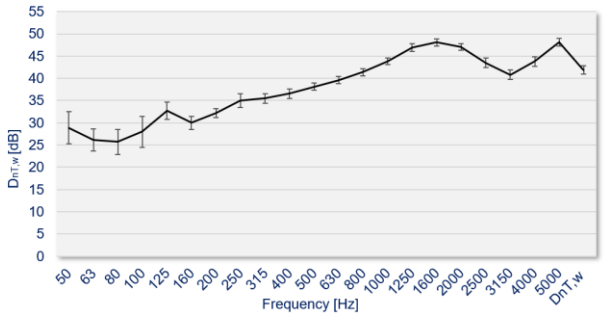
- For $|Z`| \leq 2$, the result of the individual participant is regarded as acceptable (satisfactory performance)/
- For $2 < |Z`| \leq 3$, the result of the individual participant is regarded questionable, being recommended to carry out an assessment of the possible causes and special caution in that values when testing.
- For $|Z'| > 3$, the result of the individual participant is regarded as non-acceptable (unsatisfactory performance).

c) The standard uncertainty of interlaboratory test (u) calculated regarding ISO 5725-1 [3] and ISO 5725-2 [4].
d) Repeatability and reproducibility of the interlaboratory test calculated regarding ISO 5725-2 [4].

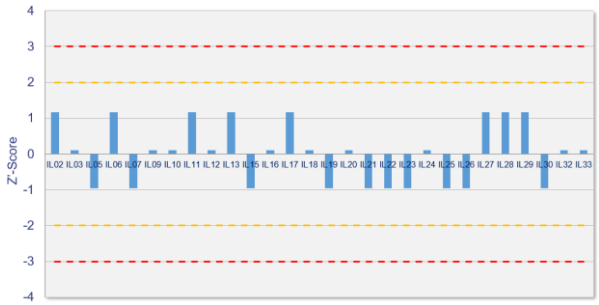
3.2. Airborne sound insulation between dwellings – $D_{nT,w}$

In this section, the results of the airborne sound insulation between dwellings – $D_{nT,w}$ are presented for the engineering method (Figure 1) and survey method (Figure 2).

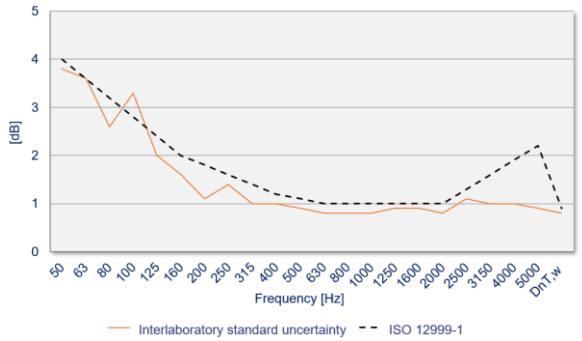
3.2.1. ISO 16283-1:2014 – Engineering method (28 laboratories)



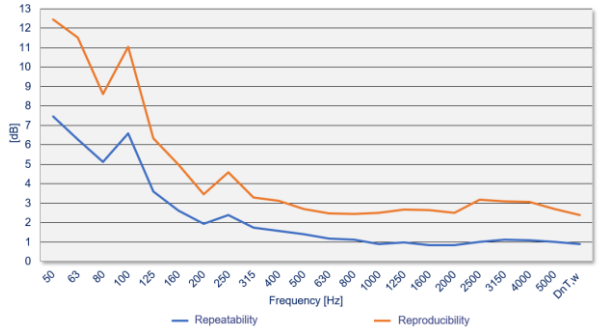
(a) True value (X) and standard deviation (σ_p)



(b) Z'score $D_{nT,w}$ for each laboratory (IL)



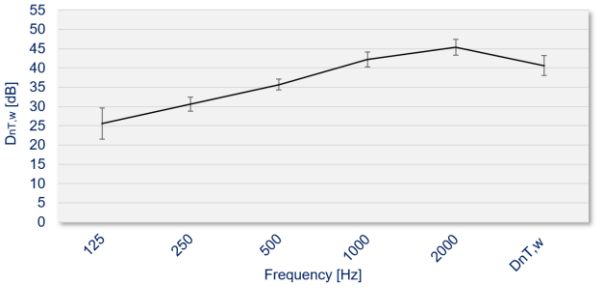
(c) Comparison between standard uncertainty (u) and ISO 12999-1



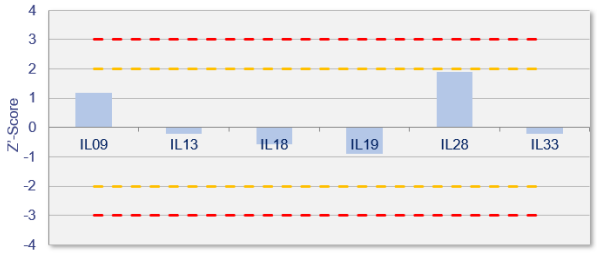
(d) Repeatability and reproducibility

Figure 1: Results obtained using ISO 16283-1:2014 – Engineering method.

