A Comparative Study of Acoustic Regulations for Hospital Bedrooms in Selected Countries in Europe

Rasmussen, Birgit; Carrascal García, Teresa; Secchi, Simone

Published in:
Buildings

DOI (link to publication from Publisher):
10.3390/buildings13030578

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

buildings

MDPI

Article

A Comparative Study of Acoustic Regulations for Hospital Bedrooms in Selected Countries in Europe

Birgit Rasmussen [1], Teresa Carrascal [2,*] and Simone Secchi [3]

[1] Department of the Built Environment, Aalborg University, A.C. Meyers Vænge 15, 2450 Copenhagen, Denmark
[2] Eduardo Torroja Institute for Construction Science, Serrano Galvache 4, 28033 Madrid, Spain
[3] Department of Architecture, University of Florence, Via San Niccolò 93, 50125 Firenze, Italy
* Correspondence: tcarrascal@ietcc.csic.es

Abstract: Regulatory acoustic requirements for hospitals exist in several countries in Europe, but many countries have either no or few regulatory limits or only recommendations. The purpose of limit values is to ensure optimal acoustic conditions for the patients under treatment and for the personnel for the various tasks taking place in many different rooms, e.g., bedrooms, examination and treatment rooms, corridors, stairwells, waiting and reception areas, canteens, offices, all with different acoustic needs. In addition, some rooms require special considerations such as psychiatric rooms and noisy MR-scanning rooms. The extent of limit values varies considerably between countries. Some specify few, others specify several criteria. The findings from a comparative study carried out by the authors in selected countries in various geographical parts of Europe show a diversity of acoustic descriptors and limit values. This paper includes updated criteria for reverberation time, airborne and impact sound insulation, noise from traffic and from service equipment for hospital bedrooms. The discrepancies between countries are discussed, aiming at potential learning and implementation of improved limits. In addition to regulations or guidelines, some countries have hospitals included in national acoustic classification schemes with different acoustic quality levels. Indications of such class criteria are included in the paper.

Keywords: hospitals; acoustic requirements; airborne sound insulation; impact noise; reverberation time; service equipment noise

Citation: Rasmussen, B.; Carrascal, T.; Secchi, S. A Comparative Study of Acoustic Regulations for Hospital Bedrooms in Selected Countries in Europe. *Buildings* **2023**, *13*, 578. https://doi.org/10.3390/buildings13030578

Academic Editor: Cinzia Buratti

Received: 13 January 2023
Revised: 7 February 2023
Accepted: 14 February 2023
Published: 21 February 2023

1. Introduction

Acoustic conditions in hospitals are important for patients under treatment as well as for the staff. In hospitals, rooms have different acoustic needs and acoustic regulations, and/or acoustic quality classes or other guidelines which exist in several countries but are missing in other countries. Good acoustic conditions are important for patients' sleep and recovery as well as for the personnel's work conditions, thus reducing mistakes. For all, including visitors, good acoustic conditions help to support comfort and a relaxed atmosphere. The purpose of this paper is to compare acoustic requirements for hospitals in selected countries in Europe, aiming at potential learning between countries and improving regulations. The selected countries and related regulations are Denmark [1], England [2], France [3], Italy [4,5], Norway [6], Portugal [7], Spain [8] and Turkey [9].

In many countries, regulations set minimum acoustic requirements to ensure a good acoustic quality and protect citizens from noise, whose detrimental effects in health are well documented [10–12]. Among non-auditory effects, long-term exposure to noise causes annoyance, cognitive impairment, sleep disturbance, cardiovascular disease, and metabolic outcomes. Moreover, it has been proved that noise also impacts mental health [13,14]. In healthcare the acoustic environment is of greater relevance as noise has an effect on the recovery of patients. The most frequent effect of noise in hospitals is sleep disturbance [15].

Lack of sleep and fragmented sleep slow down patient restoration and alter physiological parameters such as heart rate, blood pressure and the glucose metabolism [16]. On the other hand, hospital personnel usually report annoyance, mental distraction and stress due to noise, which may reduce the productivity [15].

The acoustic environment of hospitals has been assessed in several studies [17]. Some studies based on questionnaires [18–21] reported that the most disturbing sources of noise were voices, both for staff and patients. Operational noises such as footsteps, carts in the corridor, and intermittent noise from medical devices such as monitor alarms and beepers were also found to be sources of annoyance. The study by Lam et al. [19] revealed that personnel perceived the overall acoustic quality of hospitals as less suitable than patients and visitors did. Lo Castro et al. [22] demonstrated that the acoustic environment in several hospitals was reported as largely noisy by the personnel and was correlated with the concentration loss.

A review paper [17] on noise in hospitals collected data on sound pressure levels measured in several hospitals and revealed that in most of the cases, measured sound pressure levels exceeded the WHO noise levels [23], which are commonly considered as the reference to determine whether a certain sound pressure level is harmful or not.

Many countries have building regulations and/or guidelines which contain minimum criteria which apply to certain construction elements, e.g., walls, floors, facades, etc. or spaces, and are used as design criteria to build and retrofit buildings.

This paper compiles and compares acoustic regulations for hospital bedrooms and is a follow-up on previous studies about hospitals, such as reverberation time regulations for corridors and stairwells in hospitals [24] and acoustic regulations and classes in the five Nordic countries for hospital bedrooms [25].

This paper is an updated and extended version of the paper presented at the Inter-Noise Conference held in Washington in August 2021 [26].

2. Materials and Methods

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

- Airborne sound insulation between rooms;
- Impact sound insulation between rooms;
- Facade sound insulation or indoor traffic noise;
- Service equipment noise;
- Reverberation time or sound absorption.

Building acoustic criteria are specified by a descriptor, a limit value and a 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 [27–34]. Traffic noise may be determined according to EU Directive 2002/49/EC [35]. At the design stage, the acoustic performance can be estimated using prediction methods, e.g., [36,37], with relevant acoustic input data.

Although many different acoustic limit values are needed for the different rooms in hospital buildings, it was decided to compare regulations for hospital bedrooms, which is a basic room type in hospitals and considered useful as a starting point for further future comparisons. This paper focuses on such hospital bedrooms, and Figure 1 illustrates the acoustic requirements analysed in this paper for the selected countries.

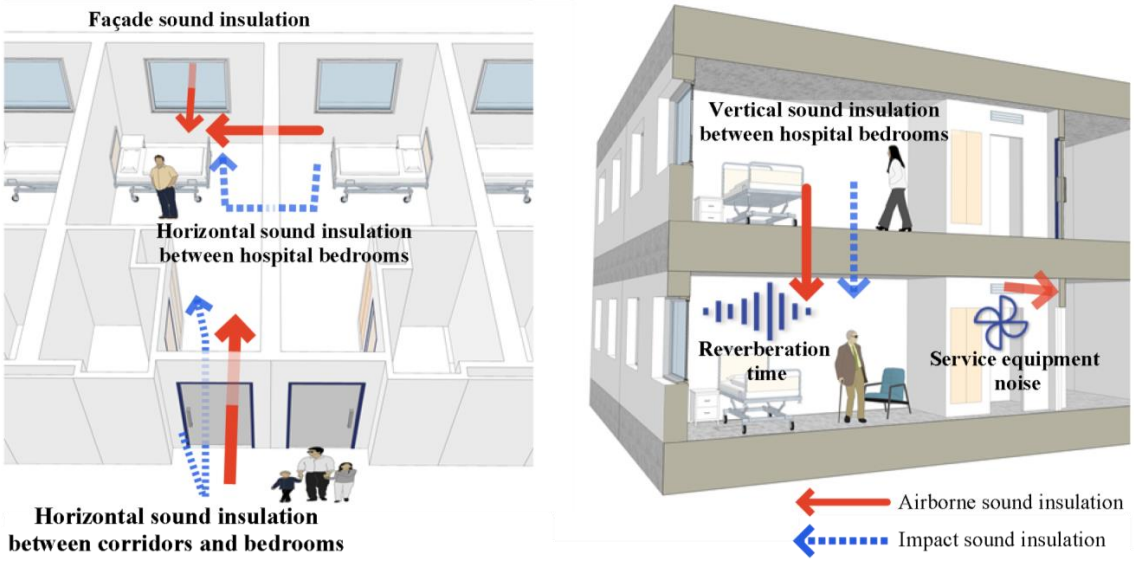

Figure 1. Acoustic requirements for hospital bedrooms analysed for selected countries in Europe.

When choosing countries for the study, it was decided to have various geographical parts of Europe presented, also considering the authors' language skills and the availability of relevant documents. Consequently, most countries in the Eastern part of Europe (from Finland in the North to Greece in South) were not included. Furthermore, only countries with completed, published regulations or guidelines were included in the study, thus omitting drafts. The study was not funded, and although it could have been interesting to include more countries, this was not feasible, and new aspects would not be anticipated.

In Table 1, the selected countries are listed in alphabetical order. For Italy, limit values are split up into public and private hospitals since regulations are different according to the 2022 decree [5].

Table 1. Acoustic regulations for hospitals—Overview countries selected for a comparative study in Europe (November 2022).

Country	BR	ACS	ACS Quality Classes *	Comments on Acoustic Classes and Relation to Building Regulations
Denmark	[1]	N/A	N/A	
England	[2]	N/A	N/A	
France	[3]	N/A	N/A	
Italy (public)	[4,5]	[39]	Superior and basic	For public hospitals, sound insulation regulations are found in [4,5] and described in [39], annexes A (superior class) and B (good performance), being mandatory for public hospitals.
Italy (private)	[4]	[39]	Superior and basic	For private hospitals, limit values are found in [4]. The Acoustic Classification Scheme [39] (superior and basic class) is voluntary for private hospitals.
Norway	[6]	[38]	A, B, C, D	For acoustic regulations, BR [6] refers to ACS [38], Class C, as mandatory minimum performance.
Portugal	[7]	N/A	N/A	
Spain	[8]	[40]	A, B, C, D, E, F	Classification according to [40] is voluntary. No reference in BR [8,40].
Turkey	[9]	[9]	A, B, C, D, E, F	For acoustic regulations, BR [9] refers to ACS [9], Class C, as mandatory minimum performance.

BR = Building Regulations (regulatory requirements); ACS = Acoustic Classification Scheme; * Upper class first; N/A: Not Applicable. Note: Even in case of the same class denotation, descriptors and limit values vary between countries.

From Table 1, it appears that two of the selected countries, Norway and Turkey, refer to Class C in the national acoustic classification scheme as the acoustic regulations. This way makes it quite easy to get an overview of the acoustic requirements for hospitals, since all limit values, including those presented in Section 4 (Tables 2–6), are found in Class C in the classification documents [9,38], respectively.

In general, regulations are mandatory and acoustic classification voluntary, unless referred to in the regulations.

