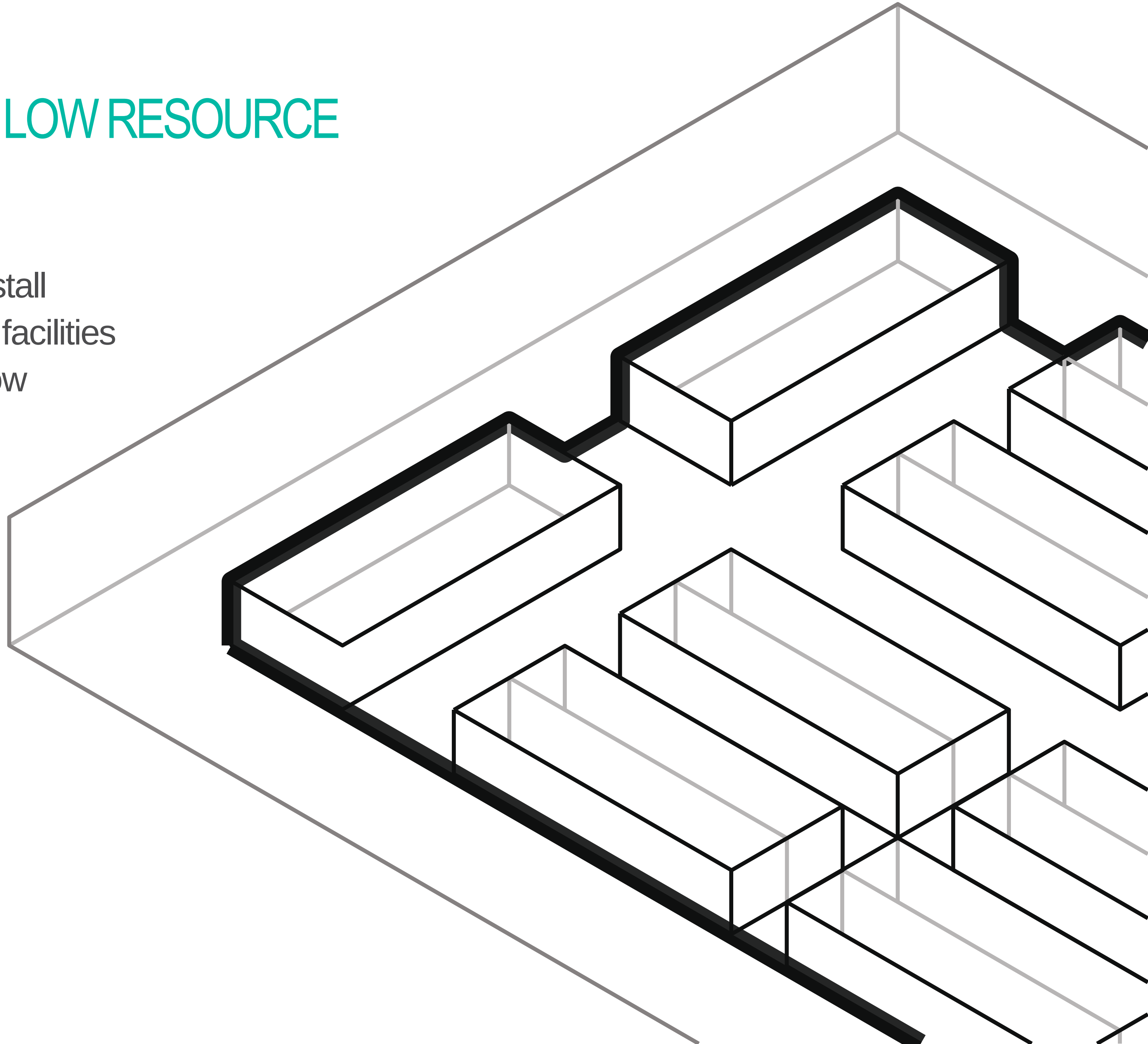
# CareBox LOW RESOURCE

A design guideline to install temporary medical care facilities in existing buildings in low resource contexts



ARUP

**As the risk of the coronavirus pandemic continues to spread globally, the potential impact in low resource contexts is significant. Arup has mobilised a multi-disciplinary team to engage directly with governments, healthcare bodies and NGOs around the world, offering our technical support and guidance.**

The purpose of this document is to provide guidance on implementing or adapting spaces into Covid-19 treatment centres. It is aimed at organisations who are working in low resource contexts where access to mechanical equipment and other construction supplies may be limited.

This document is designed to be read in conjunction with the WHO Guidance: "Severe Acute Respiratory Infections Treatment Centre: Practical manual to set up and manage a SARI treatment centre and a SARI screening facility in health care facilities." The scope of this document is to provide supplementary guidance on how to achieve the design criteria stated in the WHO document while working within the given contextual constraints, whether that be within an existing hospital complex or as a stand-alone facility.

It also provides information on fire strategy which, while not included within the WHO guidance, is nonetheless important in facilities where many patients are likely to be immobile and there is oxygen being supplied for medical use. This is particularly important in dense urban areas such as informal settlements where fire risk is already high.

The document is a part of the CareBox series[1] developed by Arup around modular healthcare expansion for COVID-19, and parallel documents have been developed for higher resource contexts as well.



*[1]Available from: https://www.arup.com/news-and-events/introducing-carebox-modular-healthcare-for-covid-19*

CONCEPT

# How it works

### DESIGN REQUIREMENTS

- Water and Sanitation
- Environmental Control
- Medical Gases
- Electrical Supply
- Fire Safety

