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Acoustic regulations for offices – Comparison between selected countries in Europe

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ABSTRACT

Regulatory acoustic requirements for offices exist in some countries in Europe, but most countries have either no regulatory limits or only recommendations. The main reason for considering acoustic conditions in office premises is to ensure satisfactory working conditions for the various tasks and activities taking place in the many different kinds of rooms. Examples of room types are offices, meeting rooms, open-plan offices, reception areas, corridors, stairwells, canteens, all with different acoustic needs. The extent of acoustic limit values vary considerably between countries. Some specify a few only, while others define several criteria. The findings from a comparative study carried out in selected countries in various geographical parts of Europe show a diversity of acoustic descriptors and limit values. The paper includes examples of criteria for reverberation time, airborne and impact sound insulation, noise from traffic and from service equipment. The discrepancies between countries are discussed, aiming at potential learning and implementation of optimized limit values for more room types. In addition to regulations or guidelines, some countries have offices included in national acoustic classification schemes with different acoustic quality levels, and references are made to publications with examples of such classification criteria.

Keywords: Building Acoustics, Regulations, Offices, Europe
I-INCE Classification of Subject Number: 83, 86

1 INTRODUCTION

Acoustic conditions in office buildings are important to ensure optimal comfort and work conditions. In office buildings, there is a variety of rooms with different acoustic needs, and acoustic regulations and/or acoustic quality classes or other guidelines exist in some countries, but are missing in other countries. The purpose of this paper is to compare examples of acoustic requirements for offices in selected countries in Europe, aiming at potential learning between countries. The countries chosen, are five in the North (DK, FI, IS, NO, SE) and five in the South (ES, FR, IT, PT, TR). The building regulations for these countries are [1-11].

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2 PERFORMANCE AREAS IN ACOUSTIC REGULATIONS AND GUIDELINES

In most countries in Europe, acoustic regulations now exist for housing and schools and in some countries also for other building categories like e.g. hospitals and office buildings. In addition and/or as an alternative, several countries also have guidelines or acoustic classification schemes. Acoustic regulations, guidelines and classification criteria for offices are typically about:

- Airborne sound insulation between rooms
- Impact sound insulation between rooms
- Facade sound insulation
- Service equipment noise
- Reverberation time or sound absorption

Building acoustic criteria are specified by a descriptor, a limit value, reference to a standard and sometimes to specific conditions, e.g. frequency range and/or test conditions. In Europe, most countries refer to ISO field measurement and rating standards, typically [12-16], which are also implemented as European (EN) standards, national standards and [17-18]. Exposure to traffic noise may be determined according to [19]. Some countries have developed additional standards to fit the national needs. In this paper references are made also to acoustic classification schemes and other standards [20-26] and to various laws, decrees and guidelines [27-33].

Experiences from previous comparative studies of acoustic regulations and classification criteria, mainly for housing and schools, show that the extent and strictness of acoustic criteria for buildings as well as descriptors in regulations and classification schemes vary considerably between countries in Europe (and globally), and it is desirable to compare such criteria and optimize by learning from other countries. Comparative studies with 5-35 countries included are described in [34-42].

Acoustic regulations for office rooms aim at providing good acoustic comfort in the rooms, enough privacy between rooms as well as controlling indoor sound pressure levels due to different sources, HVAC systems, lifts, outdoor noise, etc., so they are not disturbing to occupants and affect productivity in the working environment.

Although many different acoustic limit values are needed for the variety of rooms in office buildings, it was decided as a first step to compare regulations for a typical office room, which is a basic room type in such buildings and considered useful as a starting point for comparison. This paper focuses on acoustic regulations for such office rooms. Figure 1 illustrates the sound insulation requirements (horizontal direction) analysed in this paper for the selected countries. Requirements for vertical direction are not included, but would typically be stricter.