3. Analysis of National Acoustic Regulations for Hospitals

The structure of regulations, scope and verification procedures vary widely from one country to another depending on their needs, culture and customs.

Also varied descriptors are used and differ from one country to the other.

The following paragraphs explain the most significant features of the regulations of the selected countries.

3.1. Denmark

The Danish building regulations and the related guidelines are found in [1]. As for most other countries, the acoustic criteria are about airborne and impact sound insulation between rooms, indoor noise from traffic, service equipment noise and reverberation time (or sound absorption), and they are included in the guideline for chapter 17 about acoustic conditions. The chapter starts with a general introductory statement requiring that buildings shall have satisfactory acoustic conditions in terms of health and comfort, considering the use.

A high number of specific, mandatory limit values exist for housing, schools (incl. other educational buildings) and kindergarten [1]. For these building categories, the number of limit values were extended considerably in 2008 and several limits were made stricter. For hospitals, there were no specific limits or recommendations before 2008, but in 2008 a few basic criteria for hospital bedrooms and a few other room types were introduced as suggestions for design values. However, in 2017, it was realized that hospitals are complex buildings needing a much more extensive set of acoustic limit values. Finally, in January 2020, new limits for several room types were introduced, although unfortunately still only as suggested design values.

Compliance with limits is related to in situ tests carried out according to corresponding ISO test methods [41], but the extent of enforcement and documentation is not known for any of the above-mentioned building categories.

In Denmark, the activities related to planning and construction of new hospitals as well as extensions and renovation have been very extensive over the past decade, and a high level of activity will continue for many years until the hospitals are completed. Denmark has five regions with specific responsibilities; one of these is construction and operation of hospitals. However, for several aspects, cooperation and sharing of experiences are done between the regions. Concerning performance requirements for new/renovated hospitals, one of the regions, Region Midtjylland, has developed and published design guides for various hospital rooms and facilities, see [42], each design guide up to approx. 70 pages covering many technical areas, one of them being acoustic conditions. The design guides include both legislative requirements (must be followed) and recommendations, which are however not just simple, soft hints, but stricter in the sense that they must be complied with or explained "Følg eller forklar" (Follow or explain). If recommendations are not followed, it must be explained why not and this explanation approved by the project group. The region also requires verification of relevant performances, including the airborne and impact sound insulation as well as reverberation time.

Descriptors and limit values for hospital bedrooms are found in Section 4. For other room types in hospitals, see [1]. Tolerances are described in the Guideline, where it is indicated that a 1 dB unfavourable deviation is normally accepted for individual tests of airborne and impact sound insulation, if the average value for all tests of the same

construction types comply with the limit. For traffic noise, a 1 dB deviation is normally accepted. For service equipment noise a 2 dB unfavourable deviation is normally accepted for individual tests, if the average of all measurements for the equal installations complies with the limit. For reverberation time the tolerances allowed are described in Table 6.

3.2. England

Building regulations [43] in England apply exclusively to schools and residential buildings. Nevertheless, the "Health Technical Memorandum HTM-08-1: Acoustics" is provided by the Department of Health as a design guidance document for hospitals and healthcare facilities [2]. These guidelines set recommended acoustic design criteria for hospitals including airborne and impact sound insulation between rooms, limits for sound pressure level inside rooms due to outdoor noise and mechanical services, room acoustics and vibrations. They also provide schematic details of construction joints, calculations methods and examples of calculations. Finally, a checklist with the most important acoustic issues is given.

Another important feature is that it covers many types of rooms: hospital bedrooms, operation theatres, examination rooms, speech and language therapy rooms, laboratories, etc. In general, it is a very complete and comprehensive document which serves as guidance for developers, designers or consultants.

In the case of airborne sound insulation, the value of standardized sound level difference, $D_{\mathrm{nT,w}}$, aims at ensuring privacy and protection against noise from adjacent rooms; for that purpose, all rooms are assessed depending on the privacy requirements of each room, the expected generation of noise and the sensitivity of each space. For instance, single bedrooms, which are one of the objects of this paper, are assessed as:

- The privacy requirement is "confidential: raised speech would be audible but not intelligible, and normal speech would be inaudible";
- The expected generation of noise is "typical";
- The sensitivity as a receiving room is "medium: room generally needs to be free from noise of other rooms".

Multi-bed rooms, rooms for children and elder people are assessed differently. Depending on the type of rooms that are adjacent, their expected generated noise and its sensitivity, different required values of $D_{\mathrm{n}T,\mathrm{w}}$ are provided.

As for impact sound insulation, $L'_{\mathrm{n}T,\mathrm{w}} \leq 65$ dB is the criteria for rooms that are one above the other, no impact insulation criteria is set between rooms on the same floor.

To protect the indoor from outdoor noises, the descriptors used are equivalent A-weighted Sound Pressure Level $L_{\mathrm{Aeq,1h}}$ daytime and night time (23:00–7:00) and maximum A-weighted Sound Pressure Level $L_{\mathrm{A,max\,f}}$ for short-term noises. In addition, there are criteria for rain noise. It is also specified that outdoor noise should be measured on site before starting the design.

For service and equipment noise, reference to the noise rating curves (NR) in the octave band range from 63 Hz to 4 kHz is the recommended criterion. It also sets vibration performance criteria, root mean square (RMS) acceleration for continuous sources, and the vibration dose value (VDV) for intermittent vibration.

Regarding reverberation control, the approach is prescriptive, a class C absorber according to ISO 11654 [34] covering at least 80% of the ceiling must be used in rooms. Whenever a class A or B absorber is installed, less area is required.

Finally, these guidelines recommend a testing program before construction, comprising airborne and impact sound insulation and NR for mechanical services and indoor noise levels. Tolerances are not specified in the guidelines [2], but it is specified that in the event of a failure to meet the acoustic criteria, remedial work must be undertaken. Small individual failures may be allowed e.g., 1 dB or 2 dB, as long as these failures are not systematic throughout the building.

Since it is non-regulatory, all the criteria are recommended and may be introduced in the contracts with designers and builders.

3.3. France

Acoustic requirements for hospitals and health care facilities in France are set in [44]. Compared to most other countries in this study, the structure of acoustic building regulations in France is quite complex, as it is composed of several laws and decrees issued by different ministries and departments which deal with the protection of noise in the building environment. Nevertheless, the joint document [3] links all the laws concerning acoustic requirements in buildings and also contains guidelines on how to apply acoustic requirements to different kinds of buildings.

As with most of the countries in this study, the French regulation sets out the requirements on airborne and impact sound insulation, as well as façade sound insulation, limits for service and equipment noise and criteria for room acoustics.

Descriptors used are A-weighted standardized sound level difference $D_{nT,A} = D_{nT,w} + C$ and weighted standardized impact noise $L'_{nT,w}$ for airborne and impact sound insulation.

With regards to impact noise, in the French regulations concerning hospitals there is no mention of whether impact pressure levels apply between corridor and bedrooms and there is no mention of whether impact requirements apply vertically or horizontally. In Table 3, it is assumed that requirements apply in both.

With regards to façade sound insulation, the minimum requirement is $D_{nT,A,tr} = D_{nT,w} + C_{tr} \geq 30$ dB, but depending on the exposure to outdoor noise the requirements are increased. When a hospital building is affected by aircraft noise, requirements for façade sound insulation vary from 30 to 47 dB. For areas where road or rail noise is the predominant noise source, façade sound insulation requirements vary from 30 to 45 dB. To obtain the corresponding sound insulation value of each room in a building, designers must know which type of infrastructure (airport, road or railway) is affecting the building. In the case of road and railway traffic, the distance of the building, as well as the presence of noise barriers or other obstacles, such as buildings, determine the minimum requirements for façade sound insulation. The guideline [3] contains worked examples on how to apply façade requirements to different buildings.

In the case of noise from building services, the descriptor used is $L_{A,nT}$ which is equivalent to $L_{Asmax,nT}$ and measured with ISO 10052 [29]. Different limits are set for common or individual equipment. There are also limits for noise produced by water supply and drainage systems of hospital bathrooms.

Regarding room acoustics, reverberation time is the average of the octave frequency bands of 500, 1000 and 2000 Hz as indicated in Table 6.

France has published very comprehensive guidelines [45] on measurements comprising many aspects, such as test methods, examples, the choice of rooms to perform measurements, report template, etc. There is a 3 dB tolerance for sound insulation and sound pressure levels from building services due to the uncertainty of the measurement method.

3.4. Italy

In Italy acoustic requirements for hospitals are different for private and public hospitals. For both, the Ministerial Decree of December 1997 [4] gives mandatory limits for impact ($L'_{n,w}$) and airborne (R'_w) insulation, façade sound insulation ($D_{2m,nT,w}$) and equipment noise ($L_{A,smax}$, $L_{A,eq}$) but for public buildings the Ministerial Decree of 23 June 2022 [5] applies and sets out stricter limits, which correspond to the limit values defined by the standards UNI 11367 [39,46,47] and UNI 11532 [48]. At the current time the fourth part of the standard UNI 11532, which will deal with acoustic requirements of internal spaces of hospitals, has not yet been published.

The standard UNI 11367 [39] describes the acoustic classification of buildings and includes annexes A and B that refer to the acoustical quality of hospitals and schools (with base and superior classes) and are voluntary for private hospitals and mandatory (with reference to the superior class) for public hospitals. These annexes give limit values for the normalized sound insulation, $D_{nT,w}$, between adjoining bedrooms and between corridors and bedrooms, the normalized impact sound insulation, $L'_{n,w}$, between overlapping

bedrooms and limit values for sound pressure levels of equipment noise. According to UNI 11367, equipment noise, distinguished between continuous, L_{ic}, and discontinuous operating, L_{id}, must be corrected for the reverberation time and for the background noise. Continuous equipment is where the sound pressure level measured with the "fast" dynamic characteristic has oscillations not greater than 5 dB for the whole duration of the operating cycle or of the operating time (i.e., heating, cooling, ventilation systems). The sound level from service equipment must be measured in a room different from that of the sound source according to the requirements given by annex D of UNI 11367:2010 (adapted from ISO 10052 [29] and ISO 16032 [30]).

$$\text{For continuous operating equipment, } L_{ic} = L_{A,eq} + K_1 + K_2;$$

$$\text{For discontinuous operating equipment, } L_{id} = L_{A,smax} + K_2;$$

where K_1 = correction for background noise; $K_2 = -10\log(T/T_0)$; T = average reverberation time in the room between 100 and 3150 Hz; T_0 = reference reverberation time given by:

$$T_0 = 0.5 \text{ s for } V \leq 100 \text{ m}^3;$$

$$T_0 = 0.05\ (V)^{0.5} \text{ for } 100 < V < 2500 \text{ m}^3;$$

$$T_0 = 2.5 \text{ s for } V \geq 2500 \text{ m}^3.$$

With reference to reverberation requirements, there are no limit values for private hospitals and for public hospitals it is necessary to refer to annex C of UNI 11367 [39] (Reverberation Time, Clarity and Speech Transmission Index).