### EXISTING BUILDING AND SITE

- Site and Surroundings
- Existing Building
- Available Utilities

+

### LOGISTICAL CONSTRAINTS

- Local Building Materials
- Supply Availability
- Logistical Capacity

### SARI TREATMENT CENTRES

- High Standard of Care
- Context Appropriate

# Examples of Application

*Improved Temporary Spaces*
*(Modified Rubb Hall Frames)*

*Confined Indoor Spaces*
*(Multi-Storey Car Parks)*

*Smaller Existing Structures*
*(Community Buildings or Halls)*

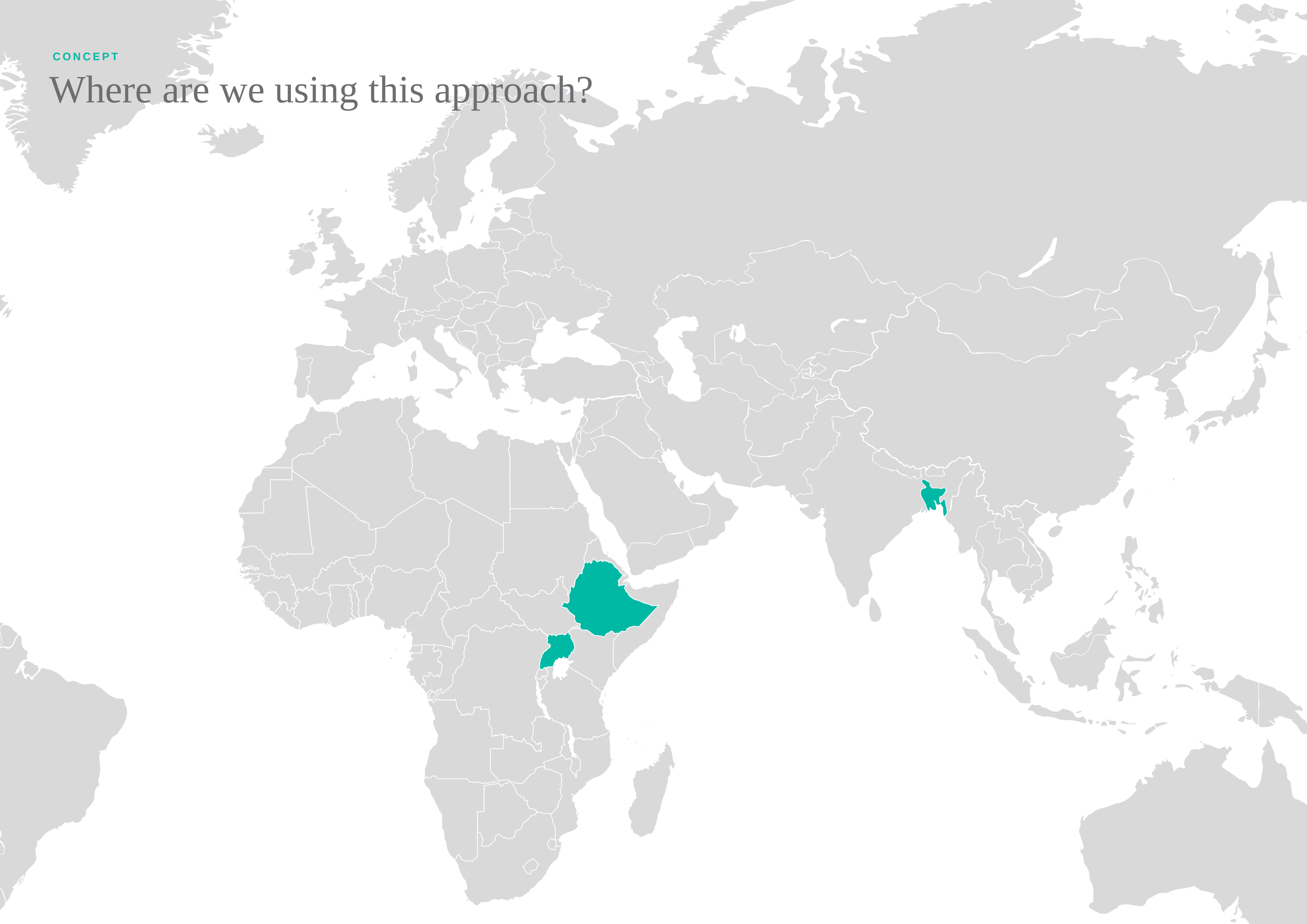
*Large Venue Spaces*
*(Conference Centres, Multi-Purpose Halls)*

*Temporary Buildings and Tents*
*(Rubb Halls, Unicef Standard Tents)*

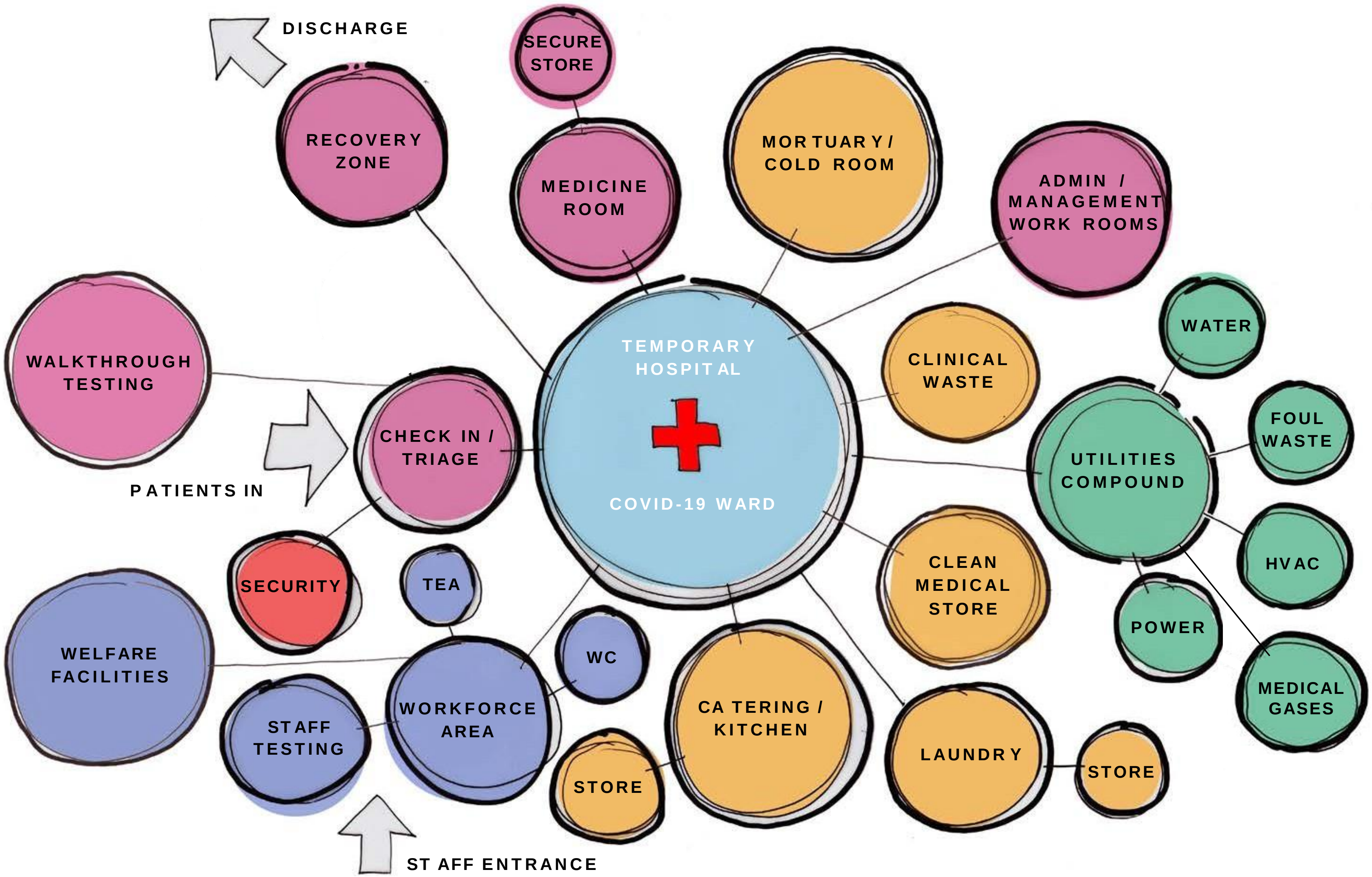
*Temporary Modular Buildings*
*(Container Conversions)*