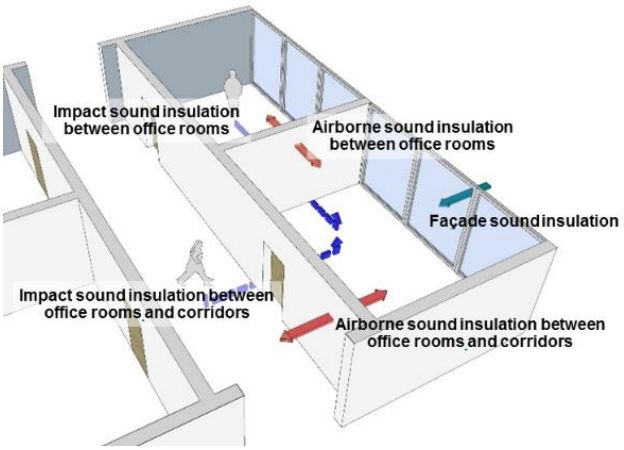

Figure 1 – Sound insulation between adjacent office rooms, towards corridor and of façade.

3 OVERVIEW COUNTRIES FOR THE COMPARATIVE STUDY

An overview of the ten countries chosen for the comparative study is found in Table 1, which includes references to building regulations and – where available – information about acoustic classes for office buildings and relation to regulations. Out of the ten countries of this study, seven have classification schemes with minimum three acoustic quality classes for one of more building categories, and six of these have several building categories included, see [36], while the French standard [26] is only for offices.

Table 1 – Acoustic regulations for OFFICES – Overview ten countries selected for a comparative study in Europe.

Acoustic regulations for OFFICES – Overview ten countries selected for a comparative study in Europe – Febr. 2019				
Coun-try	**BR**	**ACS**	**Quality classes***	**Comments on acoustic classes and relation to building regulations**
DK	[1]	N/A	N/A	
FI	[2]	[20]	A, B, C; D	No formal relation between BR and ACS. For some performance areas, D = C, and/or some upper classes have the same limit values.
IS	[3]	[21]	A, B, C, D	For acoustic regulations, BR refers to Class C.
NO	[4]	[22]	A, B, C, D	For acoustic regulations, BR refers to Class C.
SE	[5]	[23]	A, B, C, D	For acoustic regulations, BR refers to Class C. Class D often = npd, i.e. no limit values.
ES	[6]	N/A	N/A	A draft of an acoustic classification scheme applicable to office buildings is under preparation [27]
FR	[7]	[26]	Standard", "Efficient" and "Highly efficient"	For various rooms in office buildings, three levels are defined. "Standard" is indicated in [26] as corresponding to regulations, which however do not seem to exist in France for offices.
IT	[8-9]	[24]	I, II, III, IV	Class II is required for public office buildings, but sound insulation limits only apply between different premises, not internally in a premise. For non-public buildings, [8] applies.
PT	[10]	N/A	N/A	
TR	[11]	[11]	A, B, C, D, E, F	For acoustic regulations, BR [11] refers to Class C in ACS [11].
BR = Building Regulations (regulatory requirements); ACS = Acoustic Classification Scheme * Upper class first. Note: Even in case of the same class denotation, descriptors and limit values vary between countries.				

From Table 1, it is seen that four countries (IS, NO, SE, TR) refer to Class C in the national acoustic classification scheme as the acoustic regulations, which makes it easier to get an overview of the acoustic requirements. In general, regulations are mandatory and acoustic classification voluntary, unless referred to in the regulations.

4 ACOUSTIC CRITERIA FOR OFFICES

It should be noted that acoustic regulations are typically for new-build only (including change of use, e.g. from offices to dwellings), and thus with no requirements related to renovation.

In the below Tables 2-6 are found acoustic regulations for normal office rooms in the selected 10 countries. The limit values concern airborne and impact sound insulation, façade sound insulation, service equipment noise and reverberation time. For further details, see explanations in the tables and the references.

As seen in tables 2 and 3, some countries do not have sound insulation requirements for offices, but may have recommendations – or requirements for offices inside other types of buildings, such as France. The Nordic countries (DK, SE, NO, IS, FI) apply the same descriptors (except impact sound in SE) and have in general similar limit values. Of the values shown, Turkey is the country with the strictest requirements.

