# CareBox PLUG-IN

Modular design guideline to provide healthcare space attached to existing hospitals

ARUP

THE NEED · THE ANSWER · PLUG-IN · MODULES · REQUIREMENTS · NEXT STEPS

**As the number of people affected by the coronavirus pandemic continues to rise globally, Arup has mobilised a multi-disciplinary team to engage directly with multiple governments, healthcare bodies and NGOs around the world, offering our technical support and guidance.**

Healthcare systems across the world are seeking new opportunities to increase their bed capacity at all levels of patient care, from the critical shortage of ICU beds to the provision of field hospitals dealing with large numbers of patients. We have developed a range of scalable, modular and rapid build solutions which can be implemented on existing healthcare campuses or as standalone facilities. This guideline is one of three scenarios to provide specific healthcare spaces for Covid-19 or similar infectious diseases:

1. Plug-in hospitals attached to existing healthcare infrastructures.
2. Confined spaces such as existing multi-storey car parks.
3. Non-confined spaces such as convention centres, sports halls or outdoor areas sheltered by tent or other temporary structure.

Through this collaboration, Arup has developed the CareBox project, applying robust engineering principles to address the immediate challenges of this pandemic. Arup is providing independent, multidisciplinary technical advice to governments, healthcare organisations, and international NGOs responding to the pandemic.

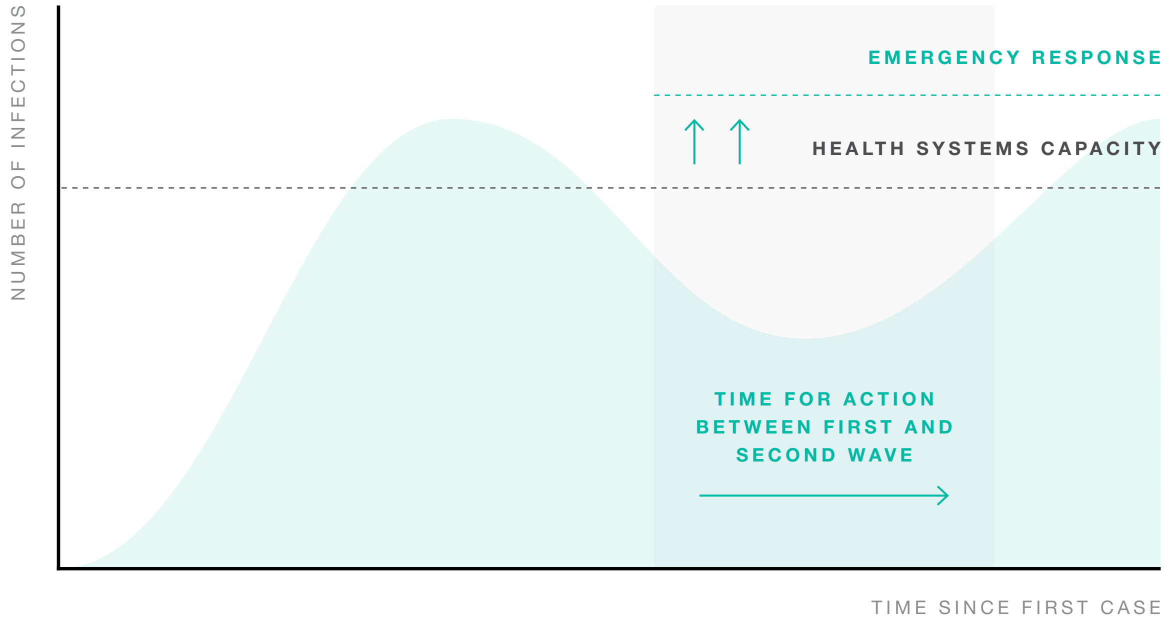
# Preventing health system collapse

Flattening the curve is not the only action governments can take to prevent the collapse of healthcare systems. A parallel action is to rapidly increase the number of beds providing care to Covid-19 infected patients. This has been tried using different strategies in China, Italy, Spain, and now everywhere across the globe.

The first strategy is to increase the number of ventilation-assisted and intensive care beds inside the existing hospitals. This is happening everywhere but has a limit due to space constraints.

The next step is to open other beds elsewhere for temporary patients. Hotels are being used in many cities, but it fragments healthcare staff and requires the installation of medical gas utilities that are not easy to deploy.

**The CareBox project** is a Covid-19 specific modular solution, engineered for rapid deployment, optimization of transportation, replicability and scalability.




*"The lessons I've learned after so many Ebola outbreaks in my career are be fast. Have no regrets. You must be the first mover. The virus will always get you if you don't move quickly. Speed trumps perfection."*

