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Empirical study on the correlation between measurement methods under diffuse and direct sound field conditions for determining sound absorption and airborne sound insulation properties of noise barriers

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ABSTRACT

In the frame of the SOPRANOISE project (funded by CEDR in the Transnational Road Research Programme 2018) the database of the European noise barrier market developed during the QUIESST project was updated with newly acquired data. This database gives the opportunity for an empirical study on the correlation between the different measurement methods for the acoustic properties of noise barriers (according to the EN 1793 series) to further investigate the interrelationships between these methods by using single-number ratings and third-octave band data. First a correlation of the measurement methods for sound absorption under diffuse field conditions (EN 1793-1) and sound reflection under direct sound field conditions (EN 1793-5) is presented. Secondly, a correlation of the measurement methods for airborne sound insulation under diffuse field conditions (EN 1793-2) and airborne sound insulation under direct sound field conditions (EN 1793-6) is shown. While for airborne sound insulation a distinct correlation is found due to the wide data range, for sound absorption no robust correlation can be found.

1. INTRODUCTION

The series of standards EN 1793 describes measurement methods for determining the acoustic performance of road traffic noise reducing devices (noise barriers). Historically the acoustic properties of sound absorption and airborne sound insulation were measured in reverberation chambers under diffuse sound field conditions according to EN 1793-1 [1] for sound absorption and EN 1793-2 [2] for airborne sound insulation. These measurement methods were also harmonized for the CE product certification according to EN 14388. Nevertheless, new measurement methods under direct sound field conditions were released as standards in 2014 as EN 1793-6 [3] for airborne sound insulation and in 2016 as EN 1793-5 [4] for sound reflection. As most noise barriers are installed under direct sound field conditions, the parts 5 and 6 of the EN 1793 series are most of

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the time applicable. The new standards have technical and practical advantages (measuring also the installation quality in situ and measuring under the relevant sound field conditions), but naturally the obtained values differ to the measurement methods for diffuse sound field conditions. But as many stakeholders such as road and provincial authorities as well as manufacturers are used to the values of the diffuse sound field conditions, the relationship between the measurement methods is often discussed.

Within the framework of the SOPRANOISE project, theoretical and practical background information on measurement methods of the acoustic performance of noise barriers is examined. In this context, one of the main objectives was focused on extending the relevant database of European noise barriers developed within the QUIESST project [5], including single-number ratings and third-octave band spectra from manufactured products and already installed noise barriers. This new SOPRANOISE database aims to show facts and figures about acoustic performances obtained from measurements performed under diffuse sound field as well as direct sound field conditions, together with a better understanding of the respective significance, similarities and differences of these standardized methods.

The empirical study presented in this paper shows correlations between results of methods for measuring sound absorption under diffuse sound field conditions and sound reflection under direct sound field conditions (EN 1793-1 versus EN 1793-5), as well as for the methods for measuring airborne sound insulation under diffuse and direct sound field conditions (EN 1793-2 versus EN 1793-6) using several regression models.

2. METHOD

From the database created in the SOPRANOISE project, the interrelationships between the measurement methods under diffuse and direct sound field conditions are examined. These interrelationships are examined for the acoustic properties of airborne sound insulation and sound reflection/absorption and for those noise barrier types, for which results are available for the respective methods under diffuse and direct sound field conditions. The generalization on comparing the same noise barrier types instead of the same noise barrier elements is necessary, as too few results are available of comparing measurement results of both methods for the same noise barrier element. Even by comparing the same noise barrier type, the analysis is limited by the small sample size.

2.1. Noise Barrier Categories

The noise barriers in the database are grouped according to the categories developed during the QUIESST project [6]. In this paper only the distinction of noise barrier material is significant, where the following categories are used:

Metal: Steel-supported structure (posts) with at least a metallic surface layer (mostly noise barriers consisting of aluminium cassettes)
Transparent: Steel-supported structure (posts) with transparent panels (e.g. acrylic glass)
Wood-Concrete: Steel-supported structure (posts) with at least a concrete surface layer (including wood-fibre concrete)
Concrete: Self-supporting concrete structure (without posts)
Timber: Steel-supported structure (posts) with at least a timber surface layer
Plastic: Steel-supported structure (posts) with at least a plastic surface layer

2.2. Measured Quantities

The main measured quantity for all four measurement methods is expressed in third-octave bands. Additionally, by weighting with the standardized traffic noise spectrum L_j according to EN 1793-3 [7] a single-number rating can be derived. In the following equations is j the index of the third-octave band.