Testing of acoustic performances is mandatory and a report by an accredited laboratory shall be issued. There is no tolerance for measured values.

3.5. Norway

The Norwegian building regulations are found in [6]. It is stated that acoustic requirements can be met by ensuring compliance with sound class C in the Norwegian Standard NS 8175:2012 [38], which is a classification standard with four acoustic quality classes A–D for various types of buildings, including, e.g., dwellings, schools, kindergarten, healthcare buildings and offices in separate chapters and with general joint information about procedures and test conditions in the introductory chapters. Class C describes the mandatory minimum performance for new builds, and there are two higher classes, A and B, for better acoustic quality, and one lower class.

The first version of NS 8175 was published in 1997. The current version of NS 8175 is the 5th version, published in 2019, see [38], and not yet referred to in the building regulations, although seemingly applied in practice. In the 2019 version, references to test and rating methods have been updated and several changes made throughout the document. A comparison of hospital bedroom class limits with the other Nordic countries is found in [25].

Examples of classification limits for sound insulation between hospital bedrooms are the following for classes A–D (in descending order) in the most recent version from 2019:

- Airborne: $R'_w \geq 52, 52, 48, 44$ dB (note that class A and B limits are the same);
- Impact: $L'_{n,w} \leq 53, 55, 58, 63$ dB.

Acoustic requirements for hospital bedrooms in new hospitals are found in Section 4. For other room types in hospitals, see [38]. Tolerances are not indicated in [38], except for reverberation time, see note in Section 4.

3.6. Portugal

The Portuguese Regulations on building acoustics [7] apply to different kinds of buildings (residential buildings, office buildings, schools, etc.) and also to hospitals. It sets minimum requirements for airborne, impact and façade sound insulation, limit values for noise from

building services and room acoustics. Concerning outdoor noise and noise from building services it refers to the Portuguese Noise Law [49], which is the transposition of Directive 2002/49/EC relating to the assessment and management of environmental noise [35].

Different rooms are considered in these regulations: operating theatres, consulting rooms, examination rooms, offices and wards.

Descriptors used are $D_{nT,w}$ and $L'_{nT,w}$ for airborne and impact sound insulation.

Regarding impact noise, in Portuguese regulations concerning hospitals there is no mention of whether impact pressure levels apply between corridor and bedrooms and there is no mention of whether impact requirements apply vertically or horizontally. In Section 4 it is assumed that requirements apply in both cases.

Regarding façade sound insulation, $D_{2m,nT,w}$ is used. Sound insulation must be at least 28 dB for sensitive areas, which are residential, school or hospital areas where L_{den} must not exceed 55 dB and L_n must not exceed 45 dB according to [49]. For mixed areas, the sound insulation of a façade must be at least 33 dB; mixed areas include different land uses, such as commercial and office areas and L_{den} must not exceed 65 dB and L_n must not exceed 55 dB. However, no requirement is given when outdoor noise exceeds the outdoor limit values established in [49] for mixed and sensitive areas. When the façade of a hospital room has a translucent area greater than 60%, $D_{2m,nT,w} + C_{tr}$ is used.

Regarding noise from building services, there are limit values different for intermittent and continuous equipment. The descriptor $L_{Ar,nT}$ is based on $L_{Aeq,nT}$ but penalties for tonal components must be assessed with a maximum value of 3 dB.

Reverberation time is also set out for rooms with a volume greater than 100 m^3 and it is a function of the volume of the rooms. The reverberation time corresponds to the average of the values of the octave frequency bands of 500, 1000 and 2000 Hz.

Regarding the verification procedure [50], testing is mandatory and is requested by municipalities before the occupation of the building. An acoustician must issue a report based on in situ tests performed by an accredited laboratory. There is a 3 dB tolerance for sound insulation and sound pressure levels from building services and a 25% tolerance for reverberation time.

3.7. Spain

Document DB HR Protection against noise [8] of the Spanish Building Code sets minimum requirements for hospital bedrooms for airborne and impact sound insulation between bedrooms and between a room and other areas, such as corridors, nurse stations, etc. It also includes requirements for façade sound insulation. Limits for service equipment noise are regulated in RD 1367/2007 [51], which is part of the transposition of Directive 2002/49/EC [35] that sets limit values for outdoor sound sources and applies also to the indoor environment of buildings. However, there are no limits for reverberation time or indications about a minimum absorption area inside bedrooms.

In Spain, requirements only apply to hospital bedrooms and the regulations do not include other rooms inside hospitals such as surgical rooms, corridors, examination rooms, etc. Guidelines for applying Basic Document DB HR Protection against noise [52] include an example on how to apply limit values to hospitals bedrooms and have recommendations for consulting rooms. These guidelines also specify that in rooms which are not specified in regulations, such as nurseries, operation theatres or laboratories, the developer, the designer or the builder should decide the acoustic conditions and seek the advice of an acoustician.

Descriptors used are $D_{nT,A}$ and $L'_{nT,w}$ for airborne and impact sound insulation. $D_{nT,A}$ is calculated using the procedure in [8] with reference values for airborne sound that differ from the ones in ISO 717:2020 [28]. Results of $D_{nT,A}$ are similar to $D_{nT,w} + C_{100–5000}$ and the Spanish Building Code permits the use of this expression for comparisons.

Regarding façade sound insulation, $D_{2m,nT,Atr}$ is used, which is calculated using the procedure in [8]. Results of $D_{2m,nT,Atr}$ are similar to $D_{2m,nT,w} + C_{tr,100–5000}$. The minimum sound insulation required depends on the daytime equivalent sound pressure level L_d of the area the building is located. The aim is to ensure a maximum sound pressure level

inside a hospital bedroom of 30 dB due to outdoor noise. Designers usually consult public noise maps available at the Information System for Noise Pollution [53] to choose the minimum requirement that applies to each façade.

As for noise from building services, descriptors, $L_{K,d}$, $L_{K,e}$ and $L_{K,n}$, for day, evening and night, are based on the $L_{A,eq}$, and corrections for low frequency, tonal and impulsive noise are applied with a maximum of 9 dB. Of these three descriptors, $L_{k,n}$ is the most restrictive.

RD 1369/2007 [51] includes the measurement and assessment method. Descriptors $L_{K,d}$, $L_{K,e}$ and $L_{K,n}$ apply to any source and there is no distinction made between continuous sources and intermittent ones.

Spanish regulations also include some specifications for detailing and workmanship. Spanish guidelines include a wide variety of examples of details, good workmanship recommendations and workmanship checklists that apply also to hospital bedrooms.

In situ testing is not mandatory in all Spain, nevertheless some regions and local authorities request in situ tests before the occupation of new buildings, including new hospitals. There is a tolerance of 3 dB for sound insulation tests.

In September 2021, a new acoustic classification scheme [40] was approved that includes hospital bedrooms. This classification system includes acoustic classes from A to F. Sound insulation requirements of the Spanish Building Code fall in category D. This classification scheme is voluntary.

3.8. Turkey

The acoustic requirements and acoustic classification for buildings in Turkey are found in the Regulation on Protection of Buildings Against Noise [9], published in 2017, and an amendment [54], published in 2018. The requirements include six performance areas: façade sound insulation, airborne sound insulation of partitions, impact sound insulation, indoor background noise levels, service equipment noise levels and reverberation time. All building categories are included, and six acoustic quality classes A–F are defined.

The sound insulation requirements are determined based on the noisiness and the noise sensitivity of rooms. The regulation includes a list of all types of buildings and room functions and corresponding classes of noisiness and noise sensitivity.

The descriptors and classification system are in line with ISO/TS 19488:2021 [55]. According to the Regulation, all new buildings shall comply with Class C performance, and Class D performance is required for retrofit projects of existing buildings when the building or its function is subject to an alteration. Information on the methodology for performance assessment and classification can be accessed from [56].

What is unique for [9,54] is that regulations and acoustic classes are described in the same documents, that all types of buildings are included, that acoustic quality classes include lower classes and that the issue of acoustic requirements for retrofitting of buildings is addressed.

Acoustic requirements for hospital bedrooms in new hospitals are found in Section 4. For other room types in hospitals, see [9,54]. Concerning tolerances, a 2 dB unfavourable deviation from the requirement is neglected in measurement results. For further details, see [9,54].

4. Analysis of Limit Values Given by Different Countries

In the Tables 2–6 below are found acoustic regulations for normal hospital bedrooms in the selected countries. The limit values concern airborne and impact sound insulation (Tables 2 and 3), façade sound insulation (Table 4), service equipment noise (Table 5), and reverberation time (Table 6). For further details, see explanations in the tables and the references.

It must be noted that the limit values included in this paper should not be applied directly, as the original regulations must be consulted, since the scope and important application details are found in the original documents listed in the Reference section and in related national guidelines. Furthermore, checks for updates should be made.

As seen in Tables 2 and 3, most of the selected countries have sound insulation requirements or recommendations for hospital bedrooms, but two countries (England and

Italy) do not have limits for horizontal impact sound insulation. Comparisons of limit values show differences of more than 10 dB between countries. Of the limits shown in Tables 2 and 3, Turkey is the country with the strictest requirements for horizontal airborne and impact sound insulation. For vertical sound insulation, slightly stricter values apply for public hospitals in Italy than for Turkey.

Table 2. Acoustic regulations for hospital bedrooms [(1)]—Airborne sound insulation. November 2022.

Country	BR	Rooms [(3)]	Requirement [dB] [(2)]		Comments
			Horizontal	Vertical	
Denmark	[1]	Between bedrooms Corridor to bedroom	($R'_{w} \geq 48$) [(2)] ($R'_{w} \geq 35$) [(2)]	($R'_{w} \geq 51$) [(2)]	
England	[2]	Between bedrooms Corridor to bedroom	($D_{nT,w} \geq 47$)[(2)] ($R_{w} \geq$ 30–35 dB)	($D_{nT,w} \geq 47$) [(2)]	Values for single bedrooms. Requirements for other bedrooms are found in [2], e.g., bedrooms for children. Recommendations for door sets.
France	[3]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C \geq 42$ $D_{nT,w} + C \geq 27$	$D_{nT,w} \geq 42$	
Italy (public)	[4,5]	Between bedrooms Corridor to bedroom	$D_{nT,w} \geq 50$ $D_{nT,w} \geq 30$	$D_{nT,w} \geq 55$	BR [5] refers to superior class of annex A in ACS [39] BR [5] refers to good performance of annex B in ACS [39].
Italy (private)	[4]	Between bedrooms Corridor to bedroom	None	None	No regulations for private hospitals, but criteria from ACS [39] may be applied voluntarily.
Norway	[6]	Between bedrooms Corridor to bedroom	$R'_{w} \geq 48$ $R'_{w} \geq 34$	$R'_{w} \geq 48$	BR [6] refers to Class C in ACS [38].
Portugal	[7]	Between bedrooms Corridor to bedroom	$D_{nT,w} \geq 45$ $D_{nT,w} \geq 30$	$D_{nT,w} \geq 45$	
Spain	[8]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C_{100–5000} \geq 50$ $R_{A} \geq$ 50–30	$D_{nT,w} + C_{100–5000} \geq 50$	Horizontal: For walls containing doors leading to corridors: $R_{A} \approx R_{w} + C_{100–5000} \geq 50$ for the wall, and ≥ 30 for the door set.
Turkey	[9]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C \geq 52$ $D_{nT,w} + C \geq 38$	$D_{nT,w} + C \geq 52$	BR [9] refers to Class C in ACS [9].