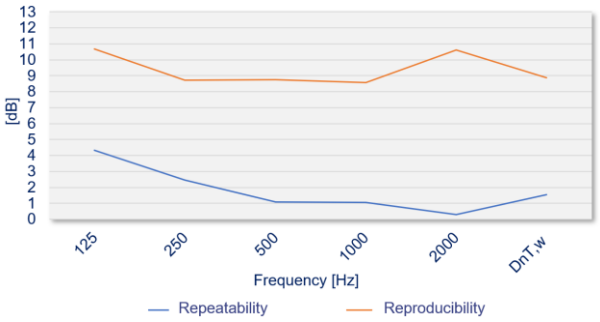
3.2.2. ISO 10052:2021 – Survey method (6 laboratories)



(a) True value (X) and standard deviation (σ_p)



(b) Z'score $D_{nT,w}$ for each laboratory (IL)



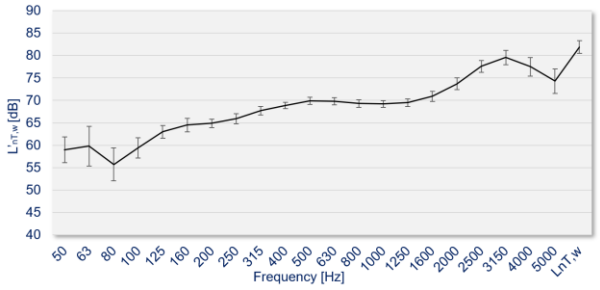
(c) Repeatability and reproducibility

Figure 2: Results obtained using ISO 10052:2021 – Survey method.

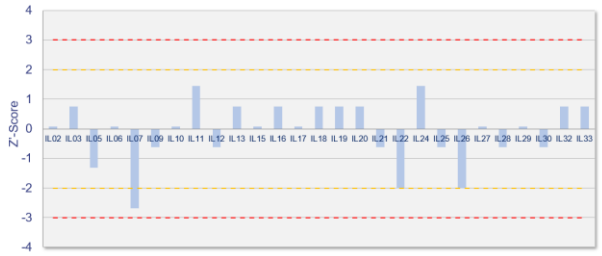
3.3. Impact sound insulation between dwellings – $L'_{nT,w}$

In this section, the results of the impact sound insulation between dwellings – $L'_{nT,w}$ are presented for the engineering method (Figure 3) and survey method (Figure 4).

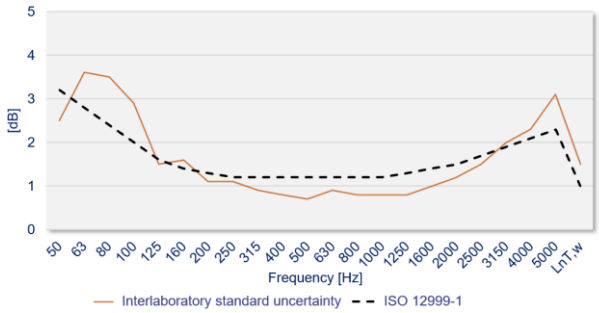
3.3.1. ISO 16283-2:2020 – Engineering method (27 laboratories)



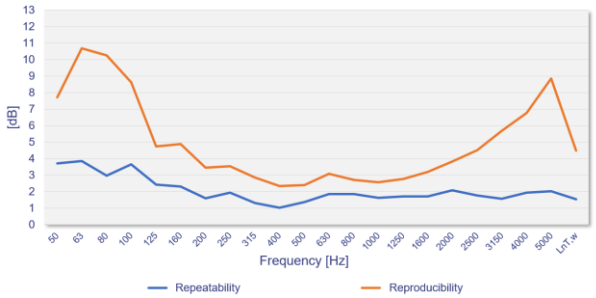
(a) True value (X) and standard deviation (σ_p)



(b) Z'score $L'_{nT,w}$ for each laboratory (IL)



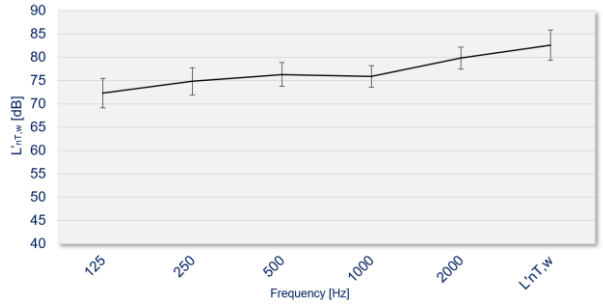
(c) Comparison between standard uncertainty (u) and ISO 12999-1



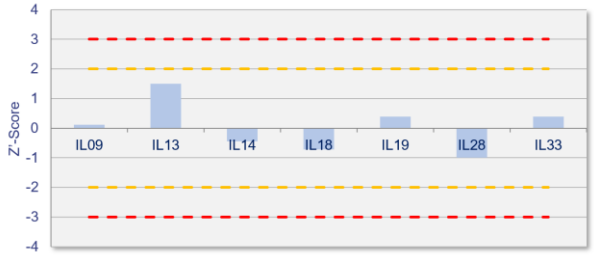
(d) Repeatability and reproducibility

Figure 3: Results obtained using ISO 16283-2:2020 – Engineering method.