According to EN 1793-1, the sound absorption coefficient α_{NRD} is defined as

$$\alpha_{\mathrm{NRD},j} = \frac{A_{T,j}}{S} \tag{1}$$

where A_T is the equivalent absorption area and S the surface area of the test sample as measured according to ISO 354 [8] with the change of reverberation time inside a reverberation chamber. The single-number rating for sound absorption under diffuse sound field conditions $DL_{\alpha,\mathrm{NRD}}$ is calculated with

$$DL_{\alpha,\mathrm{NRD}} = -10\log_{10}\left[1 - \frac{\sum_{j=1}^{18} \alpha_{\mathrm{NRD},j} 10^{0.1L_j}}{\sum_{j=1}^{18} 10^{0.1L_j}}\right]. \tag{2}$$

According to EN 1793-2, the sound reduction index R is defined as

$$R_j = L_{1,j} - L_{2,j} + 10\log_{10}\left(\frac{S}{A_j}\right) \tag{3}$$

with the averaged sound pressure levels in the sender (L_1) and receiver (L_2) (reverberation) rooms and the area of the connecting window S and the equivalent absorption area A_j in the receiver room. The single-number rating for airborne sound insulation under diffuse sound field conditions DL_R is defined as

$$DL_R = -10\log_{10}\left[\frac{\sum_{j=1}^{18} 10^{0.1L_j} 10^{-0.1R_j}}{\sum_{i=1}^{18} 10^{0.1L_j}}\right]. \tag{4}$$

According to EN 1793-5, the sound reflection index RI is defined as

$$RI_j = \frac{1}{n_k}\sum_{k=1}^{n_k}\left[\frac{w_{\mathrm{r},j,k}}{w_{\mathrm{i},j,k}}\, c_{\mathrm{geo},k}\; c_{\mathrm{dir},j,k}(\Delta f_j)\; c_{\mathrm{gain},j,k}(\Delta f_g)\right] \tag{5}$$

and is the ratio between the incident ($w_{\mathrm{i},j,k}$) and reflected ($w_{\mathrm{r},j,k}$) sound energy in front of the noise barrier atd microphone position k with correction factors for geometrical divergence ($c_{\mathrm{geo},k}$), sound source directivity ($c_{\mathrm{dir},j,k}(\Delta f_j)$) and sound source amplification changes ($c_{\mathrm{gain},j,k}(\Delta f_g)$).The single-number rating for sound reflection under direct sound field conditions DL_{RI} is calculated with

$$DL_{RI} = -10\log_{10}\left[\frac{\sum_{j=1}^{18} \mathrm{RI}_j 10^{0.1L_j}}{\sum_{j=1}^{18} 10^{0.1L_j}}\right]. \tag{6}$$

According to EN 1793-6, the airborne sound insulation index SI is defined as

$$SI_j = -10\,\log_{10}\left[\frac{1}{n_k}\sum_{k=1}^{n_k}\frac{w_{\mathrm{t},j,k}}{w_{\mathrm{i},j,k}}\right] \tag{7}$$

and is the ratio between the incident ($w_{\mathrm{i},j}$) and transmitted ($w_{\mathrm{t},j}$) sound energy at microphone position k behind the noise barrier. The single-number rating for airborne sound insulation under direct sound field conditions DL_{SI} is calculated with

$$DL_{SI} = -10\log_{10}\left[\frac{\sum_{j=1}^{18} 10^{0.1L_j}10^{-0.1\mathrm{SI}_j}}{\sum_{j=1}^{18} 10^{0.1L_j}}\right]. \tag{8}$$

The airborne sound insulation index can be measured in front of an acoustic element ($DL_{SI,\mathrm{E}}$) or a post ($DL_{SI,\mathrm{P}}$) of the noise barrier. For better comparison, the global value of airborne sound insulation $DL_{SI,\mathrm{G}}$ is defined as an energetic average of $DL_{SI,\mathrm{E}}$ and $DL_{SI,\mathrm{P}}$.

2.3. Comparing Single-Number Ratings

The first approach compares the single-number ratings for the corresponding measurement methods under diffuse and direct sound field conditions ($DL_{\alpha,\mathrm{NRD}}$ vs. DL_{RI} and DL_R vs DL_{SI}) for the new database with regression models, as was shown in [5] for linear models solely.

As $DL_{\alpha,\mathrm{NRD}}$ vs. DL_{RI} show a poor linear relationship, two additional regression models are compared to a linear regression model. First, a linear regression model is presented between the natural logarithm of the $DL_{\alpha,\mathrm{NRD}}$ and the DL_{RI}. Although, the natural logarithm is not suitable to predict small values (i.e. < 1) as it diverges to minus infinity for approaching 0, it gives for smaller values a steeper curve and flattens for higher values. Secondly, a locally weighted scatterplot smoothing (*lowess*) regression model was used, to account for non-linear effects. A possible origin of non-linear effects is that the test sample may alter the diffuse field in the reverberation room and the diffuse sound field method may systematically overestimate the sound absorption with the diffuse sound field method for highly absorbing test samples [9]. Nevertheless, for applying the *lowess* model more caution is necessary as it may overfit for small sample sizes.

