SCOTTISH HOSPITALS INQUIRY

Hearing Commencing
9 May 2022

Bundle 8 - Mott MacDonald
Position paper, Expert CV and SCIM

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Scottish Hospitals Inquiry

Mott MacDonald Position Paper

April 2022

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Mott MacDonald Position Paper

April 2022

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
Rev1.0	25/04/2022	Steven Bentley	Ross Mitchell	Richard Peace	Initial Issue

Document reference: 100104028 |

Information class: Standard

Contents

Executive summary

Within NHS NSS document “NHS Lothian - Royal Hospital for Children and Young People & Department of Clinical Neurosciences NHS National Services Scotland – Review of: Water, Ventilation, Drainage and Plumbing Systems” is the following statement (see section 4.2.6):

"From an infection prevention and control perspective, there is low-quality to no evidence from outbreak reports and current guidance, respectively, to support minimum ventilation requirements. Therefore, it is not possible to make conclusive statements regarding the individual minimum ventilation parameters for inpatient care areas. A rapid review of the literature found limited clinical evidence to directly implicate air change rates alone in having a direct impact on the development of an outbreak or incidence of infection. Therefore, it is reasonable that, in the absence of evidence, healthcare design teams should continue to adhere to current national guidance. In the event of a deviation from the current recommended ventilation parameters, design teams should ensure that air changes per hour are maintained as close as possible to the recommended air changes per hour without compromising other aspects of the ventilation system requirements. In addition, a full assessment of the services and patient population should be carried out and mechanisms for monitoring established. Caution is advised in relying on air change rates alone to provide adequate protection from infection; this is only one part of a multifactorial process involved in creating the appropriate airflow patterns with appropriate mixing and dilution of contaminants. Nationally, further research is required to look beyond air change rates to examine the effects that other factors such as supply and exhaust location, door position and motion, spatial orientation, surface composition, temperature, humidity, and air distribution patterns have on particle migration in clinical areas."

I broadly concur with this statement.

There are a myriad number of potential sources of hospital acquired infection (HAI), with ventilation potentially a less onerous influence compared to direct contact sources of infection such as hands, linens, clothing and intravenous equipment[1]. Whilst there have been a number of academic studies to assess the potential prevalence of virus, bacteria, and fungal spores in the air around a patient, it is very, very difficult to link these airborne contaminants directly to a HAI incident.

Malcolm Thomas (the coordinating author of HTM 03-01 (2021)) recently stated that “*With very small infection rates – which fortunately we have now – it’s much more difficult to understand what influences acquired infections, whether that be from changing the surgeon’s gowns, or the room ventilation air change rate”*[2].

Whilst the link between surgical site infection and operating theatre air quality has been well established, there remains an inability to conclusively link reducing ventilation air change rates to HAI’s, the only remaining avenue available by which to base a healthcare building ventilation system design is minimum legislative/regulatory requirements and historical precedent.

In Scotland the minimum mechanical ventilation requirement for an occupied space is to provide 8 litres of “fresh” air per person per second[3]. The Scottish Building Standards is the only document defining the minimum regulatory requirement for ventilation in healthcare buildings.

1. CB Beggs “The Airborne Transmission of Infection in Hospital Buildings: Fact or Fiction” 04.11 2003.
2. IHEEM Magazine January 2022.
3. Sec ion 3.14.5 Mechanical Ventilation, Environment (Non-domestic buildings, Technical Handbook 2017.

However, the ventilation requirements of a healthcare building perform a number of further important functions including temperature and/or humidity control, room pressurisation (to control air movement), life safety (smoke control), odour control, and to provide protection from harmful material (laboratory fume cabinets). So, the design of ventilation systems in healthcare buildings is complex.

Given the complexity of design decisions needed when selecting ventilation systems, a set of guidance documents have been developed to aid the designer. The guidance documents include: -

- Scottish Health Technical Memorandum (specifically SHTM 03-01 Part A and B)
- Scottish Health Building Notes (SHBN)

These documents provide a design assurance mechanism, as the guidance is rooted in historical precedent developed over a significant period of healthcare building design.

As Malcolm Thomas identifies[2] "..*ventilation rates noted in the HTM 03-01 guidance are not 'opinion' they have been proven to work in practice and over an extended period of hospital design and operation. History appears to show that this is a correct way of doing things*'"

When commencing any new healthcare building design, it is of paramount importance to understand how each department and associated room functions, via attendance at user group briefing sessions, and the development of operational policies and clinical output specifications. These briefing sessions provide the designer with the means to "ask the right questions at the right time" and to inform the final ventilation design criteria on which ventilation systems are then developed. This design criteria might include:

- Desired room temperature (summer and winter)
- Desired type of room temperature control (set point or allowable swing)
- Air quality requirement (expressed as an air filtration value)
- Air Flow rate (often expressed as a room air change rate)
- Room pressure (either balanced/positive/negative – or a defined Pascal rating).

The above design criteria can then be documented at the client briefing stage and to take account of any project specific variances that might see historical precedents for rooms of this particular function derogated against.

The conventional mechanism to record room data, including ventilation design criteria, is a Room Data Sheet. Again, like the HTM's and HBN's, there are historical precedent Room Data Sheets developed to aid the designer; with the Activity Data Base (ADB) system often used as the starting reference point. The ADB system provides a platform on which a designer, working with the client, can develop a project specific set of ADB room data sheets. For a traditional procurement process it is convention to prepare a full suite of room data sheets for the whole building and to have these formally approved by the client and their authorising engineers in advance of commencing detailed design.

With project contractual documents often referencing "compliance" with the SHTM and SHBN guidance, it is advisable to formally record where derogations from these guidance documents have occurred, the reasoning for the derogation, and with a "wet signature" formally accepting this derogation provided by the Client.

1 Career History and Professional Background

I am a Chartered Engineer and a Chartered Project Professional with over 30 years' experience in engineering design consultancy. My particular specialism is Building Services Engineering (Mechanical, Electrical and Public Health Engineering). I am a Member of the Chartered Institute of Building Services Engineers, a Member of the Institute of Healthcare Engineering and Estate Management, and a Member of the Association for Project Management.

I graduated with a BSc (Hons) degree in Building Engineering (specialising in Building Services) from the University of Bath in 1989. I worked for a number of engineering consultancy businesses in my twenties, gaining a wide range of project design experience, and gaining Chartered Engineer status at thirty.

From the age of 28 to 35 I worked for Hoare Lea, a private partnership engineering design consultancy with experience in leading the building services design of hospital buildings. During my time at Hoare Lea I led the detailed design of the new Nobles Hospital on the Isle of Man, the detailed design of the PFI funded Bishop Auckland Hospital, and the preliminary briefing and early design stages of the PFI funded Norfolk and Norwich Hospital.

At 35 I joined Gifford, a private partnership engineering design consultancy. I established Gifford's Manchester Office, took on the management of their Northern region building services business, and ultimately the management of the whole of Gifford's UK building services business. I became an Equity Partner at the age of 40. During this period I was a visiting expert for the University of Manchester Architecture School.

Gifford were acquired by the Danish engineering consultancy business Ramboll in 2012, and I was retained to manage the whole of Ramboll UK's building services business, directing a resource group in excess of 200 engineers and as a member of the Ramboll UK Management Group.

In 2014 I relinquished my position on the Ramboll UK Management Group to lead the engineering design of the New Hospital Northzealand, one of Ramboll UK's largest design commissions. The New Hospital Northzealand is located on a greenfield site north of Copenhagen. The hospital comprises some 125,000m^2 of acute hospital accommodation including 24 Operating Theatres, 5 Endoscopy Theatres, 24 Intensive Care beds, 640 In-Patient beds, 5 MRI scanner, 7 CT scanners, and the remaining clinical departments to be expected of a stand-alone acute hospital building. Over the following 7 years I led the all the engineering design disciplines from the initial client briefing stages through to finalised design, tender, and appointment of a Contractor.

In the Summer of 2021 I joined Mott MacDonald as the EUNA region healthcare sector technical lead. My role is to support the technical delivery of all healthcare commissions for Mott MacDonald. I am currently assisting NHS England and NHS Improvement on the New Hospital Programme, including the technical assessment of the first wave of new hospital buildings to be built in the UK, and the development of a set of Technical Standards on which the New Hospital Programme will be founded.

I am a peer reviewer of the forthcoming CIBSE Healthcare Design Guide.

In preparing the position paper I have used the questions raised by the Inquiry and asked of the external experts as a guide.

The responses provided are based on my experience designing hospitals over an extended period. Science and research continues to seek to understand the link between patient infection and ventilation design; the wide extent of academic papers related to the risk of transfer of Covid 19 in enclosed spaces demonstrates that we are still seeking answers.

2 The purpose and operation of building ventilation systems

Ventilation in buildings is needed to: -

- Provide a minimum level of air quality to a permanently occupied space. Approved Document F of the Building Regulations is the regulatory requirement for this aspect in England. In Scotland, Building Standard 3.14 covers Ventilation and states “Every building must be designed and constructed in a way that ventilation is provided so that the air quality inside the building is not a threat to the building or the health of the occupants”.
- Control odours – toilet or kitchen extract fans and associated ventilation as an example.
- Support safety procedures when handling hazardous material, or pathogens– such as safety/fume cabinets in laboratories. In laboratories ventilation can also ensure the creation of a sterile space / clean room, for example in a human fertility laboratory / Aseptic Suite for the production of drugs & medicines.
- Support life safety systems – such as smoke extract systems which control the build up of smoke to allow safe evacuation of a building in the event of a fire.
- Control the temperature and/or humidity and where they are the primary means to heat and/or cool a space.
- Provide a pressure differential between spaces that supports air movement from ‘clean’ spaces to ‘less clean’ defined spaces.
- Provide air for combustion, for example boiler houses.

Ventilation systems fall into 3 main categories: -

- Natural ventilation. Natural ventilation systems rely either on wind pressure, or thermal stack as the motive force, to move air around the space or building. With wind driven natural ventilation systems, it is possible to have single-sided ventilation, typically with opening windows on one side of the room, double-sided ventilation, typically with opening windows on opposite sides of a room, or more complex systems with roof mounted ‘air scoops’ which either supply outdoor air into the occupied space or draw vitiated indoor air from the occupied space to the outside. With thermal stack driven natural ventilation systems, the natural buoyancy of warm air drives the flow of air with warm, vitiated, air exiting the space at high level and cooler, outdoor air, allowed to enter the space at low level.
- Mechanical Ventilation. Where there is a necessity to closely control the amount of ventilation introduced into a building (as wind is unreliable), or where external noise/air quality means natural ventilation is undesirable, then mechanical ‘fan driven’ ventilation is used. Air is ‘pushed’ by air handling units (which filter/heat/cool the inlet air) and their associated fans, through ductwork which distributes air through the building to deliver pre-set air volumes to individual rooms/spaces. Similarly, air is then ‘sucked’ from the room via an extract ductwork distribution system (also at pre-set air volumes) to an extract fan, and hence to a safe discharge location. In most instances a heat recovery device is used to take heat from the warm vitiated extract air to pre-heat the cold outdoor incoming air.
- Hybrid/Mixed Mode Ventilation. This is an assisted form of natural ventilation. Fans are fitted in purpose-made damper-controlled ventilation openings. Dampers and fans are then controlled by temperature and air quality sensors (measuring the CO_2 concentration level) to ensure a minimum airflow ventilation rate while taking advantage of natural ventilation effects when present. This ventilation strategy provides a careful

balance between ventilation need, air volume flow, local comfort conditions, and energy/carbon consumption.

3 The importance of ventilation in a healthcare setting

The importance of ventilation in a healthcare setting is similar to that of any other type of building, namely to:

- Provide a minimum level of incoming fresh air to an occupied space. In Scotland Section 3 of the Building Standards requests 8 litres/sec/person, whilst SHTM03-01 recommends 10 litres/sec/person.
- Control odours.
- Support safety procedures when handling hazardous material.
- Support life safety systems.
- Control the temperature and/or humidity and where ventilation is the primary means to heat and/or cool a space.
- Provide a pressure differential that supports air movement between ‘clean’ and ‘less clean’ defined spaces.

Section 2.1 of SHTM 2025 (Part 2) (refer to Stephen Maddocks expert report) provides a further definition of the purposes of ventilation in healthcare building.

Where hospitals vary from conventional buildings is the acuity of the occupant of the building (a sick patient), and their susceptibility to acquiring an infection whilst in hospital. On this basis the ventilation system in a healthcare building provides an additional important function, namely to reduce the risk of infection through airborne contaminants. As a consequence, there is a focus in healthcare buildings on air quality introduced into a space (filtration), and the extent of supply air introduced (to dilute the level of airborne contamination in the space).

Ventilation should be seen as a constituent part of a number of operational procedures in hospitals that together have been proven, through historical precedents, to reduce (not secure) the risk of infection. These operational procedures include:

- Washing hands and/or wearing surgical gloves.
- Movement around the patient (particularly important in Operating Theatres).
- Wearing clean gowns/aprons.
- Clean bedding.
- Good levels of clean fresh air.

Pressure differentials in hospitals play an important role in reducing the passage of air from a perceived ‘non clean’ space into a ‘clean’ space. HTM 03-01 calls this the ‘hierarchy of cleanliness’. So an operating room has more supply air introduced than is extracted. This over-provision of supply air needs to escape through openings (such as the gaps around doors, or when doors are opened) into the adjacent space – and this reduces air transfer from the ‘non clean space’ such as a circulation corridor entering the operating room.

The temperature at which air is introduced into a space influences the overall room temperature. Where a room is hot (from humans, or other heat sources such as equipment emitting heat), the introduction of air at a cooler temperature than the required room temperature will provide a cooling effect, and vice versa. Ventilation can be one means to control the room temperature and to ensure the patient is thermally comfortable. There are air distribution benefits in keeping the temperature of the supply air as close to the room temperature as possible – and to limit uncomfortable cold down draughts, and heat stratification.

A room air change rate, or its supply and/or extract air flow rate, will influence:

- The potential pressure the room can be maintained. Introduce more air and there is an opportunity to increase the room pressure compared to adjacent areas.
- The extent of heating and/or cooling that can be provided by the supply air, and the supply temperature at which the air is introduced into the room.
- The rate of churn of ‘clean’ air into the room compared to the ‘vitiated air’ that builds up in the room over a period of time.
- It is important to note that the air change rate provided by a ventilation system does not on its own determine the quality of the air in the space. Other factors that influence the quality of the air in the space include the layout of the room, the positioning of the supply diffusers and extract grilles in the space, the quality of the air provided by the system into the space, and the ability of the supply air diffusers to effectively distribute the air within the space.

4 Room function impact on pressure, supply air temperature and air change rate

Critical care areas in hospitals house patients who are requiring permanent observation and care from the staff. They may be acutely ill or be recovering from a major operation - so the perceived risk of a patient's condition worsening if they acquire an infection, or if the room is not closely controlled for temperature will be greater than that of a normal in-patient. The room in which they are located (whether a single bed or multi-bed room) is also likely to include a large extent of medical equipment which will emit heat to the room – elevating the room temperature and requiring cooling to maintain comfortable room temperatures.

For these reasons the ventilation air change rate to a critical care area is generally higher than a conventional ward in order to;

Provide sufficient air into the room to offset the room heat gains, limit cold draughts, or heat stratification, and maintain the room at closely controlled room temperature.

There is the potential additional benefit in elevating the room's 'hierarchy of cleanliness' by pressurising the room compared to adjacent spaces.

Neutropenic/immunocompromised patients have low white blood cell counts which have been proven to increase the risk of infection. For these reasons the ventilation air change rate (and particularly the supply air flow rate) to a neutropenic/immunocompromised patient is generally higher than a conventional ward in order to elevate the room's 'hierarchy of cleanliness' by pressurising the room/ward compared to adjacent spaces.

The risk of infection is most acute in an operating theatre due to the invasive nature of operations undertaken in the room. An operating room, and its support preparation room, is therefore at the apex of the hospital's 'hierarchy of cleanliness'. The operating room has a number of doors that allow potential contaminants to enter the room when the door is opened – requiring a large amount of 'barrier protection' air to pass from the operating room to the adjacent rooms and to maintain the 'hierarchy of cleanliness'.

In addition, an operating room contains a myriad number of medical equipment, surgeons, anaesthetists, and support staff – all of whom emit heat to the space and hence necessitate cooling to maintain acceptable room conditions. The room temperature of an operating room requires very close control to reduce the risk of patient hypothermia.

Taking account of the above it is no surprise that an operating room has one of the highest levels of supply air ventilation flow.

5 The specific requirements for source and protective isolation

Isolation rooms are provided to reduce the risk of infection to or from the patient by limiting the extent of human contact to the patient whilst in the room. A conventional isolation room design will include a gowning lobby (or PPVL), which will be pressurised by supply air introduced into the space, with the supply air then allowed to 'leak' through the gaps in the door to the adjacent corridor, and to pass through a pressure stabiliser to the patient room. The pressure stabiliser maintains a pre-set positive pressure to the gowning lobby compared to the patient isolation room.

In normal operation, and with the patient isolation room door closed to the gowning lobby, air will pass through the pressure stabiliser into the patient isolation room and to provide supply air to the patient room. When the door to the patient room is opened, the pressure stabiliser closes – and the supply air (and associated air pressure) in the gowning lobby will move air from the gowning lobby into the isolation room and to limit air from the patient room escaping into the gowning lobby and hence to the adjacent corridor.

Isolation rooms are served from dedicated air handling units supplying fresh air, at an increased cleanliness level (via higher efficiency air filters), and remote from the general air handling units serving conventional in-patient wards (where the air filtration requirement can be less stringent). Isolation rooms are served by dedicated extract fans which discharge the air from the isolation room to atmosphere in a safely dispersed/diluted manner.

6 The significance of room design/configuration to the design of a ventilation system in a hospital

Room design and configuration will influence the design of a hospital ventilation system.

- A standard single in-patient room will generally include an en-suite bathroom. The ventilation design will seek to supply air into the ‘clean’ zone (the patient bed area), and extract air from the ‘less clean’ zone (the adjacent en-suite bathroom). The overall suite (patient room and adjacent en-suite) ventilation system would be sized on the basis of maintaining a balanced or negative pressure to the adjacent corridor.
- A multi-bed room will comprise a series of in-patient beds along with a shared bathroom. Supply air would generally be introduced in the centre circulation space and extracted locally in each bed bay (either at ceiling, or better low level). An additional extraction of air would happen in the bathroom and to move air from the ‘clean’ patient zone to the ‘less clean’ bathroom zone.
- PPVL rooms require closely controlled ventilation design. Supply air is provided to the gowning lobby and to provide a positive pressure in relation to the ‘isolated patient’ area as well as the ‘less clean’ adjacent corridor.

7 Statutory provisions for the design, construction, commissioning and maintenance of a ventilation system for a hospital

The following statutory documents are relevant for the design, construction, commissioning, and maintenance of a ventilation system for a hospital:

- Health and Safety at Work Act 1974,
- Management of Health and Safety at Work Regulations 1999,
- The Health Act 2009,
- The Control of Substances Hazardous to Health (COSHH) Regulations 2002,
- Building (Scotland) Regulations 2004, which were made under the Building (Scotland) Act 2003,
- Construction Design Management (CDM) Regulations 2015,
- Specific hospital function regulations such as the Medicines Act 1968 which require accurate records of plant performance, room conditions and maintenance events.