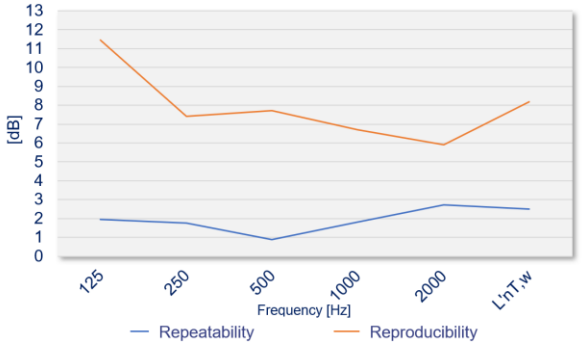
3.3.2. ISO 10052:2021 – Survey method (7 laboratories)



(a) True value (X) and standard deviation (σ_p)



(b) Z'score $L'_{nT,w}$ for each laboratory (IL)



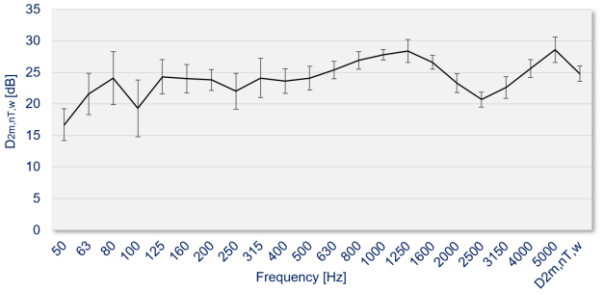
(c) Repeatability and reproducibility

Figure 4: Results obtained using ISO 10052:2021 – Survey method.

3.4. Airborne façade sound insulation – $D_{2m,nT,w}$

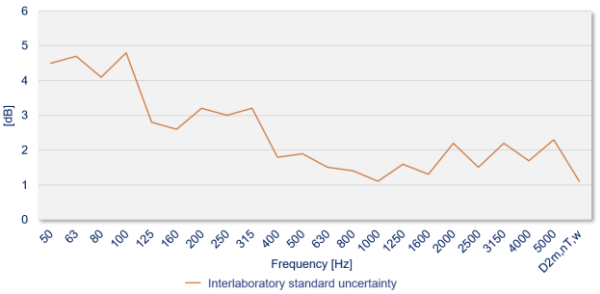
In this section, the results of the airborne façade sound insulation – $D_{2m,nT,w}$ are presented for the engineering method (Figure 5) and survey method (Figure 6).

3.4.1. ISO 16283-3:2016 – Engineering method (28 laboratories)

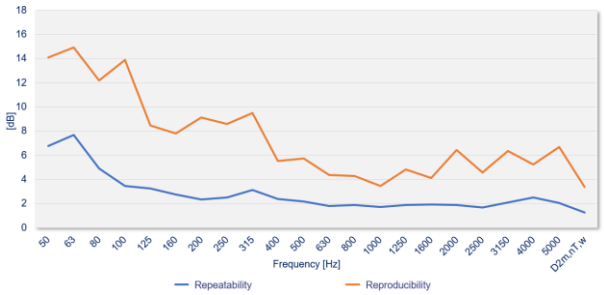


(a) True value (X) and standard deviation (σ_p)

(b) Z'score $D_{2m,nT,w}$ for each laboratory (IL)



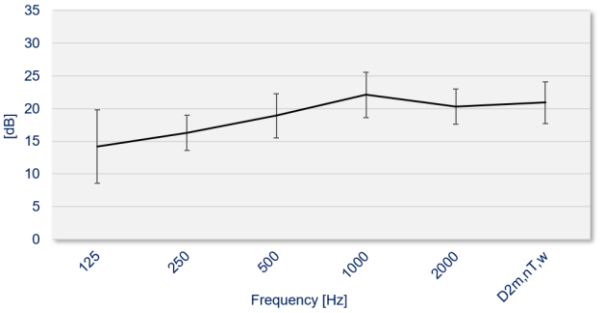
(c) Standard uncertainty (u)



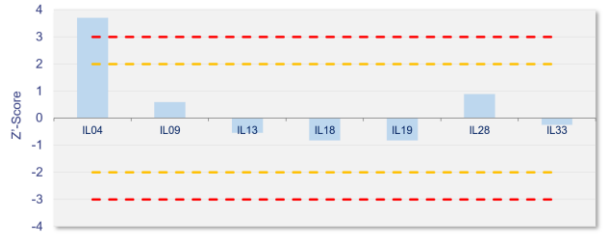
(d) Repeatability and reproducibility

Figure 5: Results obtained using ISO 16283-3:2016 – Engineering method.