2.4. Using Third-Octave Bands

Due to the averaging process in the calculation, the single-number ratings contain less information about the test sample. Therefore, to improve the correlation analysis, the second approach uses the third-octave band data of the measurement methods. To study the relationship between the diffuse and direct sound field methods, the third-octave band values of the diffuse sound field method are used as independent variables for constrained multi-variate linear regression models for each third-octave band value of the corresponding direct sound field method as the dependent variable.

To avoid overfitting for the small sample sizes, the models are constrained in regard to the number of third-octave bands which are used for the regression model. For the relationship between sound absorption under diffuse sound field conditions and sound reflection under direct sound field conditions, each regression model is constrained to a maximum of two third-octave bands. Due to the availability of more data, the regression models for airborne sound insulation are constrained to a maximum of three third-octave bands.

To select the third-octave bands a sequential-forward-selection (SFS) algorithm is used to search for each third-octave band of the direct sound field method the best selection of third-octave bands of the diffuse sound field method for the multi-variate linear regression models. For the SFS, the coefficient of determination of a linear regression model was used as metric. With these best fitting third-octave bands from the diffuse sound field method, the third-octave bands of the direct sound field method are estimated and the single-number rating of the direct sound field method is calculated accordingly.

Due to the different sound fields it is possible, that third-octave bands with a different center-frequency are more correlated than the same center frequency. This is implicitly handled with the SFS algorithm.

To improve the fit between the third-octave bands, various transformations of the independent variables ($\alpha_{\text{NRD},j}$) as as well as the dependent variable ($\widehat{RI_j}$) were tested for the relationship between sound absorption under diffuse sound field conditions and sound reflection under direct sound field conditions. The best performing approach only transforms the independent variables to a logarithmic scale. For consistency this logarithmic value was then defined similar as the single-number rating for sound absorption, cf. Equation 2:

$$L_{\alpha,\text{NRD},j} = -10 * \log_{10}(1 - \alpha_{\text{NRD},j}) \tag{9}$$

where $\alpha_{\text{NRD},j}$ is constrained to a maximum value of 0.99.[4]

2.5. Performance Measures

The different regression models presented will be evaluated by three performance measures, which are calculated from the measured values (y), the estimated values ($\hat{y}$) (by applying the regression model on the measured values) and the total number of samples (n):

1. the coefficient of determination to give the proportion of the explained variance of the model,
2. the mean absolute error,
3. the root mean squared error.

The definition of the performance measures as well as the values for the worst and best case are given in Table 1. It should be noted that the coefficient of determination is a dimensionless number, whereas the two error measures are in the unit of the estimated value. The mean absolute error MAE is an easy measure to understand, whereas the root mean squared error RMSE can be interpreted as the standard deviation of an unbiased estimator.

Table 1: Performance measures for evaluating the regression models.

Name	**Formula**	**"Worst"**	**"Best"**
Coefficient of Determination	$R^2 = 1 - \frac{\sum_i (y_i - \bar{y})^2}{\sum_i (y_i - \hat{y}_i)^2}$, with $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$	0	1
Mean Absolute Error	$MAE = \frac{1}{n}\sum_{i=1}^{n} \lvert \hat{y}_i - y_i \rvert$	∞	0
Root Mean Squared Error	$RMSE = \frac{1}{\sqrt{n}}\sqrt{\sum_{i=1}^{n} (\hat{y}_i - y_i)^2}$	∞	0

3. RESULTS AND DISCUSSION

In this section the interrelationships between the corresponding measurement methods are shown. Section 3.1 shows the correlation of the measurement methods for sound reflection under direct sound field conditions and sound absorption under diffuse field conditions. Section 3.2 shows the correlation of the measurement methods for airborne sound insulation under direct and diffuse field conditions.

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[4] Therefore $L_{\alpha,\text{NRD},j}$ is constrained in the same way to a maximum value of 20 dB as the single-number rating $DL_{\alpha,\text{NRD}}$.

3.1. Sound Reflection / Absorption

In this chapter, the estimation of the single-number rating for sound reflection under direct sound field conditions (DL_{RI}) is presented. As estimator the single-number rating for sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) is used as well as the corresponding third-octave band values (α_{NRD}). For using only single-number ratings, the database consists of 35 datasets, where the single-number rating is available for measurements on the same noise barrier types for sound absorption under diffuse sound field conditions as well as for sound reflection under direct sound field conditions. For 20 of these datasets, the required third-octave band values are available for use in the regression analysis.

