The future of UK hospital design

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Abstract
The importance of acoustic conditions within hospitals is highlighted by recent research indicating that patient recovery times are significantly influenced by the noise levels within wards. Added to this are concerns about speech privacy and confidentiality, patient and staff comfort, communication between patient and doctor, and the effects of vibration on sensitive medical equipment, all of which makes the acoustic design a key parameter in any hospital development.

This paper will discuss the practical issues associated with the implementation of the current national guidance on hospital acoustics (Health Technical Memorandum 2045) and the new, currently unpublished replacement, Health Technical Memorandum 08-01. The experiences of the author with several large Private Finance Initiative projects, designed to the current standard, have illustrated the practical difficulties of fully complying with all its requirements and the design solutions which can be adopted.

Speech privacy and confidentiality has been a critical issue in developing the new design standard. The implementation of this document is currently being assessed on two major projects, the first in the UK to be designed to the new standard.

1 Introduction

The National Health Service in the United Kingdom celebrates its 60th birthday this year. Founded on 5 July 1948 by Health Secretary Aneurin Bevan the aims of the NHS were clear: to provide a health service which will be available to all, financed entirely from taxation. The opening of Park Hospital in Manchester was the first hospital bringing together doctor, nurses, pharmacists, opticians and dentists to provide care to everyone, free at the point of delivery.

60 years on, the NHS is very different from the original system, although the desire to bring about change seems largely the same. The current Labour government's 2005 manifesto stated that *"The revolution in quantity of care must be matched by a revolution in quality of care."* This commitment was made against a background of confusing national design guidance. With large numbers of separate documents dealing with all aspects of healthcare design, a programme of review and simplification was embarked upon by NHS Estates.

This paper presents the latest position in that review process as it relates to acoustic design of healthcare facilities, and presents the author's practical experience of implementing the new design standards.

2 Previous guidance

2.1 Health Technical Memorandum 56

HTM56 Partitions was published in 1997 and gave general design guidance on the construction and performance of internal partitions. It included acoustic performance criteria which were based on a laboratory (R_w) value only. Brief, generic advice was given about what should be considered to avoid compromising the internal sound insulation in practice, such as "*…perimeter junctions with other elements and around pipes and ducts* [must be] *adequately sealed…"* but there was no requirement to achieve any specified standard of sound insulation in the finished building. The lowest specified performance standard was R_w33 increasing to R_w53 between for example Consulting Rooms and Day Rooms.

The document was revised in 2005 to remove all guidance on acoustic performance, referring instead to HTM2045.

3 Current guidance

3.1 Health Technical Memorandum 2045

Although intended to take precedence over HTM56, HTM2045 *Acoustics: Design Considerations* was actually published in 1996, one year before HTM56 was issued. It contained partition performance requirements as well as guidance on many other aspects of acoustic design of healthcare buildings; mechanical services noise, intrusive noise, vibration, internal sound insulation (partitions), façade sound insulation, impact sound, reverberation times, audio system intelligibility and environmental noise emission. Although comprehensive in scope, the application of some of the guidance has proved to be problematic. Here are a few examples of specific practical issues encountered by Arup Acoustics' healthcare team.

3.1.1 Impractical criteria

Operating Theatres:

The building services criterion for operating theatres is NR30. Theatres will usually have dedicated air handling plant operating at high duties, located close to the theatre itself. To achieve NR30, roomside attenuators would typically need to be 1.8 – 2.4m long depending on the geometry of the system. Given the inherently short duct runs between local plant and the theatres, installing attenuators of this length is often problematic. In addition, the over-riding need for infection control in operating theatres can preclude the use of fibrous materials used in in-duct attenuators, further reducing their effectiveness. Also, the relatively high volumes of air required can also result in significant noise generation in duct fittings, making NR30 difficult to achieve.

