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Sound Insulation between Dwellings – Overview of the Variety of Descriptors and Requirements in Europe

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Summary

Regulatory sound insulation requirements for dwellings exist in more than 30 countries in Europe. In some countries, requirements have existed since the 1950s. Findings from comparative studies show that sound insulation descriptors and requirements represent a high degree of diversity. Unfortunately, there is no sign on increasing harmonization, rather the contrary, i.e. evidence for an even more diverse situation in Europe. The studies conclude that harmonization is needed to facilitate exchange of data and construction experience between countries, to reduce trade barriers and to support and initiate – where needed – improvement of sound insulation of new and existing dwellings in Europe to the benefit of the inhabitants and the society. A European COST Action TU0901 "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions", has been established and runs 2009-2013. The main objectives of TU0901 are to prepare proposals for harmonized sound insulation descriptors and for a European sound classification scheme with a number of quality classes for dwellings. Findings from the studies provide input for the discussions in COST TU0901.

Data collected from 24 countries in 2008 have been published in 2010. This paper presents an updated and extended overview of airborne and impact sound insulation descriptors applied for regulatory requirements in Europe in 2011, thus providing some insight in trends.

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1. Introduction

Social surveys in several European countries have shown that inhabitants of multifamily dwellings are considerably annoyed by noise from their neighbours' activities. This is also the case in countries where sound insulation minimum requirements exist and have been enforced for many years. An overview of the results of social surveys in some European countries has been compiled in 2009 [1].

Regulatory sound insulation requirements for dwellings exist in more than 30 countries in Europe. In some countries, requirements have existed since the 1950s. Comparative studies of sound insulation descriptors and regulatory requirements (2008) in Europe are described in [2-3] and sound classification schemes in [4]. Findings from [1-3] show that descriptors, requirements and classification schemes in Europe represent a high degree of diversity, thus impeding exchange of experience of

housing design and construction details for different levels of sound insulation. The need for harmonization is emphasized in [2-3] and several research initiatives suggested.

The paper will summarize the situation in Europe, present an updated and extended overview of requirements in Europe and describe the joint efforts to reduce the diversity in Europe, thus supporting and initiating – where needed – improvement of sound insulation of new and existing dwellings in Europe to the benefit of the inhabitants and the society.

2. The need for sound insulation in housing

When ranking annoyance from different noise sources, road traffic noise is the most dominant source, followed by neighbour noise. Based on statistics about populations and findings from noise annoyance surveys, see e.g. [1], it seems that more than 50 million Europeans are exposed to neighbour noise causing adverse effects on quality of life.

(c) European Acoustics Association

The World Health Organisation (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. Based on this definition, noise effects on health should not simply be understood as the adverse physical effects due to noise exposure, but also as disturbance of well-being, i.e. psychological effects of noise, which in the long term may lead to adverse physical effects. WHO has identified a considerable number of specific adverse health effects caused by environmental noise, cf. [5]. These effects can be medical conditions, but can also include sleep disturbance, stress etc.

Neighbour noise has been addressed in a large pan-European LARES study (Large Analysis and Review of European housing and health Status) coordinated by WHO/Europe. Results are found at the WHO website [5]. More references and quotes from the WHO LARES study are found in [2].

3. Sound insulation descriptors

Sound insulation requirements are expressed by descriptors defined in standards. Within building acoustics, ISO standards are implemented as European (EN) standards and national standards.

The current international descriptors for evaluation of airborne and impact sound insulation are defined in ISO 717:1996 [6]. Table I provides an overview of the basic 1/3 octave ISO 717 field descriptors (single-number quantities) and the spectrum adaptation terms intended for specification and test of:

- Airborne sound insulation between dwellings
- Airborne sound insulation for facades
- Impact sound insulation between dwellings

The single-number quantities and the spectrum adaptation terms are derived from values measured according to ISO 140 [7].

A requirement may be expressed as the sum of a single-number quantity and a spectrum adaptation term or solely as the single-number quantity. Examples of airborne and impact sound insulation requirements could be:

$$D_{nT,w} \geq 55 \text{ dB}; \quad L'_{nT,w} \leq 50 \text{ dB};$$

$$D_{nT,w} + C \geq 55 \text{ dB}; \quad L'_{nT,w} + C_l \leq 50 \text{ dB};$$

$$D_{nT,w} + C_{50-3150} \geq 55 \text{ dB}; \quad L'_{nT,w} + C_{1,50-2500} \leq 50 \text{ dB}$$

For some types of buildings, e.g. for light-weight buildings, it is important to include low-frequency spectrum adaptation terms or other low-frequency criteria, cf. e.g. references in [2-3].