The potential consequences of not complying with the statutory provisions from the perspective of patient care and safety could see an increase in the risk of:

- inadequate levels of ventilation for occupant breathing, and a consequent increase in CO_2 levels in occupied spaces.
- poor odour control (for example the ventilation of toilets).
- potentially dangerous exposure of people to harmful concentrations of air contaminants that might be poisonous, corrosive or explosive.
- infection.

8 Guidance documents and accepted industry standards relevant to the design, construction, commissioning and maintenance of a ventilation system for a hospital

8.1 Design stage guidance documents

'SHTM 03-01 Part A; Design and Validation', has been developed from historical precedent, industry best practice, and academic research to provide guidance on how to design and validate ventilation systems in healthcare buildings.

'SHPN 04-01 Supplement 1 Isolation facilities in acute settings' has been developed to provide guidance on the design of single occupancy isolation rooms in healthcare buildings. The document includes extensive information on the control of room pressure and associated mechanical ventilation design.

The above documents are not statutory or mandatory documents – but are used as a guiding reference set of documents. They are often referenced as part of an initial briefing document, with the designer expected to follow the general principles contained within. However, it is normal practice in the design of healthcare buildings to assess what guidance is applicable to a particular project, and where relevant seek approval of derogations from the guidance.

8.2 Construction stage guidance documents

'DW144 Specification for Sheet Metal Ductwork'. DW144 is the Standard Specification for ductwork manufacture and installation and is aligned to all current BS, BS EN ISO, and other standards and regulations. The document defines specifications for sheet metal ductwork for low, medium and high pressure/velocity air systems and covers ductwork application, materials, classification and air leakage. It highlights the technical information to be provided by system designers to ductwork contractors and looks in detail at rectangular, circular, and flat oval ductwork. It also contains updated information on hangers and supports, smoke and fire dampers, external ductwork, internal duct linings, thermal insulation, and air terminal units.

BS EN 15780. The advice contained within the BS EN 15780 document identifies the reasonable endeavours to be taken to maintain cleanliness and cleaning procedures for both new and existing ventilation and air conditioning systems. British Standards are not statutory documents, but like the SHTM documents are provided for the purposes of guidance.

8.3 Commissioning stage guidance documents

'CIBSE Commissioning Code A: Air Distribution Systems'. The document is generally referenced in most ventilation system tender documents, defining the methodology to be followed by the Ventilation Contractor and/or Commissioning Specialist to correctly balance and set to work a ventilation system and based on the defined performance requirements of the system.

8.4 Operation and on-going maintenance

‘SHTM 03-01 Part B: operational management and performance verification’ has been developed from historical precedent, industry best practice, and academic research to provide guidance on how to operate and maintain ventilation systems in healthcare buildings.

BS EN 15780. As above for construction stage.

Adherence to the guidance contained in the SHTM, DW144, CIBSE and British Standard documents provides the designer/constructor with an enhanced level of technical assurance and with reference to previous precedents.

However, adherence to the guidance will not fully eliminate risk to patient safety and care, which are influenced by a wide-ranging number of factors unaffected by the ventilation design.

9 Planning, Designing, Commissioning and Installing a Hospital Ventilation System

I have nothing further to add than has been succinctly defined in Stephen Maddocks' expert report and specifically:

- section 2.0 - Project Design Process and Drivers
- section 3.3 - Key Briefing Requirements for Designers
- section 8.0 - Design Challenges

10 The key components of a hospital ventilation system

The key components of a mechanical ventilation system in a hospital are: -

- Inlet louvre/exhaust louvre. These are architecturally designed grilles on the external façade of a building which provide an inlet or exhaust path for the air. Their position on the building is critical to ensure outdoor air is not unduly contaminated in advance of entry to the building, that exhaust air is discharged to atmosphere in a safe manner, and that there is limited risk of exhaust air being re-introduced into the building through the inlet path through recirculation.
- Silencer/Attenuator. This reduces the extent of external noise and/or fan noise introduced into the building through the ventilation ductwork, and of fan generated noise from breaking out to outside of the building.
- Air Handling unit. This is a purpose designed series of components forming a singular item of equipment used to deliver tempered air into a building, and in certain instances to also remove stale air from the building.
- Heating Coil. This is a series of pipes and associated fins in the air stream which warm the air as it enters the building.
- Cooling Coil. This is a series of pipes and associated fins in the air stream which cool the air as it enters the building. Due to the likely risk of condensation forming on the pipes and fins as the warm air passes across the cold surface, cooling coils are also provided with a condensation drip tray to safely remove the condensate from the air stream.
- Heat recovery device. To reduce energy consumption there are a number of technologies available (plate heat exchanger/thermal wheel/run-around-coil) which seek to transfer heat from the exhaust air exiting the building, to warm the air entering the building.
- Supply/Extract fan. This provides the force needed to move the incoming/outgoing air through the ductwork distribution system in the building. There are a number of fan types including propeller type axial fans, and centrifugal fans.
- Filters to remove particulate matter from the air stream.
- In certain climates, humidifiers may be required to increase the amount of moisture in the airstream.
- A control system that can monitor the operation of the mechanical ventilation system and control the functioning of the heating and cooling components to maintain the required setpoints.
- Ductwork. This is primarily galvanised metal sheeting in either rectangular or circular form, which directs the supply and extract air through the building.
- Dampers. These comprise an adjustable restriction that seeks to control the extent of air passing through a section of ductwork.
- Diffuser/Grille. These are the terminals at the end of the ductwork system which diffuse the air into the room or provide a return air path for extracted air.

A. Appendix

A.1 CB Beggs “The Airborne Transmission of Infection in Hospital Buildings: Fact or Fiction” 04.11.2003.

A.2 IHEEM Magazine January 2022.

A.3 Section 3.14.5 Mechanical Ventilation, Environment (Non-domestic buildings, Technical Handbook 2017.

Airborne Infections in Hospitals
Original Paper

Indoor and Built Environment

Indoor Built Environ 2003;12:9 18

Accepted: November 4, 2003

The Airborne Transmission of Infection in Hospital Buildings: Fact or Fiction?

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Key Words
Nosocomial · Infection · Hospital · Airborne · Droplet nuclei · *Staphylococcus aureus* · MRSA · Tuberculosis · TB · *Acinetobacter* · *Aspergillus* · *Pseudomonas* · *Legionella*

Abstract
Airborne transmission is known to be the route of infection for diseases such as tuberculosis and aspergillosis. It has also been implicated in nosocomial outbreaks of MRSA, *Acinetobacter* spp. and *Pseudomonas* spp. Despite this there is much scepticism about the role that airborne transmission plays in nosocomial outbreaks. This paper investigates the airborne spread of infection in hospital buildings, and evaluates the extent to which it is a problem. It is concluded that although contact-spread is the principle route of transmission for most infections, the contribution of airborne micro-organisms to the spread of infection is likely to be greater than is currently recognised. This is partly because many airborne micro-organisms remain viable while being non-culturable, with the result that they are not detected, and also because some infections arising from contact transmission involve the airborne transportation of micro-organisms onto inanimate surfaces.

Introduction

Nosocomial infection (i.e. infection originating in hospital) is a serious problem in many hospitals. In the United Kingdom (UK) approximately 1 in 10 patients acquire an infection during a hospital stay [1]. Nosocomial infections are often difficult to eradicate, with many being drug resistant. For example, methicillin resistant *Staphylococcus aureus* (MRSA) is a major problem in healthcare facilities around the world, despite the considerable efforts made to control its spread. In England and Wales alone, 1597 incidents (i.e. nosocomial outbreaks) of MRSA were recorded in 1998 [2]. While nosocomial infections cause much morbidity and mortality, they also have considerable economic impact on healthcare systems. A recent study in the UK estimated that at least 100,000 hospital acquired infections occur each year, costing the National Health Service (NHS) approximately £1 billion per annum [2]. Indeed, the cost of implementing control measures in a district general hospital, following an outbreak of MRSA has been calculated to be £403,600 (at 1994 prices) [3].

Airborne transmission is known to be the route of infection for diseases such as tuberculosis (TB) and aspergillosis. It has also been implicated in nosocomial outbreaks of MRSA [4], *Acinetobacter baumannii* [5] and *Pseudomonas aeruginosa* [6]. Despite this there is much

DOI: 10.1177/142032603032201
Accessible online at:
www.sagepublications.com

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scepticism about the role that airborne transmission plays in nosocomial outbreaks [7,8]. This paper investigates the airborne spread of infection in hospital buildings, and evaluates the extent to which it is a problem.

Transmission of Nosocomial Infection

It is generally recognised that most nosocomial infections are spread by contact [8–10]. Contact-spread includes all infections where the victim is in direct or indirect contact with the source of the infectious agent. Direct contact spread refers to person-to-person contact. Many infections are spread by the direct contact route, because healthcare workers do not wash their hands effectively, before attending to patients [11]. Indirect contact is distinguished from direct contact by the participation of intermediate objects, which are often inanimate. For example, implants can become contaminated with micro-organisms from the hands of healthcare workers before insertion into patients, with the result that infection occurs [12]. In a similar manner, endoscopes can transmit infection [9]. Endogenous transmission is also classified as a form of contact-spread. Endogenous infections are caused by the patient's own flora; transmission is therefore from one part of the host's body to another.

Airborne transmission refers to infections which are contracted from micro-organisms which have become airborne. As such the term generally applies to micro-organisms contained in droplet nuclei produced by coughing, sneezing or some other form of aerosolisation. However, it can equally apply to dust particles and skin squamae carrying pathogenic micro-organisms. Fungal spores are also widely disseminated via the airborne route.

When a person coughs or sneezes many thousands of droplets are expelled at high velocity into the atmosphere. In the case of sneezing, the most violent expiratory process, initial velocities can be as high as $100\,m.s^{-1}$ [13]. During sneezing most of the droplets are approximately 10 μm in diameter, although some may be in excess of 100 μm [14]. The larger droplets fall to the ground, while evaporation of the smaller droplets takes place and they rapidly decrease in size to become droplet nuclei. The evaporation time for smaller droplets is very short, because they have an enormous surface area compared with their mass. For example, a 12 μm droplet will take approximately 0.02 s to evaporate [14]. Consequently, most of the droplets produced by a sneeze evaporate to form droplet nuclei. An infectious patient coughing or sneezing will produce thousands of droplet nuclei, some of which will contain pathogenic micro-organisms.

Droplet nuclei are so small that they settle slowly and remain suspended in air for a considerable period of time. For example, a 2 μm droplet nuclei settling in air in a calm room will take approximately 4.2 h to fall a distance of 2 m [15]. Given this long suspension time, particles can be carried long distances by convection currents and thus can be distributed widely throughout hospital buildings. The chain of infection is therefore very much influenced by the ventilation conditions that exist within healthcare facilities.

Although many nosocomial infections are associated with person-to-person contact, there is increasing evidence that some nosocomial infections are transmitted via the airborne route. Indeed, it has been estimated that the airborne route of transmission accounts for between 10 and 20% of endemic nosocomial infections [16]. However, with the exception of TB and pulmonary aspergillosis, where the airborne route of infection has long been recognised, the contribution made by airborne pathogens towards nosocomial infection is unclear and much scepticism exists about the role played by aerosolised micro-organisms. Rhame [7] for example, states:

"*The airborne route of transmission is more frequently assumed to be the route of an infection than is the case. Creation of an infectious aerosol is more difficult than is usually recognised.*"

Over a period lasting from the 1950s to the 1980s a number of investigators in the UK demonstrated how carriers of *Staphylococcus* spp. could contaminate room air. However, their findings have not been readily accepted in the USA. Sands and Goldmann [17] state:

"*British investigators performed a vast number of detailed microbiological studies to demonstrate how carriers of staphylococci could heavily contaminate the air. This extensive literature is not well known in the United States, and Americans with an interest in staphylococcal epidemiology have largely ignored the careful work of Hare, Ridley, Shooter, Nobel, Davies, Blowers, Lidwell and many other British colleagues.*"

As a result of this sceptical attitude the role of airborne transmission in nosocomial infection has been played down.

Droplets and Droplet Nuclei

Contact-spread is generally deemed to include the droplet-spread of infectious agents [9]. While this classification may appear strange to engineers and physical scientists, who would generally consider particles passing through the air to be airborne, the medical profession reserve the term *airborne* for particles that are transported by convective air currents. A demarcation is therefore made between larger droplets, which fall rapidly to the floor and which do not travel more than a metre or so, and droplet nuclei which can remain airborne almost indefinitely. Respiratory droplets produced by patients coughing or sneezing can impact upon the conjunctivae or oro-nasal mucosae of susceptible patients and healthcare personnel resulting in subsequent infection. As these droplets are relatively large they cannot remain suspended in the air for long, and therefore close contact between the index case and a susceptible contact is necessary for transmission to occur. By contrast, droplet nuclei remain suspended in air for long periods and can travel considerable distances, so close contact is not always necessary for transmission to occur. Examples of infections transmitted in this manner include pulmonary TB, measles and chicken pox.

While there is some logic in distinguishing between infections spread by droplets and those spread by droplet nuclei, the physical demarcation between droplets and droplet nuclei is very ambiguous. For example, a 25 μm droplet will take approximately 0.08 s to evaporate [14] and will therefore become a droplet nuclei long before it reaches the ground. This fact is generally not well understood. For example, Ayliffe et al. [8] state:

"*Droplets are large particles* (*5* μm *or larger*) *that rapidly settle out on horizontal surfaces; thus they are not transmitted beyond a radius of several feet from the source*."

While this statement is true in part, it is also misleading since a great many droplets of say, 10 μm or greater, will very quickly evaporate and become droplet nuclei.

Air Bio-burden

Most airborne micro-organisms found in hospitals are generated within the building by the staff, patients and visitors [18]. Only a minority of the micro-organisms in the air, usually fungal spores, originate outside. Generally the higher the occupancy level the greater the microbial bio-burden in the air. Consequently, the air bio-burden within hospitals tends to be very transient and can fluctuate wildly, depending on occupancy levels and the tasks being performed [18].

Infectious micro-organisms can enter the air by a variety of routes. They can be violently dispersed into the atmosphere as droplet nuclei through sneezing or coughing, or released into the air on skin squamae. Activities, such as bed making, release large quantities of micro-organisms into the atmosphere. One study found that the total viable count (TVC) in a patient room exceeded 6000 colony forming units per cubic meter ($cfu \cdot m^{-3}$) of air during vigorous bed making [19].

Surprisingly, few good microbial air sample surveys exist for hospital buildings. Some of the most comprehensive studies were undertaken by Greene et al. in the early 1960s [19–21]. These studies found the mean bacterial count in hospital air to be in the region 350–700 $cfu \cdot m^{-3}$, with the highest counts in laundry-handling areas and the lowest counts in operating and delivery rooms. The important findings of these studies were that:

- Approximately one third of micro-organisms recovered from the air were gram-positive cocci, one third were gram-positive bacilli, with the remainder being made up of gram-negative bacilli and fungi.
- Gram-positive cocci made-up a higher proportion of micro-organisms in operating rooms.
- Gram-positive bacilli made-up a higher proportion of micro-organisms in laundry and waste storage rooms.
- Gram-negative bacilli were found in relatively high numbers in corridors.

Greene et al. also found that the process of bed making caused a significant increase in the microbial bio-burden [19]. Table 1 illustrates the impact that bed making can have on the bacterial counts in surrounding spaces.

Table 1. Influence of bed making on airborne bacterial count in hospitals [19]

Item	Inside patient room ($cfu\ m^{-3}$)	Hallway near patient room ($cfu\ m^{-3}$)
Background	1200	1060
During bed making	4940	2260
10 min after bed making	2120	1470
30 min after bed making	1270	950
Background	560	n.a.
Normal bed making	3520	n.a.
Vigorous bed making	6070	n.a.

The data in Table 1 clearly demonstrates the transient nature of the microbial bio-burden in the air within hospitals. In the patient room the bacterial count rose from 1200 to 4940 $cfu \cdot m^{-3}$ during the bed making process, only to fall back to 1270 $cfu \cdot m^{-3}$ 30 min after bed making. The data for the hallway also reveals that the bed making process dispersed micro-organisms around the building.

Airborne Micro-organisms

While some hardy bio-aerosol types, such as fungal spores and pollen, are designed for airborne transportation, many others, particularly vegetative cells of bacteria are easily damaged by the environmental stresses experienced when in the aerosolised state. Many bacteria, used to moist surroundings, find the airborne domain a hostile environment in which they are subject to desiccation, nutrient starvation, radiation damage, oxygen toxicity and attack from free-radicals [22]. Not surprisingly, many bacteria have developed defence mechanisms which enable them to survive in the aerosolised state. Certain bacterial genera, such as *Bacillus* and *Clostridium*, form endospores which are the dormant form of the cell. Bacterial spores can remain viable for years and are very resistant to environmental stresses such as heat, cold and UV radiation [23]. Vegetative bacteria also develop defence mechanisms. Many species appear to lower their metabolic rate and reduce in size under conditions of nutrient starvation [24]. Indeed, it has been observed by a number of investigators [21,25,26] that under starvation conditions bacteria will cease to replicate while still being viable. In other words, the bacteria remain viable but are non-culturable using standard microbiological techniques [24,28]. Consequently, they are not detected by conventional microbial air sampling techniques, which require the micro-organisms to be cultured on plates. As a result many viable micro-organisms in the air are not detected, even though they are still be capable of causing infection in humans. It has been estimated that less than 1% of the viable micro-organisms present in air are culturable [23]; a figure which is corroborated by Heidelberg et al. [28] who compared direct counts achieved using the acridine orange direct count procedure with those achieved by cultures on tryptic soy agar plates. The fact that many airborne micro-organisms may be viable yet non-culturable, means that the bio-burden of air is generally underestimated and that the contribution to general nosocomial infection made by airborne micro-organisms could be greater than is currently recognised.

It is generally the case that gram-positive micro-organisms survive much longer in the aerosolised state than Gram-negative bacteria. Gram-positive bacteria, such as *S. aureus*, possess a peptidoglycan-rich cell wall, which gives them relative resistance to desiccation. Consequently, they can survive for considerable time in the environment and can be easily distributed around buildings by air currents. Gram-positives such as *Staphylococcus* spp. can remain viable on aerosolised skin squamae for long periods of time [17]. By contrast, most Gram-negatives are not thought to survive for long in the aerosolised state. Although it is generally true that Gram-positives survive longer in the aerosolised state than Gram-negatives, there is growing evidence that Gram-negatives can survive in the aerosolised state. Blessing-Moore et al. [29] recovered *P. aeruginosa* from settle plates located near patients with cystic fibrosis and airborne *Pseudomonas* spp. were linked with an outbreak of nosocomial bacteraemia at a hospital in the USA [6]. Heidelberg et al. [28] using the acridine orange direct count procedure found that viable counts of *Serratia marcescens*, *Klebsiella planticola a*nd *Cytophaga allerginae* in 4 h old aerosol particles were respectively 47.9, 72.8 and 65.8% of the original counts, even though the micro-organisms were not culturable on tryptic soy agar plates. Further evidence that Gram-negatives can survive for long periods in air came from Jawad et al. [30], who found that the mean survival time for *A. baumannii* on a dry surface was 26.6 days. Collectively these findings suggest that Gram-negative bacteria can remain viable in air for significant periods of time, even though they may not be culturable.

Airborne Contribution to Nosocomial Infection

There is increasing evidence that airborne micro-organisms contribute to some nosocomial infections. These infections are mostly bacterial, but can also be caused by airborne fungal and viral agents.