[(1)] Overview information only. Detailed criteria and conditions are found in references. [(2)] Limits in (brackets) = Recommendation. [(3)] Corridor means there is a door between the hospital bedroom and the corridor. If there is no door, stricter limits may apply.

Table 3. Acoustic regulations for hospital bedrooms [(1)]—Impact sound insulation. November 2022.

Country	BR	Rooms	Requirement [dB] [(2)]		Comments
			Horizontal	Vertical	
Denmark	[1]	Between bedrooms Corridor to bedroom	($L'_{n,w} \leq 58$) [(2)] ($L'_{n,w} \leq 58$) [(2)]	($L'_{n,w} \leq 58$) [(2)] ($L'_{n,w} \leq 58$) [(2)]	
England	[2]	Between bedrooms Corridor to bedroom	None	($L'_{nT,w} \leq 65$) [(2)]	
France	[3]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 60$ $L'_{nT,w} \leq 60$	$L'_{nT,w} \leq 60$ $L'_{nT,w} \leq 60$	See comments in Section 3.3.
Italy (public)	[4,5]	Between bedrooms Corridor to bedroom	None	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	BR [5] refers to Annex A of ACS [39].
Italy (private)	[4]	Between bedrooms Corridor to bedroom	None	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	For private hospitals, limit values are given in the Decree 5/12/1997 [4].
Norway	[6]	Between bedrooms Corridor to bedroom	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 58$	BR [6] refers to Class C in ACS [38].
Portugal	[7]	Between bedrooms Corridor to bedroom	$L'_{n,w} \leq 65$ $L'_{n,w} \leq 65$	$L'_{n,w} \leq 65$ $L'_{n,w} \leq 65$	See comments in Section 3.6.
Spain	[8]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 65$ $L'_{nT,w} \leq 65$	$L'_{nT,w} \leq 65$ $L'_{nT,w} \leq 65$	
Turkey	[9]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 54$ $L'_{nT,w} \leq 54$	$L'_{nT,w} \leq 54$	BR [9] refers to Class C in ACS [9].

[(1)] Overview information only. Detailed criteria and conditions are found in references. [(2)] Limits in (brackets) = Recommendation.

Table 4 shows façade sound insulation required for hospital bedrooms. Whereas Italy has facade sound insulation limits independent from outdoor noise, all other countries have increasing limits with increasing outdoor traffic noise levels. In Denmark, England, Norway, and Turkey, the requirements are expressed directly as A-weighted equivalent indoor sound pressure levels, implying stricter sound insulation limits for higher traffic noise levels. France, Portugal and Spain express their requirements as façade sound insulation with limits depending on the outdoor noise levels. For further details, see Table 4 and the references.

Table 4. Acoustic regulations for hospital bedrooms [(1)]—Facade sound insulation. November 2022.

Country	BR	Requirement [dB] [(2)]	Furnished [(5)]	Comments
Denmark	[1]	(L_{den} (indoor) [(3)] ≤ 33) [(2)]	+	
England	[2]	($L_{Aeq,1h}$ daytime ≤ 40) [(2)] ($L_{Aeq,1h}$ night ≤ 35) [(2)] ($L_{Amax,f,}$ night ≤ 45) [(2)]	+	Limits for single bedrooms. Limits increase 5 dB for multi-bedrooms.
France	[3]	$D_{nT,A,tr} \geq 30$	N/A	Required $D_{nT,A,tr}$ varies from 30 to 45 dB, depending on the type of road and its distance to the façade. Requirement corrected depending on the existence of noise barriers, adjacent buildings, etc.
Italy (public)	[4,5]	$D_{2m,nT,w} \geq 45$ [(4)]	N/A	Fixed façade sound insulation limit independent of the outdoor SPL.
Italy (private)	[4]	$D_{2m,nT,w} \geq 45$ [(4)]	N/A	Fixed façade sound insulation limit independent of the outdoor SPL.

Table 4. *Cont.*

Country	BR	Requirement [dB] [2]	Furnished [5]	Comments
Norway	[6]	$L_{p,A,24h}$ (indoor) ≤ 30 $L_{p,AF,max,\ 23–07}$ (indoor) ≤ 45	+	BR [6] refers to Class C in ACS [38].
Portugal	[7]	$D_{2m,nT,w} \geq 28$	N/A	$D_{2m,nT,w} \geq 28$ dB or $\geq$33 dB depending on the type of area the hospital is located [49]
Spain	[8]	$D_{2m,nT,Atr} \approx D_{2m,nT,w} + C_{tr,100–5000} \geq 30$	N/A	Valid for $L_{day} \leq 60$ dB. For $L_{day} \leq 65$, $\leq$70, $\leq$75 or >75 dB, limits 32, 37, 42, 47 dB apply.
Turkey	[9]	$L_{A,eq}$ (indoor) ≤ 34	+	BR [9] refers to Class C in ACS [9]. Day-evening-night period applied.

[1] Overview information only. Detailed criteria and conditions are found in the references. [2] Limits in (brackets) = Recommendation. (3) DK: Day 07–19 (default), Evening 19–22, Night 22–07. L_{den} is defined in END (2002) [35]. The Danish Building Code refers to L_{den} as the only limit and valid for roads and railways separately. [4] The superior limit given by the Decree 23 June 2022 [5] (public hospitals) is lower than that given by the decree 5 December 1997 [4]. Therefore, the same limit applies both to public and private hospitals. [5] +: Requirements apply to furnished rooms. N/A: Not applicable, e.g., if requirements are expressed as airborne sound insulation.

Limit values for service equipment noise are found in Table 5. Measurement methods are found in the building regulations. It is seen that different descriptors are applied, which make comparisons more complicated. In general, all countries rely on a descriptor based on the A-weighted equivalent sound pressure level L_{Aeq}. The standards referred to are basically either ISO 10052 [29] or ISO 16032 [30], but then additional methods apply for low-frequency noise and correction for pure tones, impulses and intermittent noise. Some countries apply different limits and procedures for continuous sources, e.g., ventilation systems, and other sources with changing noise emission during the operating cycle.

Table 5. Acoustic regulations for hospital bedrooms [1]—Service equipment noise. November 2022.

Country	BR	Requirement [dB] [2]	Furnished [4]	Comments
Denmark	[1]	($L_{A,eq} \leq 30$) [2]	+	
England	[2]	($NR \leq 30$) [2]	+	
France	[3]	$L_{nAT} \leq 30 L_{nAT} \leq 35$	Not specified	Noise produced by communal equipment or individual equipment inside the room. Noise produced by plumbing and drainage systems in adjacent rooms.
Italy (public)	[4,5]	$L_{ic} \leq 28$ [3] $L_{id} \leq 34$ [3]	Not specified	Equivalent SPL from service equipment with continuous operation. Maximum SPL from service equipment with discontinuous operation.
Italy (private)	[4]	$L_{Aeq} \leq 25$ $L_{Asmax} \leq 35$	Not specified	Equivalent SPL from service equipment with continuous operation. Maximum SPL from service equipment with discontinuous operation.
Norway	[6]	$L_{p,A,T} \leq 28$ $L_{p,AF,max} \leq 30$	+	BR [6] refers to Class C in ACS [38].

Table 5. *Cont.*

Country	BR	Requirement [dB] [2]	Furnished [4]	Comments
Portugal	[7]	$L_{Ar,nT} \leq 30$ $L_{Ar,nT} \leq 35$	Not specified	For building services producing a continuous noise. For building services producing intermittent noises. $L_{Ar,nT} = L_{A,eq}$ (standardized to the reference reverberation time) corrections for background noise and tonal noise.
Spain	[8,51]	$L_{k,d}$; $L_{k,e} \leq 35$ $L_{k,n} \leq 25$	Not specified	Limit value $L_k = L_{A,eq,T}$ + corrections for background noise, tonal, impulsive and low frequency noise.
Turkey	[9]	$L_{A,eq} \leq 30$ $L_{AF,max,nT} \leq 34$	+	BR [9] refers to Class C in ACS [9]. The two limits are for continuous and intermittent noise, respectively.

[1] Overview information only. Detailed criteria and conditions are found in references. [2] Limits in (brackets) = Recommendation. [3] The descriptors are explained in Section 3.4. The stricter limit between those given by [4,5] applies. [4] +: Requirements apply to furnished rooms. Not specified: Regulations do not specify if requirements apply to furnished rooms.

Table 6 shows reverberation time requirements for hospital bedrooms. Of eight countries, six have limits for T, but with different frequency ranges, one has a limit for sound absorption, and Spain has no limits. In some countries, reverberation time requirements depend on the room volume, indicated as V in Table 6.

Table 6. Acoustic regulations for hospital bedrooms [1]—Reverberation time. November 2022.

Country	BR	Requirement [dB] [2][3]	Furnished [4]	Freq. Range [Hz]	Comments
Denmark	[1]	($T \leq 0.6$) [2]	+	125–4000 [5]	
England	[2]	See comment	N/A	250–4000	No T limit, but a minimum absorption area equivalent to a class C absorber, ISO 11654 [34], for 80% of the floor area is recommended.
France	[3]	$T_r \leq 0.8$ [4]	+	500–2000 [6]	Volume $\leq$ 250 m^3. A typical bedroom for two beds is estimated to <60 m^3. For rooms with a bigger volume, see reference [3].
Italy (public)	[5]	$T_r \leq 1.2 \cdot (0.32 \cdot \lg(V) + 0.03)$	Not specified	250–4000	
Italy (private)		None	N/A	N/A	No limits values.
Norway	[6]	$T \leq 0.6$ [3]	+	125–4000 [7]	BR [6] refers to Class C in ACS [38].
Portugal	[7]	$T \leq 0.15 \cdot V^{1/3}$	+	500–2000 [6]	Only limits for multi-bedrooms. Volume $\geq$ 100 m^3. No limits for smaller bedrooms
Spain	[8]	None	N/A	N/A	
Turkey	[9]	$T \leq 0.5$	+	250–2000 [6]	BR [9] refers to Class C in ACS [9].

