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Translation of existing impact sound insulation descriptors into new proposed ones, based on a large set of in situ measurements

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Abstract

The need for revision and harmonization of sound insulation descriptors is generally accepted among most building acoustics specialists. Undoubtedly, if all countries used the same descriptors, it would be a great advantage to all the sectors related to the building construction industry, legislators and final users.

Concerning sound insulation regulations, the most common impact sound insulation descriptors used are $L'_{nT,w}$ and $L'_{n,w}$. In some countries, the spectral adaptation term C_I is also considered, including different frequency ranges, which widens the choices for impact sound insulation descriptors used in regulations.

The purpose of this paper is to determine, based on a large set of in situ measurements, how existing impact sound insulation descriptors relate to new proposed ones, in order to be able to make empirical translations of descriptors. The effect of the spectral adaptation term C_I and the effect of the building system (heavy/light floors) are also analysed. Based on the translation equations found, one of the main conclusions is that heavy and light floors yield different empirical translation equations and that it would not be correct to use the same translation equation for all types of floors.

Keywords: Impact sound insulation; descriptors’ translation

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1 Introduction

Impact sound insulation assessment has been discussed and researched since over half a century. The critical issues have been similar over the years: How well does a single number quantity (SNQ) correspond to the subjective judgment of different types of noise? Which of the many existing and proposed reference curves deliver a most adequate SNQ, if subjective judgment is considered? Should new impact sources be introduced to measure and assess impact sound insulation? Which frequency range assessment is most adequate? Can a spectral adaptation index adequately reflect low frequency effects?

Over the years, in fact, rating methods have been modified [1–4] new impact sources have been considered [5–7] (i.e. soft impact sources such as the rubber ball, bang machine...), new descriptors have been introduced (i.e. impact sound pressure level) [8,9] impact spectrum adaptation term (C_I) has been investigated and different assessment frequency ranges have been used [10–12]. The debate is still ongoing in the XXIst century. The noise sources have changed, the construction materials and technologies have changed… and what is more important, globalization and sustainability have reached many technological aspects of building construction such as thermal and acoustic performance.

On top of the aforementioned changes, one more reason for the ongoing debate is the fact that impact sound insulation can be assessed using many different SNQs as already pointed out by some authors [13,14] and in fact there is a widespread of sound insulation descriptors used around the world.

Aiming at harmonizing, improving sustainability and simplifying the understanding of the acoustic performance of a building, the European project, COST TU 0901 delivered both a proposal for harmonized sound insulation descriptors and a draft acoustic classification scheme for dwellings. All the information concerning this project as well as its outputs can be found at http://www.costtu0901.eu/.

Concerning impact sound insulation, the proposed descriptor is $L'_{nT,w}$, although the use of the spectral adaptation index C_I and the frequency range used for the SNQ assessment could not clearly be agreed. The fact of proposing one SNQ to be used (hopefully) as impact sound insulation around the world may have consequences at many different levels: product performance description, legislation, measurement procedures, correlation of the proposed descriptor to subjective impression of impact sound insulation…

This paper focuses in an important issue: the translation of existing descriptors used in regulations, into the proposed ones, including (or not) the spectral adaptation term C_I.

2 Objectives

Note: Hereinafter, the "*new proposed* harmonized descriptors" will be three: $L'_{nT,w}$; $L'_{nT,50} = L'_{nT,w} + C_{I,50\text{-}2500}$ and $L'_{nT,100} = L'_{nT,w} + C_{I,100\text{-}2500}$. The notation $L'_{nT,50}$ and $L'_{nT,100}$ does not correspond to ISO 717-2. It is used as suggested in Chapter 5 in reference [15].

Although translation equations between several impact sound insulation descriptors have already been proposed by Gerretsen and Dunbavin in Chapter 4, reference [15], the possible effect of different building systems in such translation equations was not considered.

The main purpose of this paper is to provide, based on a large set of in situ measurements, translation equations between some selected "*existing"* impact sound insulation descriptors and the previously proposed ones, taking into account the constructive solution type. The selected existing descriptors are L'_{w}, $L'_{n,w}$, $L'_{n,w} + C_{I\ (50\text{-}2500Hz)}$ and $L'_{nT,w}$. It might seem estrange to select $L'_{nT,w}$ both as "*existing*" and "*new proposed*" descriptor, but this will enable to translate $L'_{nT,w}$ into $L'_{nT,50}$ and $L'_{nT,100}$ as well. For the pair of descriptors $L'_{nT,50}$ / L'_{nw} our results will be compared to those obtained by Gerretsen et al. based on basic building acoustics equations and geometrical assumptions [15].

