Design and maintenance of health care facilities to minimize airborne disease transmission

Sidney A Parsons, Ph D., Pr Eng.
CSIR: Built Environment, Architectural Sciences.

The Hospital in History

“For the world, I count it not an inn but an hospital, and a place, not to live, but to die in.”
Sir Thomas Browne 1605-1682
Planning, Design & Metrics

In attempting to arrive at the truth, I have applied everywhere for information but scarcely in an instance have I been able to obtain hospital records fit for any purpose of comparison.”

Florence Nightingale

Notes on Hospitals:
- Infection
- Ventilation
- Space (spacing and volume)
- Lighting
- Observation
- Nursing care
- Hospital administration
- Steel beds (not wood), Glass mugs...

Health Systems Performance and Delivery Framework

Abbott et al, 2008, adapted from World Bank, 2000; Schneider et al, 2007
Planning, Procurement and Management

- Facility life cycle

**Strategy**
- Service objectives
- Needs assessment
- Integration plan
- Resource plan

**Procurement**
- Planning
- Design
- Construction
- Commissioning

**Operation**
- Service management
- Property management
- Facilities management
- Maintenance management

**Disposal**
- Transition strategy
- Disposal process

± 5% life-cycle cost
± 95% life-cycle cost

---

TB Related Infrastructure

**Planning**
- Identify sites
- Briefing workshop
- Site assessment
- Planning workshop
- Master plan

**Design**
- Operational narratives
- Concept design
- Detail design
- Documentation

**Construction**
- Tender
- Construction

**Commissioning**
- Equipment schedules
- Equipment acquisition
- Staffing
- Supplies

**Operation and Maintenance**
Introduction

1. Strategic Infrastructure Planning Overview

2. The need for an appropriate Briefing process
3. The design approach

4. Operational management
5. Maintenance

1. **Strategic Infrastructure Planning Overview**

Alignment of physical infrastructure with service needs:

- Understand the health service
- Understand the community
- Understand what infrastructure currently exists
- Understand what resources are available
  - People
  - Funding (capital and operating)
Operating cost: 80-90%
Facility design life: 50-60 years
Facility life cycle

Life cycle costs:
- Planning, design, construction
- Infrastructure renovation/addition
- Commissioning
- New/replacement equipment
- Decommissioning/disposal
- Facility maintenance & management cost
- Facility service cost
- Immovable asset cost
- Equipment/movable asset cost

Capital cost: 10-20%

Available Resources Per Capita Health Expenditure (2003)

Interpretation from The World Health Report 2006
E de L H Hertzog 2006
1. **Strategic Infrastructure Planning Overview**

- **Basic principles**
  - What is the service need of the community to be served?
  - What service is required to meet the need?
  - What resources are required to meet the need?
    - What resources are currently deployed?
    - What is the gap between what need and availability?

- **Stewardship**
  - Oversight, managing resources, powers, expectations

- **Responsiveness**

- **Creating resources**
  - People, buildings, equipment, drugs, supplies

- **Delivering services**
  - At appropriate level, in/outside fixed service platform

- **Health / wellbeing**

- **Financing**
  - Raising, pooling, allocating revenues

---

**Strategic Infrastructure Planning Overview**

- **What is the service need of the community to be served?**
  - Demographic profile
    - Current, projected – migration, economy…
  - Disease profile
    - M(X)DR case load – past, present, future projections in relation to planning / service structures and communities
    - TB case load
    - Other related diseases (HIV…)**
Strategic Infrastructure Planning Overview

• Basic principles
  • What is the service need of the community to be served?
  • What service is required to meet the need?
    • Policy
    • Service delivery structure
  • What resources are required to meet the need?
    • What resources are currently deployed?
  • What is the gap between what need and availability?

Stewardship (oversight, managing resources, powers, expectations)
Responsiveness
Fairness
Creating resources (people, facilities, equipment, drugs, supplies)
Delivering services (at appropriate level, in/ outside fixed service platform)
Financing (raising, pooling, allocating revenues)

Functions the system performs
Objectives of the system

Community Based Care
TB and MDR Patients – home visitation and patient support – PHC / hospital based outreach or community volunteers

Drug Supply
Network to ensure supply of essential MDR, XDR drugs

Laboratory
Laboratory tests required to confirm MDR, XDR diagnosis

Clinic / Health Centre
Outpatient visit – identify patients at risk, initial diagnosis refer to hospital OPD for confirmation

District Hospital
Outpatient visit – identify patients at risk, initial diagnosis basic laboratory tests for TB
Acute patients – treat in TB ward until diagnosis confirmed or well enough to return home for home based/ outpatient care
Non-acute patients – hold in TB ward until diagnosis confirmed or return home for home based / outpatient care
Confirmed M/XDR patients – referred to long term care facility; temporary referral back for acute hospital based care

M(X)DR-TB Centre (Long Term Care Facility)
M/XDR-TB patients – long term treatment (approximately 6 months – 2 years); treatment of non-acute co-infections; refer to District Hospital for surgery/ acute hospitalisation
1. Strategic Infrastructure Planning Overview

- Basic principles
  - What is the service need of the community to be served?
  - What service is required to meet the need?
  - What resources are required to meet the need?
    - What resources are currently deployed?
    - What is the gap between what need and availability?