CONCEPT

# Where are we using this approach?



# Temporary hospital facilities diagram



# Site Assessment

In order to maximise the use of the existing site, gather the following information is before starting, if possible:

### SUR VEY

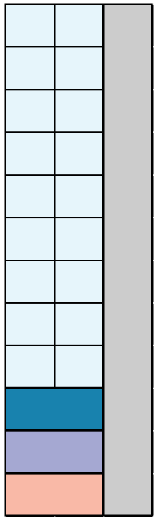
- Assess the surrounding site (see site hazard section) – topography, utilities, adjacencies, access
- Create a floor plan of the existing building including the location of any entrances and exits.
- Measure each room on plan and in height including the size and height of any existing windows and doors; take pictures of the window types.

### SERVICES

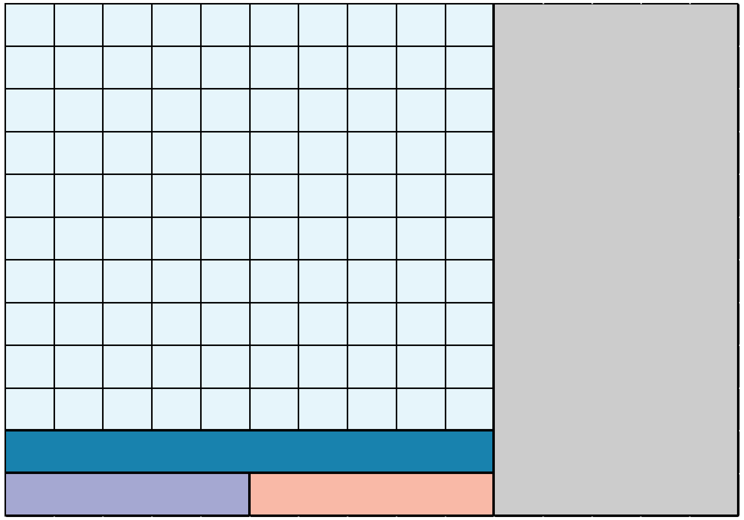
- Existing water supply: source and reliability
- Is there any existing mechanical plant such as fans or AC units?
- Existing sanitation facilities: latrines, showers, treatment, supply and outflow connections
- Existing power supply: source, capacity of any generator, any UPS or battery (e.g. Victron) units

# Approximate dimensions / areas for implementation of temporary general wards

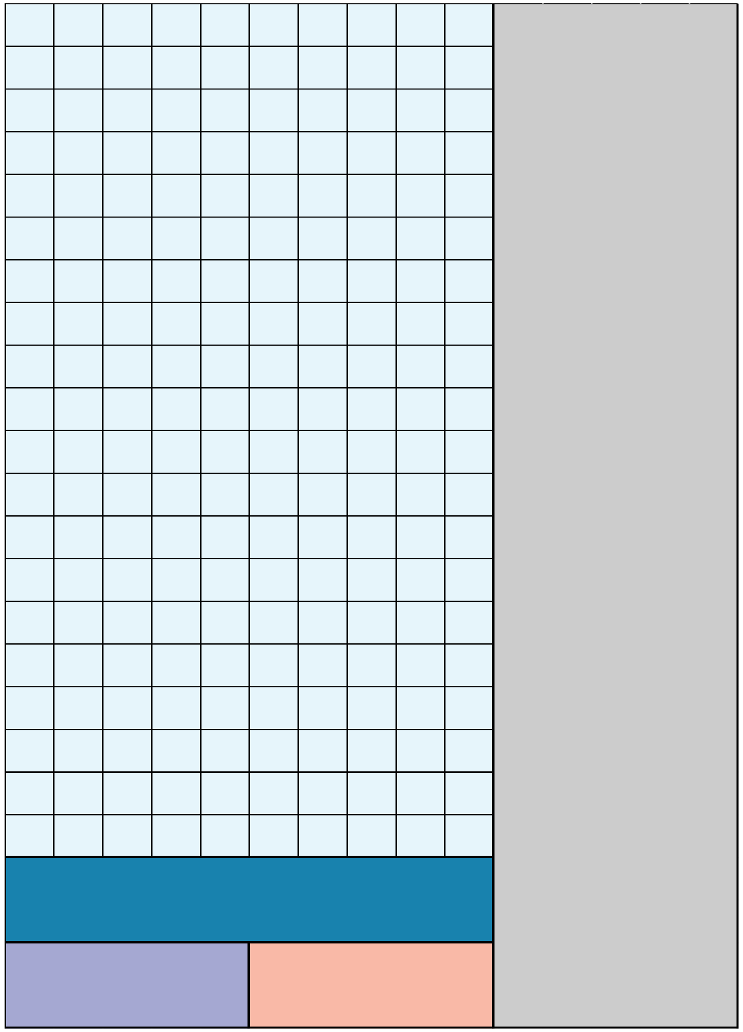
- Bed area – 3.0m x 3.5m per bed
- Ward support modules – 01 module for every 18 – 24 beds
- Medical support areas – estimated
- Services / Operational support areas - estimated
- Circulation / services corridors