Figure 1 shows the three regression models between the single-number ratings for sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) and sound reflection under direct sound field conditions (DL_{RI}). The material of the respective noise barrier is color-coded into the scatter plot. The left diagram of Figure 1 shows the relationship for all available data points. For small values a more or less linear relationship can be seen. Comparatively high values show high deviations. Nevertheless, nearly all of the high deviating datapoints from the overall linear regression are metal noise barriers. Therefore, the right diagram of Figure 1 shows the same scatter plot, but without the metal data points, as well as newly fitted models to the reduced dataset. The models are very similar to each other, with some deviations at the edges.

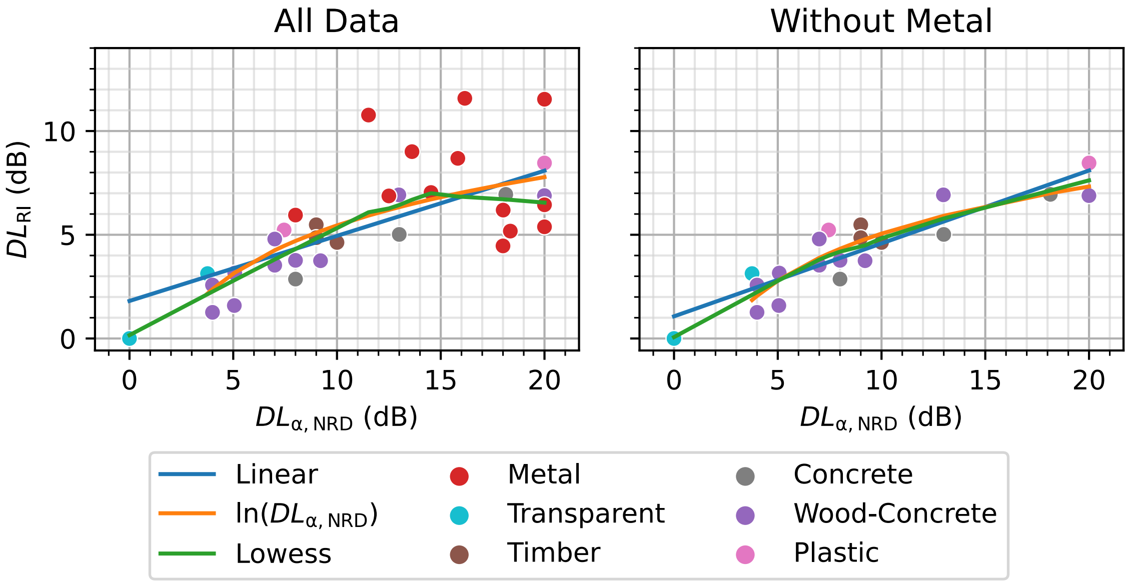

Figure 1: Result of the calculated fit for the three regression models between the single-number ratings for sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) and sound reflection under direct sound field conditions (DL_{RI}) for all available data (left diagram) and all available data without metal noise barriers (right diagram).

Figure 2 compares the estimated $\widehat{DL_{RI}}$ from the logarithmic $L_{\alpha,\mathrm{NRD},j}$ third-octave band values for all available data (left diagram) and all available data without metal noise barriers (right diagram). Due to the wide spread in the original data, most of the metal noise barriers are estimated at around 6 to 8 dB with no real connection to the measured values. If the metal noise barriers are discarded, only eight data points are left in the dataset, which can be estimated quite well.

Table 2 and 3 show the model formulations and performance parameters for the regression models between between sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) and sound