Functions the system performs

- Stewardship
  - Oversight, managing resources, powers, expectations
- Creating resources
  - People, buildings, equipment, drugs, supplies
- Delivering services
  - At appropriate level, in/outside fixed service platform
- Financing
  - Raising, pooling, allocating revenues

Objectives of the system

- Responsiveness
- Health / wellbeing
- Fairness
Infrastructure Planning

- What infrastructure is needed to comply with Policy direction and the strategic plan for service delivery?
- What options does the Department have for providing the required infrastructure?
- What is the long term plan for providing the infrastructure defined in the documented and agreed option. (Infrastructure is defined in terms of Projects and Financial Resources linked to time.)
- What infrastructure does the Department have and what is its location and status?
- What infrastructure is required?
- What alternatives to physical infrastructure can the Department use?

Facility Data

- Immovable Asset Register
- Field Assessments
  - Plans, buildings, materials, building and engineering services, functionality, risk, compliance, replacement value
    - Fit for purpose
    - Fit for service
    - FM operating budget – services, maintenance, backlog maintenance
- Management and healthcare planning utilising GIS
1 Admission & OPD
2 Gateway clinic
3 Male medical ward
4 Female medical ward
5 Paediatric ward
6 X-Ray
7 Male TB ward
8 Female TB ward
9 Surgical wards
10 Psychiatric wards
11 Maternity ward

Key
1 Primary patient area
2 Critical control point

Church of Scotland Hospital
1. Immovable Asset Management

- ... aligning the physical environment with the service to be delivered ...
  - in the most cost effective and efficient manner ...
  - through the full life cycle and service life of the asset ...
  - while ensuring a safe and sustainable environment for users, and
  - while remaining legally compliant
- Ensuring that the facility remains both “fit for service” and “fit for purpose”
- Strategic planning and operational management both require quality data
  - Service related data
  - Immovable asset data

“Good buildings don’t just happen”

There is no perfect building, as there are no perfect people, or budgets, nor endless time ...

The best is reached through briefing based on realistic, cost-effective standards that are achieved through teamwork, with a balance between acceptance of a no-blame ethos and responsibility

Penâ, W et.al.
The need for an appropriate Briefing process

The Briefing document must provide written comment, explaining explicitly the hospitals:

- The definition of objectives as defined during the planning stage.
- Its plan of operation,
- Relating the entire system of operational procedures consistently to these objectives in particular those related to all the functional areas.
- Adapting policies and commissioning to changes in the objectives or their implications

The interaction of planning, commissioning and the ongoing task of hospital management and functionality must be recognized during the briefing stage.
2 **The briefing document**

It must convey the “Functional planning” requirements of the facility:

- The functional requirements for all services must be outlined provided for the professional team,
- The functions to be carried out, the methods to be used, the personnel needed the working relationships should be developed and;
- All major equipment needed defined.

---

### Equipment Guide List

**AFB Isolation Bedroom**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>QTY</th>
<th>AI</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ISOLATION BEDROOM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 VV</td>
<td>BED WITH MATTRESS, HOSPITAL PATIENT, HI-LO 450mm W x 964mm L, (420mm x 1444mm) WITH 75mm (3”) dia. WHEELS AND TRAFECE BAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>BUMPER GUARD, 35mm (2”) DEEP, WALL MOUNTED OFF THE FLOOR BEHIND HEAD OF BED (AVOID RETURN AIR GRILL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 VV</td>
<td>TABLE, OVER BED, ADJUSTABLE HEIGHT 120mm H x 1250mm D x 320mm W X 140mm ON CASTERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 VV</td>
<td>CABINET, BEDSIDE, PORTABLE 500mm W x 450mm D x 970mm H (200mm x 180mm x 34 1/2”)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 VV</td>
<td>CHAIRS, STACKING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>WARDROBE LOCKER, PATIENT, WITH PULL OUT SECURITY LOCK (190mm W x 600mm D x 1000mm H) (100mm x 25 1/2” D x 75” TOP SHELF FOR PILLOW AND BLANKET STORAGE) WALL MOUNTED</td>
<td>(PB-16-4)</td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>OUTLET, MASTER TELEVISION ANTENNA (PG-16-1, MCS 15781, H-16-3, CS 984-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>BRACKET FOR TELEVISION RECEIVER, CEILING MOUNTED AT FOOT OF PATIENT BED (PG-15-1, MCS 15781)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 VV</td>
<td>RECEIVER, TELEVISION, FULL SIZE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>RECEPTACLE, ELECTRICAL, CEILING MOUNTED, 120 VOLT, 20 AMP FOR CEILING MOUNTED TELEVISION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>LIGHT, BED, 1/2 W, WALL OVER BED 2050mm H (7’4”) ABOVE FLOOR (PG-19-1, MCS 16510)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AR</strong></td>
<td>RECEPTACLE, ELECTRICAL, 120 VOLT, 20 AMP WITH GROUND FAULT INTERRUPTER, ADJACENT TO LAVATORY (PG-18-1, MCS 16410, H-18-3, CS 501-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>RECEPTACLE, ELECTRICAL, DUPLEX, 120 VOLT, (PG-18-1, MCS 16410, H-18-3, CS 501-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>NURSE CALL STATION WITH CORRIDOR SIGNAL LIGHT (PG-18-1, MCS 15781)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>LAVATORY, SENSOR CONTROL (PG-18-1, MCS 15450, VOL. 350 (2004))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>PREFABRICATED BEDSIDE PATIENT UNIT (PBPU) STYLE A1 (PG-18-1, MCS 16055)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2 The briefing document