[1] Overview information only. Detailed criteria and conditions are found in references. [2] Limits in (brackets) = Recommendation. [3] V: Room volume, m^3. [4] +: Requirements apply to furnished rooms. Not specified: Regulations do not specify if requirements apply to furnished rooms. N/A: Not applicable, e.g., if there is not a requirement in regulations. [5] Denmark: Max. in each 1/1 octave band. For 125 Hz, +20% accepted. [6] T is defined as the average for the frequency bands indicated. [7] Norway, NS8175:2019 [38]: Max. in each 1/1 octave band. For 125 Hz, +40% accepted. For 250–4000 Hz, deviations up to +20% accepted, if the mean value for those frequencies does not exceed the limit value.

5. Results of the Comparison between Recommended Values

As shown in Tables 2–6, acoustic requirements of hospital bedrooms are expressed by different national regulations with a multitude of indicators. For this reason, the comparison between different values is possible only with some assumptions.

In the following paragraphs, the hypotheses assumed for the conversion of indicators are summarized.

5.1. Airborne Sound Insulation between Bedrooms and between Bedrooms and Corridors

For sound insulation between bedrooms (horizontal and vertical), two countries (Denmark and Norway) use the rating of apparent Sound Reduction Index R'_{w}, three countries (England, Italy and Portugal) use the rating of normalized sound insulation $D_{\mathrm{n}T,\mathrm{w}}$, two countries (France and Turkey) use the same parameter plus the spectrum adaptation term, $D_{\mathrm{n}T,\mathrm{w}} + C$, and one country (Spain) uses the spectrum adaptation term $C_{100–5000}$, $D_{\mathrm{n}T,\mathrm{w}} + C_{100–5000}$.

R' and $D_{\mathrm{n}T}$ are descriptors that express the in situ airborne sound insulation. $D_{\mathrm{n}T}$ depends on the room volume of the receiving room, which means that the bigger the receiving room volume, the higher the result of $D_{\mathrm{n}T}$ and the easier to fulfil the requirements. See Equation (1).

For sound insulation between bedroom and corridors (horizontal), two countries (Denmark, and Norway) use the rating of apparent Sound Reduction Index, R'_{w}, two countries (Italy and Portugal) use the rating of normalized sound insulation $D_{\mathrm{n}T,\mathrm{w}}$, and two countries (France and Turkey) use $D_{\mathrm{n}T,\mathrm{w}} + C$.

In the case of Spain and England, the approach is prescriptive for the sound insulation between rooms and corridors where there is a door. Both countries include a laboratory descriptor for the door set, R_{w} in England and $R_{\mathrm{A}} \approx R_{\mathrm{w}} + C_{100–5000}$ in Spain, which also requires a minimum $R_{\mathrm{A}} \approx R_{\mathrm{w}} + C_{100–5000}$ for the partition between the corridor and bedroom with a door.

The conversion between the different parameters mentioned above is based on the following equation, taken from ISO 16283-1 [27].

$$D_{\mathrm{n}T} = R' + 10lg\frac{0.16 \cdot V}{T_0 \cdot S_{\mathrm{S}}} = R' + 10lg\frac{0.32 \cdot V}{S_{\mathrm{S}}}\ \mathrm{dB} \quad (1)$$

where V is the volume of the receiving room (m^3), T_0 is the reference value of the reverberation time (0.5 s) and S_{S} is the surface of the partition (m^2).

The conversion presented in Figure 2 is therefore based on the following assumptions:

- $0.32 \cdot V = S_{\mathrm{S}}$ (corresponding to the case of two bedrooms separated by a common partition of area *S*s and 3.1 m wide). In this case, $D_{\mathrm{n}T}$ equals R'_{w};
- $C_{100–5000} = C = -1$ dB.

English and Spanish requirements for partitions between bedrooms and corridors are not shown in this graph as they are expressed as laboratory sound reduction index, and the conversion is not straightforward.

5.2. Impact Sound Insulation between Bedrooms and between Bedrooms and Corridors (Horizontal and Vertical)

Four countries (Denmark, Italy, Norway and Portugal) use the rating of normalized impact sound pressure level, $L'_{\mathrm{n,w}}$, and four countries (England, France, Spain and Turkey) use the rating of standardized impact sound pressure level, $L'_{\mathrm{n}T,\mathrm{w}}$.

The conversion between different parameters above mentioned is based on the following equation, taken from ISO 16283-2 [27].

$$L'_{nT} = L'_n - 10lg\left(\frac{0.16 \cdot V}{A_0 T_0}\right) = L'_n - 10lg(0.032 \cdot \mathrm{V})\ \mathrm{dB} \quad (2)$$

where V is the volume of the receiving room (m^3), T_0 is the reference value of the reverberation time (0.5 s) and A_0 is the reference value of the equivalent absorption area (10 m^2) in the receiving room.

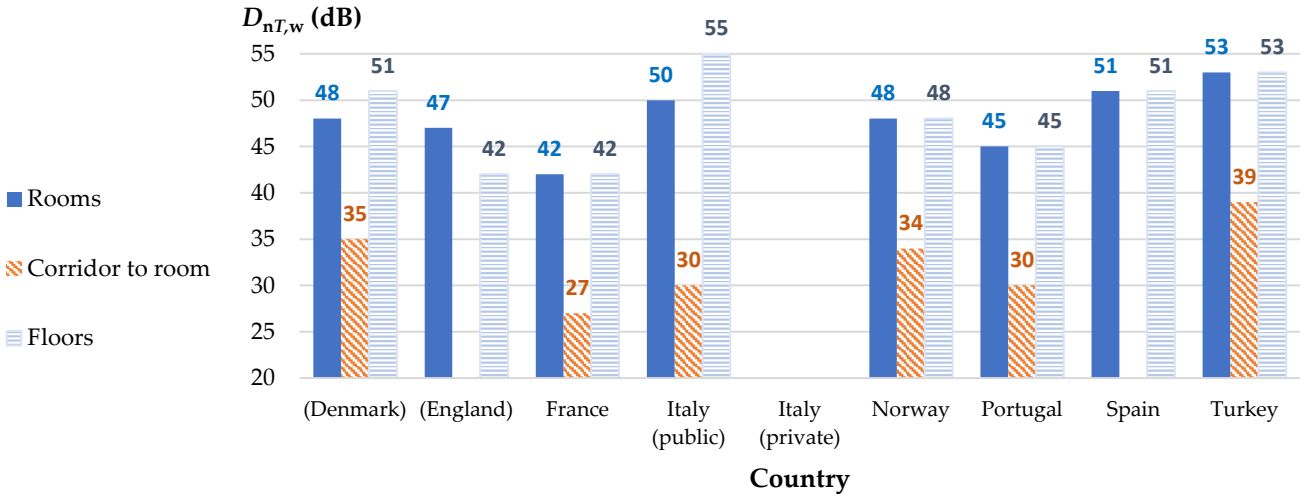

Figure 2. Comparison between limit values for airborne sound insulation between bedrooms and between bedrooms and corridors.

The conversion presented in Figure 3 is therefore based on the assumptions that the bedroom volume V = 40 m^3.

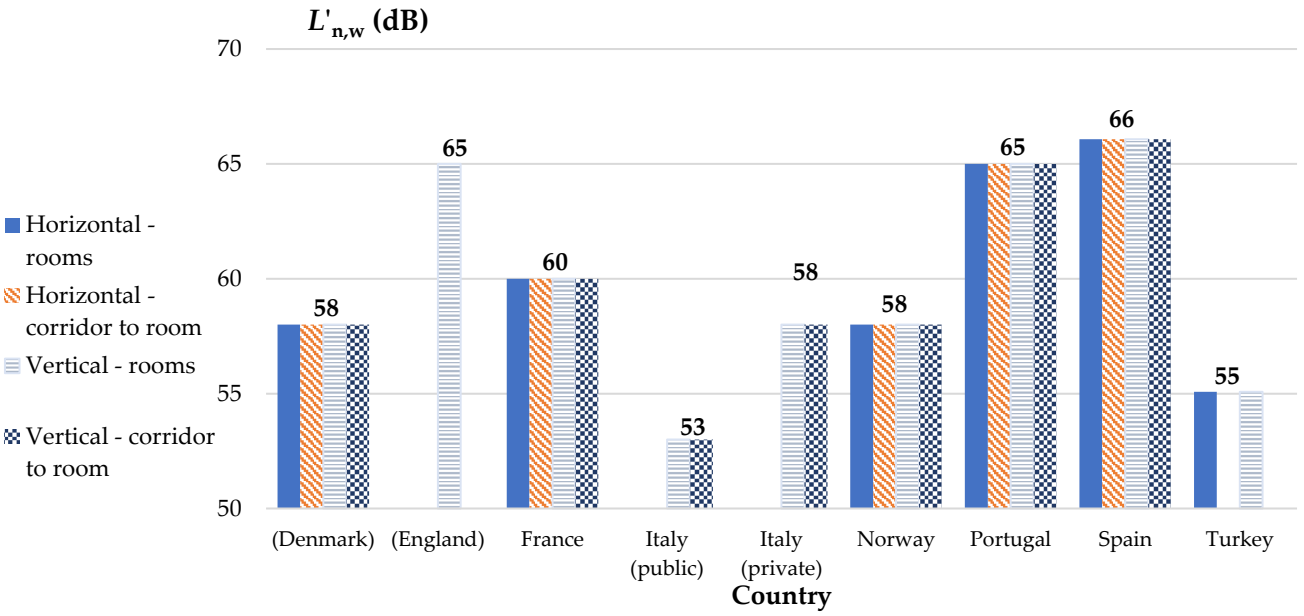

Figure 3. Comparison between limit values for impact sound insulation between bedrooms and between bedrooms and corridors.

5.3. Façade Sound Insulation

The aim of facade requirements is to ensure that the sound pressure levels transmitted from outdoor sources, such as traffic noise, are not too excessive so that they could compromise the health of patients. With this idea, the regulations in some countries are more direct and give limits for sound pressure levels (Denmark, England, Norway and Turkey), but the descriptors used in each country are measured in different time periods (day, night, L_{den}). On the other hand, other countries use the facade sound insulation requirements. In particular, Italy and Portugal use the rating of the standardized façade sound insulation,

$D_{2m,nT,w}$, and two countries (France and Spain) use the A-weighted standardized façade sound insulation, $D_{2m,nT,Atr} = D_{2m,nT,w}+C_{tr}$, but in Spain uses $C_{tr,100–5000}$. Moreover, Italy does not differentiate the limit values for façade sound insulation according to the outdoor noise level.