Gram-Positive Bacterial Infections

(*a*) *S. aureus and MRSA: S. aureus* is a cluster forming Gram-positive cocci which is coagulase-positive. At any one time approximately 30% of healthy people are carriers of *S. aureus* [12]. It is an opportunistic pathogen which causes infection at sites of lowered host resistance, such as damaged skin or mucous membranes [12]. In recent years, drug resistant strains of *S. aureus*, including MRSA have

become widespread. MRSA, which was first identified in 1961, is now found in hospitals throughout the world [31]. It causes a range of infections including surgical site infections, septicaemia and pneumonia.

MRSA infections are generally associated with person-to-person contact. Notwithstanding this, airborne transmission of *S. aureus* and MRSA has been reported in operating theatres, intensive care, burns and orthopaedic units [32–35]. Airborne dispersal has also occurred in cases where MRSA has colonised the respiratory tract of patients [36]. Walter et al. [32] found that surgical site infections occurred because *S. aureus* was shed from a disseminating carrier in an operating theatre. Carriers who disseminate large numbers of cocci into the environment are called 'shedders'. Shedding is more likely to occur in nasal carriers who exhibit a heavy growth of *S. aureus* on nasal swab cultures and in those with upper respiratory infections [17]. Shedders can disperse large numbers of cocci into the environment, resulting in high concentrations of airborne staphylococci which may remain viable for long periods of time [17]. Rutala et al. [33] investigating an MRSA outbreak, found that MRSA comprised 16% of all bacterial isolates sampled from the air and 31% of the isolates from elevated surfaces. Since it is unlikely that healthcare personnel or patients ever touch elevated surfaces, the presence of MRSA isolates on these surfaces suggests that staphylococci are transported through the air. Hospital ventilation systems have also been implicated with nosocomial MRSA outbreaks. Wagenvoort et al. [37] found MRSA isolates on ventilation grilles in an orthopaedic ward and Cotterill et al. [38] identified colonies of MRSA in the exhaust air from an isolation room as the source of an outbreak in an intensive care unit; the MRSA bacteria were re-entering the unit via an open window.

Although airborne transmission has been implicated in a number of *S. aureus* and MRSA outbreaks, the overall importance of the airborne route of transmission is unclear and there is considerable debate about the subject. One of the strongest pieces of evidence against the airborne spread of *S. aureus* comes from a 1964 study in the USA of the use of ultraviolet (UV) lamps in an operating theatre [39]. The study concluded that although the use of the UV lamps achieved a 52 or 63% reduction (depending on the UV intensity used) in the airborne bacterial count, no reduction in the post-operative wound infections was achieved; implying that the infections occurred because of contact-spread and not airborne transmission. Notwithstanding this, there is a solid theoretical basis for thinking that *S. aureus* can be transmitted by the airborne route [7]. A study by Noble et al. [40] found that the size distribution of particles containing *S. aureus* was approximately 4–25 μm, which is roughly the size of skin squamae and well in excess of the size of single *S. aureus* cells (i.e. about 1 μm diameter). Noble et al. therefore surmised that most of the airborne *S. aureus* organisms were carried on skin squamae. Humans liberate approximately 3×10^8 squamae per day. Noble et al. concluded that in many people a closed loop exists; contaminated skin squamae are released into the air; they become impacted on the nasal turbinates; *S. aureus* grows on the nasal mucosa; hands then touch the nose and *S. aureus* bacteria are transferred to the skin; they colonise the skin and are ultimately disseminated back into the air on skin squamae.

(*b*) *Coagulase-negative staphylococci:* Coagulase-negative staphylococci comprise a large group of related Gram-positive species, including *S. epidermidis*, *S. hominis*, *S. simulans* and *S. haemolyticus*. They are commonly found on the skin of healthy persons and rarely cause infections, except in immuno-compromised patients [12]. Coagulase-negative staphylococci are opportunistic pathogens which cause infection in immuno-compromised patients, often by colonising implants and catheters [12]. The transmission route for coagulase-negative staphylococci is generally thought to be by direct contact, although airborne spread has been observed from staff in an operating room during implant surgery [41].

(*c*) *Mycobacterium tuberculosis:* Tuberculosis is a classic example of a disease which is transmitted by the airborne route. It is endemic in many parts of the world. Indeed, it has been estimated that a third of the world's population is infected with *Mycobacterium tuberculosis* [42]. Primary TB infection occurs when droplet nuclei containing *M. tuberculosis* bacilli are inhaled. Those who become infected have a 10% lifetime risk of developing a secondary TB infection [43]. In recent years new multi-drug resistant strains of *M. tuberculosis* (MDR-TB) have emerged. MDR-TB is of particular concern since it is associated with high mortality rates; case : fatality rates of up to 93% have been recorded [44]. It is estimated that 50 million people will become infected with MDR-TB by 2008 [45].

Tuberculosis is not normally considered a nosocomial infection since the disease is generally contracted outside of the hospital setting. However, when patients with pulmonary TB enter the clinical environment, they can infect staff and other patients. It is therefore not unreasonable to consider *M. tuberculosis* a nosocomial pathogen. Indeed, the Centers for Disease Control and Prevention (CDC) found in a study undertaken in the early 1990s, that more than 100 healthcare workers in eight US

hospitals had skin test conversions following exposure to patients with TB and that at least 17 developed MDR-TB [46]. In the TB outbreak which occurred in New York City during the late 1980s and early 1990s, hospital transmission played a significant role in the spread of the disease, with almost two-thirds of all the MDR-TB cases linked to four hospitals [47]. Also, in the UK an outbreak of nosocomial MDR-TB occurred in a London teaching hospital [48,49].

In common with other airborne infectious agents, *M. tuberculosis* can be transported on aerosol particles over long distances by convection currents. If ventilation systems are poorly designed and maintained, then bacilli can be distributed widely around healthcare facilities. There have been a number of cases where mechanical ventilation systems have been implicated in TB outbreaks [50–52]. One such case involved an AIDS treatment clinic in Florida [52], where widespread cross-infection occurred from patients with unsuspected TB. Analysis of the situation revealed that the mechanical ventilation system was re-circulating contaminated air, with the result that *M. tuberculosis* bacilli were evenly distributed throughout the building. The important role that ventilation can play in the spread of TB is illustrated by an outbreak in a US hospital [52] in which a hip abscess on a patient was irrigated by a high-pressure water jet. The medical staff did not know that the abscess contained many tubercle bacilli, which were subsequently aerosolised by the water-jet. TB was not suspected until secondary TB cases were later diagnosed. Investigations revealed that the treatment room was under positive pressure, and that over a 3 day period, 58 postoperative patients in rooms off a common corridor had been exposed to *M. tuberculosis*. It was surmised that contaminated aerosol particles had entered a corridor adjacent to the treatment room due to the positive pressure of the room, and had then travelled down the corridor infecting patients in the side rooms. In another outbreak, this time at St. Thomas's Hospital, London [48,49], a patient with MDR-TB was admitted and placed in a ward side-room, adjacent to a ward containing HIV patients. Unfortunately, the side-room was positively pressurised relative to the adjacent ward, and 7 HIV-positive patents contracted MDR-TB. This ultimately resulted in the deaths of the index patient and 2 of the contact patents.

Gram-Negative Bacteria

(*a*) *Acinetobacter spp.*: *Acinetobacter* spp. are aerobic, non-spore-forming, Gram-negative coccobacilli which can be isolated from soil, water, sewage and the skin of healthy persons [30]. *Acinetobacter* spp. can cause a wide range of infections, particularly in those who are immuno-compromised. *A. baumannii*, in particular, is an important nosocomial pathogen, which can cause respiratory, blood and wound infections. Drug resistant strains of *A. baumannii* are becoming more frequent, with the result that infections caused by this micro-organism are often difficult to treat [53–55].

There is increasing evidence that *Acinetobacter* spp. can be transmitted through the airborne route. Allen and Green [56], for example, identified the airborne spread of "*A. anitratus*" in an outbreak involving two hospitals. Bernards et al. [5] investigating outbreaks of *A. baumannii* in two Dutch hospitals, found that the infection was transmitted by the airborne route. Other investigators have found *A. baumannii* capable of surviving for considerable periods of time on dry surfaces under typical room air conditions [53], which suggests that the micro-organism could remain viable in the airborne state. It has also been shown that *Acinetobacter* spp. can survive on fingertips and on dry surfaces under environmental conditions typically found in hospitals [30,57].

(*b*) *Pseudomonas spp.*: *P. aeruginosa* are Gram-negative bacilli which can infect almost any external site or organ [58]. In hospitals it is generally associated with catheter-related urinary tract infections, infected ulcers, bed sores, burns and eye infections [58]. In particular, cystic fibrosis patients are prone to *P. aeruginosa* infection. *P. aeruginosa* can be difficult to eradicate from hospital wards as it is resistant to, and may multiply in, many of the disinfectants and antiseptics commonly used in hospitals [58].

Pseudomonas spp. along with other Gram-negative bacilli can be recovered from hospital air, but it is generally considered that most *Pseudomonas* spp. infections occur because of direct contact and not airborne transmission. There are however, a few studies which suggest that airborne transmission can play an important part in *Pseudomonas* spp. infection. *P. aeruginosa* has been isolated from the air in burns units, which suggests that infection may be via the airborne route [58]. An outbreak of nosocomial bacteraemia at the Hines Veterans Administration Hospital, was linked to the installation of a new chute hydro-pulping waste disposal system [6]. Air sampling revealed an air bio-burden in excess of 5600 $cfu \cdot m^{-3}$, comprised mostly of *Pseudomonas* spp. and *Enterobacteriaceae*. When the hydro-pulping system was closed the microbial bioburden fell back to baseline levels. In a study in an intensive care unit, Kelsen and McGuckin [59] found a significant correlation between the monthly rate of nosocomial respiratory tract infection and the

average bacterial count in the ward air. During periods of heavy air contamination, unusually high concentrations of Gram-negative bacilli were found, with the *P. aeruginosa* content reaching a maximum of 1050 cfu·m^{-3}. Kelsen and McGuckin found that infections appeared to result from airborne bacteria seeding reservoirs on inanimate objects such as nebulizers.

There is some debate about the role of airborne micro-organisms in the *Pseudomonas* spp. infection of cystic fibrosis patients. *P. aeruginosa* has been recovered from settle plates located near patients with cystic fibrosis [29]. However, the evidence for the airborne transmission of *Pseudomonas* spp. infection is not conclusive as there are many interactions between patients with cystic fibrosis and thus plenty of opportunity for infection to be transmitted by other means [7].

(*c*)*Legionella pneumophila: L. pneumophila* is well known to engineers as the organism which causes Legionnaires' disease, which is a form of pneumonia. *Legionella* spp. are Gram-negative bacilli whose natural habitat is water. True airborne transmission of *L. pneumophila* is known to occur, as droplet nuclei have infected people at long distances from the source. There have been a number of nosocomial *L. pneumophila* outbreaks [7], most of which have been linked either to cooling towers, air handling units and showers.

In hospitals most attention is focused on the prevention of the droplet nuclei spread of *L. pneumophila* from taps and showers. *L. pneumophila* bacilli tend to grow on bio-films which form in water pipes when the water is static. Eradication can be particularly difficult because the bacilli are often ingested by amoebae present in the bio-film [8]. The *L. pneumophila* bacilli survive in the amoebae, which protect them from any chemical disinfectants used in the water pipes.

Fungal Infections

Pulmonary aspergillosis results from the inhalation of spores of *Aspergillus fumigatus*. These fungal spores are widespread in the outdoor environment, where they colonise soil, leaves and living plants. Unlike most airborne infectious agents in hospital buildings, which are principally generated by patients and staff, *A. fumigatus* spores generally originate in the external environment. Indeed, in the winter months *Aspergillus* spore counts may reach 600 spores.m^{-3} [60]. *A. fumigatus* spores often enter hospital buildings through open windows or through mechanical ventilation ducts. Construction work tends to liberate large numbers of fungal spores into the air. Consequently, outbreaks of pulmonary aspergillosis are often associated with this type of work. Immuno-compromised patients are particularly vulnerable to infection from *A. fumigatus*. Invasive aspergillosis in immuno-compromised patients has a very poor prognosis [60]. Indeed, case : fatality rates of 85% are typical amongst bone marrow transplant recipients [61].

There is strong evidence that aspergillosis in immuno-suppressed patients is caused by the airborne transmission of *A. fumigatus*. *Aspergillus* spores are almost always present in unfiltered air [7] and there is clear evidence that improving hospital air filtration systems, leads to a decline in infection rates in hospitals which have an endemic aspergillosis problem [7].

Evidence that fungal pathogens, other than *Aspergillus* spp., are spread by the airborne route, comes from a recent outbreak of airborne nosocomial *Scedosporium prolificans* infection in Spain [62]. *S. prolificans* is an opportunistic fungal pathogen. In the reported outbreak 6 acute non-lymphocytic leukaemia patients died. They were treated in individual isolation rooms which were mechanically ventilated, but did not have high-efficiency particulate air (HEPA) filters or laminar air-flow systems. After the outbreak a positive-pressure system with HEPA filters was installed and in the 2 years after installation no cases of infection with *S. prolificans* were reported.

Viral Infections

Many nosocomial infections involve viral agents which can easily be spread via the air. Respiratory viruses such as influenza and respiratory syncytial virus are mainly spread by droplet nuclei and droplet transmission [8]. Both the influenza and respiratory syncytial viruses can survive on inanimate surfaces for several hours [8] and therefore can also be spread by the indirect contact route. Indeed, it has been demonstrated that the influenza virus can remain viable in dust for as long as 14 days [63]. Although respiratory viruses are transmitted through the air, other non-respiratory viral infections, such as chicken pox and measles [64] are also spread by the airborne route. The airborne route also contributes to the spread of viral gastro-enteritis [65]. Viral infections often cause patients to vomit. When vomiting occurs millions of virus particles are liberated into the air [66] and these can become widely distributed by air currents in hospital buildings, with the result that attack rates for some viral infections can be very high.

Discussion

From the evidence presented above, it is clear that a number of bacterial, fungal and viral infections found in hospitals can be transmitted by the airborne route. In particular, there is increasing evidence that some infections caused by Gram-negative bacilli are, at least in part, spread by airborne transmission [5,6,29,56]. However, great care must be taken when analysing data from reported nosocomial outbreaks. It is all too easy to jump to the false conclusion that a particular infection is transmitted by the airborne route, simply because isolates of the outbreak strain are found in the air or on inanimate surfaces near the patient. In fact, transmission may be by person-to-person contact, with the infected patient contaminating the environment. Finding an outbreak strain in the environment does not establish a causal role [7]. In order to establish causality the direction of the transmission must also be determined. Notwithstanding this, while the presence of airborne or surface isolates does not establish the direction of the transmission, it does demonstrate that airborne transmission might be occurring. This is especially true if an outbreak strain is found on elevated horizontal surfaces, which are inaccessible to both patients and healthcare workers. It is also possible that airborne transmission may be contributing to the contact-spread of infection. Nosocomial pathogens may be deposited by the air on inanimate surfaces and then transported from these surfaces to patients on the hands of healthcare personnel.

The role that skin squamae play in promoting infection is worthy of note. It is recognised that skin squamae can be colonised by coagulase-negative staphylococci and *S. aureus*. Skin squamae containing *S. aureus* tend to be shed from the face and hands of colonised individuals, which explains why masks are of little value in preventing the transfer of *S. aureus* from healthcare workers to patients [8]. Shedders who disseminate large numbers of staphylococci into the air can be a particular danger in operating theatres and in intensive care wards. As well as having large numbers of staphylococci in their nose or perineum, shedders tend to have greater numbers of staphylococci on other areas of their skin, compared with normal carriers [67]. When patients are heavy shedders it is often because they have discharging purulent lesions, bed sores, burns and skin lesions [8].

Since the skin squamae that are dispersed into the air are very small, they are carried away by convection currents and become truly airborne. Evidence that skin squamae can be distributed widely around room spaces by convection currents comes from the fact that dust (which is made-up of skin squamae) is precipitated on high horizontal surfaces. In this way inanimate surfaces can become contaminated with harmful micro-organisms. If these surfaces are touched by healthcare workers then pathogens can be transported to patients by the contact route. For example, a heavy shedder will often contaminate clothing and bedding with *S. aureus*, which in turn will readily contaminate the clothing and hands of healthcare workers [68]. However, the contribution that airborne skin squamae make to nosocomial infection is unknown, since much greater opportunities exist to transfer large numbers of micro-organisms by direct contact rather than through the air [8]. Therefore, it is generally considered much more important to undertake measures, such as hand washing, which control the contact-spread of nosocomial pathogens, rather than concentrate on the airborne spread of these agents. This view is aptly summed-up by Ayliffe, Babb and Taylor [8]:

"*This demonstrates again that hand washing and wearing a protective plastic apron when in contact with an infected patient is much more important than an expensive ventilation system. . . . Airborne contamination of fomites, e.g. curtains and furnishings, and of floors, plays a minor role in the spread of staphylococci and a room left overnight after occupation by a patient infected with staphylococci is unlikely to be responsible for infecting a subsequent patient. Nevertheless, it is advisable to clean a room thoroughly and change the curtains after occupation by a heavy disperser of a virulent or epidemic strain.*"

The above opinion is however challenged to some extent by the findings of a recent study undertaken at a teaching hospital in the USA [69], in which inanimate surfaces were sampled for MRSA isolates. The study found that 27% of the surfaces sampled in rooms containing MRSA infected patients were contaminated with MRSA. When MRSA isolates were found in a wound or in urine, 36% of surfaces were contaminated. By contrast, when MRSA was isolated from other body sites, only 6% of surfaces were contaminated. Environmental contamination occurred in the rooms of 73% of infected patients and 69% of colonised patients. Frequently contaminated objects included the floor, bed linens, the patient's gown, over-bed tables, and blood pressure cuffs. It was found that 65% of the nurses who performed activities on patients with MRSA in wounds or urine, contaminated their nursing uniforms or gowns with MRSA. Furthermore, 42% of personnel who had no direct contact with such patients, but had touched con-

taminated surfaces, contaminated their gloves with MRSA. The authors of the study therefore concluded that:

- Inanimate surfaces near infected patients frequently become contaminated with MRSA.
- The frequency with which contamination occurred was affected by the MRSA infection site.
- Healthcare workers contaminated their gloves or hands simply by touching contaminated surfaces.
- The contaminated environmental surfaces may have served as a reservoir for MRSA in the hospital.

While the findings of this study suggest that the MRSA infected/colonised patients were contaminating the inanimate surfaces in their rooms and not the other way round, the study presents strong evidence that contaminated environmental surfaces may be acting as reservoirs. If this indeed was the case, then the bacteria on the inanimate surfaces may have both prolonged and increased the spread of the MRSA outbreak.

The fact that many airborne micro-organisms are viable even though they are non-culturable [23,24,28] is of importance. This suggests that traditional microbial air sampling techniques produce results which greatly underestimate the numbers of viable airborne micro-organisms in hospital buildings. This is particularly the case with Gram-negative bacilli such as *Acinetobacter* spp. and *Pseudomonas* spp., which are difficult to culture from the air. Indeed, it might explain why Greene et al. [19–21] found relatively few Gram-negative bacilli when they sampled the air in hospitals. It therefore follows that airborne transmission of infectious agents in hospital buildings is likely to be greater than is currently recognised.

Conclusions

While it is true that some airborne pathogens cause hospital acquired infections, the general role that airborne transmission plays in nosocomial infection is unclear and not well understood. However, despite the uncertainty that surrounds the subject, it appears likely that the contribution made by airborne micro-organisms towards nosocomial infection is greater than is currently recognised. This is because:

- Many micro-organisms remain viable in the aerosolised state even though they are non-culturable, with the result that true air bio-burden counts are usually underestimated.
- Some infections arising from contact transmission involve, in part, the airborne transportation of micro-organisms onto inanimate surfaces.