Table I. Overview ISO 717 descriptors for evaluation of sound insulation in buildings

ISO 717:1996 descriptors for evaluation of field sound insulation	Airborne sound insulation between rooms (ISO 717-1) ^(b)	Airborne sound insulation of facades ^(a) (ISO 717-1) ^(b)	Impact sound insulation between rooms (ISO 717-2) ^(b)
Basic descriptors (single-number quantities)	R'_w $D_{n,w}$ $D_{nT,w}$	R'_w $D_{n,w}$ $D_{nT,w}$	$L'_{n,w}$ $L'_{nT,w}$
Spectrum adaptation terms (listed according to intended main applications)	None C $C_{50-3150}$ $C_{100-5000}$ $C_{50-5000}$	None C C_{tr} $C_{50-3150}$ $C_{tr,50-3150}$ $C_{100-5000}$ $C_{tr,100-5000}$ $C_{50-5000}$ $C_{tr,50-5000}$	None C_l $C_{1,50-2500}$
Total number of descriptors	3 x 5 = 15	3 x 9 = 27	2 x 3 = 6
Notes			
(a) For facades, the complete indices for R'_w , $D_{n,w}$, $D_{nT,w}$ are found in ISO 717.			
(b) For simplicity, only 1/3 octave quantities and C-terms are included in the table, although some countries allow 1/1 octave measurements for field check.			

4. Requirements for sound insulation between dwellings

Comparative studies of descriptors and regulatory sound insulation requirements in 24 countries in Europe are described in [2-3]. An extended study has been made early in 2011 to get an updated and extended overview of requirements, now covering 35 countries. New countries are Bulgaria, Croatia, Cyprus, Greece, Luxembourg, Macedonia, Malta,

Romania, Scotland, Serbia and Turkey. Of these five have no requirements. For Greece no information has been received. Main requirements for airborne and impact sound insulation requirements are presented in Tables II and III. The results clearly indicate the diversity in Europe. The comparison reveals significant discrepancies in descriptors and requirements for dwellings. For both airborne and impact sound insulation, several descriptors are applied in Europe.

Table II: Airborne sound insulation between dwellings
- Main requirements in 35 European countries ^{(1), (2)}

Status March 2011 ^{(1), (2)}		Multi-storey housing	Row housing
Country ⁽¹⁵⁾	Descriptor ⁽³⁾	Req. [dB]	Req. [dB]
Austria	$D_{nT,w}$	≥ 55	≥ 60
Belgium	$D_{nT,w}$	≥ 54	≥ 58
Bulgaria	R'_w	≥ 53	≥ 53
Croatia	R'_w	≥ 52	≥ 52
Cyprus (13)	N/A	N/A	N/A
Czech Rep.	R'_w	≥ 53	≥ 57
Denmark	R'_w	≥ 55	≥ 55
England & Wales	$D_{nT,w} + C_{tr}$	≥ 45	≥ 45
Estonia	R'_w	≥ 55	≥ 55
Finland	R'_w	≥ 55	≥ 55
France	$D_{nT,w} + C$	≥ 53	≥ 53
Germany (10)	R'_w	≥ 53 (8)	≥ 57
Greece (14)	No info	No info	No info
Hungary	$R'_w + C$	≥ 51	≥ 56
Iceland (6)	R'_w (6)	≥ 55 (6)	≥ 55 (6)
Ireland	$D_{nT,w}$	≥ 53 (8)	≥ 53
Italy	R'_w	≥ 50	≥ 50
Latvia	R'_w	≥ 54	≥ 54
Lithuania	$D_{nT,w}$ or R'_w	≥ 55	≥ 55
Luxembourg (13)	N/A	N/A	N/A
Macedonia FYR (13)	N/A	N/A	N/A
Malta (13)	N/A	N/A	N/A
Netherlands	$I_{lu,k}$ (4)	≥ 0	≥ 0
Norway	R'_w (7)	≥ 55 (7)	≥ 55 (7)
Poland	$R'_w + C$	≥ 50 (8)	≥ 52 (9)
Portugal	$D_{nT,w}$	≥ 50	≥ 50
Romania (10)	R'_w	≥ 51	≥ 51
Scotland	$D_{nT,w}$	≥ 56	≥ 56
Serbia	R'_w	≥ 52	≥ 52
Slovakia	R'_w	≥ 52	≥ 52
Slovenia	R'_w	≥ 52	≥ 52
Spain	$D_{nT,A}$ (5)	≥ 50	≥ 50
Sweden	$R'_w + C_{50-3150}$	≥ 53	≥ 53
Switzerland	$D_{nT,w} + C$	≥ 52 (11)	≥ 55
Turkey (12)	N/A	N/A	N/A