**18 BED WARD**
**11 X 45M**



**100 BED WARD**
**45 X 55M**



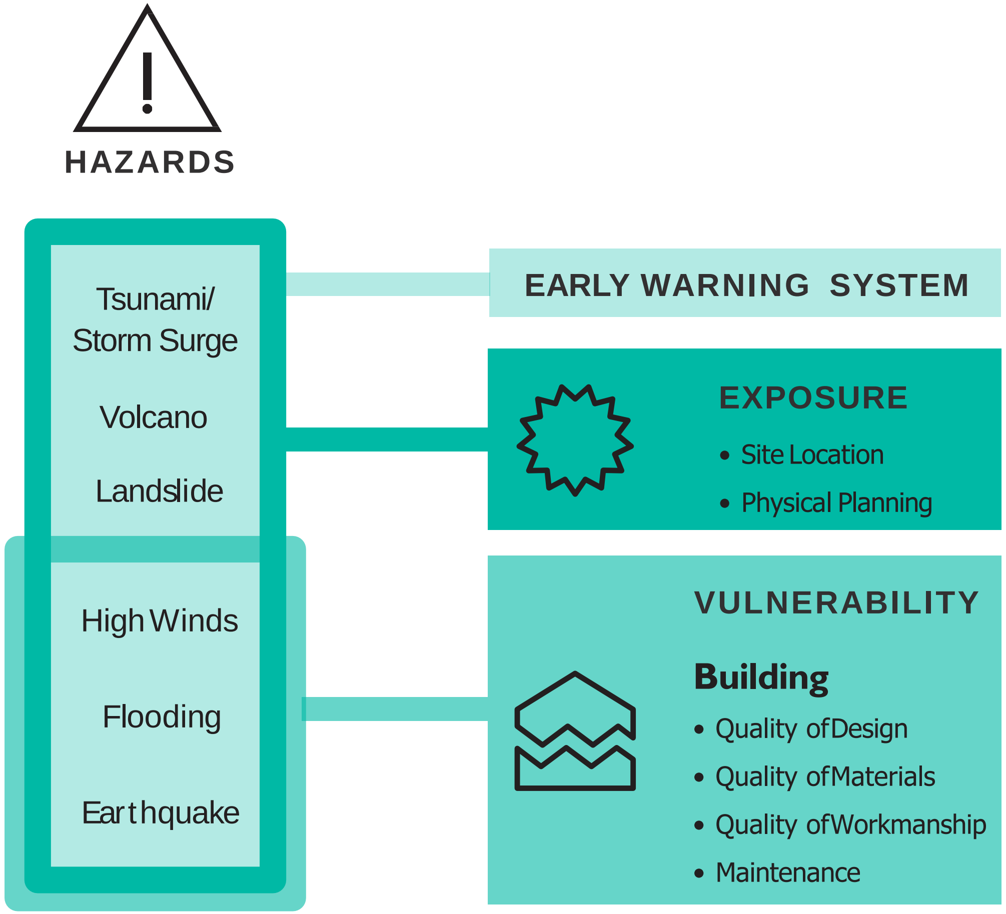
**200 BED WARD**
**55 X 90M**

# Risk to Natural Hazard

The existing building should be assessed to ensure that it is not at risk from damage in the event of a natural hazard.

This basic 3-step process is designed to highlight the steps which should be undertaken to ensure the building is adequately protected from natural hazards. The work should be carried out by a technically qualified person.

| | | |
|---|---|---|
| 1 | Hazard Assessment | • To identify the frequency and intensity of hazards in the area of the facility which the design of the facility needs to account for. |
| 2 | Exposure Assessment | • To identify whether the physical characteristics of the site make the hazards worse.<br>• To identify the mitigation measures relating to the layout of buildings and site-wide civil engineering works compound or reduce exposure to specific hazards. |
| 3 | Vulnerability Assessment | • To determine whether the design and construction of the buildings reduces disaster risk (flood, earthquake and high winds) to an acceptable level, or whether there are aspects that make it inherently vulnerable and therefore unsafe.<br>• To assess the level of maintenance that the building has received since it's construction and identify areas of concern.<br>• To identify further features which may contribute to the resilience of the facility to natural hazards. |




*Adapted from Characteristics of Safer Schools, Arup 2017*

REQUIREMENTS

# Water & Sewage

Ensuring there is a sufficient quantity of safe water which is always accessible is key.

**100-200**
litres per bed per day

## WATER SUPPLY

- Normal supply and demand calculations should be used to size the initial storage required for one days' water supply.
- 2 days' additional back-up is recommended to ensure continuity of supply.

## WATER QUALITY

- SARI treatment centres should be able to test and monitor the quality and safety of their treated water.
- An FRC level >0.5mg/l should be achieved, as is standard practice.

## WASTEWATER

- Wastewater should be treated as per normal in a hospital setting.
- As a minimum, treatment for wastewater should include a well-sized grease trap that is properly maintained, followed by an infiltration trench sized according to the ground characteristics.

## SANITATION

- For smaller health care facilities in low-resource settings, if space and local conditions allow, pit latrines may be the preferred option.
- Standard precautions should be taken to prevent contamination of the environment by excreta (i.e. 1.5m between the bottom of the pit and the groundwater table and 30m horizontally between any groundwater source).

## SOLID WASTE

- Best practices for safely managing health care waste should be followed.

*Refer to the WHO's Guidance on WASH in Covid-19 for further information.*

| WHO estimate ranges | Water demand | Number of patients/staff | Daily Water demand | Storage required if no backup (water trucking assumed) | Storage required with 1 day backup | Storage required with 2 days of backup |
|---|---|---|---|---|---|---|
| Patients high estimate | 200 l/day | 200 | $40m^3$ | $40m^3$ | $80m^3$ | $120m^3$ |
| Patients medium estimate | 150 l/day | 200 | $30m^3$ | $30m^3$ | $60m^3$ | $90m^3$ |
| Patients low estimate | 100 l/day | 200 | $20m^3$ | $20m^3$ | $40m^3$ | $60m^3$ |

* It is assumed that there is one delivery of water per day when water trucking. The initial storage requirement when sourcing water from a source such as a borehole, river or spring will be lower based on supply and demand calculations.

# Environmental Control

## Without mechanical systems, achieving adequate ventilation will require careful planning. Size and configuration of openings will affect what is possible with natural ventilation.

The WHO state the following ventilation rates should be provided

- **160l/s/bed** (where aerosol generating procedures occurs, the critical care ward)
- **60l/s/bed** (for general wards)

Natural ventilation is driven by two things: (1) wind and (2) buoyancy (hot air rises). Typically, air inside a space will pick up heat from sources in the space, such as the occupants, equipment and lighting, which are relatively consistent; whereas wind speed will vary throughout the day. Therefore we have based the example sizing requirements on buoyancy driven natural ventilation; any wind driven ventilation will simply enhance the performance.

The performance of natural ventilation is dependant on a number of factors, including:

- The size and position of openings
- The depth and height of the space
- The external conditions – air temperature and wind speed
- The internal temperature – influenced by heat sources such as occupants, equipment, lights, solar energy.

Since many of these things are variable and not possible to control, the rate of ventilation will also vary and have limited controllability.

This guidance aims to help you assess the available ventilation openings and identify whether remedial work is needed to improve the potential performance.

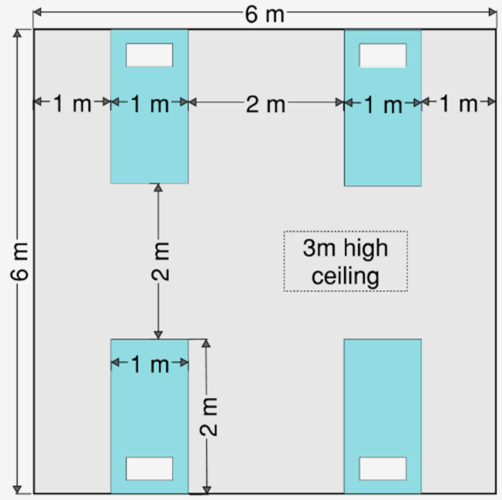
It is important to understand the term Free Area – this describes the actual opening size excluding any solid components such as window frames and insect meshes. The opening size requirements provided relate to free area of the opening. More information about free area is provided on the next page.