Due to the variety of descriptors for sound pressure levels obtained in different time periods and the different descriptors used for airborne sound insulation against traffic noise, it is not possible to have a reliable comparison between the limit values used in different countries for protection against outdoor noise. See Table 4.

5.4. Service Equipment Noise of Continuous Operating Systems

For continuous operating equipment noise, all countries refer to the equivalent A-weighted sound pressure level but three countries (Italy, Norway, Portugal) normalize the measured value to the Reverberation Time and four countries (Denmark, England, Spain and Turkey) have no normalization to Reverberation Time.

In Spain, France and England the same limits and descriptors apply independently of the fact that the source is continuous or not. England recommends the values of Noise Rating 30 for equipment noise.

In France, the descriptor for service equipment noise is $L_{A,Smax,nT,}$ independently of source; continuous or not. Values are different for plumbing and drainage systems outside the bedroom and for other systems, such as ventilation.

In Spain there are three limits: day, evening and night, which are based on L_{Aeq}, corrected by tonal, impulsive and low frequency components. In Portugal, corrections due to tonal noise are also applied.

Figure 4 shows a comparison of service equipment regulations between countries and includes limits for continuous sources and intermittent ones. The conversion between different indicators may be based on the following assumption:

For England, noise equal to values of NR30 between 31.5 and 8000 Hz;
$A = A_0 = 10\ m^2$;
$T = T_0 = 0.5$ s;
No impulsive, tonal or low frequency noise corrections are included in Figure 4.

For France, it is assumed that for continuous sources, L_{Aeq} is equal to $L_{A,Smax,nT}$. The limit expressed in Figure 4 is the required maximum sound pressure level for centralized services and services inside the room, except for drainage and plumbing systems.

For Spain, $L_{k,n}$, the most restrictive value that applies at night is represented in Figure 4.

5.5. Service Equipment Noise of Discontinuous Operating Systems

For discontinuous operating equipment noise, four countries (Italy, Norway, France and Turkey) refer to the maximum A-weighted sound pressure level, $L_{A,max}$; measured with "slow" time weighting in Italy and France and "fast" time weighting in Norway and Turkey.

The conversion between different indicators is based on the same assumption above described. It is also assumed that $L_{A,Smax}$ measured with "slow" time weighting equals $L_{A,Fmax}$ measured with "fast" time weighting, although for quick intermittent sounds, $L_{A,Fmax}$ measurements will result in higher values and therefore, requirements expressed as $L_{A,Fmax}$ are stricter.

For Italy, the limit for discontinuous sources corresponds to that given by the decree of December 1997 because in the case of the hypothesis assumed ($T = T_0 = 0.5$ s), this limit is stricter than that of the Decree of June 2023.

5.6. Reverberation Time

Six countries (Denmark, France, Italy, Norway, Portugal, Turkey) give limits or recommended values for Reverberation Time of bedrooms, and England recommends a minimum absorption area equivalent to a class C absorber [34] for 80% of the floor area.

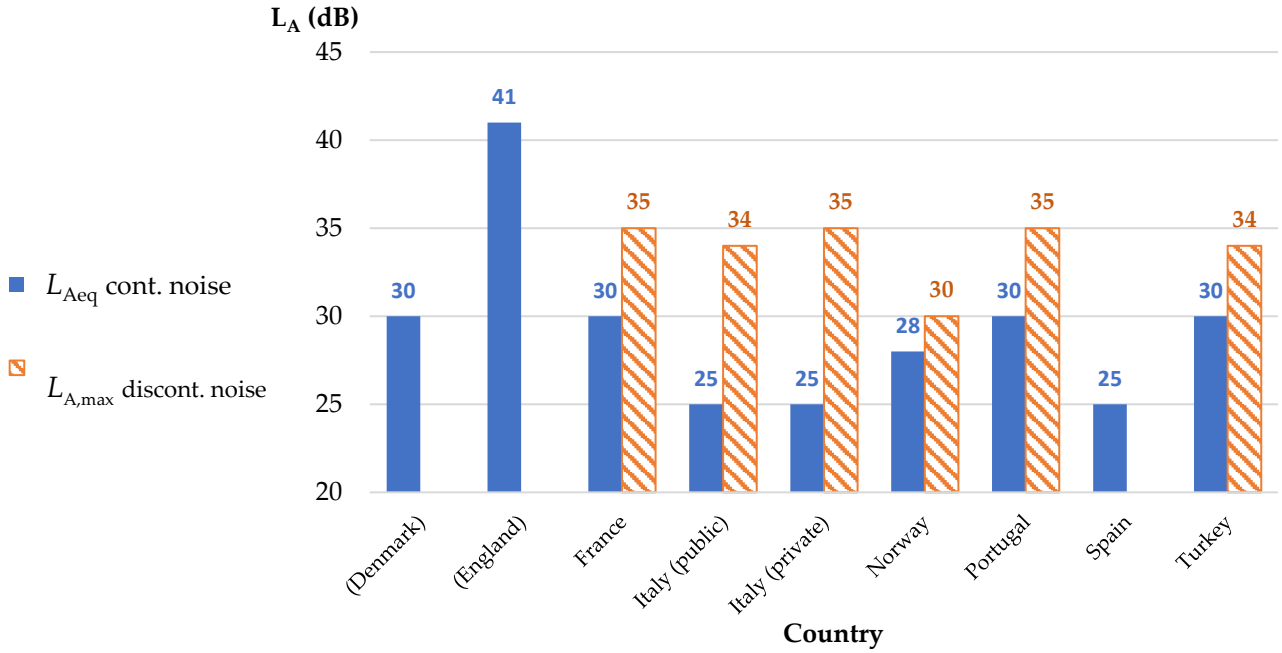

Figure 4. Comparison between limit values for equipment noise.

The limit $L_{A,max}$ expressed in the table for France corresponds to the requirement for drainage and plumbing systems, which are intermittent sources.

The frequencies considered in the verification of Reverberation Time are different for different countries, see Table 6. Limits for the frequency range 500–2000 Hz are easier to fulfil than for a wider frequency range down to 250 Hz or even 125 Hz, since the sound absorption is typically much lower at the low frequencies than for higher frequencies.

Since Italy and Portugal limit values are function of the bedroom volume, to compare values it was necessary to refer to a room volume of 40 m^3.

Concerning England, a bedroom of 40 m^3, 2.70 m high and with 80% of the ceiling covered by a class C absorber was considered to obtain the value of T = 0.8 s.

Figure 5 shows the comparison between limit values for reverberation time according to these assumptions.

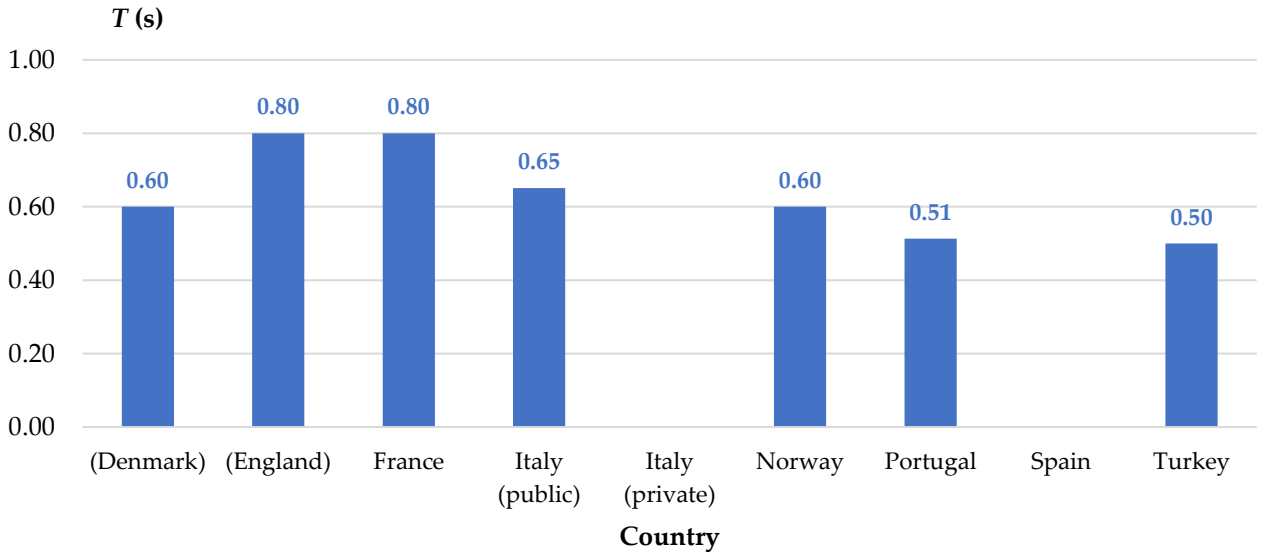

Figure 5. Comparison between limit values for reverberation time.

6. Discussion and Conclusions

Acoustic design is essential to the quality of hospitals, as it is well known that "unwanted sound" has detrimental effects in health. In this sense, a good layout that avoids noisy areas from being adjacent to hospital bedrooms and other quiet areas is the best way to maximize comfort and privacy. In addition, it is fundamental to set the appropriate acoustic design criteria for each type of room.

Acoustic regulations for hospitals aim on one hand at providing comfort and wellbeing for the patients, which is essential for recovery, and on the other hand at providing good working conditions for the staff. For these reasons, various limits for airborne and impact sound insulation, indoor traffic noise, service equipment noise and reverberation time are relevant and exist in national regulations or recommendations in several countries. Since it is known from comparative studies of housing, schools and offices, cf. e.g., [57–62], that acoustic requirements vary considerably between countries, it was found relevant to compare acoustic limit values for hospitals also, again aiming at mutual learning between countries.

Limit values depend upon the room types. As a first step to know more about hospitals, it was decided to compare acoustic limit values for hospital bedrooms in eight countries in Europe. In hospital rooms, the protection from disturbing indoor sources of sound, such as voices in other rooms, carts in the corridors, ventilation noise, etc., is essential for the wellbeing of patients and personnel. In this study, it has been noticed that certain requirements related to the protection of noise from indoor sounds are missing in some countries, specifically horizontal impact sound insulation and reverberation time requirements.

For all types of limits, both descriptors and limit values vary between countries. For airborne and impact sound insulation, differences between countries are more than 10 dB, and for two countries there are no requirements for horizontal impact sound insulation. For traffic noise, a detailed comparison would require a very extensive study of national regulations and guidelines and this is not within the scope of this paper, since descriptors and methods of evaluation are different from one country to the other. For service equipment noise, some countries have different limit values for continuous sources (such as ventilation noise) and discontinuous sources (such as flushing water). For reverberation time in hospital bedrooms, both frequency ranges and limit values vary, but what is especially important to notice is that only Spain and Italy for private hospitals do not have such requirements for hospital bedrooms, confirming that the comfort of patients and staff—including communication—is highly dependent on the builders' and contractors' choice of design values for reverberation time.