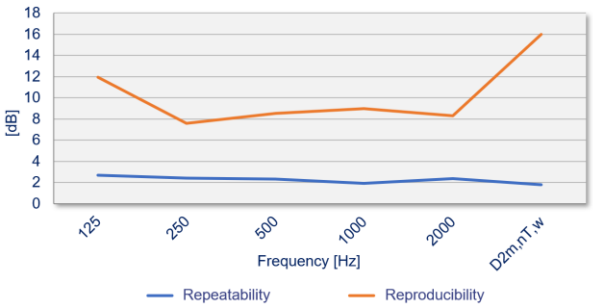
3.4.2. ISO 10052:2021 – Survey method (7 laboratories)



(a) True value (X) and standard deviation (σ_p)



(b) Z'score $D_{2m,nT,w}$ for each laboratory (IL)



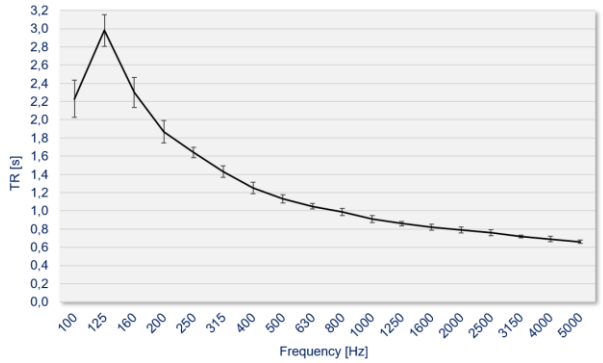
(c) Repeatability and reproducibility

Figure 6: Results obtained using ISO 10052:2021 – Survey method.

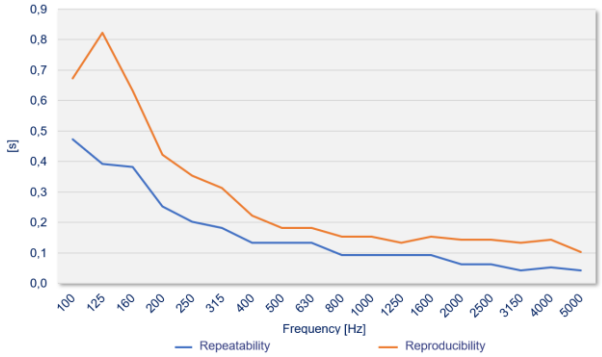
3.5. Reverberation Time – TR

This section presents the results of the reverberation time measurements, as illustrated in Figure 7.

3.5.1. ISO 3382-2:2008 (26 laboratories)



(a) True value (X) and standard deviation (σ_p)



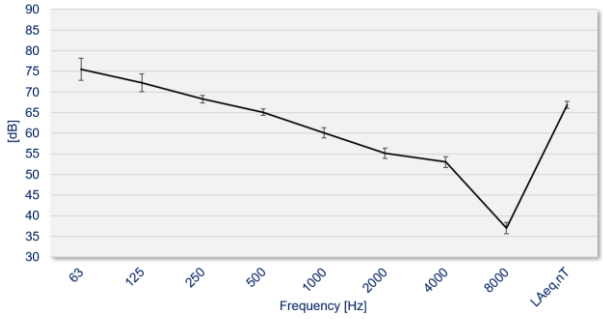
(b) Repeatability and reproducibility

Figure 7: Results obtained using 3382-2:2008.

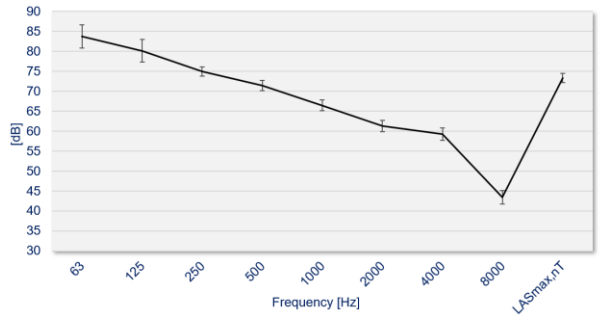
3.6. Noise level from service equipment – $L_{Aeq,nT}$ and $L_{ASmax,nT}$

This section presents the results of the service equipment noise measurements, as illustrated in Figure 8.

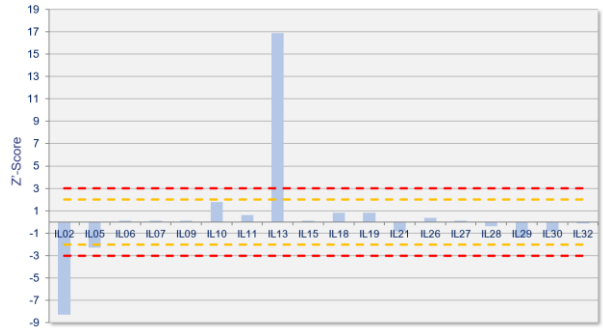
3.6.1. ISO 16032:2004 (18 laboratories)



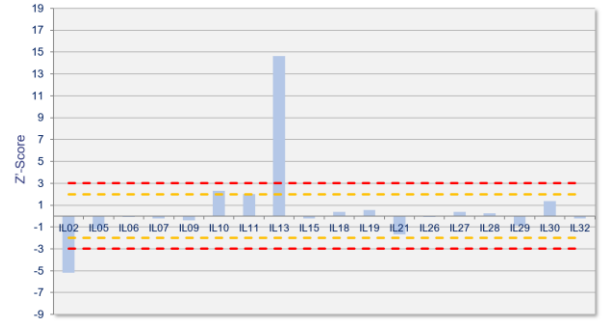
(a) True value (X) and standard deviation (σ_p) – $L_{Aeq,nT}$