Notes

- (1) Overview information only. Detailed requirements and conditions are found in the building codes. All data to be verified/corrected in 2011.
- (2) Bulgaria, Croatia, Cyprus, Greece, Luxembourg, Macedonia FYR, Malta, Romania, Scotland, Serbia, Turkey are new countries added in March 2011. The original study for 24 countries is from 2008 [2]. Data for CZ, IS, PT have been updated due to revision of building codes.
- (3) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
- (4) $I_{lu,k} = R'_w + C - 52$ dB. Ref. NEN 5077:2006.
- (5) $D_{nT,A} \approx D_{nT,w} + C$. Ref. DB-HR CTE. Corrected compared to [2].
- (6) Proposal, approval expected end 2011, cf. [8]. For present regulations, see [2].
- (7) It is recommended that the same criteria are fulfilled by $R'_w + C_{50-5000}$.
- (8) Horizontal, requirement for vertical is 1 dB higher (Bulgaria, Germany, Poland) / lower (Ireland).
- (9) 55 dB recommended.
- (10) Under revision. In Germany, use of $D_{nT,w}$ has been proposed.
- (11) Flats for rent. If owned by occupants, same limit as for row housing.
- (12) No regulatory requirements. Requirements in preparation.
- (13) No regulatory requirements. In Luxembourg, most often limits from Belgium or other neighbouring countries are applied, dependant on the consultant.
- (14) No information available.
- (15) Although England & Wales and Scotland are parts of UK, they are listed as separate countries due to different requirements.

Table III: Impact sound insulation between dwellings
- Main requirements in 35 European countries ^{(1), (2)}

Status March 2011 ^{(1), (2)}		Multi-storey housing	Row housing
Country ⁽¹⁵⁾	Descriptor ⁽³⁾	Req. [dB]	Req. [dB]
Austria	$L'_{nT,w}$	≤ 48	≤ 43
Belgium	$L'_{nT,w}$	≤ 58 (4)	≤ 50
Bulgaria	$L'_{n,w}$	≤ 53	≤ 53
Croatia	L'_w (8)	≤ 68	≤ 68
Cyprus (13)	N/A	N/A	N/A
Czech Rep.	$L'_{n,w}$	≤ 55	≤ 48
Denmark	$L'_{n,w}$	≤ 53	≤ 53
England & Wales	$L'_{nT,w}$	≤ 62	None
Estonia	$L'_{n,w}$	≤ 53	≤ 53
Finland	$L'_{n,w}$ (7)	≤ 53 (7)	≤ 53 (7)
France	$L'_{nT,w}$	≤ 58	≤ 58
Germany (10)	$L'_{n,w}$	≤ 53	≤ 48
Greece (14)	No info	No info	No
Hungary	$L'_{n,w}$	≤ 55	≤ 45
Iceland (6)	$L'_{n,w}$ (6)	≤ 53 (6)	≤ 53 (6)
Ireland	$L'_{nT,w}$	≤ 62	None
Italy	$L'_{n,w}$	≤ 63	≤ 63
Latvia	$L'_{n,w}$	≤ 54	≤ 54
Lithuania	$L'_{n,w}$	≤ 53	≤ 53
Luxembourg (13)	N/A	N/A	N/A
Macedonia FYR (13)	N/A	N/A	N/A
Malta (13)	N/A	N/A	N/A
Netherlands	I_{co} (5)	≥ +5	≥ +5
Norway	$L'_{n,w}$ (7)	≤ 53 (7)	≤ 53 (7)
Poland	$L'_{n,w}$	≤ 58	≤ 53
Portugal	$L'_{nT,w}$	≤ 60	≤ 60
Romania (10)	$L'_{n,w}$	≤ 59	≤ 59
Scotland	$L'_{nT,w}$	≤ 56	None
Serbia	$L'_{n,w}$	≤ 68	≤ 68
Slovakia	$L'_{n,w}$	≤ 58	≤ 58
Slovenia	$L'_{n,w}$	≤ 58	≤ 58
Spain	$L'_{nT,w}$	≤ 65	≤ 65
Sweden	$L'_{n,w} + C_{1,50-2500}$	≤ 56 (9)	≤ 56 (9)
Switzerland	$L'_{nT,w} + C_1$	≤ 53 (11)	≤ 50
Turkey (12)	N/A	N/A	N/A