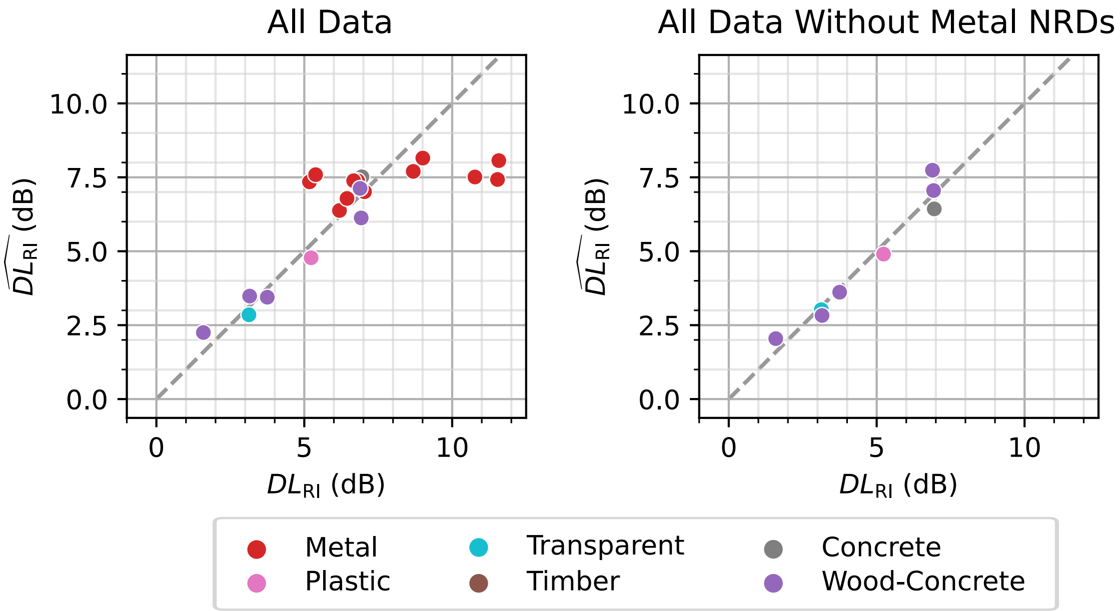

Figure 2: Estimation of the $\widehat{DL_{RI}}$ from third-octave bands of the logarithmic $L_{\alpha,\mathrm{NRD},j}$ third-octave band values for all available data (left diagram) and all available data without metal noise barriers (right diagram).

reflection under direct sound field conditions (DL_{RI}) for all available data and for the reduced data set without metal noise barriers.

Table 2: Model and performance parameters for the regression models between sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) and sound reflection under direct sound field conditions (DL_{RI}) for all available data.

	Model	n	**R^2**	**MAE (dB)**	**RMSE (dB)**
Linear	$\widehat{DL_{RI}} = 0.31\, DL_{\alpha,\mathrm{NRD}} + 1.81$	35	0.48	1.50	1.92
$\ln(DL_{\alpha,\mathrm{NRD}})$	$\widehat{DL_{RI}} = 3.36 \ln(DL_{\alpha,\mathrm{NRD}}) - 2.28$	35	0.49	1.39	1.81
Lowess	$LOWESS(DL_{\alpha,\mathrm{NRD}})$	35	0.57	1.21	1.75
Third-octave bands	$\widehat{RI_j} \sim (L_{\alpha,\mathrm{NRD},j})_{2-\mathrm{best}}$	20	0.61	1.19	1.64

If all data points are considered the explained variance (R^2) is rather poor and between 48 % and 61 %. Due to its' capability of adapting to non-linearities the *lowess* model performs best for the single-number ratings. Nevertheless, by using the third-octave band data, the estimation quality can be improved further, although only a reduced data set is available.

If the metal noise barriers are discarded from the data set, the regression quality improves significantly, where by only using the single number ratings 79 % to 84 % of the variance can be explained. The high coefficient of determination of 0.95 for the estimation by using third-octave band data should be considered with special attention, as it is based on 8 data points. Nevertheless, it is based on independently trained regression models, where only two third-octave bands are used as independent variables for each model.

Table 3: Model and performance parameters for the regression models between sound absorption under diffuse sound field conditions ($DL_{\alpha,\mathrm{NRD}}$) and sound reflection under direct sound field conditions (DL_{RI}) for all available data without metal noise barriers.

	Model	n	**R^2**	**MAE (dB)**	**RMSE (dB)**
Linear	$\widehat{DL_{RI}} = 0.35\,DL_{\alpha,\mathrm{NRD}} + 1.07$	20	0.81	0.75	0.89
$\ln(DL_{\alpha,\mathrm{NRD}})$	$\widehat{DL_{RI}} = 3.27\,\ln(DL_{\alpha,\mathrm{NRD}}) - 2.49$	20	0.79	0.76	0.86
Lowess	$LOWESS(DL_{\alpha,\mathrm{NRD}})$	20	0.84	0.71	0.81
Third-octave bands	$\widehat{RI_j} \sim (L_{\alpha,\mathrm{NRD},j})_{2-\mathrm{best}}$	8	0.95	0.36	0.43

Therefore, with the exclusion of metal noise barriers some interrelationship between the measurement methods for sound absorption under diffuse sound field conditions and sound reflection under direct sound field conditions can be found. Due to the generally light weight structure, metal noise barriers may behave significantly different if placed on the acoustically hard floor in the reverberation room for the diffuse sound field method than free standing as for the direct sound field method.

Although the coefficient of determination points to a stable regression, the RMSE must be considered. All of the regressions produce symmetrical errors, therefore the RMSE can be seen as the standard deviation of an unbiased estimator. This standard deviation is in the same order of magnitude as the standard deviation of reproducibility of the measurement methods (e.g. $s_R = 0.68$ dB for DL_{RI} [4]). Therefore, this regression models should be seen as *inference* models of showing the interrelationship between these models and useable for value prediction. In regard to the measurement uncertainties of the methods and the limited range of values, these models are only suitable to give very rough estimates of prediction.