Functional planning meetings provide platform for discussing TB patient flow patterns:

2 The briefing document must provide concise instruction of requirements to the professional team.

"Health care facilities are essentially only shelters in which health care functions can be performed. Until those functions are defined, the actual building requirements cannot be identified"

Kleczkowski and Nilsson 1984:4
The need for an appropriate briefing document

The Modern Challenge for facilities in airborne disease burdened countries:

• Scant appreciation of the need of a detailed brief for the planners, with very little input by healthcare staff on needs (in particular where environs are predisposed to airborne infectious diseases), with planners confusing the difference between a business plan and briefing document.

• Functional environments predisposed to infection which is not conducive to healthcare provision, least of all healing. Resulting in the inappropriate accommodation and mixing of:
  - Patients with infectious diseases
  - Immune-compromised patients (and staff)
  - Paediatric patients

• Limited understanding of the dynamics of infection control needs (e.g., airborne infectious diseases) by building professionals and maintenance staff

The design approach

Build quality
"Good" Design?

- Design addresses the function accommodated, the built fabric and the impact of the facility on people.
- Good design enhances service delivery and outcome, satisfies users and staff, optimises life cycle costs.
- Good design is about getting the balance between function, building and impact right.
- Conversely poor design (and a poor environment) can impede service delivery, increase the cost of service delivery, frustrate and endanger users.
- Design and the Quality of the Environment need to stay constant through the life of the facility.
Research - Roger Ulrich et al. (2004)

Research Questions related to design:

• What can research tell about “good” and “bad” hospital design?

• Is there compelling credible scientific evidence that design genuinely impacts staff and clinical outcomes?

• Can improved design make hospitals less risky and stressful for patients, their families, and for staff?

• How to Improve patient and staff safety

• Understanding functional requirements?

• Understanding Procedural Requirements of Protocols?

Safe, Functional and Sustainable Healthcare Facilities

To design with airborne Infection control in mind:

• Patient treatment requirements and patient flow patterns throughout the facility must be determined, with the functional requirements for all services defined.

• The functions to be carried out, the methods/protocols to be followed, the personnel needed, and the working relationships between all functional departments should then be developed.

• Undertake ongoing risk assessments via the HACCP process to ensure development of the Design Qualification, Construction Qualification and Operational Qualification are all satisfied.
Designing for the facilities function

Understand what health related service the facility is required to render (i.e. patient care process).

- Clinic
- Community Health Centre
- District or level 1 Hospital
- Referral Hospitals
- Specialised TB care facility (for treatment of M(X)DR –TB patients)

The functional performance (Treatment and patient type) is facility specific. Each facility will need to be designed to allow for the appropriate procedures to be undertaken and concomitant IC measures to be implemented.

SA Health Service & Infrastructure

- Hospital Services
  - Level 3 – Tertiary
  - Level 2 - Regional
  - Level 1 - District
- Primary Health Care
  - CHC / Clinics
  - 27 Tertiary Hospitals
  - 49 Regional Hospitals
  - 259 District Hospitals
  - 2 63 Health Centres
  - 2 367 Clinics
### Understanding the functional performance: Case Identification

- Undiagnosed patients with possible drug-resistant TB will normally first present themselves as an outpatient either at a primary health clinic or health centre or as a normal out-patient at a hospital.

### Understanding the functional performance: Diagnosis

- Initial diagnosis is normally undertaken as part of the normal outpatient diagnosis and treatment process. This could include clinical examination – chest X-Ray – sputum collection – laboratory test, time – patient held (or returns?) for diagnosis.

- Patients may be admitted pending the outcome of laboratory tests or while undergoing treatment for other co-infections. Sputum from the patients suspected of drug-resistant TB will be sent through to a designated diagnostic laboratory for analysis.

- Due to time required to culture … and current workload pressures at these laboratories, sputum samples can take at least 3 weeks and sometimes longer to be processed.