The reverberation time criterion in operating theatres is typically 0.4 – 0.5 seconds. In an environment where absorptive finishes are not feasible because of hygiene control and cleanliness requirements, our experience is that it is not possible to meet this requirement. It is questionable whether such low reverberation times are needed in practice. Given that most operating theatres are relatively small rooms, where staff are physically close together, speech communication is generally good, regardless of the room acoustic. Control of noise may be an issue, but since the majority of noise is generated by medical equipment used by the staff undertaking the operation, it is not considered to be particularly problematic. It is feasible that during long operations, fatigue may be an issue for the staff, and this may be alleviated to some extent by a more controlled acoustic environment, but on a day to day basis, this is unlikely to be a major issue.

3.1.2 Shouting

The calculation of internal sound insulation criteria between rooms is based on the concept of a 'privacy factor', essentially the sum of the on-site partition performance requirement (R'_w) and the ambient noise level in the receiving room. There are some discrepancies in the definition of ambient noise within the document but Equation 1 below gives the stated calculation.

$$PF = R'w + B \qquad (1)$$

Where:

PF is Privacy Factor

R'_w is the site tested weighted apparent sound reduction index

B is the total NR noise level (mechanical services + intrusive) criterion

The basic sound insulation requirements under HTM2045 range from approximately R_w 35 – R_w 55. In practice the most common adjacencies are those between single bed wards, or between consulting/examination rooms, with a performance criterion of R_w55.

In addition to the basic sound insulation values, HTM2045 recommends a +20dB correction factor be added to the resulting privacy factor where "*…increased voice effort…that is shouts or screams"* are likely. The practical implication of this is that between delivery rooms in maternity units for example, or around nurseries, or in Accident & Emergency units, an on-site partition or floor performance of up to R'_w 70 would be required. Achieving such a performance would require separated stud drywall constructions, with large air gaps, typically around 550mm overall depth, and/or floating floor slabs. In addition, flanking sound transmission would be significant, requiring complex detailing to maintain the required sound insulation.

Whilst achievable in multi-plex cinemas or recording studios, where such constructions are expected and influence the design and layout of the entire building, it is not realistic to incorporate such constructions into healthcare buildings, where usable floor area is at a premium and cost, ease and speed of construction is vitally important to the feasibility of any individual project.

3.1.3 Impact noise control

Domestic standards of impact sound insulation are required by HTM2045; effectively the average sound insulation of a number of floors must not exceed than L'_{nTw} 61 dB, with no single measurement being higher than L'_{nTw} 65 dB.

The key issue in healthcare buildings is that the procurement method, typically Private Finance Initiative schemes for large hospitals, is fundamentally based on a transfer of risk to the contractor. Naturally, contractors wish to minimise that risk wherever possible, including the risk that the finished building will fail to meet the agreed performance standards. The specified performance of the wall/floor in question must be high enough to guarantee that the required criterion will be met, taking into account factors such as the statistical distribution of the results of a number of sound insulation tests, variations in test method etc.

A similar desire to guarantee domestic sound insulation values in new or refurbished houses in the UK in the last few years has led to a published collection of floor and wall constructions referred to as Robust Details, which have effectively been approved for use under the Building Regulations: Approved Document E *DATE*. Although generally considered to have been effective in driving up the standard of domestic sound insulation, all the approved floor constructions in the Robust Details document incorporate resilient elements in either the floor or ceiling build-up, or in both, and solid heavy ceilings.

There are significant issues in using such constructions in healthcare facilities; not least the requirement for easy access to ceiling voids for maintenance in heavily serviced hospital buildings, but also infection control and cleanliness requirements which effectively preclude the use of resilient floor constructions. There are also issues with point loads on separated floor screed from hospital beds and equipment.

In our experience it is very difficult for contractors to be able to *guarantee* that the impact sound insulation performance required in HTM2045 will be met.

3.1.4 Implied cost

For several years whilst both HTM56 and HTM2045 were considered current guidance the construction industry generally regarded building hospitals to HTM2045 as being more expensive than building to HTM56 standards. The internal sound insulation standards are lower (the most comment adjacencies requiring sound insulation performances of R_w 43 – 48 dB in HTM56, as opposed to R_w55), and the more wide ranging scope of HTM2045 requires acoustics to be considered in the design of more aspects of the building. This higher internal sound insulation performance implies the use of a double-boarded partition (2 layers of board either side of the stud), with a consequent impact on construction costs and programme.