**Dr Michael Ryan,**
Executive Director, WHO Health Emergencies Programme.

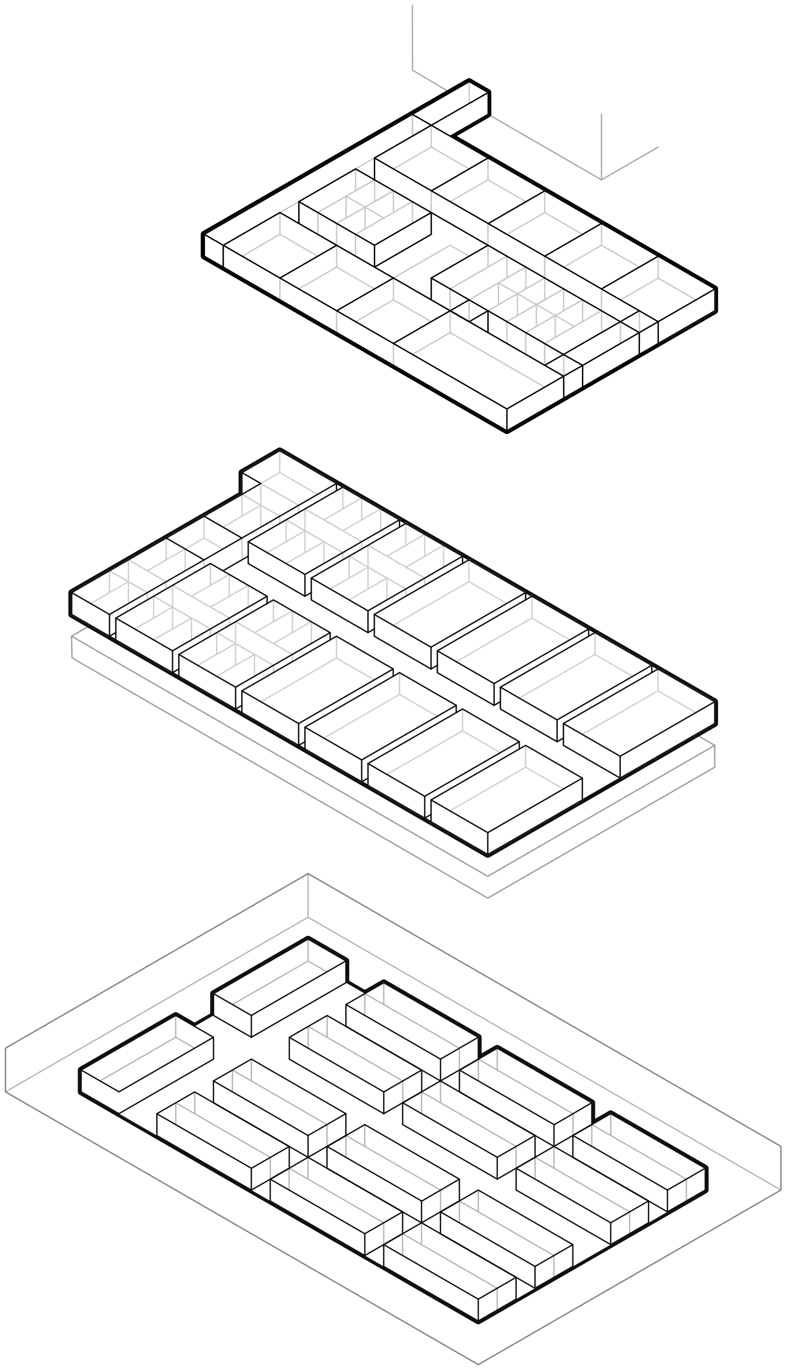
**FLATTENING THE CURVE**

The priority should be to flatten the curve. But it could still exceed the capacity of the health system. In that case, it is essential to plan for an increase in capacity that can be implemented in a very short time.

THE ANSWER

# Prefabricated modules

The CareBox project identifies a range of solutions, which can be adapted to suit the available space and facilities.



**A** PLUG-IN
One or more wards connected to an existing hospital.

**B** MULTI-STOREY
Modules deployed in multi-storey car parks, next to a hospital or not.

**C** IN-DOOR
Beds and equipment inside existing convention centres or sport halls.

### ADAPTABLE DESIGN

The success of any scenario is to apply the core basis of design to a specific location, adapting the principle without losing its values.

### FAST PRODUCTION

Units are prefabricated off-site using a worldwide supply chain under clear design principles.

### TRANSPORTABLE

Modules and elements are shipped as flat panels in containers to allow for ship, truck or air cargo.

### EASY TO DEPLOY

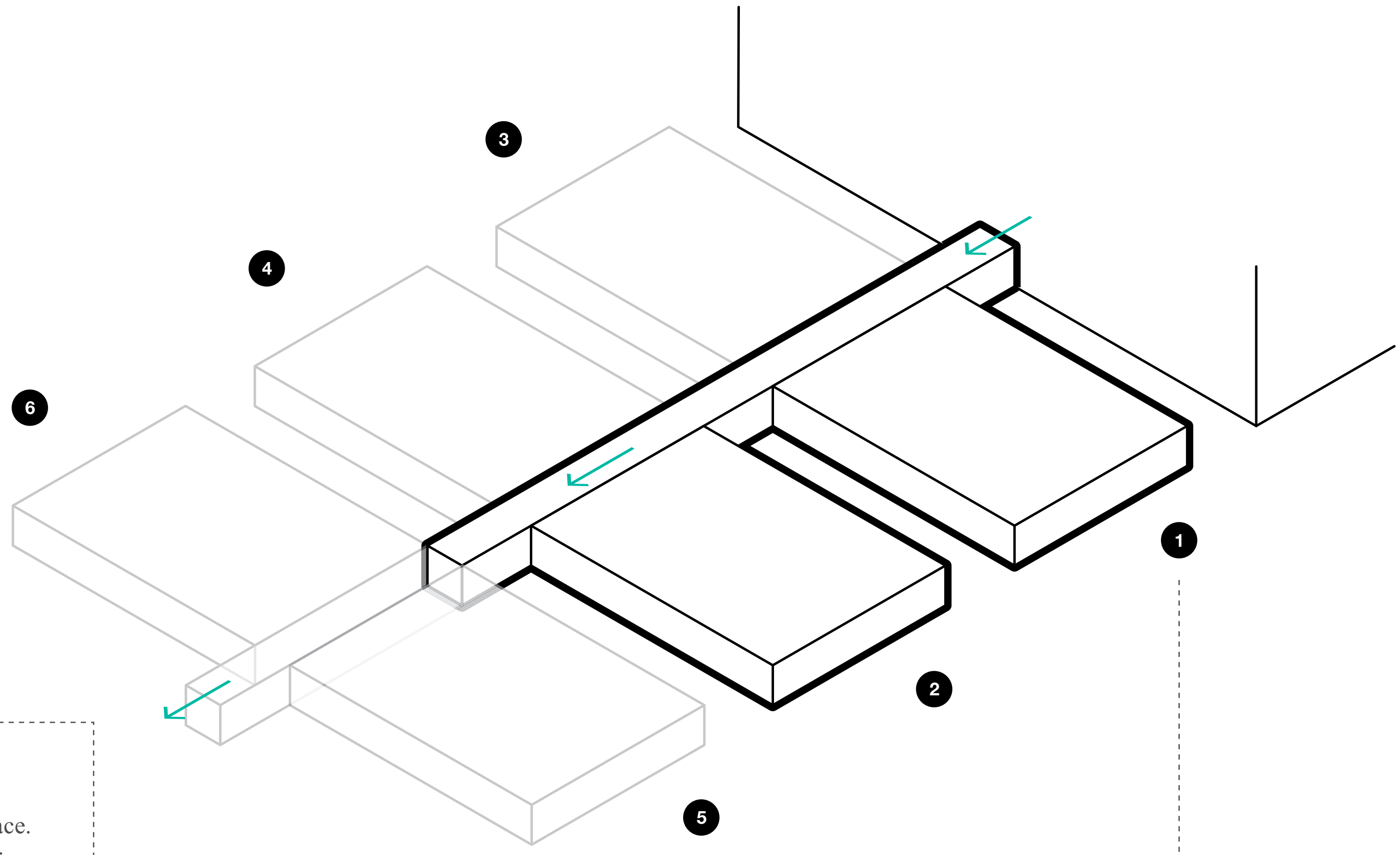
Once on site, their assembly is easy and repetitive, with a simple modular solution which can be implemented quickly.

### COST-EFFECTIVE

The use of modular technologies enables economies of scale to maximise the speed of construction in an efficient manner.

# The Plug-in concept

The idea combines the concept of a ready to use field hospital with the advantage of connection to an existing healthcare centre in terms of medical staff, logistics and access to medical gases and other services.