Notwithstanding this, there is strong evidence that (with the exception of some respiratory infections such as TB and aspergillosis) most nosocomial infections are spread by the contact route. Control measures should therefore primarily focus on strategies designed to prevent the contact-spread of infection.

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Guidance on ventilation revised and updated

Speaking in the 'System Governance' stream on the first day of last October's IHEEM Healthcare Estates 2021 conference, consulting engineer, Malcolm Thomas, the main author of the 2021 version of HTM 03-01, *Specialist Ventilation for Healthcare Premises*, published last June, explained the background to, and aims behind, the HTM's revision, and highlighted some of the major changes that those responsible for ventilation plant in hospitals and other healthcare facilities need to be aware of. *HEJ* editor, Jonathan Baillie, reports.

Malcolm Thomas was the lead author for both editions (published in 2007 and last year) of HTM 03-01, and also of the ventilation-related HTM 2025 that preceded them. Also the lead author of the engineering section of several HBNs, he has worked in the healthcare sector for over 40 years – both within and outside the NHS. He is President of the Specialised Ventilation for Healthcare Society, and a visiting lecturer at the University of Leeds.

Welcoming attendees to his presentation, he explained that as the lead author of HTM 03-01 (2021), he would explain some of the main thinking behind it, and set out the reasons for a number of key changes in the 'rewritten version'. He began: "As some background to where the HTMs and other guidance on ventilation originated, back in 1972 Dr Owen Lidwell led a Joint Working Party on ventilation and operating suites, and this was the foundation of all the guidance that has emerged since. Many people have asked me," he continued," why we bother with material that is 'so old'? The reason is that when this work was done, it was very evident what worked well in practice, and what didn't, in a way that's no longer nearly so clear. When you have significant infection rates in operating theatres, it's quite easy to see whether – if you change the colour of the paintwork – it makes any difference. Conversely, with very small infection rates – which fortunately we have now – it's very difficult to know whether changing the surgeons' gowns, the air change rate, or the colour of the walls, or putting carpet in, makes any significant difference. We're talking about low percentage changes. We're in a situation now where people think changes will improve things, but they don't actually know, and it's hard to prove what is a good or a bad thing. Back when Owen Lidwell did this work, it was relatively easy, there were step-changes, and he was able to conduct a number of trials."

Malcolm Thomas, the main author of the HTM 03-01 (2021), *Specialist Ventilation for Healthcare Premises*, published last June.

Comparative trials

Malcolm Thomas explained that in one, Owen Lidwell and his team took a particular acute hospital, and identified two operating theatres as theatres 'A' and 'B', with had two surgical teams – also named 'A' and 'B', staffing them. He elaborated: "They picked out patients at random, drawing lots to decide which theatre they were operated in. They could thus see which team and which patients fared better under certain circumstances, and thus demonstrate changes in the outcomes in infection rate terms." From this work, and drawing on theatres with low infection rates and good patient outcomes, Owen Lidwell and his team were able to determine the optimal airflow and temperature, and consider elements such as the impact of different gowning procedures. This in turn enabled them to draw some conclusions.

"The conclusions they drew have stood the test of time," said Malcolm Thomas. Following Owen Lidwell's work, the Department of Health and Social Security – as it was then – set up a working group, and codified the ventilation of operating departments in a document called DV4, specifying what was required for the theatre, and what worked and what didn't, 'taking Lidwell's work forward'.

Request to update guidance

"When I came on board," Malcolm Thomas explained, "I was asked to update DV4, but soon after I'd finished doing this, I was told it was now going to be an HTM, and HTM 2025 was duly published in 1994. Some years later I was asked if I could I take that forward again, and HTM 03-01, *Specialised ventilation healthcare*, was published in 2007. It was delayed by SARS, and avian flu, just as the Coronavirus outbreak delayed the publication of the current version of HTM 03-01. So, all of these iterations are based on some good solid work many years ago. I've been working in this area for some time, and it's very evident that these earlier learnings have stood the test of time. Where we have encountered problems, it's generally been clear that the guidance wasn't followed."

Historical reasons for not following guidance

Among the historical reasons for failure to follow established guidance, the speaker explained, had been changing procedures in both operating suites, and other 'spaces' in healthcare facilities, while on occasions people 'had not perhaps been as careful as they should have been' –

> **We're in a situation now where people think changes will improve things, but they don't actually know, and it's hard to prove what is a good or a bad thing**

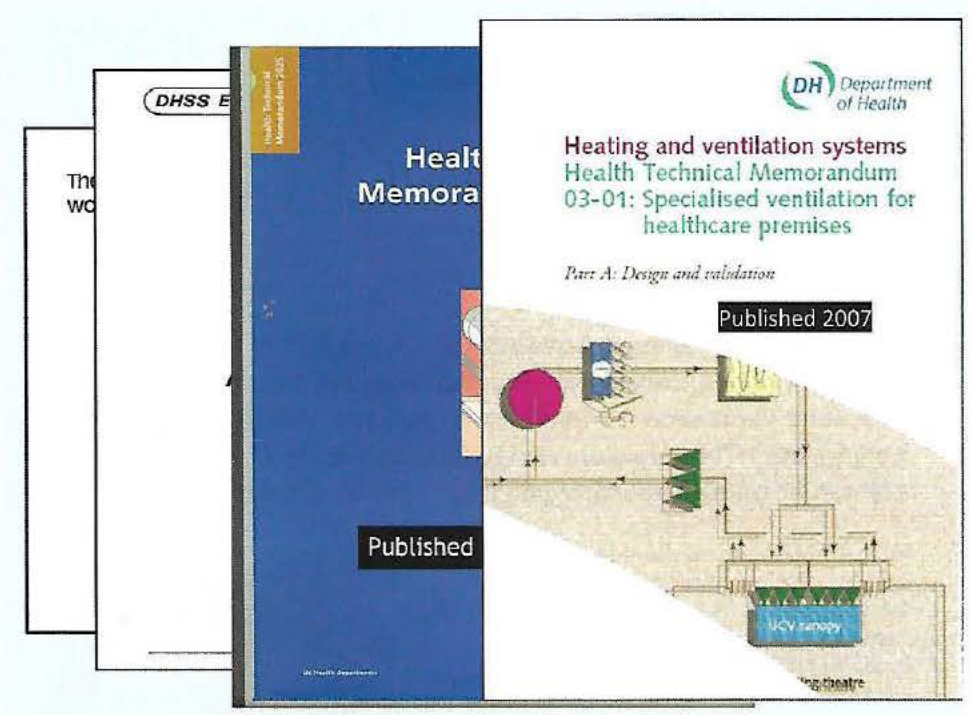
leading to 'something going wrong with the ventilation'. Malcolm Thomas said: "Put the people right, and – if I can put it like that – we'll get the ventilation right. There's a good pedigree, a good history, and we can have some confidence in past learnings and guidance. It isn't just people's opinion; it's what works."
'Backing this up, he added, was 'a fair amount of ongoing research by Department of Health, the NHS, and private companies', with the findings taken on board when HTMs were revised and updated. He said: "So, in these guidance documents we try to avoid just featuring people's opinion of what works and what doesn't, and instead coming down to some facts. History appears to show that this is a correct way of doing it."

Do we need the HTM guidance?

'Back in 2017/18', he explained, when it was decided to look at revising HTM 03-01, one of the questions asked had been: 'Do we need it?' He explained: "We have, in fact, been trying to reduce the amount of guidance issued, because at one point there were something like 400 different pieces of guidance, and it's almost impossible to keep that sort of volume of guidance up to date." Over the years there had thus been some 'pruning', together with a 'focus on what is different about ventilation in healthcare'. The speaker said: "What matters to us is, for example, whether CIBSE guidance on ventilation is adequate. If so, that's great, but if not, do we need to do more than CIBSE is suggesting, or perhaps less in some cases? Things that CIBSE would allow may not be what we want to do. They may not be appropriate in a hospital or other healthcare setting. So," he said, "having decided we did indeed need HTM 03-01, we questioned whether it needed updating, and, having determined that it did, began looking at how." This resulted in a 'scoping exercise' which ran for over a year with wide-ranging consultation, to look at what was in the documents, whether the HTM could just be given 'a dust down' and a little updating, or whether indeed some fundamental changes were needed He said: "That led to the move to produce a new document, in two parts, with part A on design and installation for those putting in something new, and Part B about how you manage an existing healthcare ventilation system."

A 'complete re-write' required

He continued: "It was decided that Part A needed to be completely rewritten, it having become clear from the scoping exercise that in existing form it assumed that designers knew what the healthcare industry needed." "Interestingly," he added, "back when I authored the HTM for the first time, I was told: 'Well, you can't put that sort of thing in, Malcolm. People who do these things already know what they're doing.' On the contrary though, it became very evident – and particularly with the PFI process – that a lot of people designing hospitals and hospital systems in fact had no idea what their customer wanted."



The latest iteration of HTM 03-01 – on which Malcolm Thomas primarily focused – followed several previous guidance documents on healthcare ventilation.

Historical context

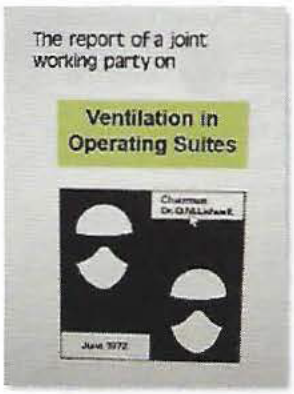
Here Malcolm Thomas showed slides of Owen Lidwell's report, followed by DV4, then HTM 2025, and then HTM 03-01, both in 2007 form and in the latest iteration. Referring to HTM 03-01 (2021), he said: "It was decided that we should produce the latest HTM 03-01 in two parts – it was clear that Part A needed to have more of an explanation, not just of what we wanted, but why – so that people understood the importance of things. We thus changed the title, the Concept, the Design, Specification, Installation, and Acceptance Testing – the whole process. We tended in the PFI days to say: 'Give us a new hospital, and give me the key when it's finished', and clearly that wasn't a good idea. While we have some very good hospitals, constructed and built and working well, some were much less successful than they should have been. Part A of the 2021 HTM 03-01 thus refers both to all new installations, and to refurbishments and changes in use of existing installations. I would stress that it's not retrospective; you don't have to rip everything out and re-start. However, if you're in the middle of the project, and you find that the new HTM would suit you better, then providing everybody else agrees, and you've addressed any cost implications, there's no reason why you can't move over to the new standard." This, Malcolm Thomas said, applied even where a project team was working to guidance set out in the 'old' HTM."

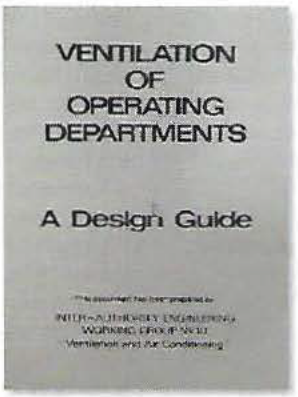
Part B of the new HTM

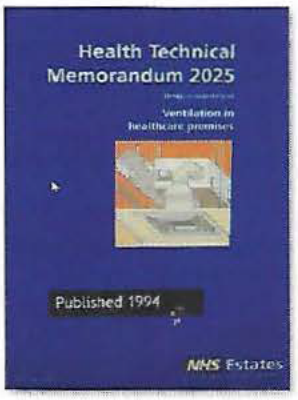
He continued: "Part B is about the management, operation, maintenance, and routine testing, of existing healthcare systems. It's much as it was, but there are some additional changes. The thing to remember with Part B is that it applies to all installations; it doesn't matter how old." He continued: "I'm often told a hospital installation dates from the time of HTM 2025, and that's why it doesn't conform. However, the minimum standards have been there ever since that HTM was published; in fact they were introduced because of the Stafford outbreak and Legionnaires' disease in 1986, and were in the Big White Book, for which I wrote a section on standards for ventilation plant." These had – he said – been carried forward in every HTM since.

Moving to the 'major themes' in HTM 03-01 Part A, he said: " One thing we have had to focus on particularly is supporting the Government's zero carbon policy – so there's quite a push in terms of energy use, and how we go about things to support this objective."

Also considered in compiling the new guidance, Malcolm Thomas explained, had been the EcoDesign Directive and regulations, which he pointed out were 'legal requirements'; he was surprised many equipment manufacturers still viewed them as 'options'.







Left: In 1972 Dr Owen Lidwell led a Joint Working Party on ventilation and operating suites, which was to be 'the foundation of all the guidance that has emerged since'. Centre: Following Owen Lidwell's work, the Department of Health and Social Security – as it was then – set up a working group and codified the ventilation of operating departments in a document called DV4. Right: On 'coming on board' with official ventilation guidance, Malcolm Thomas was asked to update DV4, but soon after doing so, he was told it was now to be an HTM, and HTM 2025 was duly published in 1994.

Taking advantage of new technology

He continued: "On carbon reduction, we changed quite a few things to try to get maximum benefit from new technology and reduced energy use – fans being a good example." He elaborated: "Those of us who grew up with belt-drive fans know we were stuck with a particular fan speed, regardless of whether it was optimal, and with specific outputs; there wasn't much you could easily do about either.

"Nowadays, we have a whole range of more efficient fans, and more coming along; control technology has moved on – we can be more accurate in how much air comes down the system, and we don't need to build in such a big margin to allow for system deterioration over time. We've striven to take advantage of all this in the new HTM." Malcolm Thomas explained that the authors had also striven to provide background information to assist the understanding of client needs.

He expanded: "So, you will find, scattered throughout, little blue boxes with little aide-memoires, which highlight why the preceding paragraph is important, particularly in a healthcare setting. They are very sound ideas, so please don't depart from them."

A clarification of design parameters

The new HTM also incorporated 'a clarification of design parameters'. "There's been problems in the past with what standards we actually want," he explained. "We've now got much more of a clarification of design parameters." In terms of 'the new elements', the HTM's authors had put in the user requirements, listed under 'surgical', 'medical', 'mental health', 'palliative care', 'and so on'. He said: "We have thus sought to answer the questions: 'What does the user want, and why have we provided ventilation?', 'What's it for?', 'Is it for infection control, comfort, or to remove odours?' What's it about?' Again, it is about trying to clarify for the designers exactly what is important, and what you can do some adjustment on." He continued: "We've also introduced the concept of the Ventilation Safety Group, mirroring what we already have with the Water Safety Group, i.e. a group of Trust stakeholders made up of people from Estates, Finance, and Infection Control, and other key

personnel, all of whom have an input, and make some decisions on the ventilation systems and their operation."

Derogations

In circumstances where somebody wanted to derogate in future, they would now need to take the matter to the Ventilation Safety Group, which must agree and sign up to the derogation. He added: "The Group must also record what the derogation was, why it was agreed, and who agreed it. It thus takes away this 'Mr Jones said it was OK'-type approach. Notice too," he said, "that somebody from Finance is involved, because some of these things have ongoing financial commitments. For example, some of the ways of installing ventilation plant mean they need more regular cleaning over time, with a financial implication ongoing for the system's lifetime, so it's essential that the Finance people are involved and recognise that if you go down that path, there needs to be provision to undertake the maintenance correctly over a period of perhaps 20 years."

Guidance on refurbishments

Malcolm Thomas explained that while the new ventilation HTM covers refurbishments and change, the old one didn't. He and his counterparts had encountered 'a lot of problems' with people refurbishing theatres, where they had 'completely gutted' an existing such facility, installed new ceilings, plastered the walls, put in new doors, a new floor, new operating tables, lamps, 'and everything', but kept a 30-year old ventilation plant. He said: "This is like buying a new car, but taking the engine out of the old one because that will save you a bit of money." He continued: "The ventilation plants are not as expensive as an operating table; you wouldn't dream of using a 30-year-old operating table, so why consider using 30-year-old ventilation plant? We should surely be taking advantage of new technology. We want new plant with good controls, not old plant 'mashed up to save a couple of bob'. That's an important aspect which is clearly spelt out.

Natural ventilation where possible

"We have also suggested various ventilation strategies; we would like natural ventilation where practical. Such ventilation can, however, 'be tricky in the case of hospitals', Malcolm Thomas acknowledged. As he put it: "You're relying on the wind blowing, and blowing in the right direction, not too much and not too little, so it's not easy, particularly in a hospital." However," he added, "mixed mode ventilation, taking advantage of natural ventilation while it's there, and then supporting it with a fan that will come on when it's needed, and perhaps some supplementary heating etc, can be one potential solution."

Natural ventilation wasn't 'just about opening a window'. The speaker elaborated: "It's about having ventilation openings, which may be supported with some ductwork attached, with a means of adjusting the ventilation rate when the natural ventilation is available, and taking advantage of it when it is." Where full ventilation, 'which costs money', was selected, the question arose about whether it needed to run 24 hours a day, seven days a week, 52 weeks a year. He said: "The answer, in most cases, is 'no'. If there's nobody there, you can turn it off – a really good energy-efficient way of doing it. This is not new; it was in EnCO$_2$de for many years."

Unnecessary plant operation

Noting that people still left theatre ventilation running '24/7' to keep the rooms sterile, which was 'absolutely not required', Malcolm Thomas explained that he and the co-authors of HTM 03-01 (2021) had expanded the 'Operating theatres' section 'quite significantly'. He said: "We've, for example, changed the parameters for air change rates to reflect what we can do to take advantage of the latest technology. We don't need to have as much slack in the systems as previously. So, the advice is much more appropriate for today, although still in line with what Owen Lidwell found worked, and history has subsequently proven right." Some of the 'old information' for where older theatres were still in use had been retained, but the new HTM 03-01 also incorporated 'a whole new set of information'.

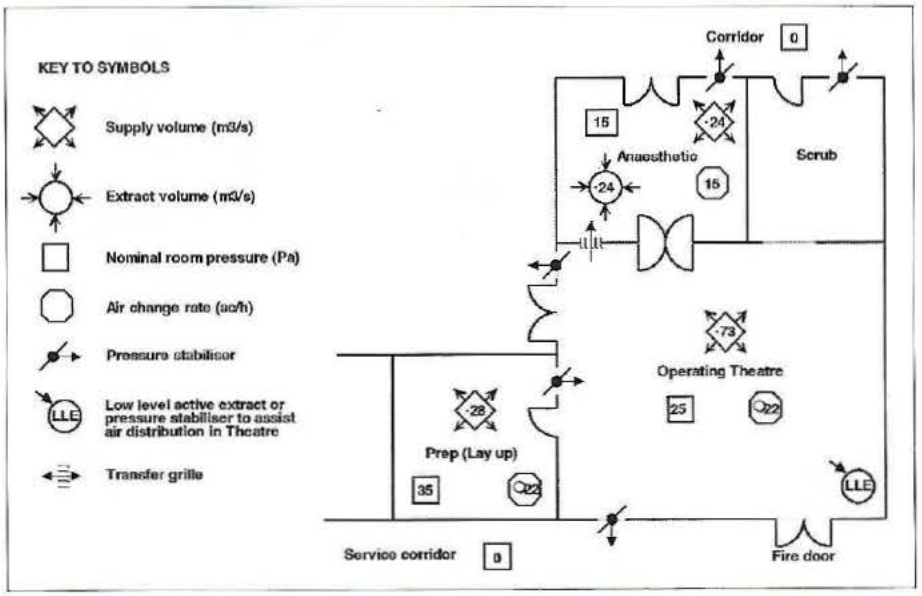
Installation guidance

Malcolm Thomas told attendees: "In a new 'Installation standards' section, we've spelt out some of the things that cause us numerous problems – including guidance on very simple things, which cost no money to do, but if not done right cost an awful lot of time and effort. So, for instance, with a basic thing like balancing damper handles, why install them at the top of the damper? When the ceiling is up, you then can't reach them. Air doesn't know where the handle is, but putting the handle on the bottom of a damper costs no more installation-wise, but means that when you come to balance, or subsequently re-balance, the system, you can reach the handle without killing yourself."