The same diagnostic procedure would apply to a level 1 or district hospital.
3 Hospital Design – The Basics

- Functional procedures
  - Patient treatment requirements
    - Effects of drugs on patients
    - Accommodation needs
    - Patient comfort
    - Safety
    - Implication of long stay patients

- Operating procedures
  - Nursing procedures
    - Travel distances (±30% time)
    - Ergonomic design
    - Safe working procedures

3 Ward design and nursing

The nurse is the key to effective and efficient functioning of the ward, and the key figure in considering ward design.

- The nurse should have maximum contact with patients
- Should travel the shortest travel distance.
  - the average distance from nurse station to bed
  - 9 m = very good – 20 m = acceptable

Other staffing considerations to be clarified at the outset:
Staff employment policies –
- shifts
- number of staff
- ward and staff policies
- practices of nursing staff
- supplementary staff

comment in article by William Tatton Brown
'a nurse working in a nightingale ward is a prima donna, always on show, vs. a nurse in a divided ward being similar to a 'bell hop'
3 Open ward design

Advantages
- Observation & control
- Communication
- Reduced travel distance to patients
- Patients more tolerable of staff, can see they are busy
- Patient privacy due to anonymity in large group
- Good staff and patient satisfaction

Disadvantages
- High noise levels
- Lack of flexibility of use of ward
- Long distance to support service rooms
- Shared ablutions
- Incorrect bed orientation (most daylight light on feet)
- Lack of privacy

3 Ward Designs

- 600mm between the non-attending side and the nearest wall
- 900mm between the attending side and the nearest wall
- 900mm between the sides of adj beds
- 1200mm between the foot of the bed and the opposite wall
- 1500mm between the foot of the bed and the opposite bed
It is essential that area and space norms be investigated for facilities where airborne transmission is possible.

It is important to avoid overcrowding of facilities.

The following, whilst being specific to South Africa, are similar to those such as the UK, Australia, India etc.

- **Gross area norms** – SAHNORMS (South African Hospital Norms) provides general guidance for gross areas of wards in district hospitals.

- The SAHNORM recommended area for general wards makes provision for patient rooms as well as all ward specific support accommodation.

- While there are no overall area standards for public hospitals in South Africa, a range of 45-60m² per bed is as an interim guideline [1].

- **Net area norms** – Minimum standards for space requirements between beds is internationally accepted. The CSIR Ward Design Guide proposes a minimum of 1.2m between beds.

[1]: Proposed by CSIR from SAHNORM guidelines and analysis of public sector district hospitals in South Africa and Namibia.

---

**Norms and Standards**

- Beds / Patient accommodation:  
  specific minimum dimensions between beds and walls  
  (diags demonstrating)

  NB wards cant be mirrored!!!

  - single ward – min 10 sq.m, min wall length 2.6m
  - proper screening between beds
  - adults and children separate (except mothers rooming-in)
  - each patient room or bay to lead onto corridor
  - surgical whb
  - oxygen & vac available (if loose 1 mobile O2 & vac / 20 beds)
  - 1 electrical switched socket per bed
3 Design: Standards, Norms and Guidelines

- The incidence and risks associated with drug-resistant forms of TB have recently been given much prominence in medical literature as well as in national and international health research and planning circles.

- There are some guidelines available internationally dealing with treatment policy and protocols, however there is little guidance available on the impact of infrastructure on M(X)DR-TB and limited design guidance on how to best plan and design for treating cases of M(X)DR-TB.

- What guidance is available is focussed on treatment in developed world countries where the incidence is low and full isolation of all TB patients is the norm (AIA, ASHRAE etc in the USA).

- Certain countries have specific regulations, standards, norms and planning guidelines, and these should be adapted. It is recommended that these be utilised as guidance only, and not be interpreted as prescriptive practice.
Design standards: Room data sheets

AFB Isolation Bedroom

ARCHITECTURAL
- Ceiling: Opaque Wallboard
- Ceiling Height: 2400 mm (6'6")
- Wall Finish: Ante Room & Bedroom: Paint
- Toilet Room: Ceramic Tile
- Wardrobe: Ante Room: Plywood, Bedroom: Composite Door
- Toilet Room: Ceramic Tile
- Floor Finish: Ante Room: Vinyl Composition Tile, Toilet Room: Ceramic Tile
- Stair Depth: -
- Notes: 1. 150mm (3'4") wide doors

SPECIAL EQUIPMENT
- None

LIGHTING
- General: Ante Room: 60 W GU10 (2.5 W/h); Toilet Room: 60 W GU10 (1.5 W/h); Bedroom: 38 W GU10 (1.5 W/h)
- Special: Bedroom: 38 W GU10 (1.5 W/h)
- Notes: 1. 1500 mm x 1000 mm (2 ft x 2 ft) recessed fluorescent light fixture, acrylic prismatic lens, W4-327W lamps, 3000K, CRI=75 (Min.)
   2. 2. 4 light 36W (1) switch mounted fluorescent light fixture, acrylic prismatic lens, 300W-32/75W lamps, Ballast, CRI=75 (Min.) with four (4) position pull cord switch (2 uplights & 2 downlights)
   3. 1500 mm x 1000 mm (2 ft x 2 ft) recessed fluorescent light fixture, acrylic prismatic lens W4-327W lamps, 3000K, CRI=75 (Min.) in Ante Room and Toilet