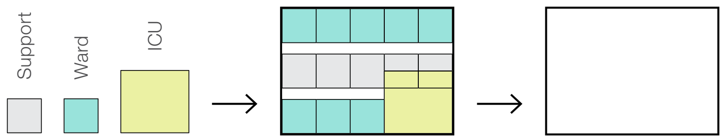



### BENEFITS AND CHALLENGES

- **Flexible plan**, adaptable to suit the available space.
- **Personnel** availability of staff and support services.
- **Medical gas and power** from the hospital.
- **Access** via a protected corridor connected directly to the hospital.
- **Waste / contaminated material** exits from the back to disposal areas.
- **Internal circulation:** from clean to dirty.
- **Accessibility / evacuation (if necessary):** in wheelchair or bed.
- **Triage, IT, canteen, laundry, etc:** from hospital.
- **Speed of installation:** in weeks not months.

### THE MINIMUM UNIT

This is the minimum replicable unit to deploy according to the needs and boundaries.



# The Plug-in concept

Addition of modular units to existing hospitals are not new. There is an immediate need for two types of bed; patients with assisted ventilation via oxygen masks or CPAP and critical patients in intensive care units (ICU) for respiratory ailments.

Industrialized assembly secures a safe operation and reduces maintenance activities on site. The process responds to circular economy: the future dismantling allows for the modules to be recovered and reused in different cities or countries after the peak has passed.

### CATEGORIZATION OF PATIENTS WITH SEVERE ACUTE RESPIRATORY INFECTION

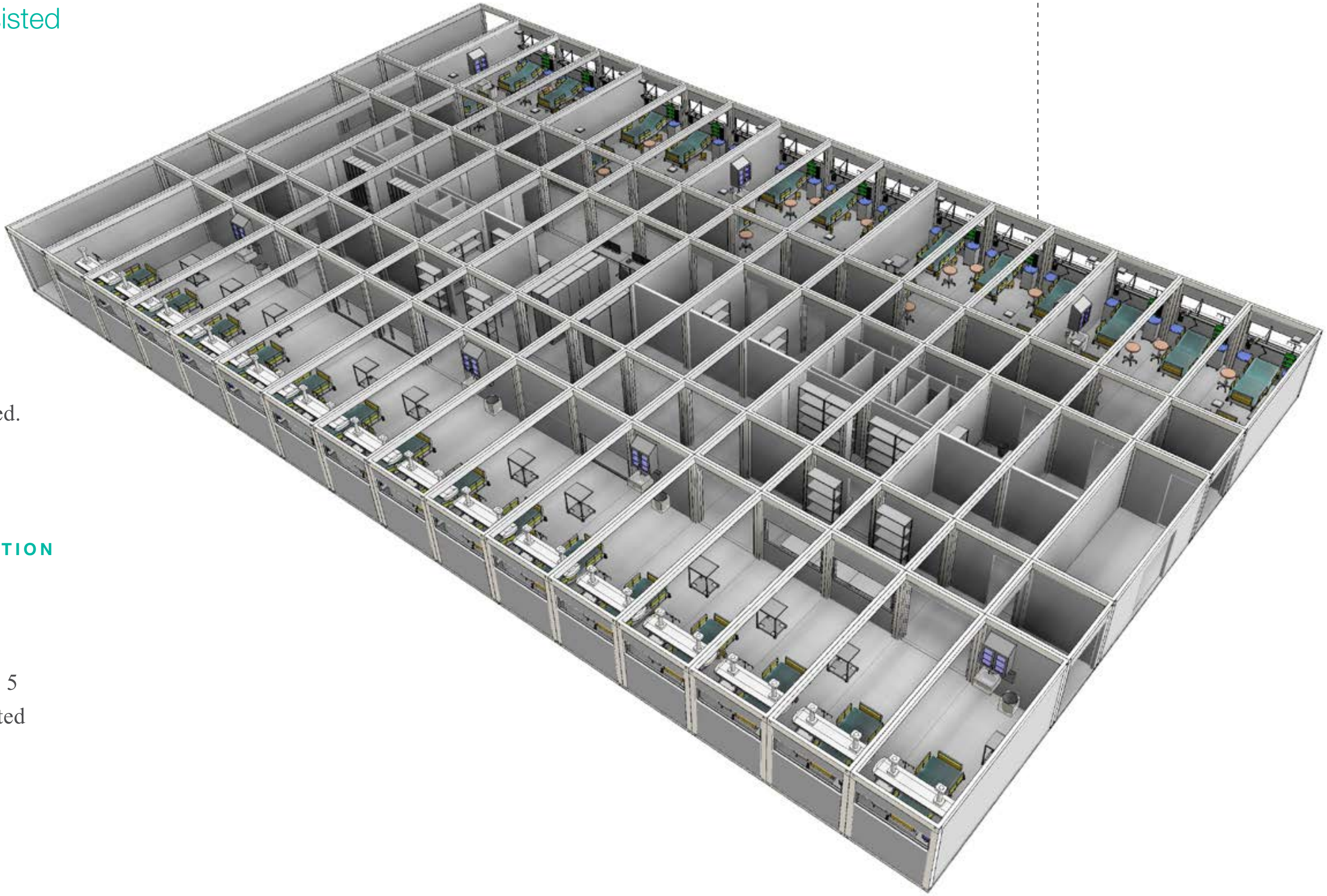
Carebox allows for the two required type of beds:

- Oxygen supplied bed wards being configured as 5 beds per rooms. This type of bed will be dedicated to moderate* and severe disease cases.
- Intensive Care beds, which will be dedicated to critical* disease cases.

* Moderate/Severe/Critical patient definition as per WHO categorization of patients with acute respiratory infection.

