Translation between existing impact sound insulation descriptors, based on a large set of in situ measurements

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Translation between existing impact sound insulation descriptors, based on a large set of in situ measurements

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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 (heavyweight/lightweight floors) are also analyzed. 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.

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1. INTRODUCTION

Impact sound insulation assessment has been discussed and investigated 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 delivers the 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, 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 21st 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 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 $L'_{nT,w}$. The use of the spectral adaptation index C_I and the frequency range used for the SNQ assessment could not clearly be agreed. Proposing one SNQ to be used 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 focus on 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}, $L'_{n,w}$, $L'_{n,w}$ + $C_{I\ 50\text{-}2500}$ and $L'_{nT,w}$. It might seem strange 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 and 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, 2, 3 and 4 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

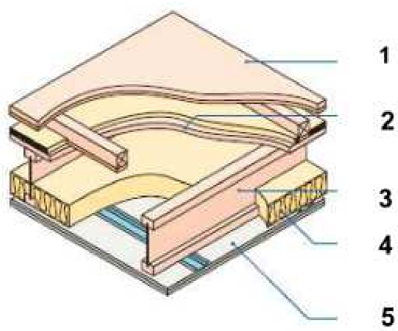
Lightweight floors	**All**	**1 LF**	**2 LF**	**3 LF**	**4 LF**
Average $L'_{nT,50}$ (dB)	58	58	60	60	58
Standard deviation	3,71	3,43	4,43	3,53	0,18
Samples	178	122	19	35	2

Table 3: All floors

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

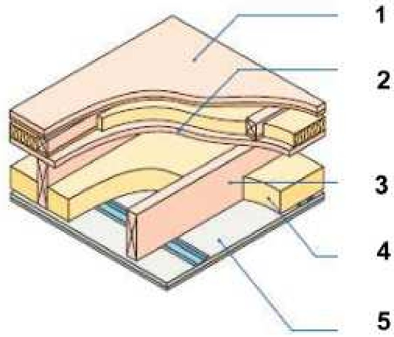
4. METHODOLOGY

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 are also determined since they provide useful information concerning the spread of the data around the linear regression. Finally, an analysis of the results is made focusing on the effect of constructive solution type (heavy/light floors) in the translation equations.



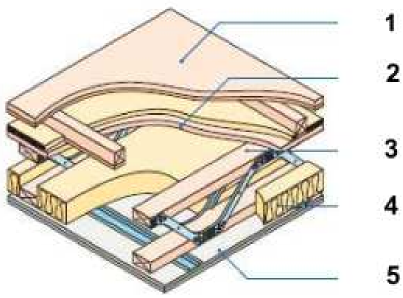
1 LF

1- Floating floor
2- 15 mm thick (min) wood based board, 600 kg/m^3 (min)
3- 235 mm (min) timber I-Joists
4- 100 mm (min) mineral wool quilt insulation (10–36 kg/m^3) between joists
5- Ceiling



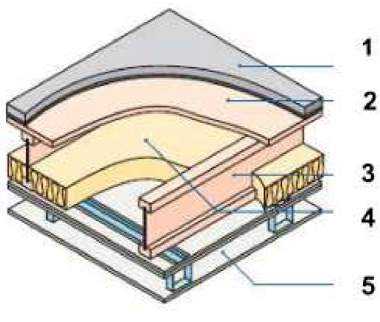
2 LF

1- Floating floor
2- 11 mm thick (min) wood based board, 600 kg/m^3 (min) or Walker Timber perforated deck system
3- 220 mm (min) solid timber joists at maximum 400 mm centres
4- 100 mm (min) mineral wool quilt insulation (10–36 kg/m^3) between joists
5- Ceiling



3 LF

1- Floating floor
2- 18 mm thick (min) wood based board, 600 kg/m^3
3- 253 mm (min) metal web joists
4- 100 mm (min) mineral wool quilt insulation (10–36 kg/m^3) between joists
5- Ceiling



4 LF

1- 28 mm screed board
2- 18 mm thick (min) wood based board, 600 kg/m^3
3- 240 mm (min) timber I-joist
4- 100 mm (min) mineral wool quilt insulation (10–36 kg/m^3) between joists
5- Ceiling