3.2 Derogations

As a result of the above, many recent hospital buildings have required a substantial list of derogations, or agreed deviations from the chosen design standard. This effectively forms part of the contractual agreement between the contractor and the client, and in conjunction with the chosen design guide states what standards the new building will meet.

Reaching an agreement as to the contents of the derogation schedule between all parties can be a time consuming and lengthy process, taking in some cases over 3 years.

4 The solution?

In an effort to simplify the design guides for all aspects of healthcare building design, NHS Estates have embarked on a programme of simplifying and coordinating the Health Technical Memoranda.

The new series of engineering specific guidance contains a suite of nine core subjects, including HTM 08 *Specialist*.

Following an initial review of the existing acoustic HTM documentation (part of the HTM 08 series), a revised technical design guide for NHS Estates was produced, which then formed the basis of a public consultation document issued in November 2006. The responses to this have been reviewed and assessed by a committee comprising key acoustics, contractor and health industry representatives. Some changes have been incorporated into the revised guide, which is expected to be published during 2008.

Known as HTM 08-01 *Acoustics* the revised guidance aims to:

- clarify the conflicts with other HTM standards;
- highlight that the document is intended for guidance (but that any deviation from the standards would have to be fully justified);
- simplify and shorten the text;
- make sure that recommendations are practicable and appropriate;
- clarify some aspects that are open to interpretation (and mis-interpretation);
- remove specific limits where these are unnecessary and impose unnecessary costs;
- allow incorporation of new technologies.

The key aspects of the new guidance are as follows.

4.1 Criteria for noise intrusion

HTM08-01 includes different criteria for sleeping areas during the daytime and the night-time. These are more stringent than HTM2045 but not fully in compliance with the latest WHO recommendations as these are considered impracticable.

Suggested L_{max} night-time levels for sleeping areas (eg for night-time train movements etc) have been included. It is recognised that hospital environments can be subject to high sporadic noise levels, including emergency vehicle sirens and helicopters. It is accepted that helicopter noise can be difficult to attenuate at the building façade to meet the L_{max} criteria and mitigation is suggested at an early stage, though strategic planning and location of noise sensitive areas.

Where windows with trickle vents are proposed, the criteria would normally apply with the windows closed but trickle vents open. If no trickle vents are provided, the acoustic criteria should be met with the windows open sufficiently to achieve adequate background ventilation. This is consistent with HTM03-01 *Specialised ventilation for healthcare premises.* Acoustically treated trickle vents may be required in noisier sites.

4.2 Criteria for mechanical services

Some modifications to criteria have been made to differentiate between sleeping areas and office areas, where a slightly higher noise level is advantageous to increase speech privacy.

Suggested relaxation of 10dB has been made for emergency plant.

4.3 Criteria for noise leaving the development

Criteria have been proposed at three locations.

Noise outside the buildings on site should also be controlled to levels that allow the internal noise criteria to be achieved **in adjacent spaces** (with background ventilation, if these spaces are naturally ventilated,).

The amenity of open external areas should also be protected. Noise from services installations shall not exceed the existing daytime background noise level or 50 dB L_{Aeq}, whichever is the higher. This limit shall be achieved in **any areas normally accessed by the staff or public** (i.e. walkways, pavements, open courtyards, accessible landscaped areas etc).

Noise levels **at the site boundary** shall meet reasonable standards required by the Local Authority.

4.4 Vibration

The guidelines on vibration are largely similar to those contained in HTM2045. Reference is made to the human response multiplication curves given in BS6472. It is important to note that the night-time criteria for Wards are to be met with the subject lying down, with the z-axis corresponding to horizontal vibration.

Guidance is given on how to calculate the force input from footsteps – this being the most significant vibration force.

4.5 Room acoustics

Specific design targets have not been included. This reflects the practical difficulties of installing acoustically absorptive materials, which tend to be porous, in clinical areas where the overriding requirement is for hygiene and cleanliness, and the limitations on surfaces that can be acoustically treated.