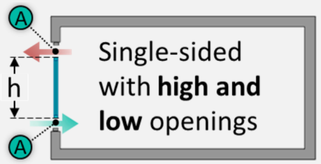
### EXAMPLE: NATURAL VENTILATION OPENING SIZE REQUIREMENTS

This example is to give an idea what is required for a standard 4-bed ward to achieve the 2 WHO criteria for ventilation rates in different configurations:

- **160l/s/bed** (where aerosol generating procedures occurs, the critical care ward)
- **60l/s/bed** (for general wards)

The figures are based on the dimensions in the diagram adjacent. This will not exactly reflect the existing building but provides an indication of the ventilation rate which may be achievable with the ventilation opening configuration options in the table below.




| Ventilation Configuration | Free Area of Opening (A) required to achieve ventilation rate* | |
|---|---|---|
| | **General Wards 60 l/s/bed** 4 Beds → 240 l/s [8 ACH] | **Critical Care Wards 160 l/s/bed** 4 Beds → 640 l/s [21 ACH] |
|  Single-sided with **single height openings** (h, A) | A = 0.9 m² h = 1.0 m | A = 2.4 m² h = 1.0 m |
|  Single-sided with **high and low** openings (h, A, A) | A = 0.75 m² h = 1.5 m | A = 2.0 m² h = 1.5 m |
|  **Double-sided** (h, A, A) | A = 0.65 m² h = 2.0 m | A = 1.7 m² h = 2.0 m |

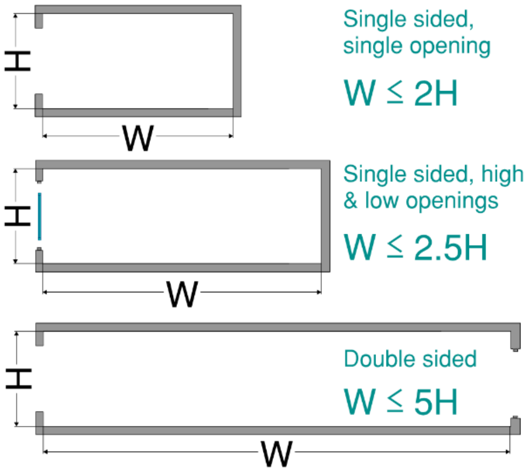
*actual ventilation rate will vary with conditions such as wind speed and internal/external temperature difference. These estimates are based on 5°C temperature difference and relying on buoyancy rather than wind driven ventilation

# Environmental Control

This page explains some of the factors to consider when assessing potential available natural ventilation.

## ROOM SIZE AND NATURAL VENTILATION

If a room is too deep there is a risk of air stagnating in areas that are distant from a natural ventilation opening.
The following rules of thumb[1] can be used to determine whether the available natural ventilation will be effective for the depth of the room:



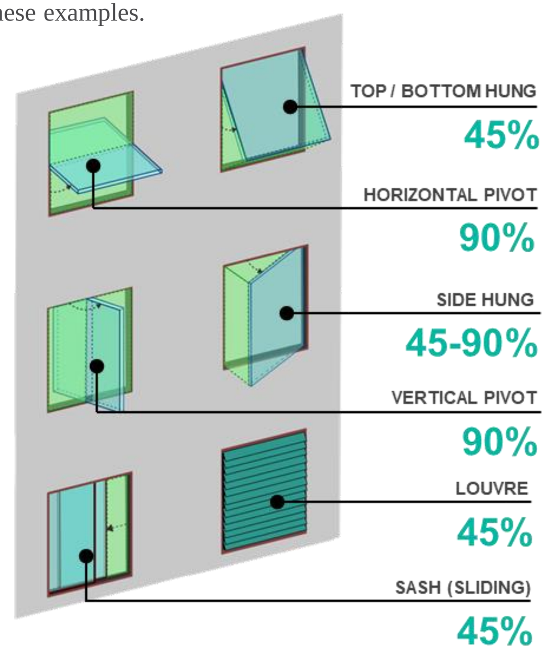

## TYPES OF NATURAL VENTILATION OPENING

Any opening to outside air can contribute to natural ventilation. Consideration should be given to the size and location of the opening – including risk of pollution from nearby sources of dust, odours etc.
Opening windows and louvres are of course typical. Doors can also contribute but if a door is being relied on for ventilation provision care must be taken to ensure it is kept open as required (e.g. users may close the door for privacy or security).

## FREE AREA

### WINDOWS AND LOUVRES

Some windows open more than others depending on their type and range of movement. This table gives some typical percentage free area of openings relative to the overall size of the window (or louvre). The extent of opening can vary considerably and you should look closely at the windows in your building which may be more or less restricted than these examples.

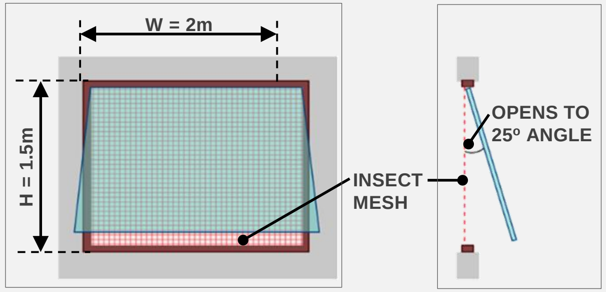



### INSECT MESH

Any mesh over the opening (for mosquitoes etc) will reduce the available free area for air to flow through.
Depending on the type of net, it can reduce it by 55 -71%[2] (i.e. insect mesh free areas can range from about 30 – 45%).

## EXAMPLE: FREE AREA CALCULATION

Total Window Area = 2 x 1.5 = 3m²
Top Hung Window, with opening restricted to 25º angle
There is an insect mesh across the opening with 30% free area




ELEVATION SECTION

Top Hung Window – 45% typical free area
Insect Mesh with 30% free area
Total Opening (Free Area) = Total area of window x % free area of window x % free area of insect mesh
= 3m² x 45% x 30%
= **1.35 m²**

## RECOMMENDATIONS TO PRIORITISE CRITICAL CARE

- Separate critical care patients from the general wards to reduce the space which is required to have the highest air flow rates.
- If limited mechanical ventilation equipment is available, prioritise it for critical care wards.
- If there is no mechanical ventilation available, put critical care wards in the area of the building which has the most windows (e.g. double or triple aspect spaces).



1 CIBSE AM10: Natural Ventilation in non-domestic buildings, 2005
2 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3441282/

# Electrical Supply

## Electrical infrastructure must be resilient and easy to operate in order to ensure the continuity of the services.

Electrical distribution and low voltage protection systems (panelboards, distribution boards) are used to facilitate the electrical supply requirements.