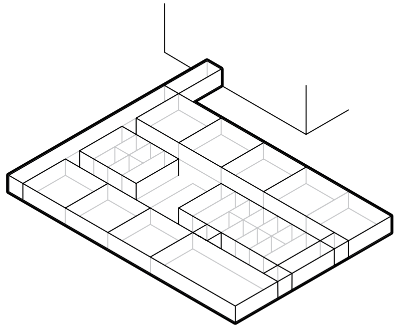
### THE MINIMUM UNIT TOP VIEW

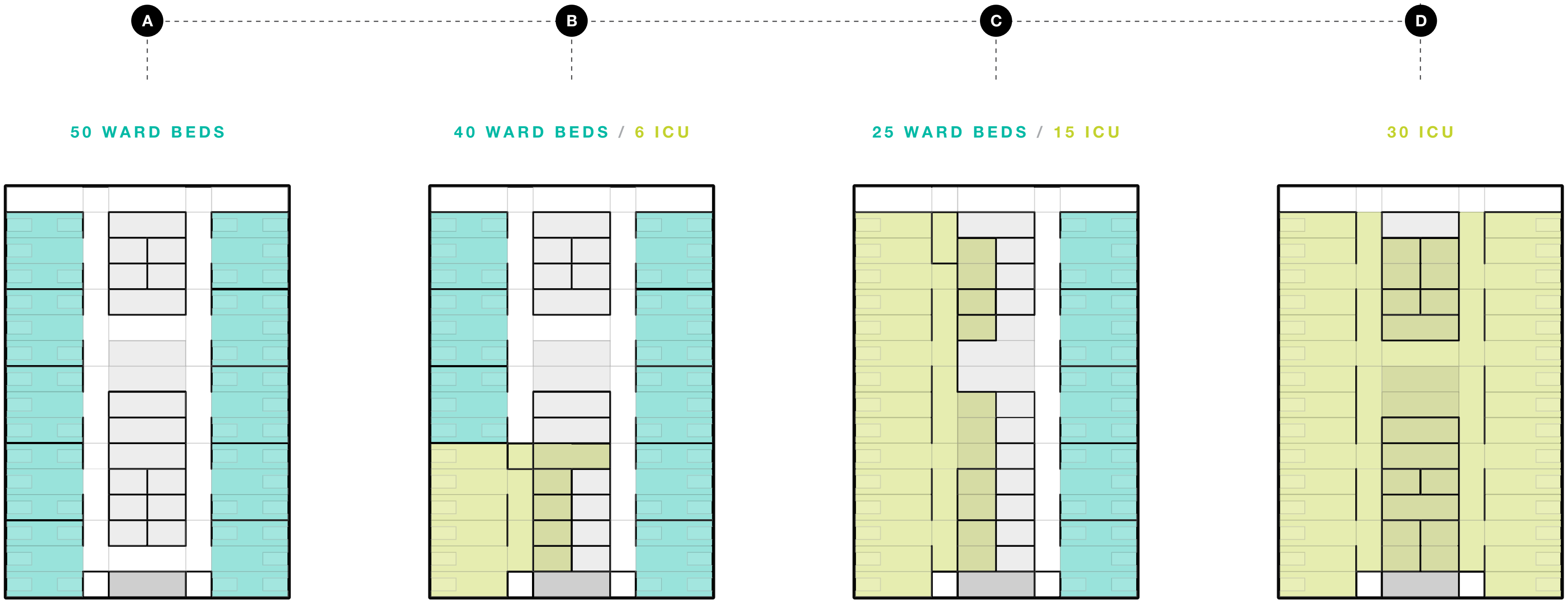
Each ward uses standard shipping container modules (20ft) with internal lightweight partitions.



# One concept, four options

Depending on the hospital needs, the concept is flexible to incorporate a varying number of ventilation-assisted beds, ICU beds, or a combination of both. Expansion or adaptation is also possible. Wards can also be used for those patients who are close to recover.





PLUG-IN

# PPE Don/Doff

Protection is critical for a Covid-19 treatment centre to work properly and safe.


WHO defines strategies for the infection prevention control during health care when COVID-19 is suspected. Providing precaution criteria and classifying them in:

- Standard precautions for all patients.
- Contact and droplet precautions.
- Airborne precautions for aerosol-generating procedures.

WHO PPE recommendations for each area whitin a severe acute respiratory infection treatment healthcare infrastructure depend on target persons and activities performed in each area.

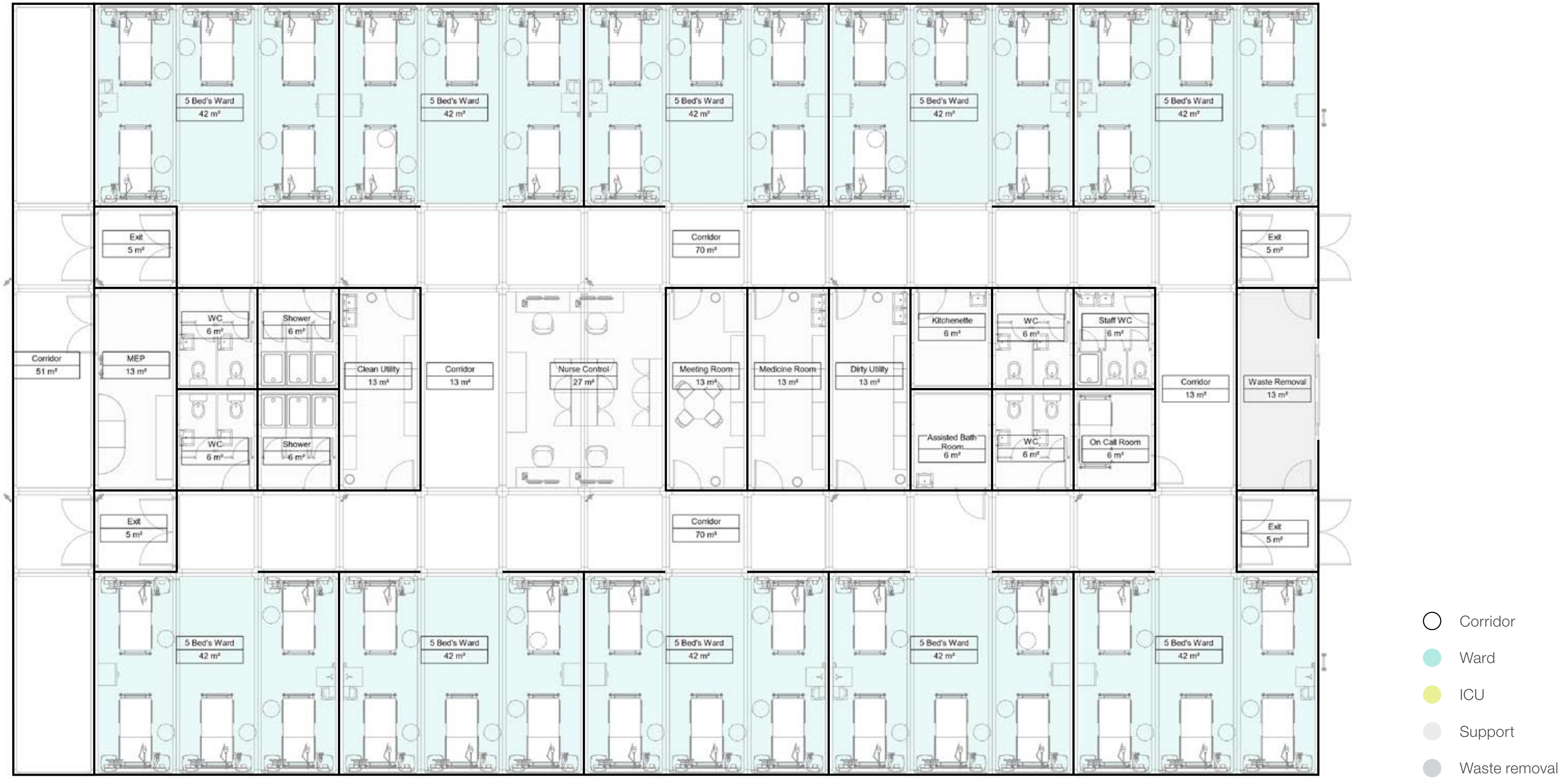
Aerosol-generating procedures, such as tracheal intubation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation and bronchoscopy would be restricted to ICU areas. Both, bed wards and ICU are mechanically ventilated ensuring negative-pressure and at least 12 air changes per hour, with controlled direction of airflow and HEPA filters in the exhaust.