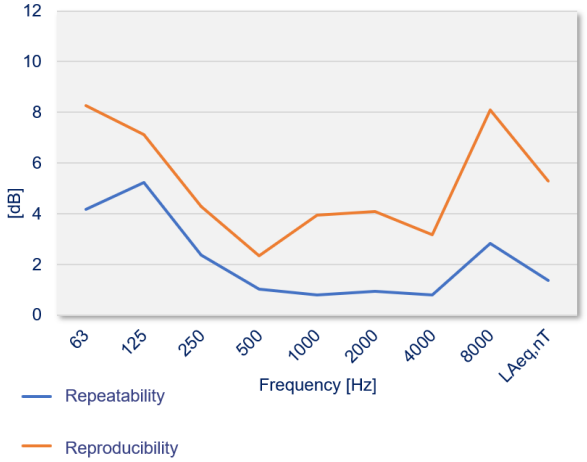
(b) True value (X) and standard deviation (σ_p) – $L_{ASmax,nT}$



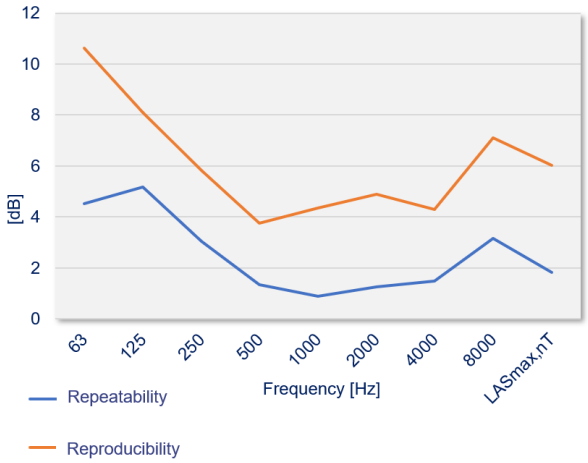
(c) Z'score $L_{Aeq,nT}$ for each laboratory (IL)



(d) Z'score $L_{ASmax,nT}$ for each laboratory (IL)



(e) Repeatability and reproducibility – $L_{\mathrm{Aeq},nT}$



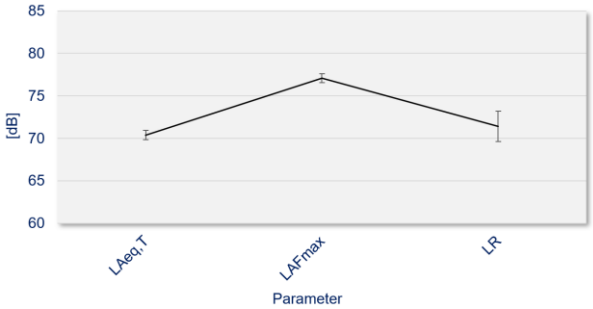
(f) Repeatability and reproducibility – $L_{\mathrm{ASmax},nT}$

Figure 8: Results obtained using ISO 16032:2004.

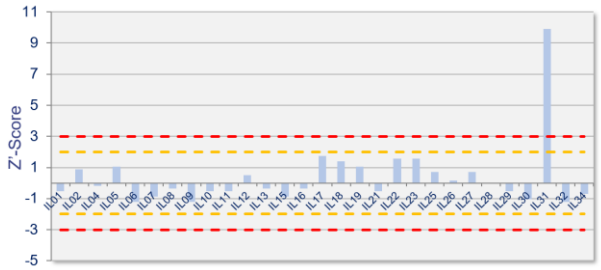
3.7. Sound pressure levels in inhabited areas – $L_{\mathrm{Aeq},T}$, L_{AFmax} and L_{R}

In this section, the results of sound pressure level measurements are presented (Figure 9), conducted in accordance with the Brazilian standard ABNT NBR 10151.

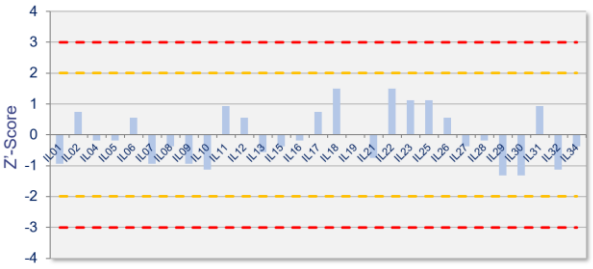
3.7.1. ABNT NBR 10151:2020 (29 laboratories)



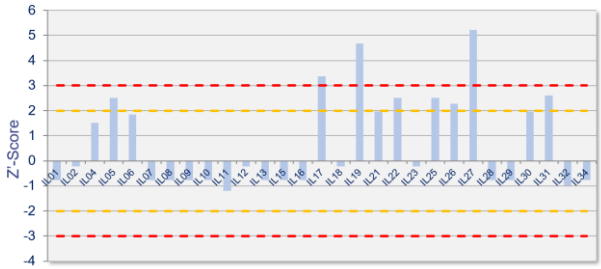
(a) True value (X) and standard deviation (σ_p)



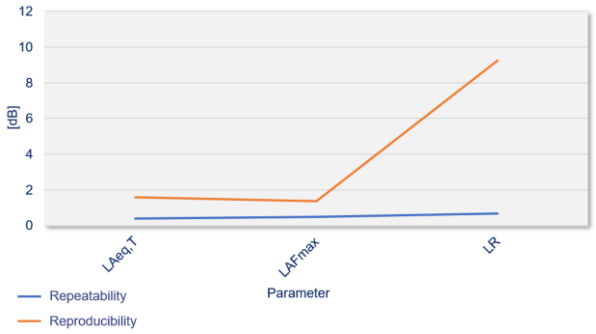
(b) Z'score $L_{\mathrm{Aeq},T}$ for each laboratory (IL)