3.2. Airborne Sound Insulation

In this chapter, the estimation of the global single-number rating for airborne sound insulation under direct sound field conditions (DL_{SI_g}) is presented. As estimator the single-number rating for airborne sound insulation under diffuse sound field conditions (DL_R) is used as well as the corresponding third-octave band values (R_j). For using only single-number ratings, the database consists of 57 datasets, where the single-number rating is available for measurements on the same noise barrier types for airborne sound insulation under diffuse and direct sound field conditions. Three noise barrier types with concrete core were discarded as outliers, as the airborne sound insulation under direct sound field conditions was significantly worse than the corresponding measurement under diffuse sound field conditions and may be caused by a poor quality of installation in situ.[5] For 27 of these datasets, the required third-octave band values are available for use in the regression analysis.

Figure 3 and Figure 4 show the regression analysis between the single-number ratings for airborne sound insulation under diffuse sound field conditions and airborne sound insulation under direct sound field conditions after removal of the outliers. Figure 4 gives a detailed view of the regression lines and distribution of the data points for each material separately as well as the overall fitted regression line (blacked dashed line).

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[5] As the measurement methods under diffuse sound field conditions are performed under laboratory conditions, generally a very good installation can be assumed.

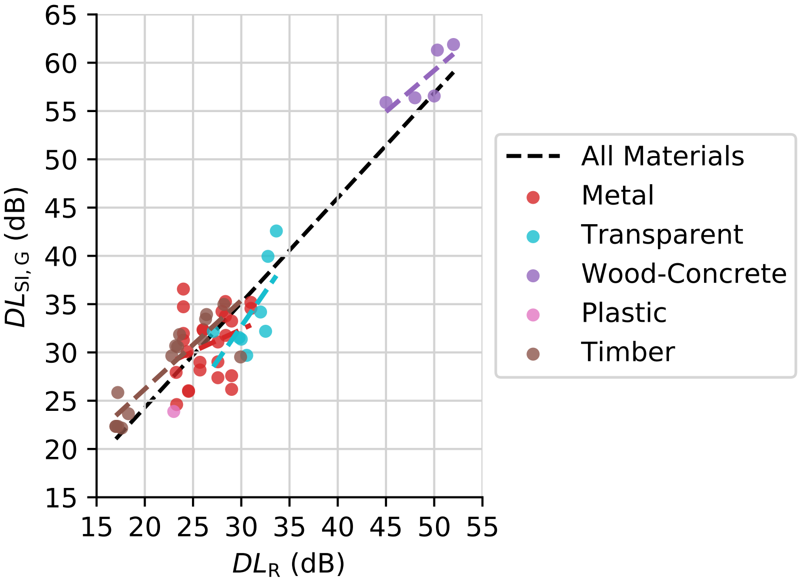

Figure 3: Fit for regression models between the single-number ratings for airborne sound insulation under diffuse sound field conditions (DL_R) and the global value for airborne sound insulation under direct sound field conditions ($DL_{SI,\mathrm{G}}$).