The findings from the current study of hospital bedrooms show that an exchange of experiences between countries would be useful, aiming at improving and optimizing acoustic requirements for hospitals. It is recommended and intended to continue comparative studies of more hospital room types to achieve a wider view of which requirements are appropriate for other important facilities in hospitals.

Author Contributions: Conceptualization, B.R.; Writing—original draft preparation, review and editing, B.R., S.S. and T.C.G.; Visualization, S.S. and T.C.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data presented in tables and graphs in this paper has been extracted from regulations and laws which were in force in November 2022. Links to the regulation in each of the selected countries can be consulted in the reference section. Warning: It must be noted that the limit values included in this paper should not be applied directly as legislation, but the original documents or updates consulted, since details and conditions are found in these documents or other documents the authors have not been aware of.

Acknowledgments: The authors are grateful to the acoustic colleagues: Gary Timmins, Jorge Patricio and Ayca Sentop for responding to questions about national acoustic regulations and guidelines in England, Portugal, and Turkey, respectively. However, the authors are solely responsible for errors in the paper, and any comments, corrections and updated information will be appreciated.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bygningsreglement 2018 (Building Regulations 2018). Danish Transport, Construction and Housing Authority, 2017. Copenhagen, Denmark. Available online: http://bygningsreglementet.dk/Tekniske-bestemmelser/17/Vejledninger (accessed on 7 February 2023).
2. Department of Health. Health Technical Memorandum HTM 08-01: Acoustics. England. 2013. Available online: https://www.england.nhs.uk/publication/health-sector-buildings-acoustic-design-requirements-htm-08-01/ (accessed on 7 February 2023).
3. Conseil National du Bruit. Guide du CNB. No 6. RéGlementations Acoustiques des Bâtiments. (Acoustic Building Regulations). Conseil National du Bruit (French Noise Council). 2017. Available online: http://www.bruit.fr/images/stories/pdf/guide-cnb-6-reglementations-acoustiques-batiments-novembre%202017.pdf (accessed on 7 February 2023).
4. Decreto 5 Dicembre 1997, Requisiti Acustici Passivi Degli Edifici (Determination of Passive Acoustic Requirements for Buildings). 1997. Available online: http://www.gazzettaufficiale.it/eli/id/1997/12/22/97A10190/sg (accessed on 7 February 2023).
5. Decreto 23 Giugno 2022, Criteri Ambientali Minimi per L'affidamento del Servizio di Progettazione di Interventi Edilizi, per L'affidamento dei Lavori per Interventi Edilizi e per L'affidamento Congiunto di Progettazione e Lavori per Interventi Edilizi. (Minimum Environmental Criteria for the Commissioning of Design Services for Building Construction, for the Commissioning of Works for Building Construction and for the Joint Commissioning of Design and Works for Building Construction). Ministero della Transizione Ecologica, Italy, 2022. Available online: https://www.gazzettaufficiale.it/eli/id/2022/08/06/22A04307/sg (accessed on 7 February 2023).
6. DIBK. Byggteknisk Forskrift (TEK17). Veiledning om Tekniske Krav til Byggverk. (Regulations on Technical Requirements for Building Works). Direktoratet for Byggkvalitet, Oslo. (Norwegian Building Authority). 2017. Available online: https://dibk.no/regelverk/byggteknisk-forskrift-tek17 (accessed on 7 February 2023).
7. Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, Decreto-Lei 96/2008. Regulamento dos Requisitos Acústicos dos Edifícios (RRAE) (Portuguese Building Acoustics Code). 2008, pp. 3359–3372. Available online: http://data.dre.pt/eli/dec-lei/96/2008/06/09/p/dre/pt/html (accessed on 7 February 2023).
8. Spain, Ministry of infrastructure, Documento Básico DB HR Protección Frente al Ruido. Código Técnico de la Edificación. (DB HR Protection against Noise. Spanish Building Code). 2019. Available online: https://www.codigotecnico.org/images/stories/pdf/proteccionRuido/DBHR.pdf (accessed on 7 February 2023).
9. Turkish Ministry of Environment and Urbanization. Binalarin Gürültüye Karşi Korunmasi Hakkinda Yönetmelik (Regulation on Protection of Buildings against Noise). Republic of Turkey Official Gazette. 2017. Available online: www.resmigazete.gov.tr/eskiler/2017/05/20170531-7.htm (accessed on 7 February 2023).
10. European Environment Agency, Good Practice Guide on Noise Exposure and Potential Health Effects—European Environment Agency, Office for Official Publications of the European Union, Luxembourg, Publication EEA Technical Report No.11/2010. 2010. Available online: https://www.eea.europa.eu/publications/good-practice-guide-on-noise (accessed on 7 February 2023).
11. WHO; Regional Office for Europe. Environmental Noise Guidelines for the European Region. World Health Organization. Regional Office for Europe. 2018. Available online: https://apps.who.int/iris/rest/bitstreams/1175318/retrieve (accessed on 7 February 2023).
12. European Environment Agency; Environmental Noise in Europe-European Environment Agency. Publications Office of the European Union, Luxembourg, EEA Report No. 22/2019, 2020. Available online: https://www.eea.europa.eu/publications/environmental-noise-in-europe (accessed on 7 February 2023).
13. Jensen, H.A.R.; Rasmussen, B.; Ekholm, O. Neighbour and traffic noise annoyance: A nationwide study of associated mental health and perceived stress. *Eur. J. Public Health* **2018**, *28*, 1050–1055. Available online: https://academic.oup.com/eurpub/article/28/6/1050/5009407 (accessed on 7 February 2023). [CrossRef] [PubMed]
14. Jensen, H.A.R.; Rasmussen, B.; Ekholm, O. Neighbour noise annoyance is associated with various mental and physical health symptoms: Results from a nationwide study among individuals living in multi-storey housing. *BMC Public Health* **2019**, *19*, 1508. Available online: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-019-7893-8 (accessed on 7 February 2023). [CrossRef] [PubMed]
15. Waye, K.P.; Ryherd, E. Achieving a healthy sound environment in hospitals. In Proceedings of the INTER-NOISE 2013 Congress and Conference Proceedings, Innsbruck, Austria, 15–18 September 2013; pp. 38–45, Keynote Paper. Available online: https://gup.ub.gu.se/file/158779 (accessed on 7 February 2023).
16. Basner, M.; Brink, M.; Bristow, A.; de Kluizenaar, Y.; Finegold, L.; Hong, J.; Janssen, S.A.; Klaeboe, R.; Leroux, T.; Liebl, A.; et al. ICBEN review of research on the biological effects of noise 2011–2014. *Noise Health* **2015**, *17*, 75. Available online: https://www.noiseandhealth.org/text.asp?2015/17/75/57/153373 (accessed on 7 February 2023). [CrossRef] [PubMed]

17. de Lima Andrade, E.; da Cunha E Silva, D.C.; de Lima, E.A.; de Oliveira, R.A.; Zannin, P.H.T.; Martins, A.C.G. Environmental noise in hospitals: A systematic review. *Environ. Sci. Pollut. Res. Int.* **2021**, *28*, 19629–19642. Available online: https://pubmed.ncbi.nlm.nih.gov/33674976/ (accessed on 7 February 2023). [CrossRef] [PubMed]
18. Larsen, T.M.; Jeong, C.-H.; Beldam, M.B.; Brunskog, J.; Weitze, C.A. An investigation of room functions and acoustic demands in selected departments in three Danish hospitals. In Proceedings of the 23rd International Congress on Acoustics, Aachen, Germany, 9–13 September 2019; pp. 7803–7810. Available online: https://backend.orbit.dtu.dk/ws/portalfiles/portal/195003278/000531.pdf (accessed on 7 February 2023).
19. Lam, B.; Peijin Fan, E.M.; Ooi, K.; Ong, Z.; Young Hong, J.; Gan, W.; Yuh Ang, S. Assessing the perceived indoor acoustic environment quality across building occupants in a tertiary-care public hospital in Singapore. *Build. Environ.* **2022**, *222*, 109403. Available online: https://www.sciencedirect.com/science/article/pii/S0360132322006369 (accessed on 7 February 2023). [CrossRef]
20. Fausti, P.; Santoni, A.; Secchi, S. Noise control in hospitals: Considerations on regulations, design and real situations. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*; Institute of Noise Control Engineering: Washington, DC, USA, 2019; Available online: http://www.sea-acustica.es/fileadmin/INTERNOISE_2019/Fchrs/Proceedings/2174.pdf (accessed on 7 February 2023).
21. Secchi, S.; Setola, N.; Marzi, L.; Amodeo, V. Analysis of the Acoustic Comfort in Hospital: The Case of Maternity Rooms. *Buildings* **2022**, *12*, 1117. Available online: https://www.mdpi.com/2075-5309/12/8/1117 (accessed on 7 February 2023). [CrossRef]
22. Lo Castro, F.; Iarossi, S.; Brambilla, G.; Mariconte, R.; Diano, M.; Bruzzaniti, V.; Strigari, L.; Raffaele, G.; Giliberti, C. Surveys on Noise in Some Hospital Wards and Self-Reported Reactions from Staff: A Case Study. *Buildings* **2022**, *12*, 2077. [CrossRef]
23. Berglund, B.; Lindvall, T.; Schwela, D.H.; W.H.O. Occupational; E. H. Team. 'Guidelines for Community Noise'. World Health Organization. Available online: https://apps.who.int/iris/handle/10665/66217 (accessed on 7 February 2023).
24. Carrascal García, T.; Rasmussen, B. Reverberation time regulations for stairwells and corridors—A pilot study for hospitals in selected countries in Europe. In Proceedings of the Forum Acusticum 2020, Online, 7–11 December 2020; Available online: https://hal.archives-ouvertes.fr/hal-03231758/document (accessed on 7 February 2023).
25. Rasmussen, B. A pilot study on acoustic regulations and classification for hospitals – Comparison between the Nordic countries. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*; Institute of Noise Control Engineering: Washington, DC, USA, 2018; Available online: https://vbn.aau.dk/ws/portalfiles/portal/286630217/Hospitals_AcouRegulations_ACS_NordicCountries_IN18_Paper2047.pdf (accessed on 7 February 2023).
26. Rasmussen, B.; Carrascal García, T.; Secchi, S. Acoustic regulations for hospital bedrooms—Comparison between selected countries in Europe. In Proceedings of the 50th International Congress and Exposition on Noise Control Engineering, InterNoise 2021, Washington, DC, USA, 1–5 August 2021.
27. *ISO 16283*; Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements—Part 1: Field Measurements of Airborne Sound Insulation between Rooms, 2014—Part 2: Field Measurements of Impact Sound Insulation of Building Elements, 2020—Part 3: Field Measurements of Airborne Sound Insulation of Facade Elements and Facades. International Organization for Standardization: Geneva, Switzerland, 2016.
28. *ISO 717:2020*; Acoustics—Rating of Sound Insulation in Buildings and of Buildings Elements—Part 1: Airborne Sound Insulation—Part 2: Impact Sound Insulation. International Organization for Standardization: Geneva, Switzerland, 2020.
29. *ISO 10052:2021*; Acoustics—Field Measurements of Airborne and Impact Sound Insulation and of Service Equipment Sound—Survey Method. International Organization for Standardization: Geneva, Switzerland, 2021.
30. *ISO 16032:2004*; Acoustics—Measurement of Sound Pressure Level from Service Equipment in Buildings—Engineering Method. International Organization for Standardization: Geneva, Switzerland, 2021.
31. *ISO 3382*; Acoustics – Measurement of Room Acoustic Parameters—Part 1: Performance Spaces, 2009—Part 2: Reverberation Time in Ordinary Rooms, 2008.—Part 3: Open Plan Offices. International Organization for Standardization: Geneva, Switzerland, 2012.
32. *ISO 1996-1:2016*; Acoustics—Description, Measurement and Assessment of Environmental Noise—Part 1: Basic Quantities and Assessment Procedures. International Organization for Standardization: Geneva, Switzerland, 2016.
33. *ISO 1996-2:2017*; Acoustics—Description, Measurement and Assessment of Environmental Noise—Part 2: Determination of Sound Pressure Levels. International Organization for Standardization: Geneva, Switzerland, 2017.
34. *ISO 11654:1997*; Acoustics. Sound Absorbers for Use in Buildings. Rating of Sound Absorption. International Organization for Standardization: Geneva, Switzerland, 1997.
35. European Parliament. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 Relating to the Assessment and Management of Environmental noise. Official Journal of the EU, L 189. 2002. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0049&from=EN (accessed on 7 February 2023).
36. *ISO 12354:2017*; Building Acoustics—Estimation of Acoustic Performance of Buildings from the Performance of Elements—Part 1: Airborne Sound Insulation between Rooms—Part 2: Impact Sound Insulation Between Rooms.—Part 3: Airborne Sound Insulation against Outdoor Sound. International Organization for Standardization: Geneva, Switzerland, 2017.
37. *EN 12354-6:2003*; Building Acoustics—Estimation of Acoustic Performance of Building from the Performance of Elements—Part 6: Sound Absorption in Enclosed Spaces. European Committee for Standardization: Brussels, Belgium, 2003.
38. *NS 8175:2012*; Lydforhold i bygninger-Lydklasser for Ulike Bygningstyper (Acoustic Conditions in Buildings—Sound Classification of Various Types of Buildings). Standards Norway: Lysaker, Norway, 2012.