3 Data set description

A set of 644 field impact sound insulation measurements of 13 different types of floors (9 heavy y 4 lightweight) were evaluated. All floors were constructed in the United Kingdom in compliance with the relevant Robust Details [16] specifications. Testing and on-site inspections were carried out on a sample of structures in dwellings under construction to ensure compliance with the construction system by workmanship and with UK Building Regulations.

Figures 1 and 2 describe the floors used in this research. Tables 1, 2 and 3 summarize some basic statistical data concerning impact sound insulation of the different types of floors.

Table 1: Basic statistical data for heavy floors

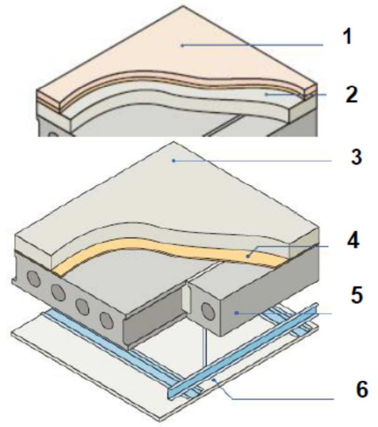
Heavyweight floors	**All**	**1 HF**	**2 HF**	**3 HF**	**4 HF**	**5 HF**	**6 HF**	**7 HF**	**8 HF**	**9 HF**
Average $L'_{nT,50}$ (dB)	53	54	53	52	51	51	53	50	53	50
Standard deviation	2,86	3,65	2,61	2,84	2,15	3,82	1,37	0,81	2,43	1,48
Samples	466	62	266	94	16	5	4	4	11	4

Table 2: Basic statistical data for light floors

Lightweight floors	**All**	**1 LF**	**2 LF**	**3 LF**	**4 LF**
Average $L'_{nT,50}$ (dB)	58	58	60	60	58
Standard deviation	3,71	3,43	4,43	3,53	0,18
Samples	178	122	19	35	2

Table 3: All floors

All H&L Floors	
Average $L'_{nT,50}$ (dB)	54
Standard deviation	3,09
Samples	644



1 HF - EFC1

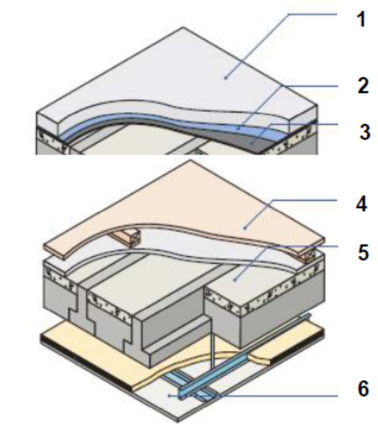
1- Floating floor
2- 40mm (min) screed directly applied to plank, 80kg/m^2 mass per unit area

2 HF - EFC4

3- 65mm (min) screed, 80 kg/m^2 mass per unit area
4- 10mm resilient layer

3 HF - EFC5

4- 6mm resilient layer
5- 150mm (min) precast concrete floor plank 300kg/m^2 (min) mass per unit area
6- Ceiling

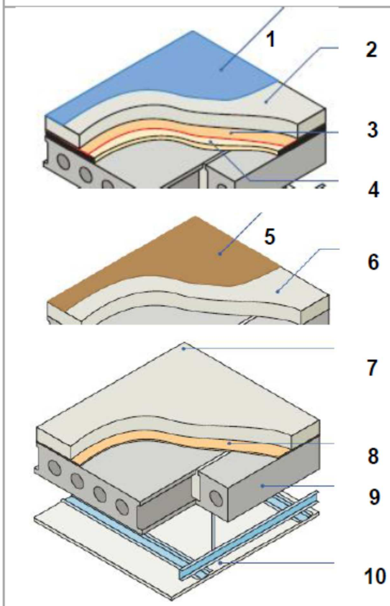


4 HF - EFC 6

1- 65mm (min) screed, 80kg/m^2 mass per unit area
2- 0.2mm (min) waterproof membrane
3- Resilient layer

5 HF - EFC 7

4- Floating Floor
5- Beam and block structural floor, min 100mm thick dense aggregate infill blocks, min 50mm concrete topping, min strength class C20, to floor blocks, min 300kg/m^2 combined mass per unit area
6- Ceiling