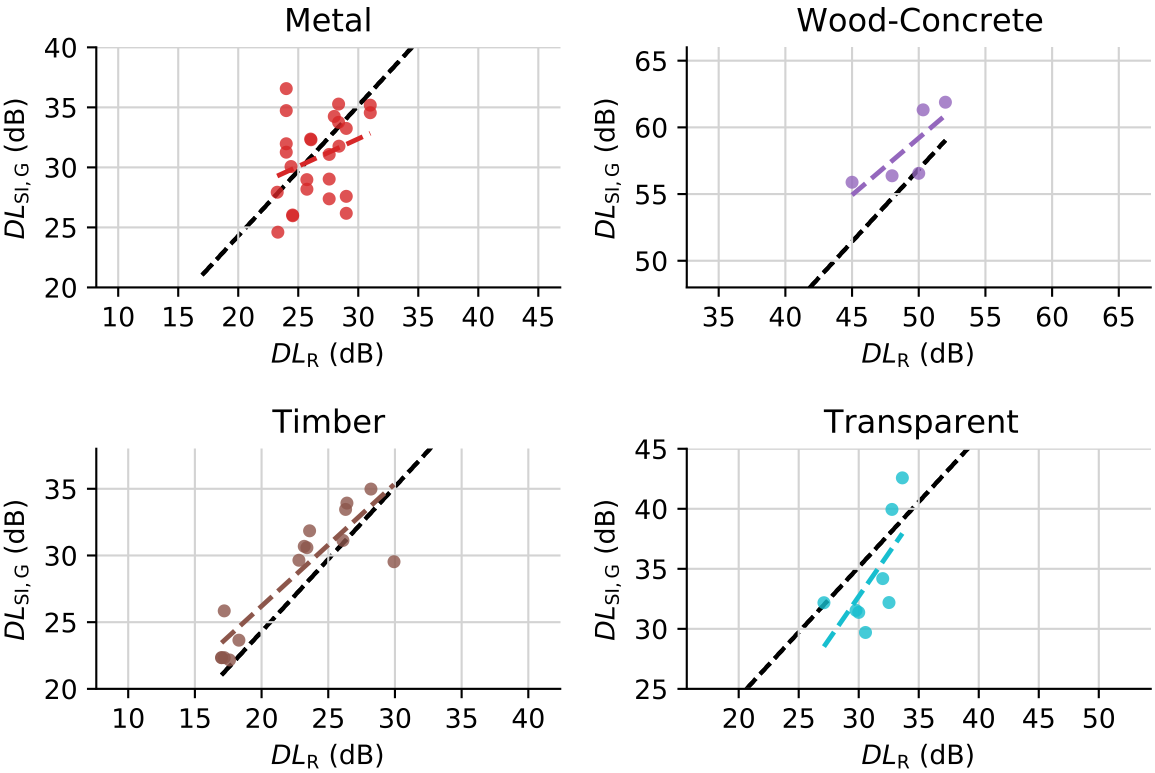

Figure 4: Fit for regression models between the single-number ratings for airborne sound insulation under diffuse sound field conditions (DL_R) and the global value for airborne sound insulation under direct sound field conditions ($DL_{SI,\mathrm{G}}$) for each material (coloured dashed lines) and for the regression model for all available data (dashed black line) after outlier removal.

For the method of measuring airborne sound insulation under direct sound field conditions the single-number ratings are in the same range but generally higher. For all materials the linear regression model shows 4 to 7 dB higher values for the direct sound field method than for the diffuse sound field method. Especially for high insulating samples (wood-concrete) this difference can be up to more than 10 dB, although it must be considered, that measuring 50-60 dB of sound energy difference has higher demands on the measurement method and the used equipment. Therefore, it is possible that one or both of the measurement methods introduce an unseen systematic error.

Figure 5 shows the estimated $\widehat{DL_{SI,\mathrm{G}}}$ by using three selected third-octave bands from the R_j data, as described in section 2.4 for all available data and only metal noise barriers. The model and performance parameters of these fitted models are shown in Table 4.

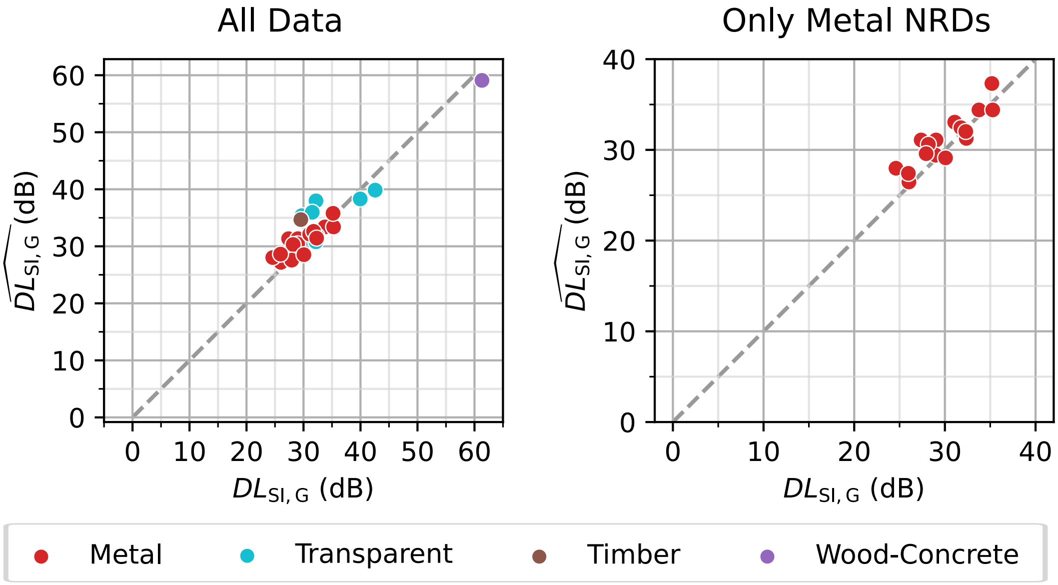

Figure 5: Estimation of the $\widehat{DL_{SI,\mathrm{G}}}$ from third-octave bands of the R_j third-octave band values for all available data (left diagram) and only metal noise barriers (right diagram).

Table 4: Model and performance parameters for the regression models for airborne sound insulation between direct and diffuse sound field measurement methods for all materials and all the materials with minimum sample size $n \geq 5$.