Delimitation of Moderate/Severe Care. Don/Doff PPE. Precautions for contact and droplet.

Delimitation of Critical Care. Don/Doff PPE. Precautions for contact, droplet and airborne.

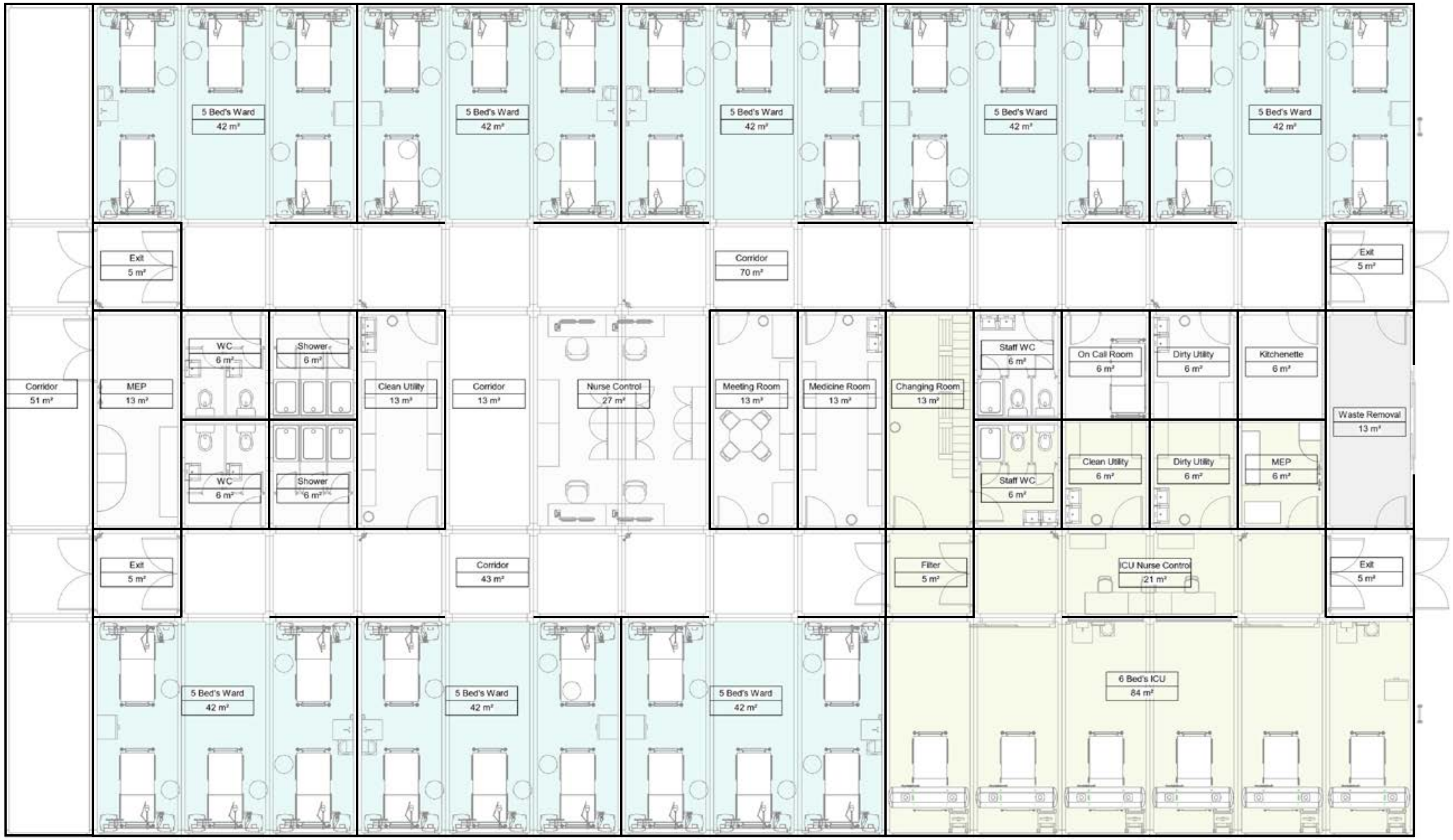
# Plan distribution

## A 50 ward beds



# Plan distribution

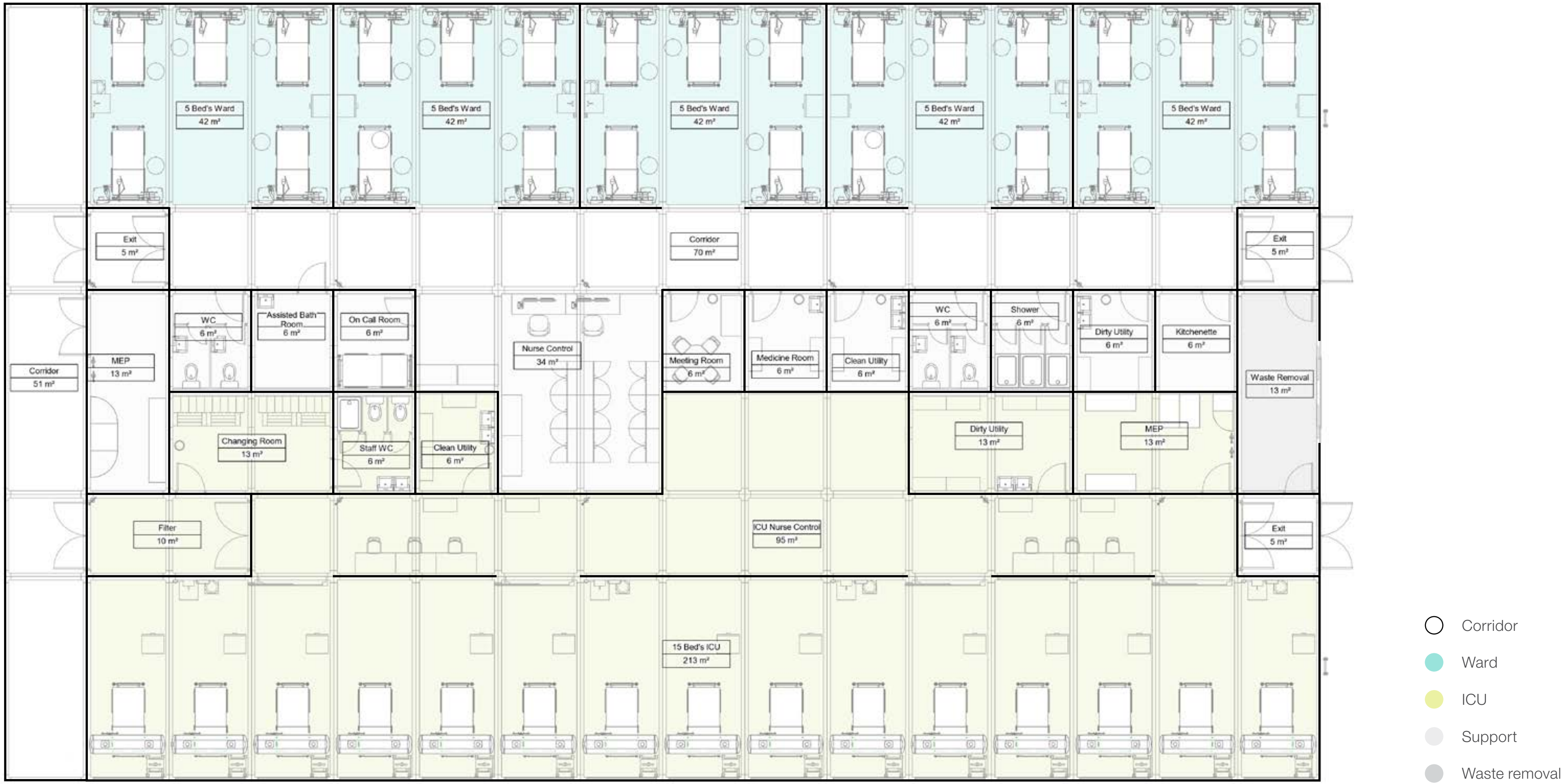
## B 40 ward beds / 6 ICU




- Corridor
- Ward
- ICU
- Support
- Waste removal

# Plan distribution

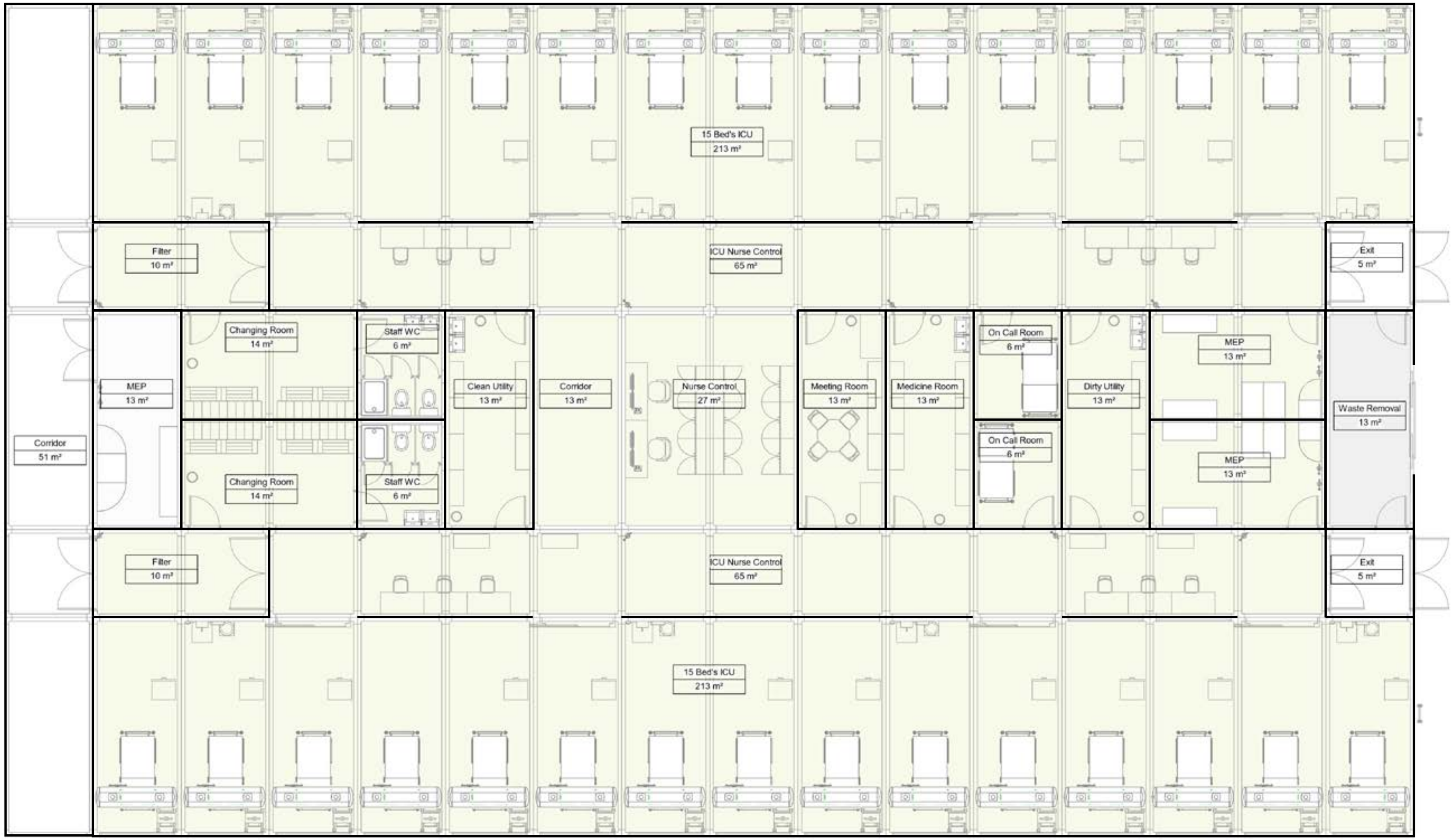
## C 25 ward beds / 15 ICU



# Plan distribution



## D 30 ICU




Corridor

Ward

ICU

Support

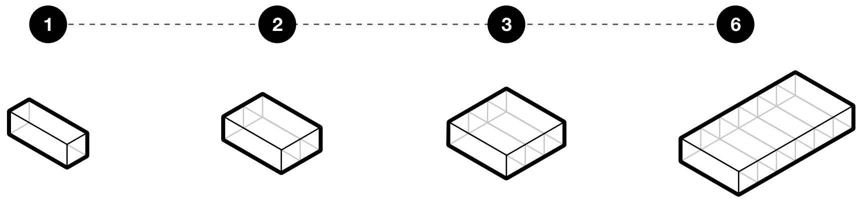
Waste removal

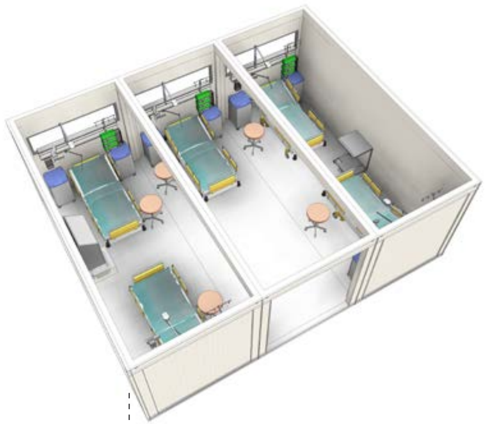
# Made by modules

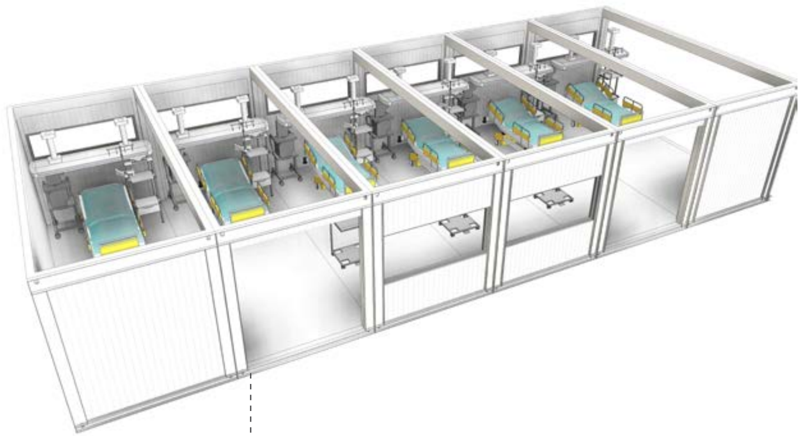
The wards are designed following the Modern Methods of Construction (MMC) and Design for Manufacture and Assembly (DfMA) concepts. Both are standard approaches in the construction industry. Module dimensions are similar to a 20 feet container: 6.1 x 2.4 metres, with a height of 2.8 metres.