6 HF - EFC 8

1- 4.5mm (min) bonded resilient floor covering
2- 65mm (min) secreed, 80kg/m^2 (min) mass per unit area
3- 5mm foamed polyethylene layer 30-36kg/m^3
4- 25mm mineral wool batt, 140kg/m^3 (min), 25mm EPS or extruded polystyrene insulation

7 HF - EFC 9

5- 3mm Thermal Economics IsoRubber Top
6- 65mm (min) screed, 80kg/m^2 mass per unit area

8 HF - EFC 11

7- 65mm (min) secreed, 80kg/m^2 (min) mass per unit area
8- 10mm resilient layer

9 HF - EFC 12

8- 3mm resilient layer
9- 150mm (min) precast concrete floor plank, 300kg/m^2 (min) mass per unit area
10- Ceiling

Figure 1: Heavy floors description

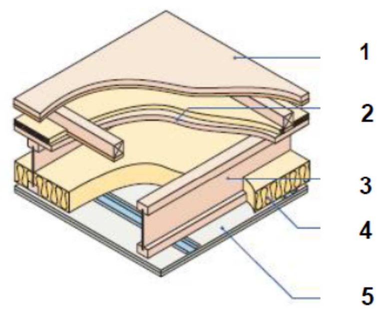
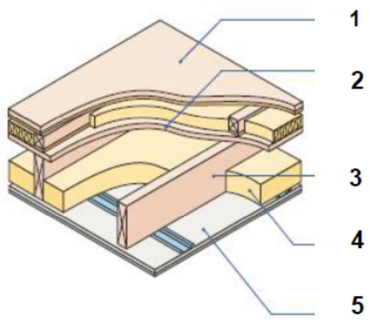
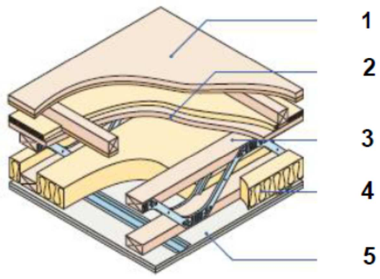
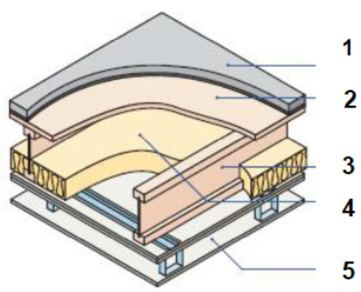
	**1 LF - EFT1** 1- Floating floor 2- 15mm thick (min) wood based board, 600kg/m^3 (min) 3- 235mm (min) timber I-Joists 4- 100mm (min) mineral wool quilt insulation (10–36kg/m^3) between joists 5- Ceiling
	**2 LF - EFT2** 1- Floating floor 2- 11mm thick (min) wood based board, 600kg/m^3 (min) or Walker Timber perforated deck system 3- 220mm (min) solid timber joists at maximum 400mm centres 4- 100mm (min) mineral wool quilt insulation (10–36kg/m^3) between joists 5- Ceiling
	**3 LF - EFT3** 1- Floating floor 2- 18mm thick (min) wood based board, 600kg/m^3 3- 253mm (min) metal web Joists 4- 100mm (min) mineral wool quilt insulation (10–36kg/m^3) between joists 5- Ceiling
	**4 LF - EFT5** 1- 28mm screed board 2- 18mm thick (min) wood based board, 600kg/m^3 3- 240mm (min) timber I-joist 4- 100mm (min) mineral wool quilt insulation (10–36kg/m^3) between joists 5- Ceiling

Figure 2: Lightweight floors description

4 Methodology

The first step consists in calculating all the previously mentioned descriptors for the full data set: L'_w $L'_{n,w}$ $L'_{n,w} + C_{I\ (50\text{-}2500Hz)}$ $L'_{nT,w}$ $L'_{nT,100}$ $L'_{nT,50}$

The second step consists in making a scatter plot for each selected pair of descriptors and calculating the corresponding linear regression, which will hereinafter be considered as a "potential" translation equation. The Pearson correlation coefficients were also determined since it provides useful information concerning the spread of the data around the lineal regression.

Finally an analysis of the results is made focusing on the effect of constructive solution type (heavy/light floors) in the translation equations.