The Italian and Spanish approach of regulations is different from the rest of the countries of this study. Airborne and impact sound insulation requirements only apply between different premises. Both building codes define the concept of "building unit" as a building or a part of a building with the same specific function whose occupants are linked like a family, a corporation or an organization. In those cases, airborne and impact sound insulation requirements between different premises are the same as the requirements between different dwellings. I.e. $D_{nT,A} \approx D_{nT,w}+C_{100\text{-}5000} \geq 50$ dBA and $L'_{nT,w} \leq 65$ dB for Spanish office buildings, and $R_w \geq 50$ dB and $L_{n,w} \leq 55$ dB for non-public office buildings in Italy, but $R'_w \geq 53$ dB and $L'_{n,w} \leq 58$ dB for public office buildings in Italy.

Table 2 – Acoustic regulations for OFFICES – Airborne sound insulation.

Acoustic regulations for OFFICES (1) – Airborne sound insulation − Febr. 2019					
Country	**BR**	**ACS**	**Rooms(2)**	**Requirement [dB]**	**Comments**
DK	[1]	N/A	Between offices Corridor to office	N/A N/A	No regulations. Recommendation [1]: $R'_w \geq 40$ dB No regulations. No recommendations.
FI	[2]	[20]	Between offices Corridor to office	$(R'_w \geq 35)$ $(R'_w \geq 25)$	A new guideline to [2] was published in 2018 in Finnish and not studied for this paper. The values in brackets are from [20], class C.
IS	[3]	[21]	Between offices Corridor to office	$R'_w \geq 40$ $R'_w \geq 30$	BR [3] refers to Class C in ACS [21].
NO	[4]	[22]	Between offices Corridor to office	$R'_w \geq 37$ $R'_w \geq 24$	BR [4] refers to Class C in ACS [22].
SE	[5]	[23]	Between offices Corridor to office	$R'_w \geq 35$ $R'_w \geq 30$	BR [5] refers to Class C in ACS [23].
ES	[6]	N/A	Between offices Corridor to office	None	Requirements for sound insulation between different premises exist, but not between rooms in the same premises.
FR	[7]	[26]	Between offices Corridor to office	None	No requirements for office buildings, only for offices in educational buildings, hospitals etc.
IT	[8-9]	[24]	Between offices Corridor to office	None	Requirements for sound insulation between different premises exist, but not between rooms in the same premises, cf. [24] [29].
PT	[10]	N/A	Between offices Corridor to office	None	
TR	[11]	[11]	Between offices Corridor to office	$D_{nT,w} + C \geq 49$ $D_{nT,w} + C \geq 35$	BR [11] refers to Class C in ACS [11].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Requirements between rooms in the same premises. Corridor means there is a door between the office room and the corridor. If there is no door, stricter limits may apply.

Table 3 – Acoustic regulations for OFFICES – Impact sound insulation.

Acoustic regulations for OFFICES (1) – Impact sound insulation − Febr. 2019					
Country	**BR**	**ACS**	**Rooms(2)**	**Requirement [dB]**	**Comments**
DK	[1]	N/A	Between offices Corridor to office	N/A	No regulations. Recommendation [1]: $L'_{n,w} \leq 63$ dB No regulations. Recommendation [1]: $L'_{n,w} \leq 58$ dB
FI	[2]	[20]	Between offices Corridor to office	$(L'_{n,w} \leq 63)$ $(L'_{n,w} \leq 63)$	A new guideline to [2] was published in 2018 in Finnish and not studied for this paper. The values in brackets are from [20], class C.
IS	[3]	[21]	Between offices Corridor to office	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	BR [3] refers to Class C in ACS [21].
NO	[4]	[22]	Between offices Corridor to office	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	BR [4] refers to Class C in ACS [22].
SE	[5]	[23]	Between offices Corridor to office	− (= npd) $L'_{nT,w} \leq 68$	BR [5] refers to Class C in ACS [23].
ES	[6]	N/A	Between offices Corridor to office	None	Requirements for sound insulation between different premises exist, but not between rooms in the same premise.
FR	[7]	[26]	Between offices Corridor to office	None	No requirements for office buildings, only for offices in educational buildings, hospitals etc.
IT	[8-9]	[24]	Between offices Corridor to office	None	Requirements for sound insulation between different premises exist, but not between rooms in the same premise.
PT	[10]	N/A	Between offices Corridor to office	$L'_{nT,w} \leq 60$ $L'_{nT,w} \leq 60$	
TR	[11]	[11]	Between offices Corridor to office	$L'_{nT,w} \leq 54$ $L'_{nT,w} \leq 54$	BR [11] refers to Class C in ACS [11].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Requirements between rooms in the same premises.