Notes

- (1) Overview information only. Detailed requirements and conditions are found in the building codes. All data to be verified/corrected in 2011.
- (2) See note (2) in Table II.
- (3) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
- (4) From "non-bedrooms" outside the dwelling to a bedroom ≤ 54 dB is required.
- (5) $I_{co} = 59 - (L'_{nT,w} + C_1)$ dB ≈ 70 - $L'_{nT,w}$ dB for bare concrete floors or $I_{co} \approx 59 - L'_{nT,w}$ dB for other floors like wooden floors, floating floors and floors with soft coverings. Ref. NEN 5077:2006.
- (6) Proposal, approval expected end 2011, cf. [9]. For present regulations, see [2].
- (7) Recommended that the same criteria are fulfilled by $L'_{n,w} + C_{1,50-2500}$.
- (8) L'_w not defined in ISO 717-2. It is assumed to be $L'_{n,w}$.
- (9) The same criteria shall also be fulfilled by $L'_{n,w}$.
- (10) Under revision. In Germany, use of $L'_{nT,w}$ has been proposed.
- (11) Flats for rent. If owned by occupants, same limit as for row housing.
- (12) No regulatory requirements. Requirements in preparation.
- (13) No regulatory requirements. In Luxembourg, most often limits from Belgium or other neighbouring countries are applied, dependant on the consultant.
- (14) No information available.
- (15) Although England & Wales and Scotland are parts of UK, they are listed as separate countries due to different requirements.

Portugal has changed from “normalized” to “standardized” descriptors. In Germany the same change has been discussed for years, but not yet made. In order to facilitate a comparison between countries, all requirements have been converted into estimated equivalent values of R'_w and $L'_{n,w}$ based on assumptions about rooms and construction types. In case of the equivalent R'_w being an interval, the average value has been used. The equivalent values are estimates only, as exact con-

version is not possible. A graphical presentation of the requirements for airborne and impact sound insulation are presented in Figures 1 and 2. The results show big differences between countries, especially for impact sound insulation requirements with max differences of equivalent $L'_{n,w}$ limits more than 20 and 25 dB for multi-storey and row housing, respectively. For more detailed findings, see [2-3]. For relation to classification schemes, see [4].