(c) Z'score L_{AFmax} for each laboratory (IL)



(d) Z'score L_{R} for each laboratory (IL)



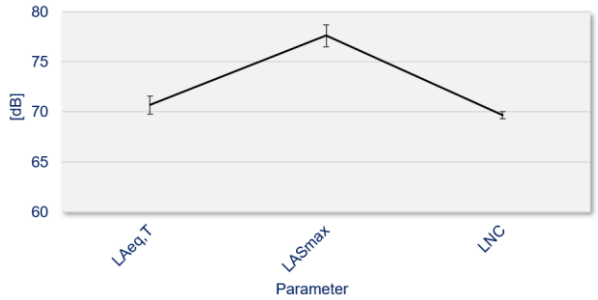
(e) Repeatability and reproducibility

Figure 9: Results obtained using ABNT NBR 10151:2020.

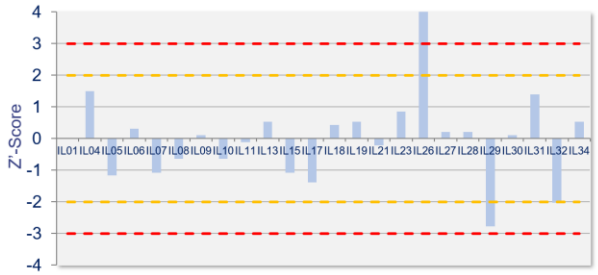
3.8. Sound pressure levels indoors – $L_{Aeq,T}$, L_{ASmax} and L_{NC}

In this section, the results of indoor sound pressure level measurements are presented (Figure 10), conducted in accordance with the Brazilian standard ABNT NBR 10152.

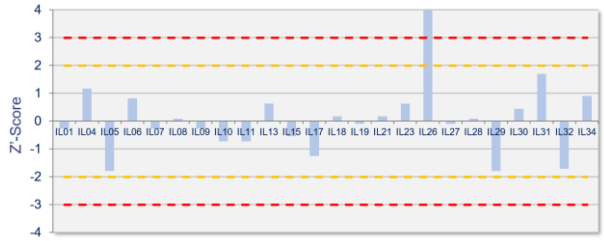
3.8.1. ABNT NBR 10152:2020 (24 laboratories)



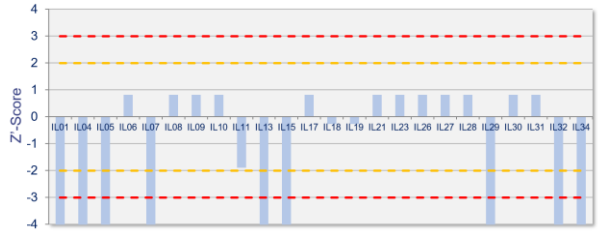
(a) True value (X) and standard deviation (σ_p)



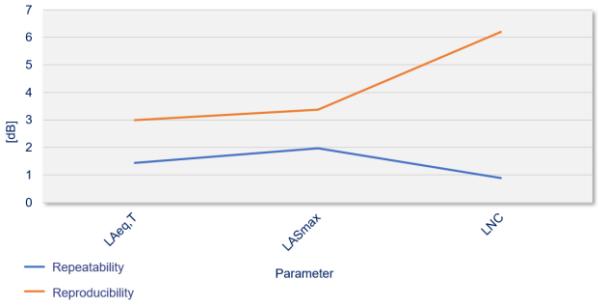
(b) Z'score $L_{Aeq,T}$ for each laboratory (IL)



(c) Z'score L_{ASmax} for each laboratory (IL)



(d) Z'score L_{NC} for each laboratory (IL)



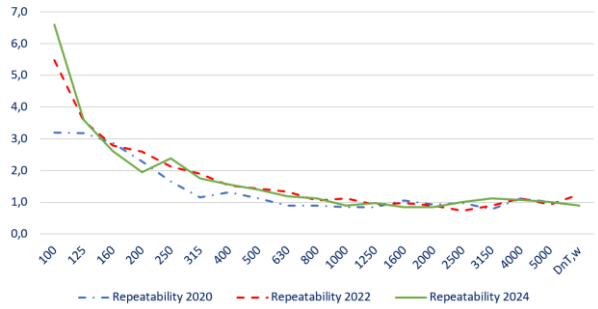
(e) Repeatability and reproducibility

Figure 10: Results obtained using ABNT NBR 10152:2020.

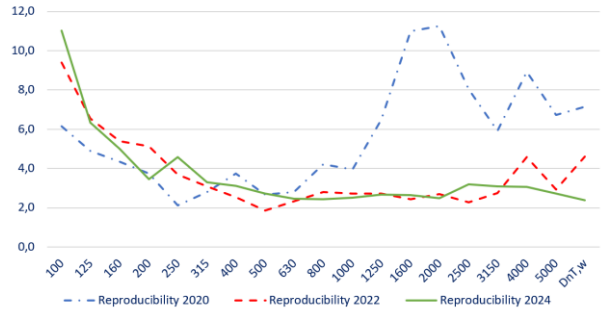
4. COMPARISON BETWEEN EDITIONS (2020 VS. 2022 VS. 2024)

This section presents the comparison of the results obtained in the 2020, 2022 and 2024 editions with the ISO 16283 standard series, for airborne sound insulation (Figure 11), impact sound insulation (Figure 12) and façade sound insulation (Figure 13).