Table 4 shows façade sound insulation required for office rooms. In the Nordic countries and Turkey, the requirements are expressed as A-weighted equivalent indoor sound pressure levels, although there are variations in limit values and time intervals. Sweden is the only country having a limit for maximum sound pressure level. Spain, Italy and Portugal express their

requirements as façade sound insulation ($D_{2m,nT}$), and of these three countries, Spain is the only country with requirements varying according to the outdoor noise level (L_{day}). In Portugal and Italy façade sound insulation requirements are invariant. In the Nordic countries with indoor level set as a limit, the required façade sound insulation varies dependant on the outdoor traffic noise level.

Table 4 – Acoustic regulations for OFFICES – Facade sound insulation.

Acoustic regulations for OFFICES (1),(2) – Traffic noise – Febr. 2019					
Coun-try	**BR**	**ACS**	**Descriptor**	**Requirement [dB]**	**Comments**
DK	[1]	N/A	N/A	N/A	No regulations. Recommendation [1]: L_{den} (indoor) (3) ≤ 38 dB
FI	[2]	[20]	$L_{Aeq,07\text{-}22}$ (indoor)	(≤ 40)	A new guideline to [2] was published in 2018 in Finnish and not studied for this paper. The values in brackets are from [20], class C.
IS	[3]	[21]	$L_{p,Aeq,24h}$ (indoor)	≤ 40	BR [3] refers to Class C in [21].
NO	[4]	[22]	$L_{p,AT}$ (indoor)	≤ 35	BR [4] refers to Class C in [22].
SE	[5]	[23]	$L_{pA,eq}$ (indoor) $L_{pA,Fmax}$ (indoor)	≤ 35 ≤ 50	BR [5] refers to Class C in [23].
ES	[6]	N/A	$D_{2m,nT,Atr}$	≥ 30	Valid for L_{day} ≤ 60 dB. For L_{day} ≤ 65, ≤ 70, ≤ 75 or > 75 dB, limits 32, 37, 42, 47 dB apply. $D_{2m,nT,Atr} \approx D_{2m,nT,w} + C_{100\text{-}5000}$
FR	[7]	[26]	N/A	None	No requirements for office buildings, only for offices in educational buildings, hospitals etc.
IT	[8-9]	[24]	$D_{2m,nT,w}$	See comments	For public buildings, class II in [29] is required. For non-public buildings, ≥ 42 dB required, cf. [8]. Same requirement independent of outdoor noise.
PT	[10]	N/A	$D_{2m,nT,w}$	≥ 30	Same requirement independent of outdoor noise
TR	[11]	[11]	$L_{A,eq}$ (indoor)	≤ 44	BR [11] refers to Class C in ACS [11]. Day-evening period applied.

(1) Overview information only. Detailed criteria and conditions are found in the references.
(2) Furnished rooms.
(3) DK: Day 07-19 (default), Evening 19-22, Night 22-07. L_{den} is defined in END (2002).
The Danish Building Code refers to L_{den} as the only limit and valid for roads and railways separately.

For buildings, there are many different indoor and outdoor sources for service equipment noise, and related noise legislation is often quite complicated, since regulations often appear in publications from both building authorities and environmental authorities, and some limit values depend on time of the day/evening/night. Concerning measurement methods for service equipment noise, most building authorities refer to the standards ISO 10052 [14] or ISO 16032 [15], but then additional methods apply for low-frequency noise and correction for pure tones, impulses and intermittent noise. Furthermore, measurement periods depend on the sound source. Different procedures apply for continuous sources like e.g. ventilation systems, and other sources with changing noise emission during the operating cycle, and many countries have instructions on which documents and measurement procedures to apply.

