A pilot study on acoustic regulations and classification for office buildings – Comparison between the Nordic countries

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ABSTRACT

Acoustic regulations or guidelines for office buildings exist in all five Nordic countries, although with varying contents. The main purpose of limit values is to ensure satisfactory acoustic working conditions for the various tasks and activities taking place in the many different kinds of rooms in such buildings. Examples of room types are offices, meeting rooms, open-plan offices, corridors, stairwells, reception areas, dining areas, all with different acoustic needs. Some of the countries specify very few acoustic limit values, while others define several criteria. Instead of or in addition to a set of regulations or guidelines, four of the Nordic countries have office buildings included in national acoustic classification standards with four acoustic quality levels A-D, class C being the regulations in three of these countries. As a pilot study, a comparison between the countries has been carried out. The paper includes examples of acoustic regulations and classification limit values for reverberation time, airborne and impact sound insulation, noise from traffic and from service equipment – aiming at discussion, potential learning and implementation of optimized limit values in acoustic regulations, guidelines or classification schemes for office buildings.

1 INTRODUCTION

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. All five Nordic countries have somehow addressed the issue, although Denmark only have a few basic limit values as recommendations, while the other four Nordic countries have extensive acoustic classification schemes including office buildings. Regulations in Norway, Sweden, Iceland are linked to the classification schemes by specifying Class C as the acoustic regulations. The Danish construction authority has decided to prepare extended acoustic guidelines with acoustic criteria for office buildings and hospitals, mainly by considering the regulations in the Nordic countries [1-5]. This paper deals with office buildings and is coordinated with another paper [6] about hospitals. The two papers have the same main structure, and parts of the introductory texts (incl. Table 1) are the same or similar.

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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. Acoustic regulations and classification criteria 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 EN ISO field measurement and rating standards, typically [7-11]. At the design stage, the acoustic performance can be estimated using prediction methods, e.g. [12-13], with relevant acoustic input data. Traffic noise may be determined according to [14].

The extent and strictness of acoustic criteria 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 are described in e.g. [15-18], and more references are found in [18]. Most studies are for housing and schools.

3 ACOUSTIC CLASSIFICATION SCHEMES IN EUROPE – OVERVIEW

In Table 1 is found a simplified overview of building categories in acoustic classification schemes (ACS) in Europe. It is seen that 11 countries have ACS for housing, 7 for schools, 7 for hospitals (incl. healthcare facilities) and 9 for office buildings (2 of those for office buildings only). More information about classes for office buildings and relation to regulations is found in Table 2.

Table 1 – Simplified overview of building categories in acoustic classification schemes in Europe.

Building categories in acoustic classification schemes in Europe − Status April 2018									
Country	Classification scheme (CS)		Dwellings	Schools	Kindergarten	Healthcare facilities	Offices	Restaurants	Other
DK	DS 490:2007	[19]	+						
FI	SFS 5907:2004	[20]	+	+	+	+	+		+
IS	IST 45:2016	[21]	+	+	+	+	+	+	+
NO	NS 8175:2012	[22]	+	+	+	+	+	+	+
SE	SS 25267:2015	[23]	+						
	SS 25268:2007	[24]		+	+	+	+	+	+
LT	STR 2.01.07:2003	[25]	+	+	+	+	(+)		+
IT	UNI 11367:2010	[26]	+	+	+	+	+		+
DE	VDI 4100:2012	[27]	+						
	DEGA 103:2018	[28]	+						
	VDI 2569:2016 Draft	[29]					+		
AT	ÖNORM B 8115-5:2012	[30]	+						
NL	NEN 1070:1999	[31]	+						
FR	NF S31-080:2006	[32]					+		
TR	Regulation on Protection of Buildings against Noise (2017)	[33]	+	+	+	+	+	+	+
ISO/WI	ISO/DIS 19488	[34]	+						
Note: The table is simplified and subject to errors due to insufficient language skills and different ways of categorizing buildings.									

Table 2 – Overview quality classes for OFFICES in acoustic classification schemes in Europe.