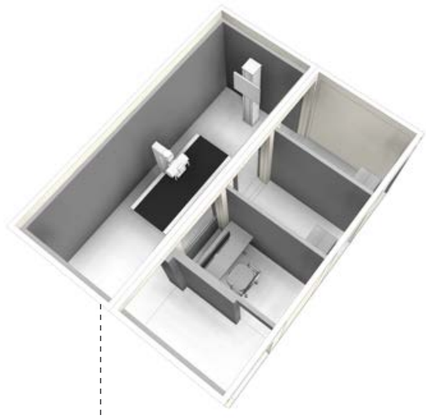
**MULTIPLE CONFIGURATIONS**

The modules are linked in multiples of 2.4 metres to create boxes or corridors.







**WARD MODULE**

Three modules become an independent box of five oxygen-assisted beds.

**ICU MODULE**

Six to twelve modules become a long box of six to twelve ICU beds.

**SUPPORT MODULES**

The central spine allocates modules for different uses: pharmacy, resting area, WC's clean/dirty utility, storage, etc.

# The ward module

Each ward module allocates five moderate or severe Covid-19 patients. Critical patients go to the ICU. Each patient has access to oxygen ventilation via face mask or Continuous Positive Airway Pressure (CPAP).

The module entrance is at the centre, to facilitate the movement of stretchers. The opening space may incorporate an automatic sliding door.

Beds are spaced at 2.4m centres to provide adequate space for clinical staff. Spaces have been optimised to ensure safe access to the patients and movement of patients throughout the circulation zones. Natural light is provided through high-level windows with an openable section to assist with smoke extract in case of fire.

The floor finish of all modules is in vinyl to facilitate ease of cleaning and infection control. The ceiling incorporates sound-absorbing materials. All finishes and insulation are in non-combustible or low- combustible materials.

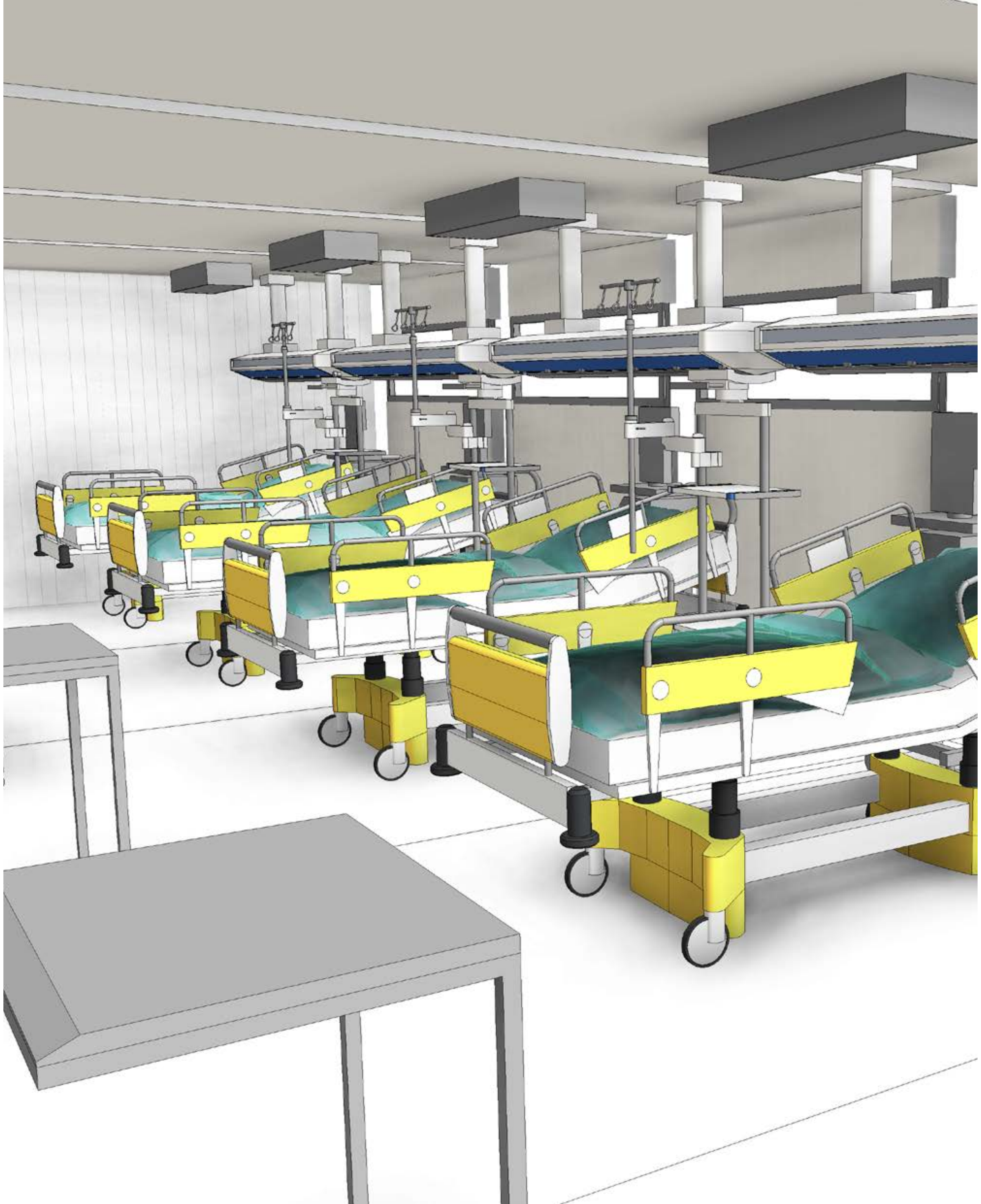
# The ICU module

There are two sizes of ICU modules: 6 and 15 beds in longitudinal boxes. Each module has glass doors and glass panels to allow for direct inspection from the nurse control areas.