Turning to another key topic in the new HTM – 'Acceptance testing and validation', Malcolm Thomas explained that 'validation is a process of accepting the whole job, the whole project', so in the theatre, wasn't 'just about how much air goes in, but rather about where the air comes from: what the air-conditioning and air-handling unit is like, what the ductwork is like, and what the fabric of the theatre is like'. The speaker stressed that it was 'very different from commissioning', and entailed looking more holistically at 'Does it work, and can we at the end of the validation say it is safe to operate?'

Appendices expanded

The authors had also expanded the appendices 'to cover some of these things'. Here he showed a diagram of 'an example of one of new standard schemes, and the amount of air in the theatre'. He said: "The air change rate has changed, and above this, if you look in the appendices, there's a whole range of information that's much more definitive compared with what we has before. So, there are four schemes – single-corridor and two-corridor schemes for standard theatres and ultraclean, and another four



A ventilation diagram for a standard operating theatre taken from HTM 03-01 (2021).

Part A

- The Concept, Design, Specification, Installation and Acceptance testing of Healthcare ventilation systems
- Applies to all new installations and refurbishments and changes of use of existing installations
- It is not retrospective

Part B

- The Management, Operation, Maintenance and Routine testing of existing Healthcare ventilation systems
- Applies to ALL installations regardless of when they were installed
- Minimum standards for all installations

Malcolm Thomas urged all those with a professional interest in, or responsibility for, healthcare, to read and familiarise themselves both Parts A and B of the new HTM 03-01 – 'including the appendices and the accompanying explanations'.

historical schemes for those of you with older, smaller, theatres."

The authors of the new HTM had also created quite a lot of application-specific guidance – for instance dividing up applications into 'Treatment and Procedure Facilities', 'Airborne Protective Facilities', 'Airborne Isolation Facilities', 'Maternity Facilities', 'Pharmacy Facilities', 'Sterile Services Facilities', and 'Extract systems and local exhaust ventilation'. Malcolm Thomas said: "We have presented that information in terms of tables." Here, by way of example, he showed a slide of an 'Airborne Isolation Facilities' table, covering Isolation rooms, Categories 2 and 3. He explained: "If you want to know what the categories are, look at the bibliography in the index at the back of the HTM, and it's all explained." Down the side of the table were the areas or zones being discussed, with the next column highlighting the reasons and purpose of the ventilation, and the next 'some typical design factors to help make it easier for people to understand what's required'.

Part B

Turning to Part B and its 'major themes', Malcolm Thomas said that, in writing it, the authors had sought to 'clarify things', 'plug up the holes', and 'explain more clearly what we require'. So," he continued, "there is a legal requirement to keep records and information on ventilation systems, but many hospitals don't, so they have broken the law."
In fact, he explained, Part B now includes a requirement for an inventory with a uniform system of identification. He said: "Go round some hospitals and they have 10 air-handling units all called 'Air-handling unit number 1' in 10 different plantrooms, so we obviously need to be a lot clearer. Part B thus suggests that each ventilation plant has a unique number, corresponding to all the information about it, what it is, the spaces it serves, all the parameters and information about the equipment, the system performance over the years, and when we should 'scrap it'. Then," he continued, "we archive that information with its number plate, and put a new number plate on the new plant. We thus have an auditable trail. Generally, when you go around hospitals, a lot of information about systems is in people's heads, so when they leave it goes with them." This, Malcolm Thomas argued, was not only 'not conducive to running an efficient system', but was also dangerous.

Phased replacement

Part B of the 2021 HTM also discusses 'mid-life refurbishment', and phased plant replacement. The speaker explained: "We suggest that after 10 years, the air-handling unit should be taken out of use, cleaned, examined, and any corrosion treated, fitted with new controls, updated to get the best from the technology available, and then put back into use. After 20 years, plant should be replaced. If you don't start thinking about this when you put the plant in the equipment doesn't get replaced, and you then find 30-40-year-old plant still in use in the NHS. We want to take the best, get the most efficient systems, and take advantage of the latest technology; not cling to the older things."

The Ventilation Safety Group

Malcolm Thomas explained that the Ventilation Safety Group had a key role here in getting a phased replacement programme going. He said: "With a brand new hospital, there may be 50 ventilation plants installed, all of the same age; you'll have a mountain to climb to replace them all at the 20-year period, so you need to try to split that up somehow, and start looking at the critical ones maybe slightly earlier."

At any time they needed specialist guidance or help, NHS healthcare engineering teams could, of course, call on an Authorised Engineer (Ventilation) – 'people with independent knowledge, totally independent of the Trust/Health Board', and thus 'there to tell you the truth'. He said: "You may not like what your AE (V) says about your ventilation, but they are there to tell you it like it is, so please listen to them. Similarly," he added, "they should be involved in the process of providing plant to advise on what goes in. The reason I say this is – and I've been a hospital engineer – is that your knowledge here will be limited, and it's very easy to be bamboozled by an outside design team into accepting something they think is alright. It may be that what's being proposed is a great solution, but, conversely, it could be that it won't benefit you long term. Authorised Engineers are there to help with those decisions."

Observing standards

Nearing the end of his presentation, Malcolm Thomas said: "There are minimum standards for all plants – as I said at the beginning – and they should certainly be observed. They are there because there are legal requirements about access, cleanliness, and the efficiency of the plant, listed in both Parts A and B; most of the major pieces of legislation that affect and handling ventilation systems, in a hospital or anywhere else. In a hospital, we also have the Medicine Act, and the Health Act, which impose a duty of care on us for our patients and what we do in healthcare settings." These, the speaker said, 'sat alongside' other legislation such as the Health & Safety At Work etc, the COSHH Regulations, *'et al'*.

Lastly, Malcolm Thomas explained, Part B of HTM 03-01 (2021) included a section on 'Verification'. He said: "This requires you to ensure, every year, that the critical systems in your hospitals are still safe to use. They may be getting slightly older, but the things that matter within your ventilation system must still be working correctly, and then there is the annual routine inspection and maintenance. All the standards on these areas have been there for a considerable time, but need to be adhered to."

He added: "So, to conclude, the HTM has been entirely revised, with many changes, and I would encourage all those with a professional interest in, or responsibility for, healthcare ventilation, to read and familiarise themselves with both Parts A and B, including the appendices and the accompanying explanations." With this, he closed his presentation, and invited questions. hej

PUBLICATION - ADVICE AND GUIDANCE

Building Standards technical handbook 2017: non-domestic buildings

Published: **1 March 2017**
Directorate: Local Government and Communities Directorate
Part of: Building, planning and design
ISBN: **978-1-78544-329-9**

The Building Standards technical handbooks provide guidance on achieving the standards set in the Building (Scotland) Regulations 2004 and are available in two volumes, Domestic buildings and Non-domestic buildings. This publication is available in html and also in PDF format (in 'supporting documents').

Supporting documents

Choose section

3.14 Ventilation

Mandatory Standard

Standard 3.14

Every building must be designed and constructed in such a way that ventilation is provided so that the air quality inside the building is not a threat to the building or the health of the occupants.

3.14.0 Introduction

Ventilation of a building is required to maintain air quality and so contribute to the health and comfort of the occupants. Without ventilation it is possible that carbon dioxide, water vapour, organic impurities, smoking, fumes and gases could reduce the air quality by humidity, dust and odours and also reduce the percentage of oxygen in the air to make the building less comfortable to work or live in.

Well designed natural ventilation has many benefits, not least financial and environmental, although it is also recognised that inside air quality can only be as good as outside air quality and in some cases filtration may be necessary. In other cases mechanical systems or systems that combine natural with mechanical (hybrid) may provide the ventilation solution for the building.

Ventilation can also have a significant affect on energy consumption and performance and so thorough assessment of natural, as against mechanical ventilation, should be made, as the decision could significantly affect the energy efficiency of the building (see Section 6, Energy).

Ventilation should not adversely affect comfort and, where necessary, designers might wish to consider security issues and protection against rain penetration prevalent in naturally ventilated buildings when windows are partially open to provide background ventilation.

Reducing air infiltration - improved insulation and 'tighter' construction of buildings will reduce the number of natural air changes but can increase the risk of condensation. However leaky buildings are draughty and uncomfortable. Sealing up air leaks improves comfort and saves energy whilst proper ventilation keeps the indoor air pleasant and healthy. If poor attention to detail occurs air leakage can account for a substantial part of the heating costs. Energy savings from building 'tighter' could make significant savings on energy bills. There is a common perception that 'tight' construction promotes indoor air pollution. However both 'tight' and 'leaky' buildings can have air quality problems. Though air leaks can dilute indoor pollutants, there is no control over how much leakage occurs, when it occurs or where it comes from. BRE GBG 67, 'Achieving air tightness: General principles' provides useful guidance on how to build new buildings tighter.

Conversions - in the case of conversions, as specified in regulation 4, the building as converted shall meet the requirement of this standard (regulation 12, schedule 6).

3.14.1 Ventilation generally

A building should have provision for ventilation by either:

a. natural means, or

b. mechanical means, or

c. a combination of natural and mechanical means (mixed-mode).

Ventilation is the process of supplying outdoor air to an enclosed space and removing stale air from the space. It can manage the indoor air quality by both diluting the indoor air with less contaminated outdoor air and removing the indoor contaminants with the exhaust air. Ventilation should have the capacity to:

- provide outside air to maintain indoor air quality sufficient for human respiration
- remove excess water vapour from areas where it is produced in sufficient quantities in order to reduce the likelihood of creating conditions that support the germination and growth of mould, harmful bacteria, pathogens and allergies
- remove pollutants that are a hazard to health from areas where they are produced in significant quantities
- rapidly dilute pollutant odours, where necessary.

Additional ventilation provision - this guidance relates to the provision of air for human respiration and is in addition to, and should be kept separate from, any air supply needed for the smoke ventilation of escape routes in the case of fire (Section 2, Fire) and for the safe operation of combustion appliances (see Standards 3.21 and 3.22).

There is no need to ventilate:

a. a store room used only for storage that requires a controlled temperature

b. a room with a floor area of not more than $4m^2$. This is not intended to include a domestic sized kitchen or utility room where ventilation should be in accordance with the recommendations in the table in clause 3.14.5.

Ventilation should be to the outside air. However clause 3.14.3 explains where trickle ventilators may be installed other than to the external air.

Calculation of volume - for ventilation purposes, a storey should be taken as the total floor area of all floors within that storey, including the floor area of any gallery or openwork floor. Where an air change rate is recommended, the volume of the space to be ventilated may be required. The volume of any space is the internal cubic capacity of the space. Any volume more than 3m above any floor level in that space may be disregarded.

3.14.2 Natural ventilation

All buildings leak air to a greater or lesser extent. However the movement of uncontrolled infiltrating air through the fabric of a building can cause draughts and can have a significant adverse effect on the energy efficiency of the building as a whole. By improving building techniques it is possible to reduce this infiltrating air to lower levels that can improve energy efficiency (see Section 6 Energy).

Some building techniques may have little effect on air leakage and so allow the uncontrolled infiltrating air to be taken into account in the building's ventilation provision. By building with

techniques designed to reduce air leakage there will need to be a reciprocal increase in the designed ventilation provision to make up for the lower levels of infiltrating air where the designer intends to use low fabric insulation rates of less than 5$m^3/h/m^2$ in the energy assessment (see Section 6 Energy). The areas of trickle ventilation shown may not suffice to maintain air quality and therefore an alternative ventilation solution should be adopted.

Natural ventilation of a room or building should be provided in accordance with the following recommendations:

a. for a room, by the provision of a ventilator with an opening area of at least 1/30th of the floor area of the room it serves, and

- a trickle ventilator with an opening area of at least 4000mm^2, if the area of the room is not more than 10m^2, or
- a trickle ventilator with an opening area of 400mm^2 for each square metre of room area, if the area of the room is more than 10m^2, or

b. for a room in a building constructed with an infiltration rate of 5 to 10$m^3/h/m^2$ at 50 Pa, by the provision of a ventilator with an opening area of at least 1/30th of the floor area of the room it serves, and

- a trickle ventilator with an opening of at least 10000mm^2 if the room is not more than 10m^2, or
- a trickle ventilator with an opening area of at least 10000mm^2 plus an additional 600mm^2 for each square metre of room area if the room is more than 10m^2

c. for a toilet, mechanical extract in accordance with the table to clause 3.14.5

d. for any other building, by following the guidance in:

- Section 3 of BS 5925: 1991 (1995), or
- CIBSE Guide A: 1999, Design data, section A4, Air infiltration and natural ventilation, or
- CIBSE AM10: Natural Ventilation in Non-Domestic Buildings (2005) Applications Manual AM10: 2005.

The options in sub-clause (d) provide more flexible solutions but may require complex calculations.

Wet areas - where a building is naturally ventilated, all moisture producing areas such, as bathrooms and shower rooms, should have the additional facility for removing such moisture before it can damage the building. Additional mechanical ventilation to such areas should be provided in accordance with the table to clause 3.14.5.

Opening height - where rapid ventilation is provided, such as an opening window or windows, some part of the opening should be at least 1.75m above floor level. This will reduce the problems of stratification of air.

3.14.3 Trickle ventilators

A trickle ventilator, sometimes called 'background ventilation', is a small ventilation opening, mostly provided in the head of a window frame, but not always, and is normally provided with a controllable shutter. They should be provided in naturally ventilated areas to allow fine control of air movement. A permanent ventilator is not recommended since occupants like control over their environment and uncontrollable ventilators are usually permanently sealed to prevent draughts.

The trickle ventilator should be so positioned that a part of it is at least 1.75m above floor level. This will allow at least some movement of air within the building and reduce stratification.

Although ventilation should normally be to the external air, a trickle ventilator serving a bathroom or shower room may open into an area that does not generate moisture, such as a bedroom or hallway, provided the room is fitted with a trickle ventilator in accordance with the guidance in clause 3.14.2.

A trickle ventilator should be provided in an area containing mechanical extraction to provide replacement air and ensure efficient operation when doors are closed. This will prevent moist air being pulled from other ‘wet areas’. Pulling moist air from other parts of a building will reduce the further apart the wet rooms are located. The trickle ventilator should be independent of the mechanical extract so that replacement air can be provided when the extract fan is operating. The location of the trickle ventilator and the extract fan should be located to prevent short-circuiting of the air.

3.14.4 Extensions built over existing windows

Constructing an extension over an existing window, or ventilators, will effectively result in an internal room, will restrict air movement and could significantly reduce natural ventilation to that room. Reference should be made to the guidance to Standards 3.21 and 3.22 on the ventilation of combustion appliances, as this may be relevant. There are other recommendations in Section 2: Fire, relating to escape from inner rooms.

A new ventilator and trickle ventilator should be provided to the existing room but, where this is not reasonably practicable, e.g. if virtually the entire external wall of the room is covered by the extension, the new extension should be treated as part of the existing room rather than the creation of a separate internal room. Because an extension will be relatively airtight, the opening area between the 2 parts of the room should be not less than 1/15th of the total combined area of the existing room plus the extension.

If the extension is constructed over an area that generates moisture, such as a kitchen, bathroom, shower room or utility room, mechanical extract, via a duct if necessary, should be

provided direct to the outside air. Any existing system disadvantaged by the work may require to be altered to ensure supply and extracted air are still to the outside air.

3.14.5 Mechanical ventilation

A mechanical ventilation or air conditioning system should be designed, installed and commissioned to perform in a way that is not be detrimental to the health of the occupants of a building and when necessary should be easily accessible for regular maintenance.

Mechanical extract should be provided in rooms where the cubic space per occupant is not more than $3m^3$, and where the rooms have low ceilings and are occupied by large numbers of people.

Mechanical ventilation should be provided in accordance with the following:

a. compliance with guidance in BS 5720: 1979, or

b. compliance with the guidance in CIBSE Guide B: 2001, Installation and equipment data, section B2, Ventilation and air-conditioning (requirements), or

c. for occupiable rooms, where a mechanical air supply is provided at a rate of at least 8 litres/second of fresh air per occupant, based on sedentary occupants and the absence of other requirements such as the removal of moisture, or

d. for domestic-sized rooms where moisture is produced, such as kitchens, bathrooms and sanitary accommodation, rapid ventilation and trickle ventilation should be provided in accordance with the guidance in the following table.

Table 3.9. Mechanical ventilation of domestic-sized kitchens, bathrooms & toilets

Space	Ventilation provision [2]	Trickle ventilation >10 $m^3/h/m^2$	Trickle ventilation 5-10 $m^3/h/m^2$
Kitchen	either: a. mechanical extraction capable of at least 30 litres/sec (intermittent) above a hob [2]; or b. mechanical extraction capable of at least 60 litres/sec (intermittent) if elsewhere [3]	$4000mm^2$	$10000mm^2$
Utility room or washroom	mechanical extraction capable of at least 30 litres/sec (intermittent) [3]	$4000mm^2$	$10000mm^2$

Space	Ventilation provision [2]	Trickle ventilation >10 $m^3/h/m^2$ [2]	Trickle ventilation 5-10 $m^3/h/m^2$ [2]
T ilet	mechanical extraction capable of at least 3 air changes per hour	4000mm^2	10000mm^2

Additional information:

1. The trickle ventilation rates recommended relate to the infiltration rate of the building fabric which can be used in SBEM calculations (see Section 6 Energy).
2. Where the building infiltration rate is designed to be less than 5$m^3/h/m^2$ the trickle vent rates in the above table might not be sufficient to maintain air quality and an alternative solution should be adopted.
3. Long duct runs, flexible ducting and bends can seriously reduce fan performance and should be carefully considered during design to ensure recommended air flows are achieved.
4. Refer to guidance to Standard 3.17 and OFTEC Technical Book 3 where an extract fan is fitted in a building containing an open-flued combustion appliance. Extract rates should be reduced.

Continuous mechanical ventilation - for smaller, domestic sized developments, a mechanical ventilation system complying with BRE Digest 398, 'Continuous mechanical ventilation in dwellings: design, installation and operation' may be appropriate.

Where a mechanical ventilation system gathers extracts into a common duct for discharge to an outlet, no connection to the system should be made between any exhaust fan and the outlet.

Mechanical ventilation should be to the outside air. However it may be via a duct or heat exchanger.

Care should be taken when installing mechanical extract systems where there is an open-flued combustion appliance in the same room or close by. Guidance is given in clause 3.17.8, extract fans.

Cross contamination - an inlet to, and an outlet from, a mechanical ventilation system should be installed so as to avoid contamination of the air supply to the system The inlet to and the outlet

installed so as to avoid contamination of the air supply to the system. The inlet to, and the outlet from, the mechanical ventilation system should be installed in accordance with the recommendations in clause 2.3.3 of BS 5720: 1979.

3.14.6 Control of legionellosis

A mechanical ventilation system should be constructed to ensure, as far as is reasonably practicable, the avoidance of contamination by legionella. The ventilation system should be constructed in accordance with the recommendations of Legionnaires' Disease: The control of legionella bacteria in water systems - approved code of practice and guidance - HSE L8.