Acoustic quality classes for offices – Europe – April 2018			
Country	**Reference**	**Quality classes** (upper class first)	**Comments on classes and relation to building regulations**
FI	[20]	A, B, C, D	For some performance areas, D = C, and/or some upper classes have the same limit values. No formal relation to the building code.
IS	[21]	A, B, C, D	For acoustic regulations, the building code refers to Class C.
NO	[22]	A, B, C, D	For acoustic regulations, the building code refers to Class C.
SE	[24]	A, B, C, D	D often = npd, i.e. no limit values. For acoustic regulations, the building code refers to Class C.
LT	[25]	See comments.	No acoustic regulations. Recommended minimum values for sound insulation of offices are included in [24]. Concerning classification, it is indicated that classes for educational premises (i.e. schools) may be applied.
IT	[26]	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.
DE	[29]	A, B, C	For various rooms in office buildings, the draft guideline [29] define three acoustic classes. There is no relation to regulations.
FR	[32]	Standard", "Efficient" and "Highly efficient"	For various rooms in office buildings, these three levels are defined. "Standard" is indicated as corresponding to regulations, which however do not seem to exist in France for offices.
TR	[34]	A, B, C, D, E, F	For acoustic regulations, the building code refers to Class C.
Note: Even in case of the same class denotation, e.g. C, the limit values may vary between countries.			

From Tables 1 and 2 it is seen that three countries (IS, NO, TR) have *all* building categories in *one* document and 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. In the following is focused on the Nordic countries, as was the task.

Regulations are typically for new-build only (including change of use, e.g. from a offices to dwellings). For buildings/situations/rooms not addressed in specific regulations (as is the case for office buildings in Finland and Denmark), it should be noted that building regulations typically have a general statement about overall purpose. For example, in the Finnish regulations [2], it is stated that offices etc. shall be designed and constructed, so satisfactory acoustic conditions are obtained, considering the activities. In the Danish regulations [1], the chapter about acoustic conditions starts with a similar, general introductory statement requiring that buildings shall have satisfactory acoustic conditions in terms of health and comfort, considering the use.

4 ACOUSTIC CRITERIA FOR OFFICES – NORDIC COUNTRIES

Since the task was to find optimized, recommended acoustic limit values for office buildings in Denmark, considering the regulations in the other Nordic countries, a comparison of the regulatory limit values [1-5] was made for various room types in office buildings. However, to get a wider perspective on quality levels in FI, IS, NO, SE, classification limit values for classes A-D and regulations were tabulated for a typical office room, which is a basic room type in such buildings and considered useful as a starting point for comparison.

In the below Tables 3-7 are found acoustic quality class criteria and regulations for normal office rooms. 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. Class denotations A / B / C / D are indicated in descending order, i.e. the best class first.

By comparing the criteria in the Nordic countries for a normal office, it was found that the basic Danish recommendations, see e.g. the DK rows in tables 3-7, generally speaking were quite close to the corresponding criteria in the other countries, although closest to those from NO and IS. It was concluded that the basic Danish recommendations could be kept and that a proposal for several other acoustic criteria could be developed based on the experience from the other Nordic countries.

Table 3 – Acoustic regulations and classification – OFFICES – Airborne sound insulation.

Nordic countries – Airborne sound insulation in OFFICES(1) – Quality levels & regulations – April 2018						
Country & reference	**Rooms(2)**	**Class A [dB]**	**Class B [dB]**	**Class C [dB]**	**Class D [dB]**	**Acoustic regulations**
DK N/A	Between Corridor	N/A	N/A	N/A	N/A	None. Recommendation [1]: $R'_w \geq 40$ dB None. No recommendations.
FI [20]	Between Corridor	$R'_w \geq 44$ $R'_w \geq 34$	$R'_w \geq 40$ $R'_w \geq 30$	$R'_w \geq 35$ $R'_w \geq 25$	$R'_w \geq 35$ $R'_w \geq 25$	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	Between Corridor	$R'_w \geq 48$ $R'_w \geq 40$	$R'_w \geq 44$ $R''_w \geq 35$	$R'_w \geq 40$ $R'_w \geq 30$	$R'_w \geq 35$ $R'_w \geq 25$	Building regulations [3] refer to Class C in [21].
NO [22]	Between Corridor	$R'_w \geq 44$ $R'_w \geq 34$	$R'_w \geq 40$ $R'_w \geq 28$	$R'_w \geq 37$ $R'_w \geq 24$	$R'_w \geq 34$ $R'_w \geq 24$	Building regulations [4] refer to Class C in [22].
SE [24]	Between Corridor	$R'_w \geq 40$ $R'_w \geq 35$	$R'_w \geq 35$ $R'_w \geq 30$	$R'_w \geq 35$ $R'_w \geq 30$	− (= npd) − (= npd)	Building regulations [5] refer to Class C in [24].
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Between means between offices. Corridor means there is a door between the office and the corridor. If there is no door, stricter limits may apply.						