In Table 5 are shown limits for service equipment noise in the selected countries, mainly from building regulations, and thus not complete, since additional legislation often applies. It is seen that different descriptors are applied, which make comparisons more complicated. In general, all countries rely on a descriptor based in L_{Aeq}, A-weighted equivalent sound pressure level. But some countries have also limit values for maximum sound pressure levels, $L_{A,max}$, and others differentiate between continuous and intermittent noise sources. In France, the limits apply only to heating systems.

In Portugal and Spain, the building regulations refer to national environmental noise laws [30], [31]. A few countries use C-weighted levels for limits related to e.g. low frequency noise coming from equipment such as HVAC or ventilators. Spain has criteria for low frequency noise, which depend on the subtraction of $L_{Ceq,T}$ and $L_{Aeq,T}$ as described in [31].

Table 5 – Acoustic regulations for OFFICES – Service equipment noise.

Acoustic regulations for OFFICES (1),(2) – Service equipment noise – Febr. 2019					
Country	**BR**	**ACS**	**Descriptor**	**Requirement [dB]**	**Comments**
DK	[1]	N/A	N/A	N/A	None. Recommendation [1]: $L_{A,eq} \leq 35$ dB
FI	[2]	[20]	$L_{A,eq}$	(≤ 35)	A new guideline to [2] was published in 2018 in Finnish and not studied for this paper. The values in brackets are from [20], class C.
IS	[3]	[21]	$L_{p,Aeq,T}$ $L_{p,Ceq,T}$	≤ 35 ≤ 55	BR [3] refers to Class C in [21].
NO	[4]	[22]	$L_{p,A,T}$ $L_{p,AF,max}$	≤ 33 ≤ 35	BR [4] refers to Class C in [22].
SE	[5]	[23]	L_{pA} L_{pC}	≤ 35 ≤ 55	BR [5] refers to Class C in [23].
ES	[6]	N/A	$L_{k,d}$, $L_{k,e}$, $L_{k,n}$	≤ 35	Limit value $L_k = L_{A,eq,T}$ + corrections for background noise, tonal, impulsive and LF noise.
FR	[7]	[24]	L_{n}AT	≤ 30	Maximum for heating systems.
IT	[8-9]	[24]	L_{Aeq} $L_{AS,max}$	≤ 35 ≤ 35	The two limits are for continuous and intermittent noise, respectively For public buildings, class II in [29] is required. $L_{ic} \leq 28$ dBA. $L_{ic} = L_{Aeq}$ + corrections for background noise and rev.time. $L_{id} \leq 33$ dBA $L_{id} = L_{ASmax}$ + correction for rev.time.
PT	[10]	N/A	$L_{Ar,nT}$	≤ 37 ≤ 42	Limit value $L_{Ar,nT} = L_{A,eq}$ + corrections for tonal and impulsive components. The two limits are for continuous and intermittent noise, respectively.
TR	[11]	[11]	$L_{A,eq}$ $L_{AF,max,nT}$	≤ 40 ≤ 34	BR [11] refers to Class C in ACS [11]. The two limits are for continuous and intermittent noise, respectively.
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Furnished rooms.					

Table 6 shows reverberation time requirements in office rooms. The differences between countries are relatively small, approximately 0.2 s. Norway requires the lowest reverberation time for a normal height 2.7-3 m, whereas Portugal allows the highest maximum reverberation time value (dependant on room volume). Three countries have no requirements at all. Denmark has also no requirement, but a recommendation is found in the guideline to the building regulations [1].

Table 6 – Acoustic regulations for OFFICES – Reverberation time.