The guidance provided in HSE catering sheet No 10, 2000: 'Ventilation of kitchens in catering establishments' provides useful information.

There are additional recommendations in Section 2, Fire where mechanical ventilation systems pass through compartment walls, separating walls and separating floors.

3.14.7 Ventilation of sanitary accommodation

Any area containing sanitary facilities should be well ventilated, so that offensive odours do not linger. Measures should be taken to prevent odours entering other rooms. This may be achieved by, for example, providing a ventilated area between the sanitary accommodation and the other room. Alternatively it may be possible to achieve it by mechanical ventilation or, if the sanitary accommodation is well sealed from a workroom and has a door with an automatic closer, by good natural ventilation.

However no room containing sanitary facilities should communicate directly with a room for the preparation or consumption of food. This does not apply to places of lawful detention, such as integral sanitation in prison cells.

3.14.8 Ventilation of small garages

The principal reason for ventilating garages is to protect the building users from the harmful effects of toxic emissions from vehicle exhausts. Where a garage is attached to a building, designers may wish to consider making the separating construction as air tight as possible. Where there is a communicating door, a lobby arrangement could be considered.

Garages of less than $30m^2$ do not require the ventilation to be designed. It is expected that a degree of fortuitous ventilation is created by the imperfect fit of 'up and over' doors or pass doors. With such garages, it is inadvisable for designers to attempt to achieve an airtight construction.

A garage with a floor area of at least $30m^2$ but not more than $60m^2$ used for the parking of motor vehicles should have provision for natural or mechanical ventilation. Ventilation should be in accordance with the following guidance:

a. where the garage is naturally ventilated, by providing at least 2 permanent ventilators, each with an open area of at least 1/3000th of the floor area they serve, positioned to encourage through ventilation with one of the permanent ventilators being not more than 600mm above

through ventilation with one of the permanent ventilators being not more than 600mm above floor level, or

b. where the garage is mechanically ventilated, by providing a system:

- capable of continuous operation, designed to provide at least 2 air changes per hour, and
- independent of any other ventilation system, and
- constructed so that two-thirds of the exhaust air is extracted from outlets not more than 600mm above floor level.

3.14.9 Ventilation of large garages

A garage with a floor area more than 60m^2 for the parking of motor vehicles should have provision for natural or mechanical ventilation on every storey. Ventilation should be in accordance with the following guidance:

a. Section 3 requirements of CIBSE Guide B2: 2001, Ventilation and air conditioning:

- to give carbon monoxide concentrations of not more than 30 parts per million averaged over an 8 hour period, and
- to restrict peak concentrations of carbon monoxide at areas of traffic concentrations such as ramps and exits to not more than 90 parts per million for periods not exceeding 15 minutes, or

b. Section 4 of the Association for Petroleum and Explosive Administration's "Code of practice for ground floor, multi-storey and underground car parks" and CIBSE Guide B, 1986, Section B2, or

c. By providing openings in the walls on every storey of at least 1/20th of the floor area of that storey with at least half of such area in opposite walls to promote extract ventilation, if the garage is naturally ventilated, or

d. By providing mechanical ventilation system capable of at least 6 air changes per hour and at least 10 air changes per hour where traffic concentrations occur, or

e. Where it is a combined natural/mechanical ventilation system, by providing:

- openings in the wall on every storey of at least 1/40th of the floor area of the storey with at least half of such area in opposite walls, and
- a mechanical system capable of at least 3 air changes per hour.

PREVIOUS
3.13 Heating

NEXT
3.15 Condensation

Was this helpful?

- ○ Yes
- ○ No
- ○ Yes, but

Curriculum vitae

of

James Francis Hilary Humphreys

March 2022

Current Position: **Emeritus Professor of Clinical Microbiology and Senior Clinical Educator**
Royal College of Surgeons in Ireland (RCSI), since 2021

Contents

Personal Details

Date of birth: [redacted]

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Registration and Professional Qualifications

Medical registration: Provisional, June l981, Full, June 1982
Medical Council Number: [redacted]

Degrees and Qualifications: MB BCh BAO (National University of Ireland) 1981
MRCPI 1983, FRCPI 1993
MRCPath 1989, FRCPath 1997
MD (NUI) 1990
FFPath, RCPI 1997
Dip Hospital Infection Control (LSHTM), 2003
FRCPEd 2012
FESCMID 2017 (Fellowship of the European Society of Clinical Microbiology and Infectious Diseases)
DSc (NUI), 2019

Secondary and University Education

Blackrock College, Blackrock, Co. Dublin 1969-1975
Department of Education Scholarship at University College Dublin 1975
University College Dublin 1975 - 1981

Postgraduate Exams and Accreditation

1981: ECFMG and VQE (entrance examinations for USA)
1983: MCC Evaluating Examination (entrance examination for Canada)
1986: Accreditation certificate for General Professional Training from The Royal

College of Physicians of Ireland (RCPI)
1991: Registration of Specialist Training from the General Medical Council, UK
2001: Registration of Medical Specialist (Microbiology), Medical Council, Ireland

Previous Appointments

Junior House Officer/Intern 1981 - 1982
The General Hospital, Portlaoise, Co Laois and
St. Vincent's University Hospital, Elm Park, Dublin.

Senior House Officer, 1982-1985
St. Vincent's University Hospital, Dublin, Medical Rotation
The Mater University Hospital, Dublin, Medical Rotation
Microbiology Department, St. James's Hospital, Dublin.

Registrar
1985 – 1987 Microbiology Department, St. James's Hospital, Dublin,
Clinical Assistant at the Department of Genitourinary Medicine, Sir Patrick Dun's Hospital and St. James's Hospital, Dublin.

Senior Registrar
1987 - 1991: Microbiology Departments at the Bristol Royal Infirmary and Southmead Hospital, Bristol, UK.

Senior Lecturer and Consultant Microbiologist
November 1990-December 1990: University of Bristol (locum)
April 1991-February 1997: University Hospital & Public Health Laboratory, Queen's Medical Centre, Nottingham

Consultant Microbiologist
February 1997-July 1998: Federated Dublin Voluntary Hospitals and subsequently re-named as Tallaght Hospital
2010-2019: National Methicilin-Resistant *Staphylococcus aureus* (MRSA) Reference Laboratory, St James's Hospital, Dublin, Ireland

Professor of Clinical Microbiology, Head of Department and Consultant Microbiologist
August 1998-August 2021, the Royal College of Surgeons in Ireland (RCSI) University of Medicine and Health Sciences and Beaumont hospital, Dublin.

Committee and Management Activities

Previous Membership
British Standards Institute, HCC/67, Sterilization of medical devices, 1995-1996
Pathological Society of Great Britain and Ireland, Committee Member, 1997- 1999
Preventing Hospital Acquired Infection, Advisory Group. Wolfson Institute of Health Sciences, Thames Valley University, London 1998 -2000
Education, Scientific and International Affairs Committee, Association of Medical Microbiologists, 1998-2002
Irish Medicines Board, Expert Sub-Committee of the Advisory Committee for Human

Medicines, 1998-2002.
Steering Group for Irish National Survey of MRSA 1998 – 2000
European Council of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID), 1998-2004
Healthcare (Hospital) Infection Society (HIS), Council Member, 1994-96, 2002-2004, 2011-2013
HIS 5th, 6th, 7th & 8th International Conferences, Scientific Committees 2002 –2012
Joint Working Party of the HIS, British Society for Antimicrobial Chemotherapy (BSAC) & Infection Control Nurses Association (ICNA) on MRSA, BSAC nominee, 1995-1998
UK MRSA Working Party (HIS/BSAC/ICNA)
Member/Chair (Prevention and Control Sub-group), 2002-06
Working Party on Infection Control and the Operating Theatre (Chairman) 1999 –2004
HIS/ICNA National Prevalence Survey of Healthcare-Associated Infection (HCAI), Steering Committee, 2005-7
HIS 9th International Conference 2014, 2012-2014 (Chair)
HIS Scientific Development Committee, 2010 – 2016
HIS Working Group on Surveillance and Neurosurgical Infections, 2012 – 2016
HIS MRSA Guidelines Working Group, 2018-21
Health Protection Surveillance Centre, Dublin.
European Antimicrobial Resistance Surveillance System Steering Group, 1998 - 2006
Viral haemorrhagic fever sub-committee, 1999-2000
CJD Infection Control Sub-Committee, 2000-2004
Invasive Group A Streptococcal Infections Sub-Committee, 2005-2006
Strategy for the control of Antimicrobial Resistance in Ireland (SARI),
National Committee (Chair), 2002-2008
Infection Control Sub-Committee (Chair), 2002 -2007
SARI Healthcare Building Standards Sub-Group 2007 –2008
Health Services Executive (HSE)
HCAI Governance Committee 2007-2008
SARI Surveillance of MRSA in ICU Sub-Group 2007-2011
SARI Committee to update National Guidelines on MRSA (Chair), 2010 – 2013
Health Information and Quality Authority, National Standards for Infection Prevention and Control Working Group 2007-2008
RCSI/RCPI Working Group on Prevention of Surgical Site Infection, 2012 –2013
Department of Health, National Clinical Effectiveness Committee (Chair), 2010 – 2016

Microbiology Training Committees & Other Activities

Royal College of Pathologists, London, Microbiology Examination Committee, 2000-2005
National Specialty Director in Microbiology (Irish Committee for Higher Medical Training, RCPI), 2001 – 2005
Microbiology Specialty Training Committee (Chair) 2002 – 2005
Trainer in Microbiology (Beaumont Hospital) 2002 –2022
Convenor & organiser of a day session as part of Diploma in Hospital Infection Control (Health Protection Agency, Hospital Infection Society and London School Hygiene & Tropical Medicine), 2005-2011
European Society of Clinical Microbiology & Infectious Diseases (ESCMID), Professional Affairs Sub-Committee, 2011 – 2015
European Society of Clinical Microbiology & Infectious Diseases (ESCMID), Professional Affairs Sub-Committee, 2011 – 2015
Carbapenemase-Producing Enterobacteriaceae Expert Group (Chair), Health Service

Executive (Ireland) 2017- 2020
Providing a Roadmap for Automated Infection Surveillance in Europe (PRAISE), 2019-21

Current Membership
The Royal College of Pathologists, Examiner 2003 -
European Study Group on Nosocomial Infections (ESGNI), Treasurer, 2016 –
HIS, President, November 2017-
HIS/ESGNI Working Group on Operating Theatre Rituals and Behaviours, Chair, 2018-
Health Service Executive Infection Prevention and Control Advisory Group, 2021-
HIS 40th Celebration Scientific Meeting, Steering Committee (Chair), 2017-2022

Involvement with the RCPI & RCSI

RCPI

Collegiate Members Committee

	1984-1987	Member
	1985-1987	Editor of Collegiate Members Newsletter. Collegiate Members representative on the Education and Examination Committee.
	1985-1986	Convener of Clinical Clubs
Council	2008-2018	Member
	2008- 2010	Censor
	2012-2013	Vice-President

Credentials Committee 2014 – 2017 Chair
2008- 2011 Chair of Healthcare-Associated Infection Policy Group
2012 Member, RCPI College, Improvement Programme Advisory Group
2016- Fellowship Governance Working Group
2017- Industry Sponsorship & Support Working Group

Faculty of Pathology

1999-2005	Education & Training Sub-Committee
2000-2004	Board Member
2003-2004	Vice-Dean
2011-2012	Board Member & Vice-Dean
2014-2020	Board Member
2015-2016	Vice-Dean
2016-2019	Dean

RCSI

2013- 2016 Vice-Director for Research (to promote translational research and clinical involvement)

Recent Courses Attended (excluding for CME/CPD)

2000 Slice of Life (Multi-media techniques in medical education), Salt Lake City,

USA

2007 Supervisor (Research) Training Workshop, RCSI, May
Being an effective educational supervisor, RCPI, September

2008 Endnote Reference Manager, RCSI, April
Multiple Choice Question (MCQ) Item Writing Workshop, RCSI, April

2009 An introduction to Cochrane Systematic Reviews (UK Cochrane Centre/ Health Research Board)

2012 Healthcare Provider Basic Life Support, Beaumont Hospital
European Point Prevalence Survey of HCAI and Antibiotic Use – Training Workshop
Microsoft PowerPoint 2009, level 1

2015 Royal College of Pathology, Examination Training Day
Ebola and the UK. What did we learn, and what action must we take?
Healthcare Providers Basic Life Support, Beaumont Hospital

2016 RCSI – Setting learning objectives
RCSI – Peer review teaching

Publications

Theses, Books and Chapters

MD

"Clinical and laboratory aspects of *Staphylococcus aureus* septicaemia in Dublin hospitals." National University of Ireland, 1990.

DSc

“The epidemiology, pathogenesis and control of *Staphylococcus aureus*, including MRSA.” National University of Ireland, 2019.

Books

Humphreys H, Irving WL. Problem-orientated clinical microbiology and infection. Churchill Livingstone, Edinburgh, 1996 (1st edition).

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17. Cheng C, **Humphreys H**, Kane B. Transition to telehealth : Engaging medical students in telemedicine healthcare delivery. *Irish Journal of Medical Science* 2021 Oct 9:1–18. doi: 10.1007/s11845-021-02720-1. (Review)

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Royal College of Physicians in Ireland Policy Group on Healthcare-Associated Infection.

- Antibiotic use and the implication for Healthcare-Associated Infection, February 2009.
- A response to the Health Infection and Quality Authority (HIQA) Infection Prevention and Control Standards Statement, May 2009.
- How to advise patients with a HCAI-Guidance for healthcare workers dealing with patients and members of the public, June 2009.
- Healthcare-associated infection and nursing homes or extended care settings, February 2010.
- Healthcare-associated infections in patients with cancer; identify the risks and implement preventative measures, June 2010.
- Advice on the prevention and control of infection for hospital visitors and patients discharged from hospital, February 2011.
- Healthcare-associated infection; What all doctors must know and do, June 2011.

Other Academic Activities

Editorial Board Member	Journal of Medical Microbiology (1994-2001)
	Clinical Microbiology and Infection, 2003 – 2010
Assistant Editor	Journal of Hospital Infection 2009 - 2015
Editorial Advisory Board	Journal of Hospital Infection 2011 - 2015
International Editorial Board	Journal of Hospital Infection 2016 -

Journal Referee	Journal of Antimicrobial Chemotherapy
	Microbial Ecology in Health and Disease
	Journal of Infection
	Journal of Hospital Infection
	Annals of the Rheumatic Diseases
	Epidemiology and Infection
	Public Health
	Clinical Drug Investigation
	Lancet
	Journal of Bacteriology
	Journal of Clinical Microbiology
	American Journal of Infection Control
	Infection Control and Hospital Epidemiology
	Lancet Infectious Diseases

The Scottish Government

SCOTTISH CAPITAL INVESTMENT MANUAL

Supporting Guidance:

Design Assessment in the Business Case Process

5 July 2011

DESIGN ASSESSMENT IN THE BUSINESS CASE PROCESS

Introduction

From the 1st July 2010 an assessment of design quality will become part of the business case approval process. This guidance should be viewed as part of the Scottish Capital Investment Manual (SCIM) notified through NHS CEL 19 (2009).

This guidance describes:

- how design standards should be established for projects,
- the Board's role in assessing progress in achieving design standards ,
- the design assessment process,
- submission requirements at each business case stage.

The Scottish Government Health Directorates' purpose in developing and implementing this process is to ensure that the outcomes of development projects meet the Government's objectives and expectations for public investment. Mapping design into the business case is intended to improve the level of design quality achieved across NHSScotland and the outcomes realised through this. The process described aims to promote a culture of continuous improvement by facilitating learning from, and projects that build upon, the best of what has gone before.

Although the full process described below, and the requirement to refer projects to the NHSScotland Design Assessment Process, applies only to projects that are to be considered by Capital Investment Group (CIG), it is intended and expected that Boards will develop 'design statements' and utilise the self assessment methodologies described below on all development projects.

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SECTION 1 - DESIGN ASSESSMENT IN THE BUSINESS CASE PROCESS

There are two complimentary areas of consideration in the design of healthcare buildings. These can broadly be described as healthcare specific design aspects – the areas generally covered by guidance issued by Health Facilities Scotland - and general good practice in design considering the human experience of being in and around buildings, sustainability and the effective and efficient use of resources directed towards achieving whole life value for money. These are brought together in this process, and in the collaboration of HFS and A+DS in the NHSScotland Design Assessment Process, by the means described below.

1.1 Compliance with Healthcare Design Guidance

A Policy on Design Quality for NHSScotland requires that:

"*The SGHD must provide guidance on compliance with those aspects of statutory and mandatory requirements which are particular to the procurement, design and delivery of healthcare buildings and guidance on best practice. This will be effected through the support to be provided by Health Facilities Scotland and Architecture and Design Scotland under the tripartite working partnership with SGHD*."

Accordingly projects submitted to the Capital Investment Group (CIG) for business case approval will be assessed for compliance with current published guidance. To facilitate this, Boards will be requested to submit a comprehensive list of the guidance that they consider to be applicable to the development under consideration (see inset on next page), together with a schedule of derogations that are required for reasons specific to the project's particular circumstances.

Projects submitted for the business case process will be assessed for compliance with the following:

a) Healthcare guidance:

Scottish Health Planning Notes (SHPN)	Health Facilities Scotland
Scottish Health Technical Memoranda (SHTM)	Health Facilities Scotland
Scottish Health Facilities Notes	Health Facilities Scotland
Health Building Notes (HBN)	Dept of Health Estates and Facilities Division
Health Technical Memoranda (HTM)	Dept of Health Estates and Facilities Division
Health Facilities Notes (HFN)	Dept of Health Estates and Facilities Division

Where there is a current SHPN or SHTM relating to a subject then it takes precedence over the equivalent HBN or HTM. Where there is no Scottish version of a document the English document can be used. For further information on the available documents refer to the Scottish Health Planning Guidance: Reference Guide. Currently Scottish guidance can be obtained in the publications section of the HFS web site and English guidance can be obtained on the Knowledge and Information Portal (KIP). A new web site, Space for Health, is under development and will replace both of these sites.

Best practice dementia and equality design guidance

b) Statutory requirements
Planning permission
Building Regulations compliance
Disability Discrimination Act compliance
Construction (Design and Management) Regulations compliance

c) Other mandatory requirements
BREEAM Healthcare (BRE Environmental & Sustainability Standard) www.breeam.org
Achieving Excellence Design Evaluation Tool (AEDET): www.dh.gov.uk
Activity Data Base (ADB): www.adb.dh.gov.uk

The NHSScotland Design Assessment Process will then make an assessment of the design information available each business case stage for compliance with the guidance. Details of the submission requirements for each stage are included in Appendix A and, the pro-forma* for submission are included in Appendix B. *(*although this is a protected document the proforma has editable regions)*

1.2 Design Statements and their role in assessment of design standards

Purpose of the Design Statement

The development of a Design Statement is intended to assist NHSScotland Boards in using good design to get the most out of their development projects. **These project specific Design Statements should both link into and inform the further development of the Boards Design Action Plan which sets the strategy for all the Board's developments.** The Design Statement is a means of setting out the Board's objectives for an individual project in a series of agreed statements of intent and then defining a benchmark for how the physical result of the project will help deliver those objectives. The benchmarks should not require a pre-determined design outcome, but provide the parameters for what success might look like. The third part of the Design Statement is a plan of action for how the objectives and benchmarks established for the project will inform key decisions throughout the project

including the development and consideration of the business case, and the eventual evaluation of the project's success.