Table 4 – Acoustic regulations and classification – OFFICES – Impact sound insulation.

Nordic countries – Impact sound insulation in OFFICES(1) – Quality levels & regulations – April 2018						
Country & reference	**Exposure(2)**	**Class A [dB]**	**Class B [dB]**	**Class C [dB]**	**Class D [dB]**	**Acoustic regulations**
DK N/A	Low impact High impact	N/A	N/A	N/A	N/A	None. Recommendation [1]: $L'_{n,w} \leq 63$ dB None. Recommendation [11: $L'_{n,w} \leq 58$ dB
FI [20]	Low impact High impact	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	$L'_{n,w} \leq 68$ $L'_{n,w} \leq 68$	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	Low impact High impact	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	$L'_{n,w} \leq 68$ $L'_{n,w} \leq 68$	Building regulations [3] refer to Class C in [21].
NO [22]	Low impact High impact	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	$L'_{n,w} \leq 68$ $L'_{n,w} \leq 68$	Building regulations [4] refer to Class C in [22].
SE [24]	Low impact High impact	$L'_{nT,w} \leq 68$ $L'_{nT,w} \leq 64$	− (= npd) $L'_{nT,w} \leq 64$	− (= npd) $L'_{nT,w} \leq 68$	− (= npd) − (= npd)	Building regulations [5] refer to Class C in [24].
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Low impact, e.g. from another office. High impact, e.g. from the corridor.						

Table 5 – Acoustic regulations and classification – OFFICES – Facade sound insulation.

Nordic countries – Traffic noise in OFFICES(1),(2) – Quality levels & regulations – April 2018						
Country & reference	**Descriptor**	**Class A [dB]**	**Class B [dB]**	**Class C [dB]**	**Class D [dB]**	**Acoustic regulations**
DK N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: L_{den} (indoor) (3) ≤ 38 dB
FI [20]	$L_{Aeq,07\text{-}22}$ (indoor)	≤ 35	≤ 35	≤ 40	≤ 40	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	$L_{p,Aeq,24h}$ (indoor)	≤ 30	≤ 35	≤ 40	≤ 45	Building regulations [3] refer to Class C in [21].
NO [22]	$L_{p,AT}$ (indoor)	≤ 30	≤ 30	≤ 35	≤ 40	Building regulations [4] refer to Class C in [22].
SE [24]	$L_{pA,eq}$ (indoor) L_{pAFmax} (indoor)	≤ 30 ≤ 50	≤ 35 ≤ 50	≤ 35 ≤ 50	≤ 40 ≤ 60	Building regulations [5] refer to Class C in [24].
(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.						

Table 6 – Acoustic regulations and classification – OFFICES – Service equipment noise.

Nordic countries – Service equipment noise in OFFICES[(1),(2)] – Quality levels & regulations – April 2018							
Country & reference		**Descriptor**	**Class A [dB]**	**Class B [dB]**	**Class C [dB]**	**Class D [dB]**	**Acoustic regulations**
DK	N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: $L_{A,eq} \leq 35$ dB
FI	[20]	$L_{A,eq}$	≤ 35	≤ 35	≤ 35	≤ 40	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS	[21]	$L_{p,Aeq,T}$ $L_{p,Ceq,T}$	≤ 30 ≤ 50	≤ 30 ≤ 50	≤ 35 ≤ 55	≤ 40 ≤ 60	Building regulations [3] refer to Class C in [21].
NO	[22]	$L_{p,A,T}$ $L_{p,AF,max}$	≤ 28 ≤ 30	≤ 28 ≤ 30	≤ 33 ≤ 35	≤ 38 ≤ 40	Building regulations [4] refer to Class C in [22].
SE	[24]	L_{pA} L_{pC}	≤ 30 ≤ 50	≤ 35 ≤ 55	≤ 35 ≤ 55	≤ 40 − (= npd)	Building regulations [5] refer to Class C in [24].
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Furnished rooms.							

Table 7 – Acoustic regulations and classification – OFFICES – Reverberation time.