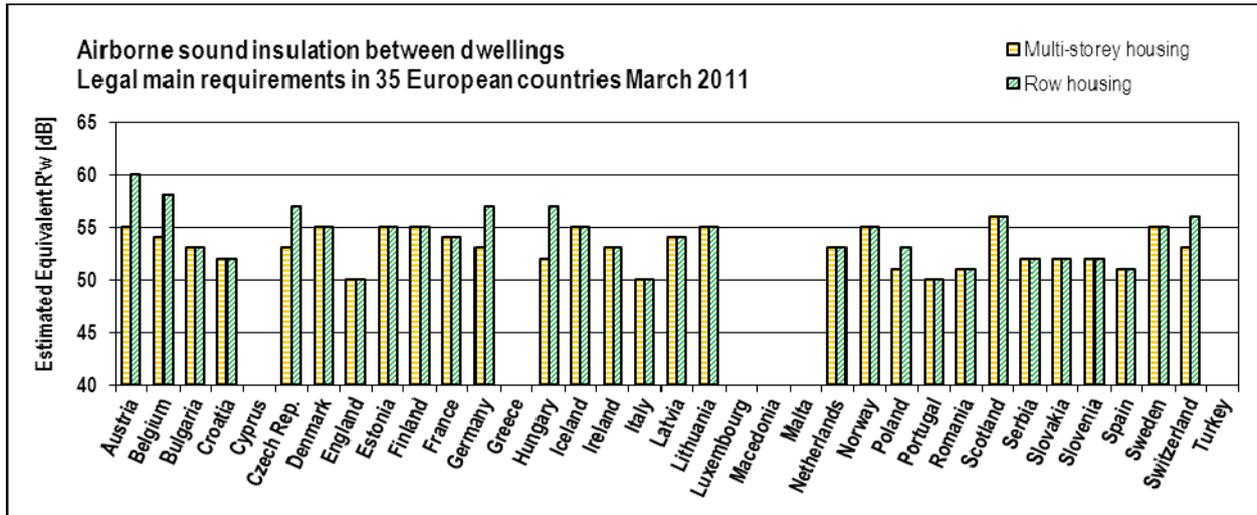


Figure 1 – Overview of airborne sound insulation requirements between dwellings. Graphical presentation of estimated equivalent values of R'_w . Note: The equivalent values are estimates only, as exact conversion is not possible. The conversion method is described in [2].

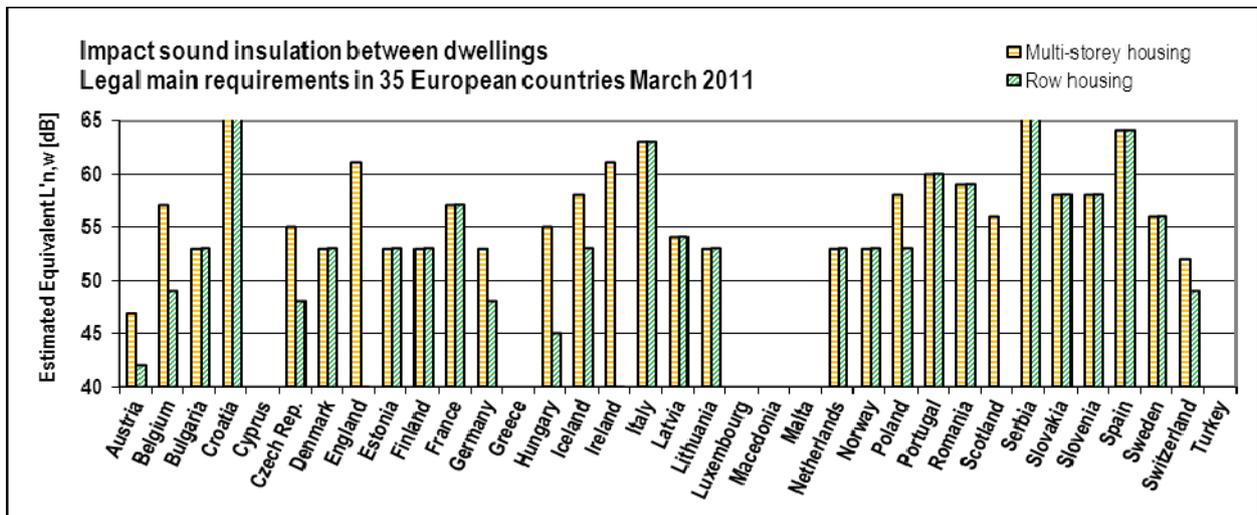


Figure 2 – Overview of impact sound insulation requirements between dwellings. Graphical presentation of estimated equivalent values of $L'_{n,w}$. Note: The equivalent values are estimates only, as exact conversion is not possible. The conversion method is described in [2].

In Table IV is indicated how many countries apply the different descriptors and besides, there are variants, recommendations and special rules. The most recent version of the standard EN ISO 717 [6] has contributed to the diversity in Europe by allowing many different descriptors and by intro-

ducing spectrum adaptation terms with different extended frequency ranges. When digging deeper into the building codes and related documents, variants, recommendations and hidden special rules and/or conditions are often revealed, thus in practice increasing the number of descriptors.

Table IV. Sound insulation descriptors applied for regulatory requirements in Europe in March 2011.