Guidance on the form and content of a 'Design Statement' is included at Appendix C, some help in developing the 'non negotiable is included in Appendix D. Example Design Statements are included at Appendix E as a illustration of the anticipated scope and content of the developed document.

It is proposed that the Design Statement should be the first design control document produced for the project which can, and ideally should, also be used as:

- **a briefing tool**: to describe the design intention, or design vision (perhaps being included in the HLIP), and subsequently be developed into the design brief, supplemented by more detailed briefing materials such as schedules of accommodation, key adjacencies and room data sheets as and when prepared. This area of briefing has been identified as frequently underdeveloped and therefore the introduction of Design Statements is intended to address this.
- **a communication tool**: to communicate the direction of the project to stakeholders and allow some early view of the benefits to assist both in building momentum, obtaining buy-in and in allaying the concerns that often accompany the commissioning of a new facility.
- **a promotional tool**: to stimulate interest in the market in the direction and viability of the project; and to motivate the market to bring its best and most appropriate skills to the table.

The Design Statement in Business Case Approvals Process

The Design Statement, which is to be produced by the Boards for each project prior to the submission of the Initial Agreement (IA), is central to the consideration of design matters within the business case approvals process as it is this document that establishes the design criteria against which the project will be assessed.

The benchmarks set by the Board will also be assessed to ensure that they are in line with the expectations established in national policy. Three Example Design Statements (for different scales and natures of project) are included in Appendix E as guidance on the form and nature of Statements that are expected and to guide boards on the level of benchmarks that will be considered acceptable.

Project teams are advised to discuss, with the NDAP, the draft version of the Design Statement in development where it is likely to differ significantly from one of the example statements, or one approved previously. Assistance may be available from A+DS to help the team develop the statement.

1.3 Referral to the NHSScotland Design Assessment Process

Health Facilities Scotland (HFS) and Architecture and Design Scotland (A+DS) will provide support to Boards in considering design matters in the

business case process. Staff from HFS and A+DS, supported as necessary by a broader panel, will have the following roles in relation to all projects that are to be assessed:

- to advise the project team if the standard of benchmarks and self assessment process being established for the project are in line with policy objectives.
- to provide an assessment of the design aspects of the project to support the Board in their consideration of the business case.
- to provide a verification, to the Capital Investment Process (CIG), of the opinion previously given to the Board to support the CIG's consideration of the business case.

The purpose of this resource is to provide support on matters relating to design policy, functionality and healthcare design guidance. The assessment considers the general areas of design being addressed by the project team as a high level verification for the Board and the CIG, as such it should not be seen as a replacement for the project team's in-depth consideration of technical and other standards. Further, the assessment does not provide assurance of the acceptability of the proposals to the Planning or Building Control Authorities. However the opinion given will inform any comment made by A+DS in the planning process (as part of A+DS's Design Review function in the Planning System) and may be used by project teams as evidence of consultation and, where appropriate, in support of their applications.

Referral to NHSScotland Design Assessment Process

Section 2 describes the assessment process and Appendix A gives the submission requirements at each stage of the business case.

Submissions should be made to:

NHSScotland Design Assessment Process
c/o Director, Health Facilities Scotland
3rd Floor, Meridian Court
5 Cadogan Street, Glasgow G2 6QE
Tel: 0141 207 1600 Fax: 0141 221 5122
nss.hfsdesignassessment@nhs.net

It is recognised that different projects and different Boards will require different lead in periods from the point of consultation to the submission to the Capital Investment Group (see CIG timetable on www.pfcu.scot.nhs.uk/CIG.htm). Therefore In order to provide the above services in a timely manner project teams are advised to establish an early dialogue with HFS and keep them informed of the project programme and key dates. Teams are also encouraged to maintain the dialogue, particularly at key design development points, rather than waiting always until the formal reporting points in the business case, to ensure that risks can be identified and addressed timeously.

Support and advice is available from HFS and A+DS staff, contact in the first instance should be with:

Peter Henderson, Principal Architect
Property and Capital Planning
Health Facilities Scotland
NHS National Services Scotland
3rd Floor, Meridian Court
5 Cadogan Street
Glasgow G2 6QE
T: [redacted] F: 0141 221 5122
[redacted]

For support and advice on the development of Design Statements see www.healthierplaces.org and contact A+DS directly:

Healthcare Design Team
Architecture and Design Scotland
Bakehouse Close
146 Canongate
Edinburgh EH8 8DD
T: 0131 556 6699 F: 0131 556 6633
health@ads.org.uk

1.4 Transitional Arrangements

This guidance shall apply to all projects submitted for approval of the Initial Agreement (IA) after 1st July 2010. Projects that have not received approval of their Outline Business Case (OBC) by 1st July 2010 shall be considered for the assessment process on a case by case basis, as part of the initial pilot phase, however the development and demonstrated application of a Design Statement should be considered as good practice for all projects from publication of this guidance.

SECTION 2 - NHSSCOTLAND DESIGN ASSESSMENT PROCESS

General Principles

The NHSScotland Design Assessment Process, for all projects over the delegated value, sits in an advisory role to decision makers in both the commissioning Board and in the Capital Investment Group within the Scottish Government Health Directorates. The service is provided to Health Boards at no cost to the board.

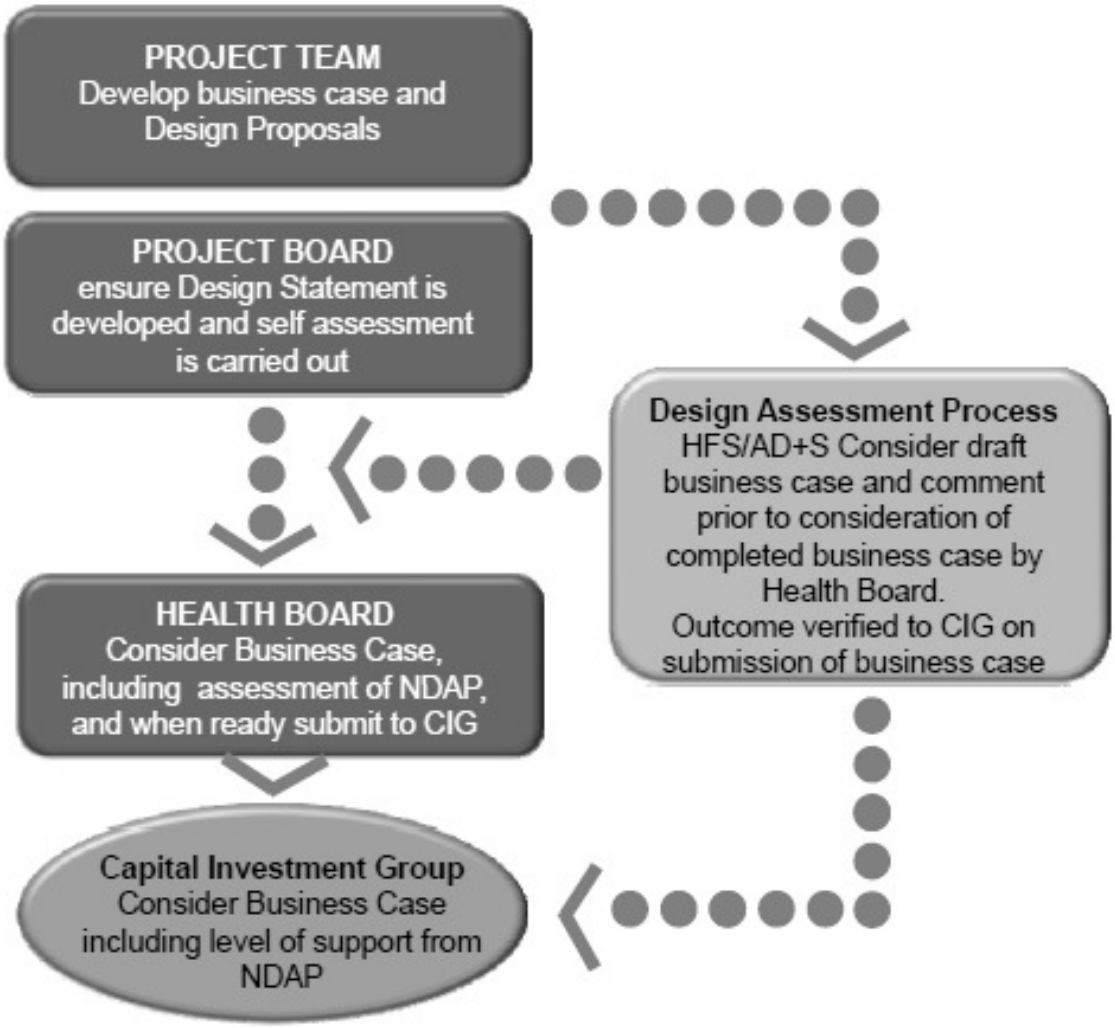

Fig. 1 : Flow diagram showing position of NHSScotland Design Assessment Process consideration in the Business Case Approvals Process ; this diagram applies to IA, OBC and FBC stages.

Types of Assessment and Timescales

There are two methods of assessment in order to provide a response at formal reporting points.

- Desktop assessment by staff at HFS and A+DS based on submitted information, supplemented by conversations with project team to clarify any matters.
- Panel assessment, based on submitted information and supplemented by presentation by, and discussion with, the project team including designers.

All schemes at IA will be viewed as a desktop assessment. Some schemes at OBC and/or FBC stage will be taken to a larger panel. If this is anticipated it will be notified to the Board in the response to the IA or OBC submitted previously. Teams are encouraged to maintain a dialogue between these reporting points to ensure that risks can be identified and addressed timeously.

Notification Period : the notice given by the Board to HFS that a scheme is to be submitted to the NDAP to allow resources to be allocated to allow timeous turn-around.

- desktop assessment: 14 days .
- panel assessment: 28 days. Information must be submitted one week in advance of the panel assessment to allow the panel to digest and prepare.

Period of consideration (from receipt of information to issue of response to Board) **:** This is dependent on the scale of group required to consider the proposals.

- desktop assessment: 14 days unless extended discussions become necessary.
- panel assessment: 21 days from receipt of draft information = circa 14 days from panel discussion.

NB: Faster turn-around may be possible by prior consultation, and a verbal response will be provided at any panel meeting to allow work to progress whilst the paperwork is being done.

Boards should ensure that the consultation is sought in a timeous manner to allow the response to be considered within the board's development of the business case; prior to completion of the business case stage and the subsequent submission to the CIG.
(See CIG timetable www.pfcu.scot.nhs.uk/CIG.htm).

Notification and Submission Process

Notification
Notification using the form included at Appendix B should be sent by e-mail to:

nss.hfsdesignassessment@nhs.net

Submission
The completed submission proforma (see appendix B) and 2 electronic copies (on CDs) of the stage specific information (see appendix A) should be submitted to:

NHSScotland Design Assessment Process
c/o Director, Health Facilities Scotland
3rd Floor, Meridian Court
5 Cadogan Street, Glasgow G2 6QE
Tel: 0141 207 1600 Fax: 0141 221 5122

Response by NHSScotland Design Assessment Process to the Board

The outcome of the assessment will be encapsulated in a brief report to cover the following areas:

Joint Statement of Support (one of following options):

- **Supported :** this may include recommendations as follows:
    - **Essential Recommendations:** those areas requiring amendment or alteration in order to meet either national guidance or established benchmarks but which, in the opinion of the panel, can be amended without significant re-working. The Board will be required to submit agreed evidence to the panel before the 'supported' statement will be verified to the CIG.
    - **Advisory Recommendations:** areas of potential for further improvement for the boards consideration, including notes on aspects which (though not falling short of standards set in the design statement) are potential risks in relation to the development planning process .
    - **Notes of potential to deliver good practice:** where the panel sees that the project is demonstrating the potential to deliver best practice in a particular area of design this will be noted.

- **Unsupported :** this will include a statement of the areas of concern that leads the panel to consider that the project is likely to fall seriously short of either the benchmarks set by the Board, the standards established for healthcare buildings, or the expectations established in national policy (i.e. if the benchmarks established by the board do not address significant areas of policy or are low). Such areas of concern are considered, by the panel, to require significant reworking or reconsideration and are therefore unable to be resolved using the 'essential recommendations' above.

Next Stage Process : the notification required for the next assessment stage and the methodology of assessment that will be applied which will vary depending on the scale and complexity of the project.

Where a project is 'unsupported' it is anticipated that a further dialogue will be established to promote improvement in the areas identified. An amended submission, addressing these areas, would allow the report to be updated and the support status amended prior to progressing the project further through the business case process and prior to any verification to CIG.

Interaction with Capital Investment Process Considerations

HFS will notify the CIG when the process is completed and verify, to the CIG, the recommendation given to the Board. The submission sent, by the Board, to the Capital Investment Process (CIG) should include the information sent previously to the NHSScotland Design Assessment Process (NDAP) and the response received.

In considering the business case the CIG will take the NDAP's response into consideration as follows:

- Supported with no qualifications : CIG can approve.
- Supported with Essential or Advisory Recommendations : Evidence of how the identified issue is being addressed will be required prior to CIG approval.
- Supported with notes of potential to deliver good practice : CIG can approve
- Unsupported : CIG will not approve.

Post Occupancy Evaluations submitted to the CIG should be copied to HFS to inform the assessment process. For projects that have been developed with the use of a 'design statement' the evaluation at POE should include an assessment against the benchmarks in the Design Statement.

Publication of Key Project Information

SGHD requires Boards to publish the outcome of Business Cases within one month of the CIG meeting. After the business case is in the public realm; key information submitted to the Design Assessment Process will be added to the NHSScotland Project Resource (Pulse) on the Healthier Places website www.healthierplaces.org .

The published information will include key project details, selected images and design documents such as the design statement. This is to aid briefing, shared learning between boards and to raise the profile of NHSScotland's developing estate. See Page 20 for further details on the web-based resource.

APPENDIX A - NDAP SUBMISSION REQUIREMENTS

Below are the anticipated submission requirements at the key reporting points. However, teams are encouraged to maintain a dialogue with HFS and A+DS staff through key decision points in the development of the emerging project to ensure that risks can be identified and addressed timeously.

INITIAL AGREEMENT

STAGE : Late in the IA process when a building project appears to be a serious possibility.

Methodology : Desktop assessment based on submitted information, supplemented by conversations with project team to clarify any matters.

Submission requirements

- Completed submission proforma identifying key contacts and dates.
- Design Statement in line with the enclosed guidance, and a note of the persons (name and role) involved in the development of the statement – i.e. those stakeholders represented in the development of both the agreed non-negotiables and the benchmarks.[1]
- Commitment to BREEAM Healthcare

OUTLINE BUSINESS CASE

STAGE : Early in the OBC process an informal consultation on site selection and strategic briefing considering:

- Site Feasibility Studies or Masterplan. Where a project is one of a series being considered for a site, a masterplan will be required to demonstrate the potential interaction of projects.
- analysis of site option(s) in terms of potential for achieving the project's non-negotiables criteria and benchmarks established in the design statement and the inherent design risks (i.e. where the site presents difficulties in achieving the benchmarked standards).
- List of relevant design guidance to be followed – SHPNs, SHTMs, SHFNs, HBNs, HTMs, HFNs, Activity Data Base (see section 1.1).
- Evidence that Activity Data Base (ADB) will be fully utilised during the preparation of the brief and throughout the design and commissioning process

STAGE : Late in the development of the OBC, when the design is becoming formed but is still open to influence – consultation and response to use in Business Case Stage.

[1] Project teams are advised to discuss, with the NDAP, the draft version of the Design Statement in development if it is likely to differ significantly from one of the examples or from one developed and approved previously. Some assistance may be available from A+DS in developing these statements.

Methodology : One of the following – as advised in the response to IA submission.

- Desktop assessment based on submitted information, supplemented by conversations with project team to clarify any matters.
- Panel assessment, based on submitted information and supplemented by presentation by, and discussion with, project team including designers.

Submission requirements

For all projects

- Completed submission proforma identifying key contacts and dates.
- Design Statement , with any updates in benchmarks highlighted.
- Evidence of completion of self assessment on design in line with the procedures set out in the design statement.
- Completed AEDET review at current stage of design development.
- Evidence of consultation with Local Authority Planning Department on their approach to site development and alignment with Local Development Plan.
- Extract from draft OBC detailing benefits and risks analysis (appendix 3 in SCIM).
- Photographs of site showing broader context.
- BREEAM assessment.
- Evidence that DDA compliance will be achieved
- Evidence that Activity Data Base (ADB) is being fully utilised during the preparation of the brief and throughout the design and commissioning process
- Updated list of relevant design guidance to be followed (see section 1.1) and schedule of any derogations in relation to these.

For capital investment schemes and projects likely to go through hub, the following information

- Developed brief.
- Outline design study showing site strategies considered and favoured development option (approaching RIBA Stage C design). Building plans should be rendered to distinguish between main use types (circulation, consult, etc) so that orientation and aspect of areas can be considered.
- 3D sketches of design intent for key spaces identified in Design Statement.

For NPD schemes, the following information

- Developed Conventionally Procured Asset Model in line with guidance.

FULL BUSINESS CASE

STAGE : Late in the development of the FBC, when the design is becoming formed but is still open to influence.

Methodology : One of the following – as advised in the NHSScotland Design Assessment Process's response to the OBC submission:

- Desktop assessment based on submitted information, supplemented by conversations with project team to clarify any matters.
- Panel assessment, based on submitted information and supplemented by presentation by, and discussion with, project team including designers.

Submission requirements

For all projects

- Completed submission pro-forma identifying key contacts and dates.
- Design Statement , with any updates in benchmarks highlighted.
- Evidence of completion of self assessment on design in line with the procedures set out in your design statement.
- Extract from draft FBC detailing benefits and risks analysis (appendix 3 in SCIM).
- Completed AEDET review at current stage of design development.
- 3D sketches of design proposals for key spaces identified in Design Statement.
- Updated list of relevant design guidance to be followed (see section 1.1) and schedule of any derogations in relation to these.
- Evidence that DDA compliance will be achieved
- Evidence that Activity Data Base (ADB) is being fully utilised during the preparation of the brief and throughout the design and commissioning process

For capital investment schemes and projects likely to go through hub, the following information is required to allow the panel to establish that the developed proposals are living up to the promise of the outline proposals at OBC stage and that the technical matters are being addressed.

- Developed design (Stage E) : main drawings only (construction details need not be submitted) including
  - Site layout showing wider context and landscape proposals
  - Plans rendered to distinguish between use types (circulation, consult)
  - Elevations showing design in context
- 3D visualisations of the building in context - perspectives should be constructed from a human eye height (rather than birds eye views).
- Confirmation of Planning Permission and Building Regulation compliance.

For NPD schemes, the following information.

- Design proposals from the Preferred bidder
- Site layout showing wider context and landscape proposals
- Plans rendered to distinguish between use types (circulation, consult)
- Elevations showing design in context
- 3D visualisations of the building in context - perspectives should be constructed from a human eye height (rather than birds eye views).
- Evidence of consultation with Local Authority Planning Department on their approach both to site development and the strategy adopted by the preferred bidder.