POWER
- General: 1200 W (ac) (including air conditioner)
- Emergency: 200 W (ac) (including air conditioner)
- Special: PBPU 500 W (ac) (including air conditioner)
- Emergency: 400 W (ac) (including air conditioner)
- Note: 1. Provide ceiling mounted combination power and switch outlet for ceiling mounted TV. Provide control box in PDU wiring for control of TV

COMMUNICATIONS
- Telephone: -
- Intercom: -
- TV: -
- NIMI: -
- Notes: -

HEATING, VENTILATING AND AIR CONDITIONING
- Dry Bulb Temp Cooling: 24°C (75°F)
- Dry Bulb Temp Heating: 20°C (68°F)
- Minimum % Outside Air: Yes (see Note 1)
- 100% Exhausted Air: Yes
- Minimum Air Change: 12
- Return Air: Negative
- AC Load Equipment: 220W m² (0.4 W/ft²)
- Special Exhaust: 1 (See Note 2)
- Notes: 1. Minimum % (2) air changes per hour. 2. Air exhausts are removed to the outside of the room. It is normally provided at the air handling unit for the building

PLUMBING AND MEDICAL GASES
- Cold Water: Yes
- Hot Water: Yes
- Laboratory Air: -
- Laboratory Vacuum: -
- Sanitary Drain: -
- Medical Air: -
- Medical Vacuum: -
- Oxygen: -
- Nitrogen Oxide: -
- Nitrogen: -
- Anaesthesia Gas: -

Design guides / Room layout requirements

AFB Isolation Exam Room Equipment & Utility Plan

FIRST DRAFT 4-15-97
Design guides / Room layout requirements

AFB Isolation Bedroom
Equipment & Utility Plan

Ventilation Notes:
1. Exhaust Air shall be drawn from all isolation room doors.
2. Anti-room is scrupulously not mandatory.
3. Exhaust Air shall be drawn from all isolation room doors.
4. Air movement shall be full height walls, ceiling, and windows.
5. Air movement shall be full height walls, ceiling, and windows.

Design guides / Engineering requirements

Class 5: Standard Pressure

Class 6: Negative Pressure

Class 7: Positive Pressure

Class 8: Alternating Pressure

Number of Isolation Rooms

Operating Procedures Rooms
Patients with drug-resistant TB will normally first present as an outpatient either at a primary health clinic or health centre or as a normal out-patient at a district or level 1 classified hospital...
3 **Designing for district or level 1 classified hospitals**

**Understanding the functional performance: Treatment**

- If the diagnosis is confirmed as a drug resistant strain, the policy\(^1\) may be for patients to be referred to a special MDR- or XDR-TB treatment centre, whilst those diagnosed with a drug susceptible strain may be retained at the hospital and treated accordingly.

- If patients are treated at a specialised MDR- or XDR-TB facility, they may also at any time require specialised treatment for any particular acute ailment, these patients may then need to be referred to a district, level 1, or specialised referral hospital.

\(^1\) Management of Drug-resistant Tuberculosis in South Africa: Policy Guidelines: June 2007. Department of National Health

---

3 **Design as a Factor in Reducing the Transmission of TB in Health Facilities.**

Hospital sustainability comes through the recognition of hazards with the provision and implementation of appropriate environmental infection control measures to ensure proper safety for patients, staff, and visitors.

Andrew J. Streifel, MPH
University of Minnesota
Minneapolis, Minn.
Design as a Factor in Reducing the Transmission of TB in Health Facilities – Case Studies

With respect to proposed or scheduled retrofitting facilities:
- The original Business case and Briefing document for needs interpretation.
- How aware the hospital management were of the Protocols and Functional Procedures called for in the TB Guidelines, and the Design to ensure implementation thereof; and;
- Appropriate Infection Controls (Administrative, Environmental and Personal), against Infection required.

With respect to existing facilities:
- How prepared and how suitable are facilities for receiving TB suspect patients?
- Were patient pathways for TB suspects being considered, or only after TB confirmation?
- Was gateway triaging being considered?

Designing for hospitals with patients with and drug susceptible and drug-resistant TB

Conclusions; No specific classification for patient referral.
- Could be country specific,
- Driven by patient need
- Influenced by district laboratory capacity and capability
- Influenced by hospital staff skills capacity
- Influenced by bed capacity

Design process needs must be hospital type specific, Due to need to address patient needs. In both cases the design must support:
- Appropriate IC Measures (Both administration and environmental) to manage risk to health care workers, hospital staff, patients and visitors.
- Address patient dignity and comfort
- Required treatment procedures
3 Designing for Specialised TB care facility (for treatment of M(x)DR –TB patients)

- M(X)DR-TB Facilities may be “Long term care” Facilities and are, by definition, high risk institutions.