Figure 1: Lightweight floors description

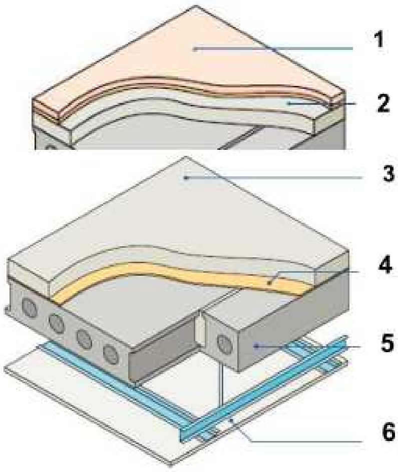
Precast concrete plank based floors (group a)	**5-** 150 mm (min) precast concrete floor plank 300 kg/m^2 (min) mass per unit area **6-** Ceiling
	**1 HF** **1-** Floating floor **2-** 40 mm (min) screed directly applied to plank, 80 kg/m^2 mass per unit area
	2 HF **3-** 65 mm (min) screed, 80 kg/m^2 mass per unit area **4-** 10 mm resilient layer
	3 HF **3-** 65 mm (min) screed, 80 kg/m^2 mass per unit area **4-** 6 mm resilient layer

Figure 2: Precast concrete plank based heavy floors (group a) description

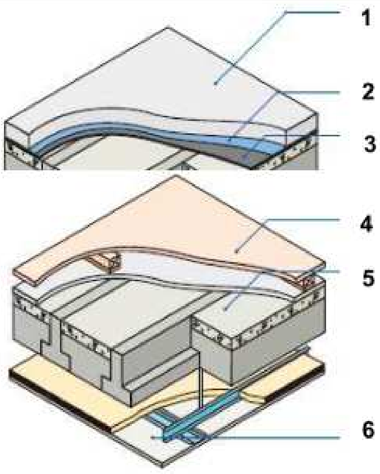
Beam and block based floors	**5-** Beam and block structural floor, min 100 mm thick dense aggregate infill blocks, min 50 mm concrete topping, min strength class C20, to floor blocks, min 300 kg/m^2 combined mass per unit area **6-** Ceiling
	**4 HF** **1-** 65 mm (min) screed, 80 kg/m^2 mass per unit area **2-** 0.2 mm (min) waterproof membrane **3-** Resilient layer
	5 HF **4-** Floating Floor

Figure 3: Beam and block based heavy floors description

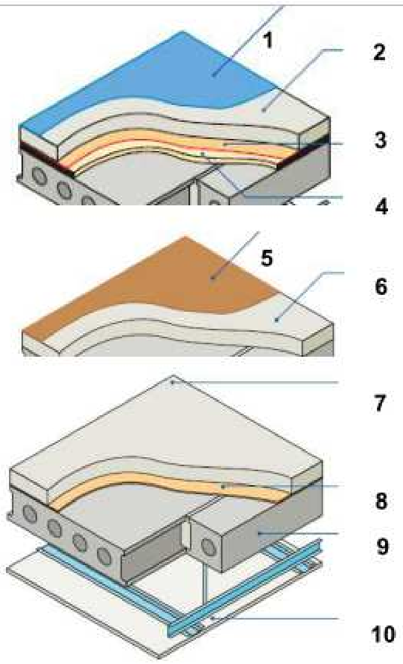
Precast concrete plank based floors (group b)	**9-** 150 mm (min) precast concrete floor plank, 300 kg/m² (min) mass per unit area **10-** Ceiling
	**6 HF** **1-** 4.5 mm (min) bonded resilient floor covering **2-** 65 mm (min) screed, 80 kg/m² (min) mass per unit area **3-** 5 mm foamed polyethylene layer 30-36 kg/m³ **4-** 25 mm mineral wool batt, 140 kg/m³ (min), 25 mm EPS or extruded polystyrene insulation
	7 HF **5-** 3 mm Thermal Economics Iso Rubber Top **6-** 65 mm (min) screed, 80 kg/m² mass per unit area
	8 HF **7-** 65 mm (min) screed, 80 kg/m² (min) mass per unit area **8-** 10 mm resilient layer
	9 HF **8-** 3 mm resilient layer

Figure 4: Beam and block based heavy floors (group b) description

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}.