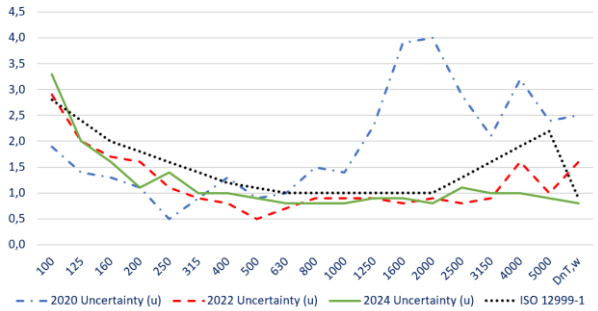
4.1. Airborne sound insulation between dwellings ($D_{nT,w}$) comparison: 2020 (24 laboratories), 2022(27 laboratories) and 2024 (28 laboratories)



(a) Comparison of $D_{nT,w}$ repeatability 2020, 2022 and 2024



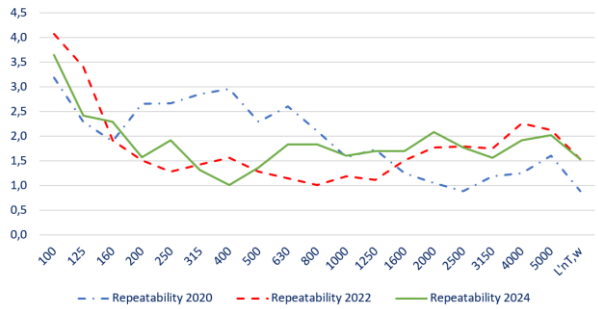
(b) Comparison of $D_{nT,w}$ reproducibility 2020, 2022 and 2024



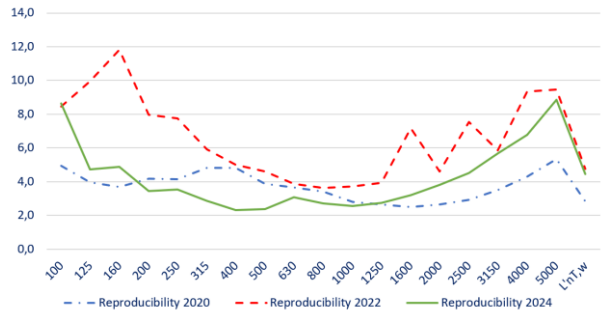
(c) Comparison of uncertainty 2020, 2022 and 2024

Figure 11: Comparison between editions – $D_{nT,w}$.

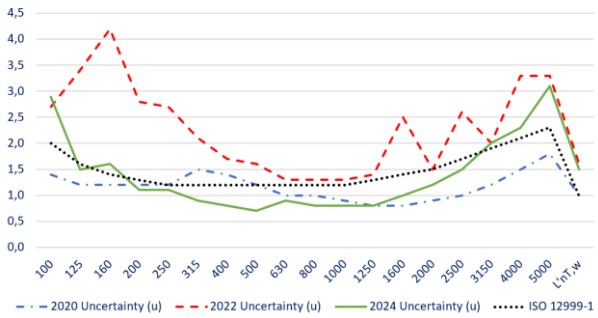
4.2. Impact sound insulation between dwellings ($L'_{nT,w}$) comparison: 2020 (24 laboratories), 2022(28 laboratories) and 2024 (27 laboratories)



(d) Comparison of $L'_{nT,w}$ repeatability 2020, 2022 and 2024



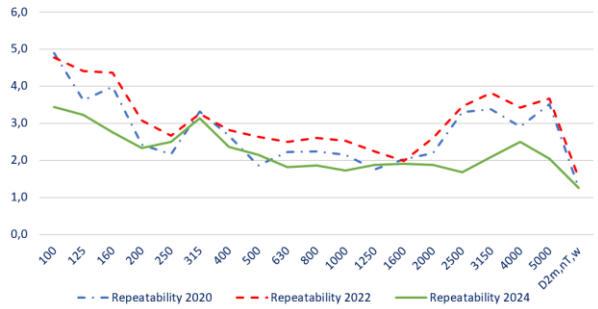
(e) Comparison of $L'_{nT,w}$ reproducibility 2020, 2022 and 2024



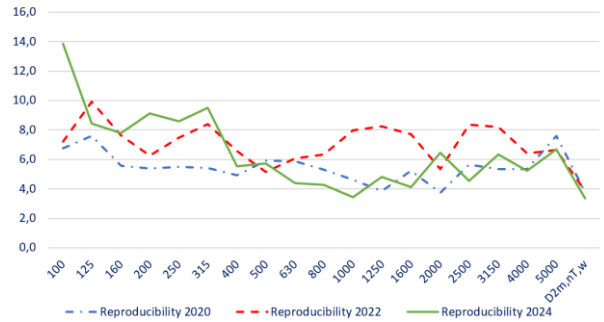
(f) Comparison of uncertainty 2020, 2022 and 2024

Figure 12: Comparison between editions – $L'_{nT,w}$.