It is stated that the presumption should be for sound absorptive ceiling treatments to be provided in all circulation and public (i.e. non-medical) areas. Acoustically absorbent ceilings should be provided in all occupied spaces where the cleaning and infection control regime or maintenance requirements allow. Washable acoustically absorbent ceilings may be required in certain areas to achieve acoustic absorption within the infection control regime. Acoustic treatments should also be included where speech intelligibility is a requirement, subject to the above non-acoustic constraints.

Acoustically absorbent ceilings should be rated Class C (or better) as defined in BS EN 11654.

4.6 Audiology

Additional criteria have proposed for internal sound insulation in audiometric test facilities as these are not explicitly stated with HTM2045. This is considered necessary to provide sufficient control over intrusive noise from local sources.

Audiometric booths should meet the following minimum sound insulation standards, in addition to meeting specific noise intrusion criteria.

- Audiometric booth to audiometric booth D_{nTw} 65 (as defined in BS EN ISO 717 Part 1)
- Audiometric booth to control room D_{nTw} 60
- Audiometric booth to corridor D_{nTw} 45 (measured from corridor to booth)

4.7 Internal sound insulation

The approach to determining internal sound insulation requirements takes account of both noise generation and the privacy needs of the affected rooms. Source rooms are categorised into four privacy categories:

- "Confidential" - speech would not normally be audible
- "Private" - speech would be audible but not intelligible.
- "Moderate"– speech would be audible and intelligible but not intrusive.
- "Not Private" –speech would be clearly audible and intelligible

The noise generation in each type of room is categorised into:

- Very high
- High
- Typical
- Low

The sensitivity of the receiving room is categorised into:

- "Sensitive" - room cannot accommodate any noticeable noise from rooms next door.
- "Medium Sensitivity" – room needs to be reasonably free from noise from rooms next door.
- "Not Sensitive" – noise from other rooms does not affect the use of the receiver room.

This approach is similar to that in the UK Building Regulations: Approved Document E, as applied to schools in the UK.

Easy to use tables are included in the document; to allow both an immediate sound insulation figure to be determined for most of the common room types found in large hospitals, and also to allow unusual rooms types to be assessed or requirements to be amended by knowledgeable users on a case by case basis. The criteria are given in terms of the installed level difference (D_{nTw}).

The sound insulation performance values contained in the public consultation document have been amended as a result of the feedback from that exercise. It was felt that sufficient account of the effects of patients speaking in raised voices had not be taken, for example as a result of some form of hearing impairment or simply though nervousness and anxiety. As a result, the constructions require sound insulation values currently ranging from R_w 37-39 to R_w 55-57. Common adjacencies such as Consultation Room to Consultation Room, or Single Bed Ward to Single Bed Ward are proposed to be R_w 54–56. There is no additional weighting for rooms where shouting might be expected, as this is taken into account in the noise generation categorisation.

An allowance of 7 – 9dB is suggested for the difference in performance between laboratory test values (R_w) and the lower on site test value (D_{nTw}). This was considered by the consultation working group to represent the current experience of the effects of flanking and site installation issues. However it should be noted that the criteria are set in terms of **on-site values** which should be achieved (D_{nTw}).

The effect of incorporating doors into partitions has also been specifically considered in the HTM. For corridor walls which include doors, the on-site measured sound insulation is not appropriate for the wall. The laboratory rated weighted sound reduction index (R_w) of the partition should be at least 10dB greater than the target laboratory performance (R_w) of the door, taking into account any gaps if doors are not able to have acoustic seals. In practice this means that there is no acoustic benefit in providing corridor partitions with an R_w higher than 45dB, unless there are especially high performance doorsets or lobbied doors.

5 Application of HTM08-01

The author is currently involved in the acoustic design of several hospitals where the criteria and approach proposed in the new HTM are being used prior to its final publication. Neither project is complete yet so the effects on the final buildings are not known but early indications are positive.