Airborne sound descriptors & No. of countries		Impact sound descriptors & No. of countries	
16	R'_w	17	$L'_{n,w}$
2	$R'_w + C$	1	$L'_{n,w} + C_{1,50-2500}$
1	$R'_w + C_{50-3150}$	8	$L'_{nT,w}$
6	$D_{nT,w}$	1	$L'_{nT,w} + C_l$
2	$D_{nT,w} + C$	1	L'_w
1	$D_{nT,A} (\approx D_{nT,w} + C)$	1	$I_{co} (= 59 - L'_{nT,w} + C_l \text{ dB})$
1	$D_{nT,w} + C_{tr}$?	Variants
1	$I_{l,w;k} (= R'_w + C - 52 \text{ dB})$?	Recommendations
?	Variants	?	Special rules
?	Recommendations		
?	Special rules		

For example, cf. [9], the Swiss standard SIA 181:2006 with sound insulation requirements has become very complex to use due to several nuisance levels and receiver sensitivity levels. Furthermore, national methods, procedures and correction terms have been defined. The symbol table in SIA 181 is 11 pages! As another example could be mentioned special rules in the Nordic countries, see [10-11]. Even in case of seemingly identical limits, sometimes they are different due to special rules, e.g. volume limitations. The analysis of special rules [10-11] has contributed to ideas for new building regulations, see [12].

Concerning regulations, a big challenge seems to be that for some types of light-weight constructions, the subjective sound insulation is ranked lower than for a heavy construction with the same objective sound insulation. Regulatory requirements are objective, and the same requirements should be applicable for all types of housing constructions and materials. Thus, an important research task is to develop new objective descriptors (evaluation methods) correlating with the subjective evaluation for all types of constructions. – In Norway, a survey [13] about satisfaction with newly built homes (2005) has been carried out in 2007. In general, people are satisfied (about 80%, 10% dissatisfied). Least satisfaction (17% dissatisfied) is found with sound insulation, especially for 2-storey housing (27% dissatisfied). According to [14], the reason is likely to be light-weight constructions applied for this type of housing. In Sweden, extensive research projects are carried out in relation to sound insulation of light-weight constructions, see e.g. [15] and [16].

In the Nordic countries, requirements have diversified, although a common Nordic proposal for a classification scheme existed in the 1990s. Regional efforts to exchange experience and

harmonize requirements are made in national and transnational projects, e.g. in Silent Spaces [16] aiming at reducing noise and vibrations in especially light-weight buildings, and contributing to harmonization of requirements in Sweden and Denmark.

Other important issues related to implementation of new or revised requirements are e.g. “robust” or “acceptable” solutions for constructions, see e.g. [17-19], verification in the field, compliance procedures, percentage of people satisfied.

5. Conclusions and perspectives

Sound insulation descriptors and regulatory requirements in Europe – as well as classification schemes – represent a high degree of diversity. Five countries have no regulatory requirements, and they should be encouraged to work on the issue of future requirements.

The majority of countries use “normalized” descriptors. There seems to be a slight, but slow trend towards “standardized” descriptors.

Unfortunately, there is no sign on increasing harmonization, rather the contrary, i.e. there is evidence for an even more diverse situation in Europe. Harmonization of descriptors and sound insulation classes are needed to facilitate exchange of construction data and experience between countries and to reduce trade barriers. Most important is, however, that review and update/upgrade of sound insulation requirements should be initiated in several countries to adapt regulations to current construction trends and peoples' needs for health, wellbeing and comfort.

Having said that, it must be emphasized that there are big jungles to fell, before “transparent” limits can be implemented, and replanting is forbidden!

Jungle 1: The variety of standardized sound insulation descriptors, cf. EN ISO 717, [6]

Jungle 2: Complex national rules making it difficult to find the limit values, see e.g. [9]

Jungle 3: National special rules in addition to standardized methods, cf. e.g. [10-11]

To initiate harmonization and coordinate research, a European Action, COST TU0901 “Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions” [20], was established in 2009 and runs until 2013.

TU0901 main objectives:

- Propose harmonized descriptors for airborne and impact sound insulation.
- Propose a European acoustic classification scheme for dwellings.

Until now (March 2011), 29 European countries and institutions from three non-COST countries (New Zealand, Australia and Canada) have been approved as members of TU0901, and about 90 people have been nominated for the management committee and working groups. Of countries listed in Tables II and III, only Bulgaria, Cyprus, Ireland, Latvia and Luxembourg are not members of COST TU0901. For detailed information about the Action, the MoU, the parties, the MC members and the activities, see [20]. At WG meetings, workshops, symposia – as e.g. the EAA & TU0901 symposium in 2010 [21] – experience with regulations, classification schemes and constructions as well as research results are shared among TU0901 member countries, thus preparing the ground for harmonization in Europe.

Changes of requirements have potential for big impacts on the building industry. Thus - as an integrated part of implementation - construction solutions, compliance procedures, education and enforcement must be well prepared.

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