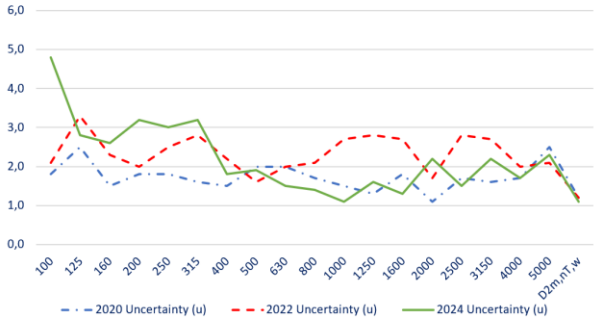
4.3. Façade sound insulation ($D_{2m,nT,w}$) comparison: 2020 (24 laboratories), 2022 (28 laboratories) and 2024 (28 laboratories)



(a) Comparison of $D_{2m,nT,w}$ repeatability 2020, 2022 and 2024



(b) Comparison of $D_{2m,nT,w}$ reproducibility 2020, 2022 and 2024



(c) Comparison of uncertainty 2020, 2022 and 2024

Figure 13: Comparison between editions – $D_{2m,nT,w}$.

6. CONCLUSIONS

- Considering the number of participants, it was observed an increasing interest in participating in proficiency tests, revealing a growing market of acoustics field measurements during the years.

- The uncertainties of the airborne and impact sound insulation results, obtained using the engineering method, showed better alignment with the reference curve defined in ISO 12999-1 when compared to previous editions. The improvement is probably due to the fact that the latest edition of the program was conducted in a controlled environment specifically designed and constructed for acoustic measurements.

- The highest uncertainties values were observed in the results of airborne, impact and façade sound insulation tests performed according to ISO 10052, which can be attributed to the low number of laboratories participating in theses tests, reducing the statistical robustness of the analysis.

- The interlaboratory standard deviation values for reverberation time were low in this latest edition. The measurement results showed good consistency, which contributed to reduced interlaboratory uncertainty, reproducibility and repeatability values. A slightly higher variation at low frequencies was already expected, given the nature of this type of measurement.

- The measurement results from the service equipment noise test showed consistent values, with low standard deviations, except for a few isolated cases among the participating laboratories.

- In the sound pressure level measurements in inhabited areas, conducted according to the Brazilian standard ABNT NBR 10151, the parameters $L_{Aeq,T}$ and L_{AFmax} mostly presented low values of interlaboratory standard deviation, reproducibility, repeatability, and interlaboratory uncertainty. These results indicate good consistency among the participating laboratories in the measurement of these parameters. However, for the parameter L_R, a significant divergence among laboratory results was observed, suggesting that there is still no clear consensus among participants regarding the application of this evaluation criterion as defined in the standard.

- In the sound pressure level measurements in indoor environments, low repeatability values were observed, indicating low interlaboratory standard deviations. For the L_{NC} parameter, greater variation in results was already expect dues to the nature of this type of measurement, which is reflected in higher reproducibility and, consequently, increased interlaboratory uncertainty.

- Based on the comparison between editions, the following conclusions can be drawn:
    - the airborne sound insulation ($D_{nT,w}$) repeatability, reproducibility and uncertainty values in the 2024 edition were significantly lower compared to previous editions, except in a few specific frequency bands. This result is probably related to the fact that the measurements in this latest edition were carried out in an environment specially built for acoustic measurements, providing more controlled and stable conditions.
    - the impact sound insulation ($L'_{nT,w}$) repeatability, reproducibility and uncertainty values of edition 2024 showed significant improvements compared to the 2022 edition. When compared to the reference values established by ISO 12999-1, the uncertainty values of $L'_{nT,w}$ in the 2024 edition were mostly within the specified limits, except in the low and high frequency ranges. This deviation may be associated with the characteristics of the slab used in the tests, which showed some failures during the measurement period.
    - the façade sound insulation ($D_{2m,nT,w}$) repeatability, reproducibility and uncertainty values also performed better overall in the 2024 edition compared to the 2020 and 2022 editions, particularly in the mid and high frequency ranges. This improvement may be attributed

to more favorable outdoor noise conditions, as the measurement site was located in an area with lower road traffic influence.

REFERENCES

1. ISO/IEC 17024:2023. *Conformity assessment – General requirements for the competence of proficiency testing providers*. Geneva, Switzerland: International Organization for Standardization, 2023.
2. ISO 13528:2022. *Statistical methods for use in proficiency testing by interlaboratory comparison*. Geneva, Switzerland: International Organization for Standardization, 2022.
3. ISO 5725-1:2023. *Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions*. Geneva, Switzerland: International Organization for Standardization, 2023.
4. ISO 5725-2:2019. *Accuracy (trueness and precision) of measurement methods and results – Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*. Geneva, Switzerland: International Organization for Standardization, 2019.
5. ISO 12999-1:2020. *Acoustics – Determination and application of measurement uncertainties in building acoustics – Part 1: Soun insulation*. Geneva, Switzerland: International Organization for Standardization, 2020.