Nordic countries – Reverberation time in OFFICES[(1),(2)] – Quality levels & regulations – April 2018							
Country & reference		**Descriptor[(3)]**	**Class A [s]**	**Class B [s]**	**Class C [s]**	**Class D [s]**	**Acoustic regulations**
DK	N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: $T \leq 0.6$ s
FI	[20]	T	≤ 0.50	≤ 0.60	≤ 0.70	≤ 0.90	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS	[21]	T	≤ 0.50	≤ 0.60	≤ 0.70	≤ 0.90	Building regulations [3] refer to Class C in [21].
NO	[22]	T_h	≤ 0,13 x h	≤ 0,16 x h	≤ 0,20 x h	≤ 0,27 x h	Building regulations [4] refer to Class C in [22].
SE	[24]	T_{20}	≤ 0.6	≤ 0.6	≤ 0.6	− (= npd)	Building regulations [5] refer to Class C in [24].
(1) Overview information only. Detailed criteria and conditions are found in references. (2) Furnished rooms. (3) Freq. range 125-4000 Hz 1/1 octave bands. For Sweden and Finland, target values. For details, see references.							

Comparing the descriptors for sound insulation between office rooms, they are the same in the five Nordic countries, except for impact sound in Sweden (using $L'_{nT,w}$ instead of $L'_{n,w}$). However, for indoor traffic noise and service equipment noise, all five Nordic countries apply descriptors being different or seemingly different. − For further differences between the countries, see Tables 2-7.

A similar process was applied for several other room types like meeting rooms, corridors, receptions etc., and a proposal has been made aiming at discussing, finalizing and publishing in DK a full set of acoustic recommendations for office buildings. For open-plan offices – being widely used, but not appreciated by many users – it is clear that optimal acoustic conditions cannot be expected, and warnings are made like e.g. *"Open-plan offices, large rooms and areas partitioned by screens are in terms of acoustics ill-suited for providing functions that have differing and somewhat conflicting needs..."*, cf. [22]. – For a few room types like e.g. auditoria and canteens differing significantly in shapes and sizes, relevant limit values must be made for each project.

5 SUMMARY, CONCLUSIONS AND SUGGESTIONS

Aiming at implementation in the acoustic guideline to the Danish building regulations [1], a proposal for acoustic criteria for offices (and hospitals, see [6]) has been made based on comparative studies of criteria from the other Nordic countries having relatively small differences in limit values, at least when comparing to other parts of Europe (and the world).

The existing eight recommendations (since 2008) in DK for offices and meeting rooms have been kept: Airborne sound insulation between offices $R'_w \geq 40$ dB; Airborne sound insulation

between meeting rooms and other rooms $R'_w \geq 48$ dB; Impact sound level $L'_{n,w} \leq 58$ dB from corridors and $L'_{n,w} \leq 63$ dB from other rooms; Noise from traffic L_{den} (indoor) ≤ 38 dB; Service equipment noise $L_{A,eq} \leq 35$ dB; Reverberation time $T \leq 0.6$ s (125-4000 Hz); Sound absorption in in open-plan offices $A \geq 1{,}1$ x floor area (125-4000 Hz). Limit values apply to furnished rooms.

The full proposal with acoustic recommendations for office buildings includes 24 limit values and a request for project dependent limit values for certain rooms like e.g. auditoria, canteens and detailed considerations of open-plan offices. A final review of the proposal will be made in the autumn of 2018, and implementation is expected in January 2019.

Based on the experience from the comparative studies of acoustic criteria in various regulations, guidelines, acoustic classification schemes from the Nordic countries and other countries and a brief look at "Green building" certification systems and indoor climate standards, a number of suggestions can be made related to acoustics in office buildings:

- Nordic discussions and cooperation about harmonizing descriptors for service equipment noise and indoor traffic noise limits - also useful for other building categories than office buildings.
- For open-plan offices, Nordic and European/international discussions and cooperation about optimal acoustic criteria and design processes would be useful. Several new publications were found, e.g. [37-42], incl. research results from extensive Finnish studies. Experience from use of standards [11, 29, 32, 43] should also be collected and included in discussions.
- Acoustic limit values for canteens in office buildings should be prepared, e.g. based on findings in [44]. Such limits would also be useful for e.g. schools, hospitals, hotels etc. as well as restaurants.
- 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. A high number of very different "Green building" certification schemes exists, and it is difficult for clients and consultants to distinguish, cf. [45]. Most green building certifications are for office buildings, and thus the performances included and ranking are highly relevant.

Finally, it should be emphasized that 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 regulations and guidelines and thus to design a building fulfilling the relevant acoustic criteria.

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