- However the risk is known and specific, targeted precautions can be taken to reduce the risk to acceptable levels through direct design interventions, through administrative protocols and through strict use of personal protection measures.

- Specific areas that need to be addressed in long term M(X)DR-TB facilities include the following:
  - Zoning and separation - high and low risk zones need to be identified and physically separated areas need to be created and demarcated. High risk areas would include all patient care areas and secure low risk areas need to be created to provide staff with areas to withdraw.
  - where administrative, environmental and personal protection measures are required

3 M(X)DR-TB Infrastructure need

Minimum standards for M(X)DR-TB accommodation

- No international/ local guidelines exist – need to be developed
- Current thinking include

  - Patient accommodation in double (MDR), single (XDR) rooms, ablutions
  - Nursing support as for medical wards
  - Clinical support including consulting, rehabilitation, dispensary…
  - Patient support including recreation, development…
  - Administrative and domestic support including administration, catering, cleaning, security, laundry, gardening…
  - Staff accommodation
M(X)DR-TB Infrastructure needs continued:

- **M(X)DR unit**
  - Area estimate per 40 bed unit (gross m²)
    - Patient accommodation (including nursing support) – 790m²
    - Clinical support – 145m²
    - Patient support – 220m²
    - Administrative and domestic support – 200m²

- **Staff accommodation**?

---

**Design guides / Design Risk Indicators for potential transmission of Airborne disease in Health Care Settings**

**Potential risk areas:**

- **Congregate settings** – any setting (usually waiting areas) where large groups of patients are kept in close proximity to each other are potentially high risk areas.

- The **highest risk** is usually in admission, main out-patient, emergency or pharmacy waiting areas where undiagnosed or untreated patients congregate, but smaller waiting areas or other functional areas, such as in X-Ray departments or even multi-bed patient rooms can equally pose a risk;

- **Areas with restricted/ inadequate ventilation** - Waiting areas need to be adequately ventilated (Mechanically or Naturally) at all times.
Potential risk areas contd.:

- Areas such as consulting, examination, counselling or treatment areas where staff spend long times in relatively small areas in close proximity to patients should be considered high risk areas.

- Minimum openable window areas are regulated but often not met (see section 5). The design of the window is also important to promote natural ventilation.

- Shape and volume – the shape and volume of a space can also be a risk indicator. Waiting rooms with inadequate floor to ceiling height (often found in multi-storey buildings) are generally higher risk areas than those with a shaped ceiling to high level clear storey windows.

- Adjacency – the distance between carriers and staff or other patients is a risk factor. Bed spacing and multi-bed wards are risk situations.
M(X)DR-TB Infrastructure: Environments that support healing

Predominantly US based research has indicated that a pleasant environment promotes the healing process. A healing environment encompasses anything that will appeal to the 5 senses, thereby making the user more comfortable and reducing stress.

P.H. DOLLARH HEATH CENTRE, USA


- Create visual privacy
- Allow channel and volume control of television
- Include gardens or grounds in facility
- Allow patients control over temperature and light levels in their rooms
- Create comfortable, private break areas for staff members
- Design staff work stations so as to keep interruptions to a minimum

A Sense of Control
M(X)DR-TB Infrastructure: Opportunities for Social Support

Overnight accommodation for family and friends. Design outdoor garden or seating areas for interaction between patients and visitors.

Light
Design Risk Indicators for potential transmission of Airborne disease in Health Care Settings

Designing for new facilities:
• While all new facilities must be planned and designed taking account of the risk posed by drug-resistant TB.

Design changes for existing facilities:
• There is an extensive estate of existing facilities which predate the development and spread of M(X)DR-TB, where drug resistant TB will be encountered with increasing frequency and where there is an increasing risk of cross infection.

• Risk assessments must be taken at all facilities to identify risk areas so that protocols can be developed and administrative, environmental and personal protection measures can be introduced.
**Hazard Analysis Critical Control Point (HACCP)**

An important aspect of the Integrated design approach
2 The briefing document

Provide permanent record of the original planning purpose and objectives:

- Provide focus on the original planning
- To help simplify the work in future operation
- To be used to orientate the hospital administrative staff to the system of operation planned
- Provide a basic reference for selection of equipment that promotes the efficient operation of the hospital
- For continued evaluation

3 Using the HACCP during the facility design phase

The HVAC Commissioning Process Flow

- Reviews and Approvals
- HVAC System Description
- Update commissioning plan
- Commissioning specification
- Reviews
- Construction documents

The Process Flow

- Use HACCP to identify CCP's
- Identify the components/systems constituting the process
- review components/systems As per requirements for recognized IC measures
Using the HACCP process and during the design phase to establish IC requirements

1. Systematically analyze hazards using process flow diagrams
2. Identify critical control points (CCP’s)
3. Establish critical limits for each CCP
4. Establish control and monitoring procedures
5. Establish corrective action procedures
6. Establish record keeping plan, a crisis response plan and assign responsibilities
7. Regularly validate and verify that the HACCP plan is being effectively implemented

The system design process

Ensure reviewed components / systems match systems operational needs for appropriate IC measures

Using HACCP to identify critical control points (CCP’s) in the hospital layout? (Identify the areas/interventions, that make up the process flow diagram which constitute each CCP?)