The beds will require a number of power socket outlets located on the bedhead trunking, providing sufficient supply to any medical devices and patient monitoring systems.

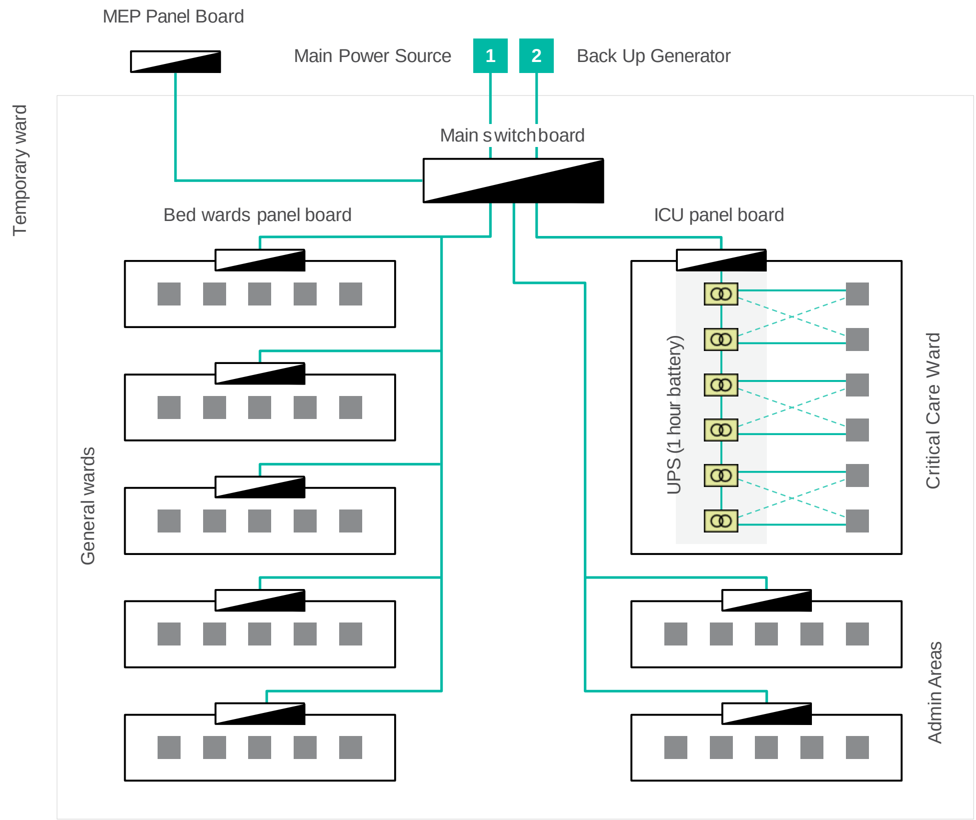
Where possible, all electrical power systems should be provided with 20% spare spatial and electrical load capacity to in case there is a need to add additional surge facilities (including tents) in future.

### BACK UP POWER

The power supply to vital services such as oxygen concentrators, respiratory support systems and medical monitoring systems should be backed-up by UPS.

Make sure all sockets supplied by lines on the UPS are marked clearly with coloured tape or labels. Accessible signage should inform users that these sockets are not to be used for other power supply needs (like mobile phone chargers or lights). Provide other sockets nearby on the regular line to discourage use of the back-up system for non-essential use.

If available, provide an isolated power supply (IPS) system to the ICU beds for patient protection.




ELECTRICAL SYSTEM

### OPERATION AND MAINTENANCE

Where possible, ensure switchboards and key access points to the system are in green/clean zones to ensure safe and efficient maintenance or repair.

One member of staff on site at all times should know how to change over the power source to the back up power in the event of a power failure. We have suggested to provide 1 hour back up power but this should be reviewed on a case-by-case basis by assessing how long a reset of the power system would take based on practicality of providing UPS, facility size, number of trained staff and system reliability and set up.

# Medical gases

Any temporary wards need to be designed to have medical gas systems. Where possible, a piped solution using liquid oxygen is preferred, however, other solutions may be required to suit the options which are availably locally.

## MEDICAL OXYGEN

A regular supply of oxygen is required in wards with severe and critical patients. Temporary oxygen solutions are also required in mild/moderate wards for patients who deteriorate before they can be transferred to another ward or facility. Oxygen supply options are:

- Bulk liquid oxygen plant (single Vacuum Insulated Evaporator (VIE)) and automatic manifold system
- **Bulk liquid oxygen plant** (2 No. VIE vessels) located together or apart
- **Liquid oxygen cylinder manifold** and automatic manifold system
- **Pressure Swing Absorption (PSA) oxygen generation** (multiplex compressors and columns) and automatic manifold system
- In contexts where these options are not feasible, **oxygen concentrators** (min 10L) should be located at each bed for severe and critical wards.

A reserve supply of medical oxygen should be provided by local cylinders.

## Where applicable:

### MEDICAL AIR (4 BAR)

A piped supplied of Medical air can be provided from central plant. A primary and secondary supply will be delivered by either:

- Duplex compressor system and automatic manifold system
- Triplex or quadruplex compressor system

A Reserve supply will be provided by either:

- Automatic manifold system
- Locally-based cylinder

### MEDICAL VACUUM

Piped medical vacuum from a central packaged plant should not be provided to an infectious diseases unit, we recommend that portable suction be used to mitigate contamination in an infectious disease unit.

## SUPPORTING INFRASTRUCTURE

Plant for oxygen storage or generation is often heavy, so consideration for access for installation and suitably sized foundations should be made in advance of any construction.

## SAFETY

The ventilation rate for the wards is kept high to prevent a dangerous build-up of oxygen. If possible, oxygen enrichment sensors should be located at regular intervals to alert staff to leaking oxygen. If not, signage to remind staff to be alert to displaced mask and nasal cannula which may be leaking oxygen into the environment.

Specific training for staff involved in these activities, such as changing cylinders, storing bottles and maintaining equipment should be in place to ensure they are aware of how to mitigate these risks. See Fire Safety section for further details on managing fire risk.

# Fire safety

Fire presents a major risk to the life safety of patients and staff, and to the continuity of essential healthcare. Temporary Covid-19 healthcare facilities present unique challenges that must be assessed and addressed in the fire safety strategy.

Many patients are likely to be *high-dependency, bedbound and possibly served by fixed O2 feeds*. Critical patients will likely be intubated on ventilators and sedated. Relocation of a patient is usually protracted, requiring connection of a portable O2 bottle and multiple staff to move their bed and all associated equipment. As such, *in the event of fire, patient evacuation or relocation should be avoided unless essential*. Instead, to *reduce the likelihood of significant fire occurring*, the focus should be on prevention, mitigation and intervention as part of a crisis response framework.