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 4: Pearson correlation

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

Table 5: Regression lines (or translation equations)

y \ x		L'_w	L'_{nw}	$L'_{nw} + C_I$ (50-2500Hz)	$L'_{nT,w}$
$L'_{nT,w}$	**Heavy**	y=0,9x+4,9	y=0,8x+9,0	y=0,9x+5,7	
	Light	y=x-0,2	y=0,8x+7,1	y=0,7x+10,0	
	All (H&L)	y=0,9x+3,8	y=0,8x+8,5	y=0,5x+23,8	
$L'_{nT,50}$	**Heavy**	y=0,4x+30,7	***y=0,3x+32,8***	y=0,6x+16,1	y=0,5x+27,2
	Light	y=0,7x+21,3	***y=0,6x+25,8***	y=0,8x+8,5	y=0,7x+22,4
	All (H&L)	y=0,3x+37,0	***y=0,3x+39,1***	y=0,8x+6,1	y=0,4x+33,7
$L'_{nT,100}$	**Heavy**	y=0,5x+23,2	y=0,4x+25,7	y=0,7x+10,3	y=0,6x+19,3
	Light	y=0,9x+4,3	y=0,8x+11,0	y=0,7x+9,6	y=x+4,1
	All (H&L)	y=0,5x+23,4	y=0,4x+26,3	y=0,7x+14,0	y=0,6x+19,7

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=0,5x+28,8	y=0,5x+27,7

It is proposed to use the set of equations presented in Table 5 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 emphasize the need for further research in this field.

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

Country	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 5 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 for the regression lines are also plotted for all cases. Notice that the impact sound insulation values were rounded to the closer integer (no decimals) so the resolution of the cloud plot is 1 dB and thus many results appear repeated. This is represented as darker dots in the plot.

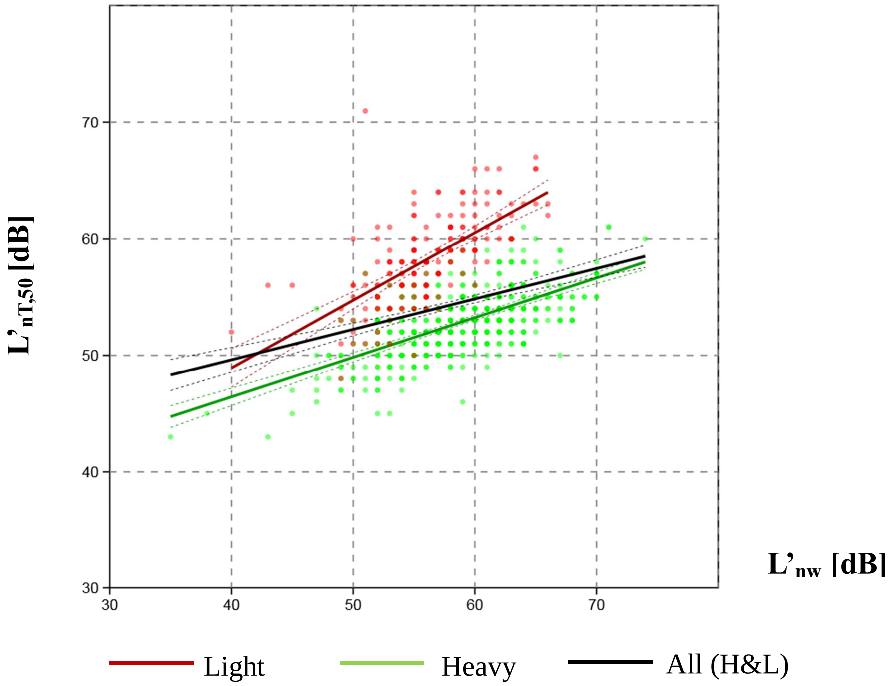


Figure 5: Scatter plot and regression lines $L'_{nT,50}$ / L'_{nw}

As it can be seen in Figure 5, 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 proposed translation equation obtained including the full data set (black line in Figure 5), the translation would only be reasonable for extremely well performing light floors with L'_{nw} around 42 dB and for extremely bad performing heavy floors with L'_{nw} around 65 to 70 dB. Around the typical regulation values ($50 < L'_{nw} < 60$ [dB]) the proposed translation should be questioned 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 calculated 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 would the updated requirements be level to comply, if any of the “new proposed” descriptors were adopted in their legislation.

Moreover, the results shown in the tables 4 and 5 and figure 3 show that the type of constructive solution, ie. heavyweight/lightweight 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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