Analyze each area of the hospital as designed and determine influences on the CCP’s in the process. Follow functional requirements for best practice / guidelines for design
M(X)DR-TB Patient issues that need to be addressed

Resulting from the policy, further attention must be paid at facilities treating infectious patients over an extended period (2-6 months) to providing access to broader basic social services e.g.:

- Postal services
- Banking facilities
- Visitors
- Education (Children, Adult and continued).
- Home Affairs processes – ID documents etc.
- Support for Children far from home
- Community Services support for breadwinners under treatment

A balance needs to be struck between the constitutional rights of patients (National patient charters?), of staff and the broader community. The affordability of public health measures in order to protect and uphold those rights needs to be addresses.

Detailed attention to air rate and flow management is needed:

- Air dilution and pressure gradient design, irrespective of wind conditions, to ensure clean air workspaces
- Effective dilution ventilation by natural or mechanical means (or by mixed mode systems)
- Pressure gradients relative to room functions and layouts
- On-site validation of ventilation design prior to occupation – standard methodology in development
- Regular re-assessment as part of facility risk management SOP
3 Environmental Controls: Natural Ventilation

“Relies on air moving through a building under the natural forces of gravity due to density differences (stack effect) and wind”.

Environmental Controls: Natural Ventilation

Wind as a driving force for natural ventilation:

\[ \Delta p = (\rho_{\text{out}} - \rho_{\text{ins}}) g [h - h_{\text{np}}] \]

Stack effect as a driving force for natural ventilation:
Density Differences (Stack driven flows due to separate columns of air at different temperatures) as a Driving forces for natural ventilation:

\[ Q_s = \frac{C_d A [2g(h - h_{npl}) (T_{ins} - T_{out})]}{T_{ins}} \]

Environmental Controls: Natural Ventilation

"Where: wind driven ventilation rate \( Q_w \) (m³/s) is:

\[ Q_w = 0.05 A U \]

Where:
- \( A \) is opening size, and
- \( U \) is wind speed in m/s.

And stack driven flow \( Q_s \) (m³/s) is:

\[ Q_s = 0.2 A [g h \Delta T / T_{ave}]^{1/2} \]

Where:
- \( g \) is acceleration due to gravity
- \( h \) is the height of the opening
- \( \Delta T \) is the differential temperature (Outside/Inside)
- \( T_{ave} \) is the average of the inside and outside temperatures

Total flow rates will then be:

\[ Q_{tot} = (Q_w + Q_s)^{1/2} \]
Environmental Controls: Natural Ventilation

Natural ventilation strategies:

1. Single-sided single opening ventilation (effective to a depth of about 2 times the floor to ceiling height).
2. Single-sided double opening ventilation (effective to a depth of about 2.5 times the floor to ceiling height).
3. Cross ventilation (effective to a depth of about 5 times the floor to ceiling height).
Environmental Controls: Natural Ventilation

Chimney ventilation combines the natural forces of gravity due to density differences (stack effect) and wind”.

Stack ventilation: Effective across a width of about 5 times the floor to ceiling height from the inlet to where the air is exhausted to the stack.

Understanding Natural Ventilation:

1. Openable windows must be well sealed when closed to minimize draughts and infiltration energy loss.

2. Good solar control is crucial in achieving an effective natural ventilation design

3. Pollution source control is the most effective way of improving Indoor Air Quality

4. Medium term average ventilation rates are more important than instantaneous rates

and is based on principal that;

“If occupants have the facility to change their environment, they are likely to use it to improve comfort”!!!
Environmental Controls: Natural Ventilation

Quality of ventilated air uncontrolled

Ventilation design techniques:

**Explicit method**: Where flow components are selected, flow characteristics are identified and driving pressures are calculated to size the flow components.

**Implicit method**: Using calculation procedures that require the size of the flow components to be entered by the user to predict the flows according to climatic and internal building conditions.

**Mathematical Modeling methods**: Using Computational Flow Dynamics (CFD) and or Combined thermal and airflow models (CTA).

**Physical Modeling methods**: Using salt bath techniques (for stack effect modeling) or wind tunneling testing of scaled models (not a method to prove the design as it can only provide input as to the external flows around the building).
Environmental Controls: Natural Ventilation

Mathematical Modeling methods: Using Computational Flow Dynamics (CFD) and or Combined thermal and airflow models (CTA).