*Oxygen-enriched atmospheres increase the likelihood and potential severity of a fire*. Rapid-build or temporary hospital construction also presents challenges sourcing non-combustible construction and installing passive and active fire protection measures.

In the face of these challenges and the various other expected project constraints, the fire safety strategy must be based on risk-reduction and an *ALARP approach (As Low As Reasonably Practicable)*. A range of potential fire safety measures may be appropriate, some of which are summarised on the following pages. To establish effective and suitable measures for a particular temporary hospital facility, *the fire safety strategy must be developed in partnership with relevant stakeholders* including the hospital operators and the local fire and rescue service.

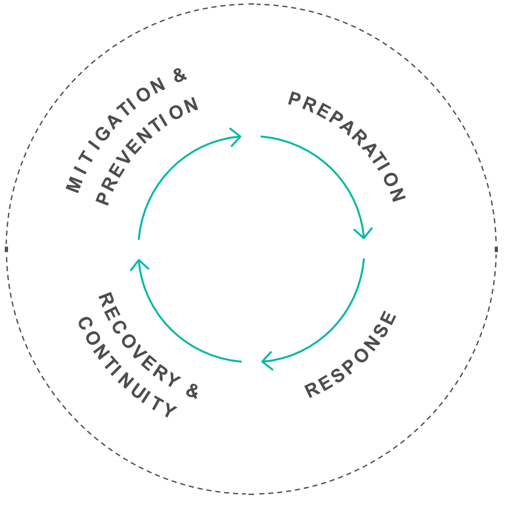
In modern permanent healthcare facilities, the evacuation strategy relies on a high degree of compartmentation and horizontal exits. In case of an uncontrolled fire, patients in the effected compartment are relocated to another compartment on the same floor, which is separated by fire resisting construction thereby protecting them from fire and smoke. *Where compartmentation is achievable this approach should be adopted*. Otherwise full evacuation may be necessary whereby clinical staff intially evacuate patients in the vicinity of the fire and ultimately the entire facility if the fire remains uncontrolled.

Should a fire occur, *early intervention to tackle the fire is key to maintain life safety and minimize the number of patients who need to be evacuated*. First responders will likely be non-clinical staff trained in firefighting and locally trained firefighting teams from the community, if relevant. If there is a local fire brigade, their response is a critical asset to control and ultimately extinguish the fire. Clinical staff should not be relied upon for firefighting intervention.

To support handover, *daily fire safety management and emergency response, clear fire safety information* must be developed, including on roles and responsibilities, emergency action plans, maintenance, monitoring and housekeeping protocols.

Note this approach is applicable for adaption of existing buildings and construction of new facilities. For both scenarios, it is critical that the existing fire safety context is understood. *In an informal settlement or camp (IDP/refugee) setting, previous/ongoing fire risk reduction efforts should be understood* and the relevant stakeholders should be engaged with (e.g. local fire and rescue services, camp managers, shelter sector, WASH sector).

Installing temporary healthcare facilities in existing spaces presents additional unique challenges. The fire strategy of the entire existing building needs to inform the *design, construction and operation of the temporary healthcare facility*, even if only a portion of the building is used for this purpose.



# Fire safety

## PREVENTION & MITIGATION

- **Electrical fires:** qualified or experienced electrical installers, robust residual circuit breakers, certified and/or well maintained installations and portable appliances.
- **Stored combustibles & waste:** minimise and remove from wards ASAP.
- **Oxygen-enriched fire risk:**
  - **Capping of Oxygen feeds**; trained staff to cap all O2 feeds (e.g. fixed feeds from central supplies or feeds from concentrators) when connecting temporary O2 bottles for patient movement purposes.
  - **Ventilation** - Provide suitable ventilation provisions to minimize oxygen enriched environments
  - **Storage** - Centralised oxygen storage supplies and oxygen generators should be located remote from the building. The storage of oxygen bottles should also be remote from the building and capped when not in use.
- **Ignition risk from static:** choose cotton PPE rather than nylon if possible.
- **Construction:** non-combustible building materials such as walls, ceilings and linings (e.g. gypsum board, metal frame, mineral wool infill – avoid foam insulation, chipboard partitions, plastic canopies, etc.). Where this cannot be achieved the extend of combustible material and location with respect to escape routes/impact on flame spread will need to be evaluated and risk assessed
- **Fire spread between bed rows:** provide reasonable separation between rows of beds; 5 m is advised as a benchmark.
- **Building Separation :** Distances between buildings should be assessed to mitigate the risk of fire spread to and from surrounding buildings. The following recommendations should be considered based on relevance to the project:

- Selection of new site – site selections should maximize distances between new building and adjacent buildings;
- Siting of new building on existing site – building geometry (incl. footprint) to allow maximise distances between new and adjacent buildings;
- Existing building on existing site – locate higher risk areas such as ICU near external walls with the highest separation from adjacent buildings (this decision needs to be balanced with other fire safety considerations such as exit proximity)

## PREPARATION

- **Early warning:** smoke detection throughout ward and all ancillary / existing areas in the building; manual call points;
- **Exits:** at least 2 opposing exits from every area of the building; exits should lead to another protected area (fire separated) or outside; exits to be remotely located to minimise single-direction travel distances; avoid dead-end corridors.
- **Fire exit doors:** outward-opening and of sufficient width to allow bed movement and evacuation with necessary equipment
- **Signage:** clear, conspicuous, graphical emergency signage (back-lit or by lights).
- **Temporary O2:** keep sufficient bottles available to support patient relocation.
- **External exit routes:** avoid steps (use ramps where possible); at least 2 remote assembly points should be identified with external signage; detailed assessment of opposing routes away from the facility will be required on a site specific basis and should include an assessment of wider site risks.
- **Emergency lighting:** all internal areas should have lighting on backup power; locate external escape routes and assembly points along normally lit paths (e.g. street lights); provide flashlights to support evacuation along external escape routes.
- **Fire extinguishers:** provide throughout (type appropriate to fire class and occupancy).
- **Fire blankets:** provide throughout.
- **Fire Fighting:**

- Non clinical staff should be suitably trained in managing fire response including fire fighting.
- Community fire fighting teams (if available) should be trained to support health care facility fire response
- Local Fire Brigade (if available) coordination and communication should take place with local fire brigade to enable response and intervention

- **Facilities for firefighters:**
- Suitable firefighting emergency vehicle access should be provided to all parts of the facility
- Suitable water supplies, firefighting equipment and firefighting connections should be provided to support initial firefighting by trained non-clinical staff and/or community fire fighting teams, as well as firefighting response by the local fire brigade (if available). Water supply design should be based on local requirements and engagement with the local fire brigade and other key stakeholders such as the WASH sector.

- **Information to support fire response:** floor plans showing firefighting facilities, access, key risks, etc.