5 Results: Correlations and translation equations

Table 4 shows the Pearson correlation coefficients between the calculated different impact sound insulation descriptors. As it can be expected there is a high correlation between any two descriptors, although lower values are obtained when considering $L'_{nT,50}$ and the full data set (in italic bold in table 4). Lower values of the Pearson coefficient point out that, in these cases, the spread of the values around the corresponding regression lines is higher. This will be discussed again later based on the pair of descriptors $L'_{nT,50}$ / L'_{nw} .

Table 4:Pearson coefficients

Proposed \ Existing		L'_w	L'_{nw}	$L'_{nw} + C_I$ (50-2500Hz)	$L'_{nT,w}$
$L'_{nT,w}$	Heavy	0.95	0.89	0.65	--
	Light	0.95	0.85	0.68	--
	All (H&L)	0.95	0.89	0.46	
$L'_{nT,50}$	Heavy	0.68	0.63	0.78	0.75
	Light	0.71	0.66	0.86	0.77
	All (H&L)	***0.38***	***0.34***	0.85	***0.44***
$L'_{nT,100}$	Heavy	0.76	0.70	0.76	0.82
	Light	0.91	0.83	0.72	0.97
	All (H&L)	0.70	0.64	0.75	0.77

As mentioned in section 2, Gerretsen and Dubanvin have proposed translation equations between different sound insulation descriptors independently of the type of constructive solution considered. As it can be seen in table 5, the results show that this is not always the case. Depending on the pair of descriptors that are considered, the translation is more or less dependent on the building system. In some cases the resulting equations for heavy and light floors are apparently similar as in the case of the pair of descriptors $L'_{nT,w}$ / L'_{w} whereas in other cases the pair of equations seem rather different, as is the case for the pair of descriptors $L'_{nT,50}$ / L'_{nw} (in bold and italic in table 5).

Table 5: Regression lines (or translation equations)

y \ x		L'w	L'nw	L'nw + CI (50-2500Hz)	L'nT,w
L'nT,w	**Heavy**	y=0,87x+4,85	y=0,77x+9,02	y=0,85x+5,73	--
	Light	y=0,96x-0,17	y=0,80x+7,11	y=0,69x+9,98	--
	All (H&L)	y=0,88x+3,80	y=0,78x+8,47	y=0,51x+23,82	
L'nT,50	**Heavy**	y=0,39x+30,70	***y=0,34x+32,75***	y=0,64x+16,14	y=0,47x+27,15
	Light	y=0,68x+21,34	***y=0,58x+25,80***	y=0,81x+8,52	y=0,73x+22,44
	All (H&L)	y=0,31x+37,01	***y=0,26x+39,13***	y=0,83x+6,07	y=0,39x+33,66
L'nT,100	**Heavy**	y=0,50x+23,21	y=0,44x+25,67	y=0,72+10,31	y=0,60x+19,29
	Light	y=0,90x+4,26	y=0,75x+10,97	y=0,71x+9,64	y=0,95x+4,10
	All (H&L)	y=0,51x+23,39	y=0,44x+26,31	y=0,65+14,04	y=0,60x+19,69

The translation equation proposed by Gerretsen et al. for the pair $L'_{nT,50}$ / $L'_{nT,w}$ is shown in table 6. This equation is close to the one shown in table 5 for heavy floors (in blue and underlined) but is far from the corresponding equation for lightweight floors (in red and underlined).

Table 6: Translation equation proposed by Gerretsen et al. [15]

y \ x	L'nT,w	L'nw
L'nT,50	y=0,49x+28,83	y=0,49x+27,7

The set of equations presented in Table 5 can be used to translate existing impact sound insulation requirements until further research is published. Table 7 shows an example of requirement translation (in this case, existing requirements for multi-storey housing). The translation has been performed for four selected countries using the equations obtained with all the data set in Table 5 "All (H&L)" and using the equations in Table 6. The differences are significant, which points out at the need of further research in this field.

Table 7: Example of translation between existing / new proposed requirement

	Existing requirement	Translated requirement (based on Table 5 –All H&L)	Translated requirement (based on table 6)
Denmark	$L'_{nw} < 53$	$L'_{nT,50} < 51$	$L'_{nT,50} < 54$
Italy	$L'_{nw} < 63$	$L'_{nT,50} < 54$	$L'_{nT,50} < 59$
Spain	$L'_{nT,w} < 65$	$L'_{nT,50} < 58$	$L'_{nT,50} < 61$
Portugal	$L'_{nT,w} < 60$	$L'_{nT,50} < 55$	$L'_{nT,50} < 58$

In order to better study the effect of the building system (heavy or light floor) in the translation equations, the pair of descriptors $L'_{nT,50}$ / L'_{nw} has been selected (according to table 5, this pair of descriptors shows a more differentiated behavior depending on the building system). Figure 3 shows the complete scatter plot for this pair of descriptors $L'_{nT,50}$ / L'_{nw} as well as the corresponding regression lines for heavy, light and all floors (H&L) together (equations in bold italic in table 5). The 95% confidence interval curves are also plotted for all cases. Notice that the impact sound insulation values were rounded to the closer integer (no decimals) so the cloud resolution is 1dB and that many results are repeated which is represented as a darker dot in the plot.