Physical Modeling methods: Using salt bath techniques (for stack effect modeling) or wind tunneling testing of scaled models.

The Africa Centre for Health & Population Studies, Somkhele, KwaZulu-Natal
Operating and Maintenance

1. Operational management.

2. Understanding the Risk of inadequate maintenance and the implications related to Infection Control

Facilities Life-cycle:

- Assume building has lifespan of 60 years
- Say the initial construction cost is US$50 million
- And you spend 4% of initial construction cost per year on maintenance, that is US$20 million per year!
- Then, you will spend 240% of the buildings initial construction cost over the next 60 years on maintenance alone, or US$120 million, which is 2.4 times more than the initial building cost!
4.1 Operating and Maintenance

**BRITAIN : In the Mid-1980's**

- Maintenance of buildings amounted to £10 billion per annum or 4% of the estimated replacement value of the building stock.
- More than 50% of the building labour force was engaged on this class of work.
- Backlog in housing repairs and maintenance : £45 billion.
- In 1972 the arrears of housing maintenance amounted to eight or nine times the volume of work actually carried out each year.
Operating and Maintenance

SOUTH AFRICA:

- During 1990 the annual expenditure on building maintenance and repairs was estimated at about 1.5% of the estimated replacement cost (Webb, 1990).
- During a survey in '89/'90, random sample of SAPOA members indicated an average of 1.8% (Mc Duling).
- In government owned hospitals in South Africa the annual expenditure on building maintenance and repairs was estimated at 1% of the estimated replacement cost (CSIR, 1999).
- UK = 4% ± vs South Africa = < 2%

Operation and Management

Understanding the risks due to operational shortcomings:

- Inadequate staffing (Understaffing)
- Excess bed capacity
- Utilised beds versus planned beds
- Utilization of unsupervised outsourced contractors
- Disconnecting the facility from community needs
- Unplanned healthcare provision (Not seeing the bigger picture to maximize utilize of all resources)
- Under estimated maintenance budgets
- Not supporting utility staff with IC process.
4.2 The Risk of Inadequate Maintenance: Environment & Health

Whilst being the prime means of intervention, certain systems may also be the primary Pathogenic transmission mechanism if not maintained:

- Water Systems
- Air Systems
- Environmental (Cleaning) Services
- Services Handling Laundry and Bedding
- Regulated Medical Waste

Guidelines for Environmental Infection Control in Health Care Facilities
Centers for Disease Control and Prevention
Healthcare Infection Control Practices Advisory Committee (HICPAC)

4.2 Operation and Management

Risk management through appropriate maintenance

- Have thorough understanding of original design brief
- Know the Original Design Specifications and drawings
- Understand the Operation of the System
- Know what Safety Devices and interventions have been installed.
- Understand the operational limitations of the interventions of the building and its systems (Control algorithms and set points etc.)
- Ensure maintenance staff are part of the IC risk management team
Health infrastructure programme development

Risk management through appropriate maintenance cont’d:

- Have clear understanding from the Testing and Balancing Validation reports what elements have suspect design features, have possible latent operational defects etc. or that which has been poorly installed.

- Ensure that all control points in the interventions are appropriately adjusted.

- Ensure that all equipment is appropriately serviced in accordance with the operational and maintenance manuals which should contain all suppliers recommendations.

The Risk of Inadequate Maintenance

- “Appropriate Design”
- “Service level Agreement Procurement Policies”
- “FM Standards of Procedures for environmental Services”
- “Operating and Maintenance Manuals”
- “Maintenance”

Review of Facilities Management and Engineering controls
4.2 The Risk of Inadequate Maintenance

Using the Integrated design, operational and maintenance approach to support the appropriate maintenance requirements of all systems to ensure effective infection control strategies.
4.2 The Risk of Inadequate Maintenance

4.2 The Risk of Inadequate Maintenance


Maintenance of Engineering services
Conclusions:

- Health facility designers and the facility management team must understand and support the need for an "Integrated Design Approach" for any new facility and its ongoing operations.

- Fundamental to the risk assessment program of any Facilities is the "Operation, Management and Maintenance" of the Facility.

- Any risk assessment program should apply throughout the full "Life Cycle of any Health Facility".
“There exists a need for researchers and professionals in the built environment to liaise and work in collaboration with various national and international medical research and public health advisory agencies to mutually seek environmental control solutions to assist in the development of appropriate tools to eliminate, reduce or prevent biological hazards that cause the risk of airborne disease transmission in built environments”.

ASHRAE EHC emerging issues document 2007

Thank you

Acknowledgements

World Health Organization

Center for Disease Control and Prevention

National Institute of Health

Colleagues and Co-Researchers (CSIR AND Project Teams):
Geoff Abbott, Peta de Jagger, Johann Mc Duling, Mladen Poluto, Renee du Toit

Provincial and National Health TB Clusters
MARU, NHS, UIA-PHG, UCT