## RESPONSE

- **Investigation and intervention:** rapid attention by nearest clinical or non-clinical staff to confirm a fire and initiate response (e.g. fire blankets, fire extinguishers, patient relocation).
- **Patient relocation:** a phased approach is necessary to minimise disruption to essential healthcare:
  - Phase 1: evacuate occupants in immediate danger away from the fire location and to outside the building ; mobilise as many staff as possible to assist.
  - Phase 2: if the fire remains uncontrolled evacuate the remaining occupants to the outside of the building
  - Phase 3: Proceed to relocate all patients to pre designated assembly points remote from the building.

## RECOVERY & CONTINUITY

- **Continuity:** relocate patients to other wards / areas with fixed O2.
- **Post-fire smoke clearance:** via doors, windows, vents. etc.
- The program of works should consider worst case contingency planning for patient relocation in the event of damaged wards or fully destroyed facilities

# Fire safety

## Site Selection

- Is the proposed site located in a high risk area (e.g. dense informal settlement, congested camp setting)?
- What are the boundary conditions between the proposed site and adjacent buildings / properties?
- What emergency vehicle access and/or water infrastructure is available to support fire response?
- What pathways and remote assembly points are available to support evacuation away from the building?

## Design

- Is a suitable person available to develop the appropriate fire safety strategy (Fire Engineer) and relevant systems design (MEP Engineer)
- What types of treatment will be provided in the facility – do they pose additional fire risks (e.g. oxygen enriched environments)?
- Is there a need to separate treatment areas (ICU) to protect the most vulnerable patients from a fire in other areas of the building?
- What building materials are available for construction?
- Is it possible to procure materials for passive fire safety measures (e.g. fire resistant construction) or active fire safety devices (e.g. smoke detectors)?
- What is the strategy for fire response – communications (incl. fire detection and alarm), evacuation and firefighting?

## Construction

- Is specific experience or training required for contractors to install passive or active fire safety measures?
- Is a suitable person (e.g. Fire Safety Engineer) available to review / propose design changes during construction in order to achieve fire safety objectives?
- Does the construction meet fire safety requirements? Has it been approved for occupation or "signed off" by an appropriate stakeholder (e.g. Facility operator, local fire and rescue services, Fire Engineer, Camp Manager)?

## Operations & Maintenance

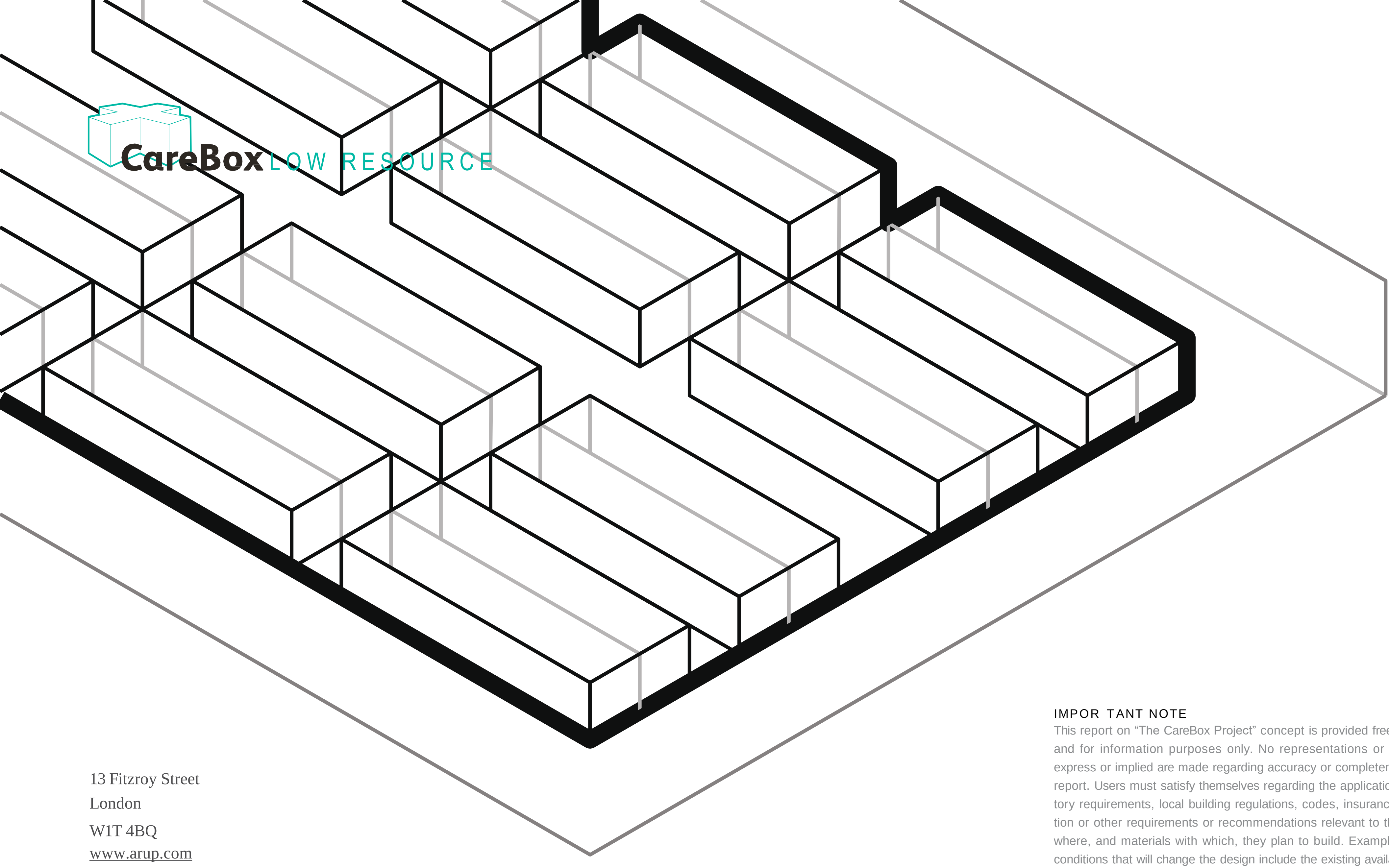
- Are roles and responsibilities for fire response clearly communicated and coordinated?
- Is fire safety training provided on a regular basis?
- Are responsibilities and intervals for maintenance and testing of fire safety measures clearly communicated?

**RESIDUAL RISK**

Fire risk that is not adequately addressed in a project stage cascades to the next project stage, and is known as **Residual Risk**. At the next project stage, residual risk should be addressed as far as reasonably practicable (ALARP), in addition to issues relevant to that next stage (see example questions at each stage).

Due to significant constraints posed by these complex contexts, residual risk is expected to cascade through each project stage and some will remain during operations. Preparedness for fire incidents therefore becomes critical to avoid catastrophic fires which could affect not only the healthcare facility but also the surrounding community.

CareBox LOW RESOURCE



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IMPOR TANT NOTE

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