Acoustic regulations for OFFICES (1) – Reverberation time – Febr. 2019						
Country	**BR**	**ACS**	**Descriptor**	**Requirement [s]**	**Furnished**	**Comments**
DK	[1]	N/A	N/A	None	+	None. Recommendation [1]: $T \leq 0.6$ s (2)
FI	[2]	[20]	T (2)	(≤ 0.7)	+	A new guideline to [2] was published in 2018 in Finnish and not studied for this paper. The values in brackets are from [20], class C.
IS	[3]	[21]	T (2)	≤ 0.7	+	BR [3] refer to Class C in [21].
NO	[4]	[22]	T_h (2)	≤ 0,20 x h	+	BR [4] refer to Class C in [22].
SE	[5]	[23]	T_{20} (2)	≤ 0.6	+	BR [5] refer to Class C in [23].
ES	[6]	N/A	N/A	None	N/A	
FR	[7]	[26]	N/A	None	N/A	No requirements for office buildings, only for offices in educational buildings, hospitals etc.
IT	[8-9]	[24]	N/A	None	N/A	
PT	[10]	N/A	T	≤ $0{,}15 \cdot V^{1/3}$	+	Only for room volumes ≥ 100 m³. Avg. 500, 1000, 2000 Hz.
TR	[11]	[11]	T	≤ 0.8	+	BR [11] refers to Class C in ACS [11]. Avg. 250, 500, 1000, 2000 Hz.
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Freq. range 125-4000 Hz 1/1 octave bands. For Sweden and Finland target values. For details, see references.						

5 DISCUSSION, CONCLUSIONS AND SUGGESTIONS

Acoustic regulations in office buildings aim at ensuring comfort and privacy, and as such promoting concentration and a feel-good climate. Comparisons between countries and exchange of information provide a useful basis for learning and improving the acoustic building regulations. This paper focuses on the acoustic requirements of a typical office room as a starting point. Sound insulation requirements, as well as indoor noise levels due to service and equipment and reverberation time requirements are analysed for the ten selected countries. Regarding airborne and impact sound insulation, the requirements presented are the ones in the horizontal direction, i.e. typically performance of rooms belonging to the same company/organization.

While the five Nordic countries (DK, NO, SE, FI, IS) have regulations or guidelines with acoustic criteria for office rooms, which include airborne, impact and façade sound insulation, protection from service equipment noise and reverberation time requirements, the southern countries present different approaches. Some countries like Portugal or France do not have airborne insulation requirements between office rooms and in Spain and Italy requirements are only applicable between different premises, leaving the sound insulation of the rooms inside the premises to the builder's choice.

There are more similarities between the Nordic countries (DK, NO, SE, FI, IS), as their regulations/guidelines for office rooms include similar airborne and impact sound insulation requirements and similar descriptors. Their approach towards the protection from outdoor noise and service and equipment noise is similar too, as they require a maximum equivalent sound pressure level for both noise sources: outdoor noise and service and equipment noise. Southern countries have façade sound insulation requirements and except for Portugal and Turkey, there are no requirements for reverberation time or sound absorption in office rooms.

Based on the experience from the comparative studies in the selected countries of acoustic criteria in various regulations, guidelines and acoustic classification schemes and a brief look at "Green building" certification systems and indoor climate standards, a few suggestions for topics from a previous study [34] related to acoustics in office buildings can be reaffirmed:

- Other types of office layouts such as open-plan offices, which are usually out of the scope of regulations, or the acoustic criteria are insufficient.
- Other type of rooms, such as corridors, meeting rooms, videoconference rooms and canteens, which have different acoustic needs. For canteens, see e.g. [43].
- Acoustic conditions in existing offices. Requirements usually apply to new-build only, but offices are usually refurbished every time a new company moves in. It is highly advisable to adapt the scope of regulations to these situations, or at least to provide some guidance or case studies to designers.
- Acoustic criteria in "Green building" certification schemes and benefits should be clearer. Points are shared between several competing performances, implying that acoustics does not necessarily get sufficient attention. Several very different "Green building" certification schemes exist, and it is difficult for clients and consultants to distinguish. Most green building certification systems include office buildings, and thus the performances included and ranking are highly relevant.
- The whole structure of building codes and related documents is important. In many countries, it is very difficult to get a complete overview of acoustic limit values, see e.g. [44] as an example for hospitals.

European/international discussions and cooperation about optimal acoustic criteria and design processes would be useful to define optimal acoustic criteria in office buildings as well as in other buildings. For such discussions, it is useful to consider quality classes for offices in acoustic classification schemes, see e.g. [11, 20-23, 26]. Examples of classification criteria for

offices are found in [34]. Relevant are also sector specific guidelines like e.g. [33] from the British Council for Offices, since requirements in such documents could become enforced by builders and employers and thus in practice almost act as legislation.

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