	Model	n	$\mathbf{R^2}$	**MAE (dB)**	**RMSE (dB)**
All Materials	$\widehat{DL_{SI,\mathrm{G}}} = 1.09\,DL_R + 2.58$	54	0.87	2.77	3.36
All Materials	$\widehat{SI_{j,\mathrm{G}}} \sim (R_j)_{3-\mathrm{best}}$	27	0.86	2.56	2.78
Metal	$\widehat{DL_{SI,\mathrm{G}}} = 0.46\,DL_R + 18.6$	25	0.09	2.71	3.21
Metal	$\widehat{SI_{j,\mathrm{G}}} \sim (R_j)_{3-\mathrm{best}}$	16	0.67	1.51	1.82
Transparent	$\widehat{DL_{SI,\mathrm{G}}} = 1.44\,DL_R - 10.59$	8	0.44	2.89	3.19
Wood-Concrete	$\widehat{DL_{SI,\mathrm{G}}} = 0.85\,DL_R + 16.47$	5	0.61	1.51	1.64
Timber	$\widehat{DL_{SI,\mathrm{G}}} = 0.92\,DL_R + 7.85$	15	0.79	1.71	2.08

The regression with all materials is strongly supported by the high values of wood-concrete noise barriers with a R^2 of 0.87 for the single-number rating model and 0.86 for the third-octave band model. Nevertheless, the third-octave model shows a significantly lower RMSE of 2.78 dB than the single-number rating model (3.36 dB).

In the dataset, noise barriers of the same material have similar values for airborne sound insulation for both measurement methods. For metal noise barriers these limited ranges show no interrelationship between the measurement methods, if the single-number ratings are directly compared ($R^2 = 0.09$). Nevertheless, by using the third-octave band data the estimation of $\widehat{DL_{SI}}_{,\mathrm{G}}$ shows a significant relationship between the two measurement methods with $R^2 = 0.67$ and $RMSE = 1.82$ dB.

For the other materials (timber, wood-concrete, transparent) also a interrelationship between the measurement methods under diffuse and direct sound field conditions can be found for each material separately. Therefore, for example, a comparatively good timber noise barrier from a reverberation room measurement under diffuse sound field conditions, will most likely yield good measurement results under direct sound field conditions. Nevertheless, as a linear regression model should not be used for extrapolation, the material specific models are only valid in a small data range and under consideration of the uncertainties of the regression can only be used for rough estimations.

4. CONCLUSIONS AND OUTLOOK

For the correlation between the measurement method for sound absorption under diffuse sound field conditions and sound reflection under direct sound field conditions statistically stable regression model could not be found by considering all materials (i.e. without differentiating between different materials). Nevertheless, the prediction of a single-number rating from one method to the other is possible for lower values of sound absorption, where a coefficient of determination of 0.81 could be reached with a linear regression model between the single-number ratings with a reasonable root mean squared error of 0.89 dB and a robust sample size. However, even for this strong fit an uncertainty of ±1.78 dB exists for applying the regression model under the theoretical and ideal assumption of no measurement uncertainty. Nonetheless, for highly absorbing noise barriers, a robust prediction of a single-number rating for sound reflection under direct sound field conditions from measurements of sound absorption under diffuse sound field conditions is not reliably possible with acceptable error margins. A specific model for every single material was not found, mainly because of the low amount of data for every material separately.

In conclusion, for the correlation between measurement results for sound absorption under diffuse sound field condition and sound reflection under direct sound field condition, only very rough estimates are possible, which are limited to low sound absorbing samples.

In the correlation analysis for airborne sound insulation between direct and diffuse sound field conditions, good correlations were found for the single-number ratings, which could not be generally improved by using third-octave band data. If the regression is fitted for all available data (i.e. all materials), the coefficient of determination shows a strong fit with a score of 0.87, but with a root mean squared error of 3.36 dB. This high score is significantly caused by the high values for the single-number ratings for the wood-fibre concrete noise barriers, as they serve as strong supporting points for the linear regression. Nevertheless, even in this small dataset and even considering the different ranges of values available, the material-specific correlations are very close to the general fit except for metal noise barriers. These again show no significant correlation between the single-number ratings resulting and a poor coefficient of determination of 0.09. In contrast, by using the developed regression models on third-octave bands for airborne sound insulation only for metal noise barriers, the prediction could be improved to a coefficient of determination of 0.67 with a root mean squared error of 1.82.

For the correlation between measurement results for airborne sound insulation obtained under diffuse sound field conditions and direct sound field conditions, a promising fit could be achieved due to the wide data range. Nevertheless, the significant uncertainties of the regression models must be considered when estimations are made.

Further research will focus on the analysis of this dataset, how and possibly why the third-octave bands of the different measurement methods interact with each other, so that the estimations shown in this study could be improved by using two or three third-octave bands instead of single-number ratings. Nevertheless, to really improve the understanding of the differences between the measurement methods, an extensive gathering of specific data would be necessary, where measurement results are obtained for all measurement methods on a significant number of noise barriers for all relevant materials (or absorbing surface types) and, if possible, on the same noise barriers and ideally even for the same noise barrier installation.

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