Contractors, other members of the design team and user groups are able to follow the methodology and view it as a pragmatic approach, given the constraints on the design imposed by other HTM requirements, particularly those relating to hygiene and cleanliness. Previously encountered uncertainties over acoustic issues have been clearly dealt with, particularly regarding criteria in naturally ventilated buildings, conflicts between the acoustic requirement for door seals and hygiene requirements, and reverberation time requirements.

In particular the internal sound insulation table has been well received by the main contractor, who commented that it was simple to use and understand.

6 Drivers of change

There are many issues in the healthcare industry which will have specific impacts on the acoustic design of healthcare facilities in the future. They are fundamentally rooted in social, technological, environmental, economic and political spheres of the industry, which in turn are affected by the wider concerns of society. The following are considered likely to be key drivers of acoustic design in the near future.

6.1 Infection Control

This is already a clear driver affecting design. However, there is a growing feeling amongst some designers that the motivation is more political and economic, rather than rooted in real understanding of the mechanisms of infection and evidence-based avoidance and mitigation of infection. This may reflect a lack of knowledge and understanding amongst designers but has lead to a drive to reduce the use of sound absorbing materials, despite the evidence that these have a positive effect on health outcomes.

Along with sustainability there is a need for acoustic materials and elements that at worst do not contribute to, and at best enhance the cleanliness and infection resistance of our healthcare facilities.

Also, where infection control was concerned, the layout of the whole healthcare facility had to be considered. An infection could be more easily controlled if it was possible to isolate blocks of accommodation. Being able to split off parts of premises also had the advantage that change and flexibility of use could be assisted. Such fundamental drivers may well have implications for acoustically problematic adjacencies.

6.2 Speech Privacy

Most acousticians will agree that internal speech privacy is an important factor in the usability of our buildings. The issue is how important is it compared to the economic implications of more complex walls or floors which take up more floor area and therefore reduce the number of patients which can be treated within a given time frame.

In the United States speech privacy is much higher up the design agenda than infection control. Indeed the US media are only just becoming aware of the existence of hospital acquired infections, which has been widely reported in the UK for several years. However, the US Department of Health and Human Services, Office for Civil Rights requires that "*health information…whether oral or recorded…*" "*must not be disclosed*". This effectively requires the same privacy issues that apply to electronic patient identifiable information also be considered in relation to spoken information.

6.3 Sustainability / Energy Efficiency

More stringent sustainability and energy efficiency requirements are driving design towards naturally ventilation solutions wherever possible. This has clear implications for intrusive noise control in healthcare buildings.

The current attenuated passive ventilation units available on the European market are reasonably effective but cannot reliably meet intrusive noise criteria in environments where the external noise levels are above 65 – 70 $dBL_{Aeq.}$ This is particularly problematic on inner city sites which are otherwise ideal for redevelopment. Perhaps a new generation of attenuators is required, able to offer high sound reduction with minimal pressure drop?

6.4 Throughput/recovery rates

This is an area of current research for several UK academic institutions, as well as cross-industry collaborations to try and quantify the effect on health outcomes of particular acoustic conditions in healthcare buildings.

It is hoped that by optimising the internal environment in healthcare facilities, such as through acoustics and access to natural external views and light, recovery times and re-admission rates can be reduced.

6.5 Move to community care and 'super clinics'

The current trend to blur the social boundaries between healthcare facilities and other types of public environment is set to continue. Will we be seeing cinemas and bowling alleys within hospitals in the next 10 years? What effect will this have on the acoustic requirements?

There are moves to both increase the focus of resource on highly complex clinical services e.g. the Academic Health Sciences Centre, as well as to devolve less complex services into more economically efficient units such as treatment centres.

7 Conclusions

The imminent publication of HTM08-01 represents current best practice in acoustic design of healthcare facilities. By presenting pragmatic and coherent guidance it is considered a significant step forward in the design of high quality healthcare facilities.

References

[1] Health Technical Memorandum 56 Partitions, *NHS Estates,* 1997

[2] Health Technical Memorandum 2045 Acoustics: Design Considerations, *NHS Estates*, 1996

[3] Health Technical Memorandum 08-01 Acoustic Performance, *SRL Healthcare*, 2006