APPENDIX B – SUBMISSION PRO-FORMA

NHSSCOTLAND DESIGN ASSESSMENT PROCESS : NOTIFICATION & SUBMISSION PRO-FORMA

PROJECT NAME	
NHSScotland Board	
Other client partners (such as Local Authority)	
Business Case Stage	IA/OBC/FBC
Type of assessment anticipated*	Desktop / panel
Client Contact Person who can respond to queries during consideration period	Name Phone e-mail
Additional Contact Such as the lead designer or design manager (if applicable)	Name Phone e-mail
Procurement route (if known)	
Project Website (if available)	
Key dates	
• Target date for business case to be submitted to own Board	
• Target date for business case to be submitted to CIG	
• Date notification submitted to NDAP	
• anticipated/actual date Information submitted to NDAP	
• (if applicable) pre-agreed date for panel assessment	
• Date response needed from NDAP	
Any other relevant information	

Complete sections highlighted grey (as a minimum) at time of **notification** and send by e-mail to
nss.hfsdesignassessment@nhs.net

Complete all sections when to accompany **submission information** to:
NHSScotland Design Assessment Process, c/o The Director, Health Facilities Scotland
3rd Floor, Meridian Court, 5 Cadogan Street, Glasgow G2 6QE

* IAs will be desktop, thereafter as advised in previous response.

KEY INFORMATION SUBMITTED TO THE DESIGN ASSESSMENT PROCESS WILL, AFTER THE BUSINESS CASE IS MADE PUBLIC, BE USED IN THE NHSSCOTLAND PROJECT RESOURCE : www.healthierplaces.org

APPENDIX C - GUIDANCE ON THE DESIGN STATEMENT

The Design Statement sets out your approach to the project and how it will be delivered. The Design Statement should have three basic elements:

- **The Non-negotiables**[2]
- **The Benchmarks**
- **The Self Assessment Process**

Three example design statements are included at Appendix E.

DESIGN STATEMENT ELEMENTS – THE NON-NEGOTIABLES

As we use buildings, for the most part, to house and support human activity, the Design Statement is built around the needs of the people who the facility will directly impact upon and whole life value for money. It is then expanded to consider the elements needed to deliver on the broader responsibilities of using public money – that of addressing local and national needs – for the public purse to achieve **economies of benefit**[3].

Fig 2 People and Policy Areas for the 'Non-negotiables'

These are incorporated into the Design Statement by establishing, early in the project's development, **agreed** statements that give the core objectives of the project: **non-negotiables** that all key stakeholders can sign up to that derive from and articulate the Investment Objectives. These are the fundamental

[2] Equivalent to Critical Success Factors (SCIM)
[3] Economies of benefit is about getting the most benefit from the money that has to be spent. i.e. if a health and social work centre is to cost £9m, then how can we spend that £9m of public money to do more than build good consulting rooms and a nice waiting space by also to contributing to local regeneration and sustainable economic growth.

aspects that define the success of the scheme - the criteria which, if you cannot achieve them, will seriously call into doubt the viability of the project.

It is anticipated that the non-negotiables will be established and agreed by the Project Board to encapsulate a broad consensus - from a range of points of view, from strategic planners to those with a more intimate and ongoing relationship with the proposed facility - rather than be written by one person. Appendix D suggests a series of questions that might be helpful in debating the non-negotiables with key stakeholders. Once established, these non-negotiables encapsulate an agreed direction and as such can help resist incremental change in the brief due to external pressures or subjective opinions.

DESIGN STATEMENT ELEMENTS – THE BENCHMARKS

One of the strategies that could bring real change, but which the public sector generally under-utilises, is benchmarking developments. The private developer knows that it has to surpass its competitor to obtain market advantage. The advantage to the public sector is less clear as we have yet to fully use the lessons learnt through POE's to understand the impact of a good design on the people and policy factors described previously. However benchmarking against the best and most relevant that NHSScotland and its sister bodies have delivered, and in doing so learning from the work of others, is perhaps the single most helpful tool available to improve both the standard of care environment and the image of the NHS in the community.

Methods of benchmarking

There are three basic ways of benchmarking.

- **Number** - by giving a numerical minima or maxima
  ...the entrance space must be at least 100m^2 in area
- **Relative** - by describing how you want it to be different to something that already exists
  ...the entrance space should be much bigger than the one in the current facility...
- **Comparator** - by pointing to something you want it to be like
  ...the entrance space should be like the one provided elsewhere ...

Each of these has its benefits and pitfalls in terms of the extent of description and even prescription given to the designer and therefore this must be balanced in the methods and skills being employed to assess if this benchmark is being achieved. When setting a benchmark by using a comparator it is important to bear in mind that the purpose of choosing comparators is not to choose a predetermined design solution; it is to provide an example (or better still a range of examples) of 'what success might look like'.

The setting of benchmarks requires an understanding of what has gone before, and this is likely to require the project team to do some research and

carry out site visits to learn from what others have done. As an initial step into this there are a number of web resources that can be used for scoping and as a source of reference projects or criteria. The most likely to be relevant are:

Healthier Places - www.healthierplaces.org

This website has been commissioned by SGHD, HFS and A+DS to house information on good healthcare design to assist boards in brief development and to raise awareness of the good practice being developed and delivered across NHSScotland and elsewhere. In addition to providing guidance on the development of 'design statements', and articles on healthcare design topics, the website holds a project resource (called 'pulse') that can be used in two main ways:

- **Search by project type :** to find out about recent and current developments in NHSScotland, and elsewhere, that are of a similar type to the one being considered by the client team. This will provide basic details on the project, the key team members involved and images where available. Key design documents, such as the 'Design Statement' and Post Occupancy Evaluations will be included once they are in the public realm to allow greater learning from what has gone before. It is envisaged client teams will use this search primarily at the outset of a project to:
    - Establish similar works by colleagues in other boards
    - Facilitate contact to allow shared learning
    - Establish possible visit lists for the client team and key stakeholders to raise awareness and understanding.

- **Search by area :** to find photographs of different areas of the healthcare estate (such as entrance areas and consulting rooms) to raise awareness of what has been achieved elsewhere. It is envisaged client teams will use this search primarily to assist benchmarking within the Design Statement being developed for projects.

This resource will be maintained by A+DS using project information submitted to the NHSScotland Design Assessment Process (once the Business Case is in the public realm), case studies of completed developments, and supplemented by images submitted by users of the site. NHS Boards are encouraged to upload photographs taken during visits to inspirational developments (especially those outwith Scotland) to assist knowledge transfer between project teams.

Ideas - **http://ideas.dh.gov.uk**
Developed by NHSEstates in England this site describes design challenges of particular built elements (such as bedrooms or consulting rooms) and numerous examples of completed buildings that respond to these challenges.

Macmillan Quality Environment Mark
This self assessment toolkit establishes aims for cancer care environments and views of what success might look like. Though

designed particularly with cancer patients in mind may of the objectives have a much wider applicability. Case studies of environments that have been awarded the mark may be added to the site over time.
http://www.macmillan.org.uk/HowWeCanHelp/CancerEnvironments/MQEM/MQEM.aspx

Over recent years, some well designed developments have been delivered in Scotland and elsewhere that are supporting care and improving community infrastructure in the areas they serve. The purpose of mapping design into the business case is to extend this higher level of design quality across NHSScotland, and to promote a culture of continuous improvement by facilitating learning from what has gone before. Boards are expected to seek out and choose examples of good practice in design against which to benchmark their projects, such as those given in the example statements attached.

Benchmarks can be refined, as the project develops and more information is understood, or if better benchmarks become available. It is anticipated that the benchmarks set at IA may be revisited in advance of the OBC and FBC to check that they are still the most relevant and useful means of checking that the project is achieving real value. The benchmarks should also be used in the Post Occupancy and Post Project Evaluation processes.

DESIGN STATEMENT ELEMENTS – THE SELF ASSESSMENT PROCESS

This section of the Design Statement should establish the key design milestones for the project; then for each milestone set out the methodology and authority of the assessment, and the information and skills needed to carry it out. There are three areas to cover, when, who and how:

When

The business case process is designed to seek approval at key financial milestones, however these do not always coincide with key design milestones. Therefore the client team must consider and set out the key milestones that are most appropriate to their particular project. These may move relative to each other and relative to the business case milestones, dependant on the procurement route chosen, but are likely to include the following key milestones:

- Site selection
- Completion of Brief (inc. Public Sector Comparator if relevant) or High Level Information Pack (HLIP)
- Selection of Delivery/Design Team
- Approval of early design concept (approx RIBA stage C) from options available
- Approval of design to submit to Planning.
- Approval of design and specification to allow construction.
- Post Project and Post Occupancy Evaluations.

Who

This is likely to be different depending on the milestone reached, the decision being made, and the risk associated with that decision.

The first thing to be decided therefore is the position of the particular assessment within the project governance - i.e. does the assessment sit within the project team (a matter that the project manager handles and reports to the project board on), or is the Project Board looking to undertake this function either itself or by seeking an opinion that is independent from the reporting being given by the project manager and forms part of the Project Board's assurance process.

Thereafter the skills set of the people, process or advisor assessing the options or proposals must be established. It is likely that specific design training and/or expertise would be of value in assessing the information being given and in differentiating between alternatives.

> *For example: A common issue in design team selection is that many people do not feel they have the competence or confidence to differentiate strongly between the ability of different designers to design. This can result in them assessing the 'quality' aspect of the scoring in terms of the clarity and coverage of the written information submitted - their essay writing skill – rather than their potential to design a facility of lasting value.*

How

Firstly, and most importantly, the decision making process for these key points must allow you to ascribe a value to the elements needed to achieve the benchmarks you have set yourself.

Secondly, you should set out how you will approach the assessment. This would include both the tools you might use (such as an AEDET or ASPECT workshop) and the information you will need to inform the decision: i.e. the shortlist of sites for selection are likely to require some level of design feasibility study to provide reliable information on whether the 'Non-negotiables' can be delivered on the site and the implications of doing so.

> *For example, a site that is ideal in terms of transport connections and immediate availability may be very close to a busy road and therefore building on that site will require significant investment in the building envelope (wall and window construction) to attenuate sound, and a more sophisticated building layout and section is likely to be needed to allow the use of natural ventilation to keep the development within the sustainability criteria. This knowledge may either prompt the choice of a different site, where all of these factors are more easily achieved, or if this site is still the preferred option will allow the proper planning and budgeting of a project on this site.*

The information required to make good and informed decisions at these key points needs to be allowed for in the programme and budget of the project and therefore the process of self assessment must be understood early in the project to allow the proper planning of this.

APPENDIX D - WORKSHOP THE 'NON-NEGOTIABLES'

The guidance document includes recommended headline areas (Fig. 2 people and policy) under which to consider and set the objectives of the project, but how these are used or interpreted will be specific to the aims of the project. To assist, the headline areas are expanded upon below by a series of questions and prompts, the responses to which should inform the development of project specific 'non-negotiables'[4].

PEOPLE

PATIENTS ...a welcoming, healing and reassuring place

Converting patient pathways into the patient experience, from leaving their home to returning home.

- Accessibility and approachability - Is this facility to be somewhere that is part of their experience of the community structure; a familiar place they go past when shopping, maybe even pop into for information or coffee, or somewhere that is likely to be a special trip for a significant purpose?
  Therefore how important is location in terms of prominence, links with public transport, parking space etc. Is it something that's an integral part of the built fabric of the community or a place apart from it? What should the initial impression be like? Can we say that drivers (other than those with a particular physical need or urgency) will not be given priority over those arriving by other means - that the facility will not face the world through a sea of car parking?
- Welcome and wayfinding - a place that doesn't stress you out just finding where you have to be.
  A single entrance space from which you can see all secondary reception points has been achieved in a number of primary and acute care buildings - is this a non-negotiable for your project?
- The overall ethos and appearance of the facility.
  A place that gives me confidence that I'll receive good care/treatment, and where I can retain some sense of myself rather than feel subsumed by the system - see also notes above on ethos.
- The patient environment - evidence based design links basic placemaking aspects such as views (positive distractions), control over your environment (noise, heat, ventilation and light etc), and a sense of privacy and human dignity to improved recovery. Can you pick a few key location types (reception/waiting areas, bedroom, and social space) and benchmark these?

- Will there be somewhere nearby I can escape to if there's an opportunity – a breath of fresh air on a difficult day.

[4] Once established these non-negotiables can be a useful tool both in developing the scope and authority of the project team's work, and in counteracting contrary pressures.

PATIENTS ...a place that supports life

- For a children's hospital - a play space I can get to from my bed – an external space I can get to every day if I want - a place my family or friends can be with me....
- For a dementia unit - a place that doesn't add to my confusion, that is reassuring and somehow familiar. A place I can still do some things for myself.
- For many wards - a place I can rest, where I can think, where I can talk in confidence or be comforted in private. A place to get away for a moment to feel I've still some choices and control.
- For outpatient facilities - a place that doesn't depress me / stress me to go to and where those that have to come with me (a carer / a driver / my children) can be kept occupied.

STAFF ...a place that supports the work

- What is the working model that is to be supported by the new/altered facility? Does it transpose current working practices or are new more integrated working methods to be used?
  Can this be embodied in any specifics such as only one reception point (as opposed to one for NHS, one for social work etc) or a commonality of room specification to allow space to be used as a resource rather than a territory?
- Is it a stand-alone facility, or are links to other services/departments/community facilities critical?
  This'll effect both the location and the facilities that'll be needed within the development.
- What do staff need to function effectively in terms of accessibility of the facility, functionality of working space and places to escape. Are there particular spaces you wish to benchmark?
  e.g. deciding early days that there's a particular theatre design that you wish to benchmark (perhaps open plan with windows) will inform very early design approaches to ensure a view that cannot be reciprocated.
- What is the ethos of the facility? What messages is it trying to convey and what behaviours are you looking to engender? The physical nature of the building (imposing or friendly) both embodies and influences the staff/patient relationship and the types, places and modes of communication.
- What level of efficiency are you looking for and how will you approach it? Does 'lean design' mean concentrating solely on staff walking distances (and potentially making the building deep plan and artificially lit/ventilated) or are you really looking at making the briefing and design work harder so that you get more than one benefit from any space (internal and external) that you build?
  eg - Designing areas that have more than one use such as combined circulation/waiting spaces with something such as an atrium that assists with daylighting and ventilation: or, placing accessible external spaces (which may be need as lightwells etc) where they can have

others uses such as formal and informal therapy, play space, additional waiting, respite and contribute to the biodiversity commitment?

- What are the additional benefits you're looking for from the development?
  Are you looking for it to help with staff retention or event to attract new staff - if so which facilities does it have to beat to attract the skilled employees you want?

STAFF ...a place that'll not constrain future work

- How serious are you about future flexibility?
  Will you require all consulting rooms to be the same, and a proportion of such rooms serviceable from more than one sub-reception to allow different users to occupy different areas as needs change? Will you require services to be routed such that walls can be removed/reconfigured more cheaply and the building refurbished on a floor by floor basis? What does flexibility mean in terms of your project?
- Is expansion space an absolute?

VISITORS ...a place to meet and discuss...a place that I can leave loved ones

- Do those accompanying, or visiting patients have a significant impact on the building function and the experience of patients?
  Will they take residents for a walk, or need space to meet and chat with in-patients? Will they be waiting for loved ones to come out of treatment, and need information and reassurance? Will they be there for extended periods and need a breath of fresh air whilst not feeling too out of touch?
- How important are play and even crèche facilities to allow patients to attend and keep accompanying children occupied?
- Are there complimentary facilities or services that'd help meet broader objectives of community perception or accessibility of services / encouraging healthy lifestyles? Are there any other visitors you'd wish to encourage by facilities such as drop-in information point?
  One of the community health facilities in Belfast has a cafe for use by those attending the GP, but it's so nice that it's popular with other locals and helps maintain the vibrancy and 'normality' of the place as it's a familiar part of the community structure rather than a place you go only when unwell.

POLICY

LOCAL NEEDS ... regeneration, community context and development

- **Local Board context**: how does this project link into the board's wider strategic asset management plan? Is it a piece in the onward development of a larger site and therefore must include elements that

deliver on broader site masterplanning and infrastructure elements or set a standard for future developments on the site?
What additional benefits does the board want from the project in terms of public perception?

- **Community Context:** The project is undoubtedly a significant investment in the community it serves, how should that be used to support the community structure including local needs for healthier places, regeneration and sustainable growth in the community?
  e.g. The construction of a facility in a run-down area is a chance to develop local civic pride and a feeling of worth (thereby potentially increasing community ownership and reducing vandalism as well as setting a benchmark for future projects in the area) as opposed to developing something that is simply 'in keeping' with the current dilapidated nature.

- **Planning and Local Development:** In broad terms, the new Planning Act shifts the emphasis of planning to consider and plan "what goes where and why" and therefore local development plans should be supporting the identification and protection of community facilities, such as those for health. This, combined with Single Outcome Agreements, is a real opportunity to plan the location of facilities to support local development rather than in response to it.
  An agreed 'non-negotiable' objective that requires the facility to be placed in a location the supports local regeneration or a planned shift in population, on a project commissioned jointly with the local authority, is likely to be a very powerful tool.

- **Local Board context**: how does this project link into the board's wider strategies such as commitments under the Single Outcome Agreement or local initiatives on health promotion, carer support etc?
  How does the project fit into the board's strategic asset management plan? Is it a piece in the onward development of a larger site and therefore must include elements that deliver on broader site masterplanning and infrastructure elements or set a standard for future developments on the site?
  What additional benefits does the board want from the project in terms of public perception of the board?
  e.g. The location and approachability of the facility can increase or reduce the likelihood of people walking or cycling to the facility and even using it.

NATIONAL NEEDS ... NHSScotland Policies

- **Better Health Better Care** : how does the project support the shift in care patterns and embody the concept of mutuality.
- **Sustainability and Asset Management** : how the project will allow you to improve your reporting on these elements.
- **Design Quality** : This is unlikely to need a specific objective as it should be met in achieving the others.

NATIONAL NEEDS ... Broader Governmental Objectives

- **The 5 Strategic Outcomes and 45 National Indicators :** Health boards, as bodies spending the public purse, are expected to contribute across all of these outcomes.
- **National policies on placemaking and design** : the call for leadership by example in the public sector.

Scotland's Infrastructure Investment Plan 2008 establishes that good design is key to achieving best value from all public sector investment.

"In developing Scotland's infrastructure, the Scottish Government recognises that good building design should be responsive to its social, environmental and physical context. It should add value and reduce whole life costs. Good building design should be flexible, durable, easy to maintain, sustainable, attractive and healthy for users and the public; and it should provide functional efficient adaptable spaces ... Equally important to the design of individual buildings is the design of sustainable places. Well-designed buildings and places can revitalise neighbourhoods and cities; reduce crime, illness and truancy; and help public services perform better".

It is this approach - which is underpinned by national policies on Architecture and on Place Making - that will inform appraisal of all projects.

APPENDIX E - EXAMPLE DESIGN STATEMENTS

The following three example design statements have been worked up based on real NHSScotland projects.

They are included in this guidance both as an illustration of the likely form and content of such statements, but also as a demonstration of the standard of benchmark that is 'deemed to satisfy' policy. Projects submitted to the NDAP that set benchmarks below these standards will be unsupported by the Process.

As stated previously - it is expected that the design statements developed for each project will be the product of cross disciplinary working and represent the core objectives and benchmarks that have been agreed by a broad spectrum of stakeholders including those involved in strategic planning for the board and those with a more intimate link to the particular facility under consideration. A list of those persons involved in the development of the statement should be appended to the initial submission. The self assessment process may more readily be written by the project manager, but must be agreed by the project board.

- **Example Primary Care Design Statement**
- **Example Acute Care Design Statement**
- **Example in-patient Design Statement**

SCOTTISH HOSPITALS INQUIRY

Hearing Commencing

9 May 2022

Bundle 8 - Mott MacDonald Position paper, Expert CV and SCIM