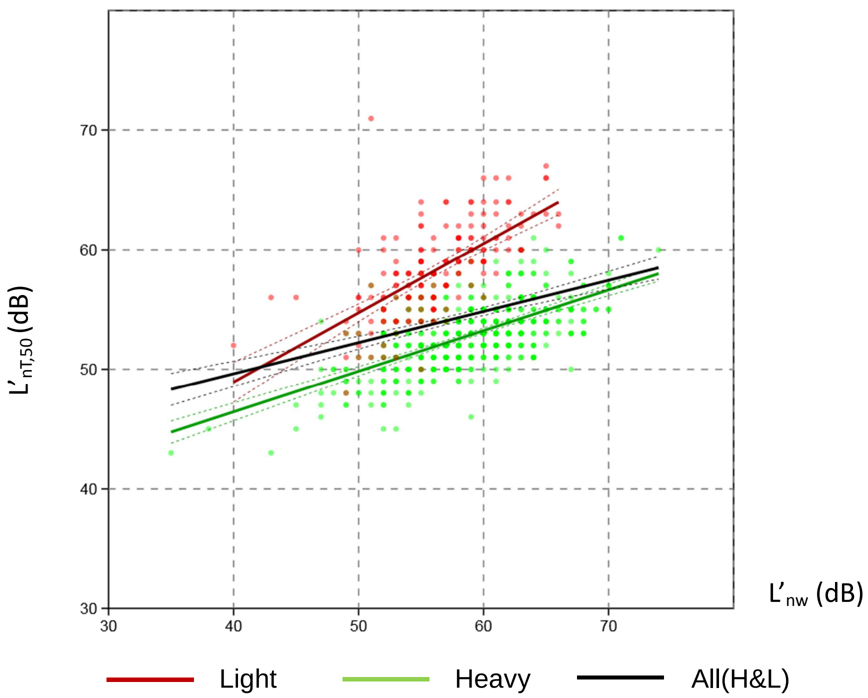


Figure 3: Scatter plot and regression lines $L'_{nT,50}$ / L'_{nw}

As it can be seen in Figure 3, the translation between the existing descriptor L'_{nw} and the proposed descriptor $L'_{nT,50}$ is strongly dependent on the building system. If it was decided to use the translation equation obtained including the full data set (black line in figure 3), the translation would only be acceptable for extremely well performing light floors L'_{nw}< 45dB and for extremely bad performing heavy floors L'_{nw}> 65dB, but around the typical regulation values (50 <L'_{nw}< 60 [dB]) the translation would be inadequate for both types of floors.

6 Conclusions

The translation between different impact sound insulation descriptors can be performed based on basic mathematical relations including simple geometrical assumptions or based on a statistical study of a sufficiently large data set. In this case, the second option has been used.

The correlation between the existing and the new proposed impact sound insulation descriptors has been studied and all the possible linear regressions have been made and analysed. The translation equations found are summarized in table 5 and can be used, at least preliminary, when trying to evaluate the effect of adopting an alternative sound insulation descriptor. Legislators and/or their technical advisors can use such equations as a tool to estimate what should be the updated requirement level to comply if any of the “new proposed” descriptors should be adopted in their legislation.

Besides, the results shown in tables 4 and 5 and figure 3 show that the type of constructive solution ie. heavy/light floors, does affect the correlation between the different impact sound insulation descriptors included in this study. It is also observed that, in most cases, when the frequency range assessment of the existing descriptor and the new descriptor is the same, the translation equations found for heavy/light/all converge better than in those cases where the frequency range assessment is different.

It is necessary to further investigate all the correlations between existing and proposed descriptors and to identify in which cases a single equation can be used for translating requirements independently of the building system, and in which cases it is necessary to use different translation equations depending on the type of floor. This will depend on the accepted confidence level for the translation.

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