39. *UNI 11367:2023*; Acustica in Edilizia—Classificazione Acustica delle Unità Immobiliari—Procedura di Valutazione e Verifica in Opera (Building Acoustics-Acoustic Classification of Building Units-Evaluation Procedure and in-situ Measurements). UNI: Florence, Italy, 2023.
40. *UNE 74201:2021*; Acústica. Esquema de Clasificación Acústica de Edificios. (Acoustics. Buildings Acoustic Classification Scheme). UNE: Madrid, Spain, 2021.
41. Rasmussen, B.; Hoffmeyer, D.; Olesen, H.S. Udførelse af bygningsakustiske målinger (Performing building acoustic field measurements). SBi-guideline No. 217, 2017 (2.ed.), SBi Forlag, Copenhagen, Denmark. Available online: https://build.dk/anvisninger/Pages/217-Udfoerelse-af-bygningsakustiske-maalinger-udgave-1-2.aspx (accessed on 16 February 2023).
42. Godkendte Designguides (Approved Design Guides). Available online: https://www.rm.dk/om-os/organisation/koncernokonomi/byggeri-og-ejendomme/designguide-for-hospitalsbyggeri/godkendte-designguides1/ (accessed on 7 February 2023).
43. HM Government, The Building Regulations 2010. The Merged Approved Documents. 2021. Available online: https://www.gov.uk/guidance/building-regulations-and-approved-documents-index#approved-documents (accessed on 7 February 2023).
44. Arrêté du 25 Avril 2003 Relatif à la Limitation du Bruit Dans les Établissements de Santé (Decree of 25 April 2003 on the Limitation of Noise in Health Establishments). Available online: https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000778136/ (accessed on 7 February 2023).
45. Guide de Mesures Acoustiques (Acoustic Measurement Guide). France: Ministère de l'Ecologie, du Developpement Durable et de l'Energie. Ministère du Logement et de l'Égalité des Territoires. 2014. Available online: http://www.ecologique-solidaire.gouv.fr/sites/default/files/Guide%20de%20mesures%20acoustiques%20-%20ao%C3%BBt%202014.pdf (accessed on 7 February 2023).
46. Di Bella, A.; Fausti, P.; Scamoni, F.; Secchi, S. Italian experiences on acoustic classification of buildings. In Proceedings of the InterNoise 2012, New York, NY, USA, 19–22 August 2012; pp. 5598–5609.
47. Fausti, P.; Di Bella, A.; Santoni, A.; Scamoni, F.; Secchi, S.; Semprini, G. The Italian classification scheme of buildings-application to apartments and schools. In Proceedings of the INTER-NOISE and NOISE-CON Congress and Conference Proceedings, InterNoise 2020, Seoul, Korea, 23–26 August 2020; pp. 1175–1185.
48. *UNI 11532:2018*; Caratteristiche Acustiche Interne di Ambienti Confinati–Metodi di Progettazione e Tecniche di Valutazione–Parte 1: Requisiti Generali (Indoor Acoustic Characteristics of Confined Environments-Design Methods and Evaluation Techniques-Part 1: General Requirements). (in Italian; UNI: Florence, Italy, 2018.
49. Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, Decreto-Lei n.o 9/2007. Regulamento geral do ruído, (Portuguese Noise Pollution Act) Diário da República n. 12/2007, Série, I. 2007, pp. 389–398. Available online: http://data.dre.pt/eli/dec-lei/9/2007/01/17/p/dre/pt/html (accessed on 7 February 2023).
50. Patrício, J. The Portuguese policy for building acoustics assessment. In Proceedings of the Internoise 2012, New York, NY, USA, 19–22 August 2012; Available online: https://www.researchgate.net/publication/278622373_The_Portuguese_policy_for_building_acoustics_assessment (accessed on 16 February 2023).
51. Ministerio de la Presidencia, RD 1367/2007 de 19 de Octubre, por el que se Desarrolla la Ley 37/2003, de 17 de Noviembre, del Ruido, en lo Referente a Zonificación Acústica, Objetivos de Calidad y Emisiones Acústicas. (BOE 23/10/2007). 2007, Volume 254, pp. 42952–42973. Available online: https://www.boe.es/diario_boe/txt.php?id=BOE-A-2007-18397 (accessed on 7 February 2023).
52. Carrascal García, M.T.; Romero Fernández, A.; Casla Herguedas, M.B. *Guía de Aplicación del DB HR Protección Frente al Ruido*; Versión V.03 Diciembre de 2016. (Guidelines for applying Basic Document DB HR Protection against noise); Ministry of Infrastructure: Madrid, Spain, 2016; Available online: https://www.codigotecnico.org/pdf/Documentos/HR/GUIA_DBHR_201612.pdf (accessed on 16 February 2023).
53. Sistema de Información sobre la Contaminación Acústica. SICA. (Information System on Noise Pollution)', SICA. Available online: https://sicaweb.cedex.es/ (accessed on 7 February 2023).
54. Republic of Turkey Ministry of Environment and Urbanization. Binaların Gürültüye Karşı Korunması Hakkında Yönetmelikte Değişiklik Yapılmasına dair Yönetmelik (Amendment to Regulation on Protection of Buildings against Noise). Official Gazette of Republic of Turkey. 2018. Available online: http://www.resmigazete.gov.tr/eskiler/2018/05/20180531-2.htm (accessed on 7 February 2023).
55. *ISO/TS 19488*; Acoustic Classification of Dwellings. International Organization for Standardization: Geneva, Switzerland, 2021.
56. Bayazit, N.; Kurra, S.; Sentop, A.; Ozbilen, B.S. Acoustical classification and proposed methodology for performance assessment of buildings in Turkey. In Proceedings of the 23rd International Congress on Sound & Vibration, Athens, Greece, 10–14 July 2016.
57. Rasmussen, B. Sound insulation between dwellings-Requirements in building regulations in Europe. *Appl. Acoust.* **2010**, *71*, 373–385. Available online: https://www.sciencedirect.com/science/article/pii/S0003682X0900214X (accessed on 7 February 2023). [CrossRef]
58. Rasmussen, B.; Rindel, J.H. Sound insulation between dwellings-Descriptors applied in building regulations in Europe. *Appl. Acoust.* **2010**, *71*, 171–180. Available online: https://www.sciencedirect.com/science/article/pii/S0003682X09001509 (accessed on 7 February 2023). [CrossRef]
59. Rasmussen, B. Sound insulation between dwellings – Comparison of national requirements in Europe and interaction with acoustic classification schemes. In Proceedings of the ICA 2019, 23rd International Congress on Acoustics, Aachen, Germany, 9–13 September 2019; Deutsche Gesellschaft für Akustik (DEGA): Berlin, Germany, 2019. [CrossRef]

60. Rasmussen, B.; Guigou-Carter, C. A pilot study on acoustic regulations for schools – Comparison between selected countries in Europe. In Proceedings of the Inter-Noise 2016. ed./Wolfgang Kropp, Hamburg, Germany, 21–24 August 2016; Deutsche Gesellschaft für Akustik (DEGA): Berlin, Germany, 2016; pp. 886–893. Available online: https://vbn.aau.dk/en/publications/a-pilot-study-on-acoustic-regulations-for-schools-comparison-betw (accessed on 7 February 2023).
61. Rasmussen, B.; Carrascal García, T. Acoustic regulations for offices – Comparison between selected countries in Europe. In Proceedings of the Inter-Noise 2019 (Noise-Con Proceedings), Madrid, Spain, 16–19 June 2019; Available online: https://vbn.aau.dk/en/publications/acoustic-regulations-for-offices-comparison-between-selected-coun (accessed on 7 February 2023).
62. Rasmussen, B. Acoustic classification of dwellings – A growing diversity of sound insulation descriptors in national schemes in Europe. In *Proceedings of the ICA 2022 Proceedings of the 24th International Congress on Acoustics*; Gyeongju, Republic of Korea, 24–28 October 2022, Available online: https://vbn.aau.dk/en/publications/acoustic-classification-of-dwellings-a-growing-diversity-of-sound (accessed on 7 February 2023).