Beds are spaced at 2.4m centres to provide adequate space for clinical staff. Spaces have been optimised to ensure safe access to the patients and movement of patients throughout the circulation zones.

ICU modules have glass surfaces between the patients area and the nursing station. This provides visual contact with patients and direct observation and monitoring. Entrance to patient areas allows to don and doff the required PPE.

The design ensures airflow from the clean to the dirty area, dragging the pathogens in the right direction. All finishes, furniture and patient care equipment are cleanable, easy to maintain and resistant to microbial growth.



# Support modules

The support modules are located at the central axis of every ward. Their purpose is to provide services to the ward and ICU beds. The location follows the scheme of clean areas near the connecting corridor and dirty areas at the back edge.

Among other uses the support modules include: Mechanical room, patients toilets and showers, clean room, nurse control, meeting room, medicine room, changing room, staff toilets and showers, on-call room, solid room, kitchenette, and waste removal container.

The size of these rooms varies between one full module (13 $m^2$) to half a module (6.5 $m^2$). The nurse control station is usually larger, around 27 $m^2$.

Dirty utilities and waste disposal are positioned on external walls to mitigate infection control risk and to facilitate ease of disposal removal.

REQUIREMENTS

# Requirements to bear in mind

The highlighted requirements have been developed in the following pages.

## PLUG-IN HOSPITAL

**MEDICAL GASES**
Critical gases such as oxygen and vacuum

**ELECTRICITY**
Power, distribution, control, safety

**HVAC**
Heating, air conditioning, HEPA filters

**WATER & SEWAGE**
Potable water, DHW, drainage, sewage

**FIRE SAFETY**
Prevention, mitigation, intervention, patient relocation, healthcare continuity

**CIVIL & STRUCTURES**
Ground capacity, fundations, structure

**ACOUSTIC & LIGHTING**
Comfort at the wards beyond temperature

**MEDICAL EQUIPMENT**
Required for patient treatment & control

**CLINICAL PLANNING**
All medical functions in place

**WASTE MANAGEMENT**
Removal of waste at every step

**SUSTAINABILITY**
Circular economy, energy saving

## ADDITIONAL FOR INDEPENDENT HOSPITAL

**PLANT & UTILITIES**
Medical Gases, water treatment and storage, temporary generators

**LOGISTICS**
Ambulance access, air ambulance, general parking, mortuary.

**SUPPORT SERVICES**
Catering, staff change, laundry, laboratory, triage, image diagnostic

# Basis of design

The design of the modular hospital facilities has been specifically conceived for the treatment of Covid-19, however it can be considered for wider purposes such as similar infectious diseases. This design is based on international standards, although in some aspects it has been specifically designed for the treatment of Covid-19.

For the definition of the values shown in this document, in addition to international standards, guidelines and recommendations issued by organisations such as the World Health Organization have been taken into account.

Arup has developed adaptable solutions which can be rapidly implemented through local supply chains. We have engaged with global clinical equipment and modular build suppliers validating the feasibility of our CareBox modular solution.

In addition to the bed ward and ICU, a number of spaces have been provided:

- Clean & Dirty Storage.
- Medicine Storage.
- Meeting rooms.
- On call rooms.
- Patient WCs & Showers.
- Staff changing rooms.
- Staff WCs and showers.
- Clinical & general Storage.
- Nurses Station.

Individual wards and ICU units are treated as contaminated space, with PPE gowning and de-gowning provided at the entrance of each space, as well as air-locks for bringing patients and goods into and out of the ward.

Door and corridor widths are suitable for the movement of beds and other equipment (2.5m), and sufficient space is provided around ward beds for the delivery of care. Accessibility requirements, such as disabled WCs and hoists, need to be reviewed on a case-by-case basis, depending on whether alternative ward spaces could be made available for patients with specifc needs.

Services are provided to meet the following criteria:

**Ventilation:**

- 12 air changes per hour provided by packaged air handling unit.
- HEPA filters on extract air.
- Temperature controlled by the ventilation system, 20-24°C.

**Medical Gases:**

- Ward beds: medical oxygen 10 l/min, medical air (4bar) 20 l/min, vacuum 40 l/min. 50% of diversity.
- ICU beds: medical oxygen 40 l/min, medical air (4bar) 40 l/min, vacuum 40 l/min. No diversity.

(The flow rates above are based on an assessment of a selection of typical equipment. The final rates will be agreed with the clinical team in accordance with local requirements).

**Water:**

- Allow for water consumes of 150 litres per bed-day in wards and 200 litres per bed-day in ICU. Allow storage for 1 day of water consume which can be increased in case of non resilient water supply.
- Hot water to be generated by local electric water heaters.
- Clinical wash hand basins provided with cold water only.

**Power:**

- 2N low voltage incoming supplies.
- UPS backup in ICU for life-critical equipment.
- ICU beds supplied through IPS.

# Medical gases

Patients affected by Covid-19 must be treated with oxygenation therapies. Medical gas networks are the most critical element of the hospital infrastructure. Oxygen, medical air and vacuum are consumed in Covid-19 centres at a much higher rate than usual.

The following tables show the recommended values for the design of facilities treating Covid-19 patients, as well as the total flows required for the proposed Plug-in solution.

The first strategy is to connect the Plug-in wards to the medical gas tanks already at the existing hospital. It should be checked whether this connection is possible and whether the existing gas plant has sufficient capacity for the increased demand.

If this is not possible, or if the existing plant does not have sufficient capacity, a temporary plant would be installed specifically for the Plug-in wards.

## GAS FLOW REQUIRED AT TERMINAL OUTLET

| | **Wards** (l/min) | **ICU** (l/min) |
|---|---|---|
| Oxygen | 10 | 40 |
| Medical Air (4 bar) | 20 | 40 |
| Medical Vacuum | 40 | 40 |

The flow rates above are based on an assessment of a selection of typical equipment. The final rates will be agreed with the clinical team in accordance with local requirements.

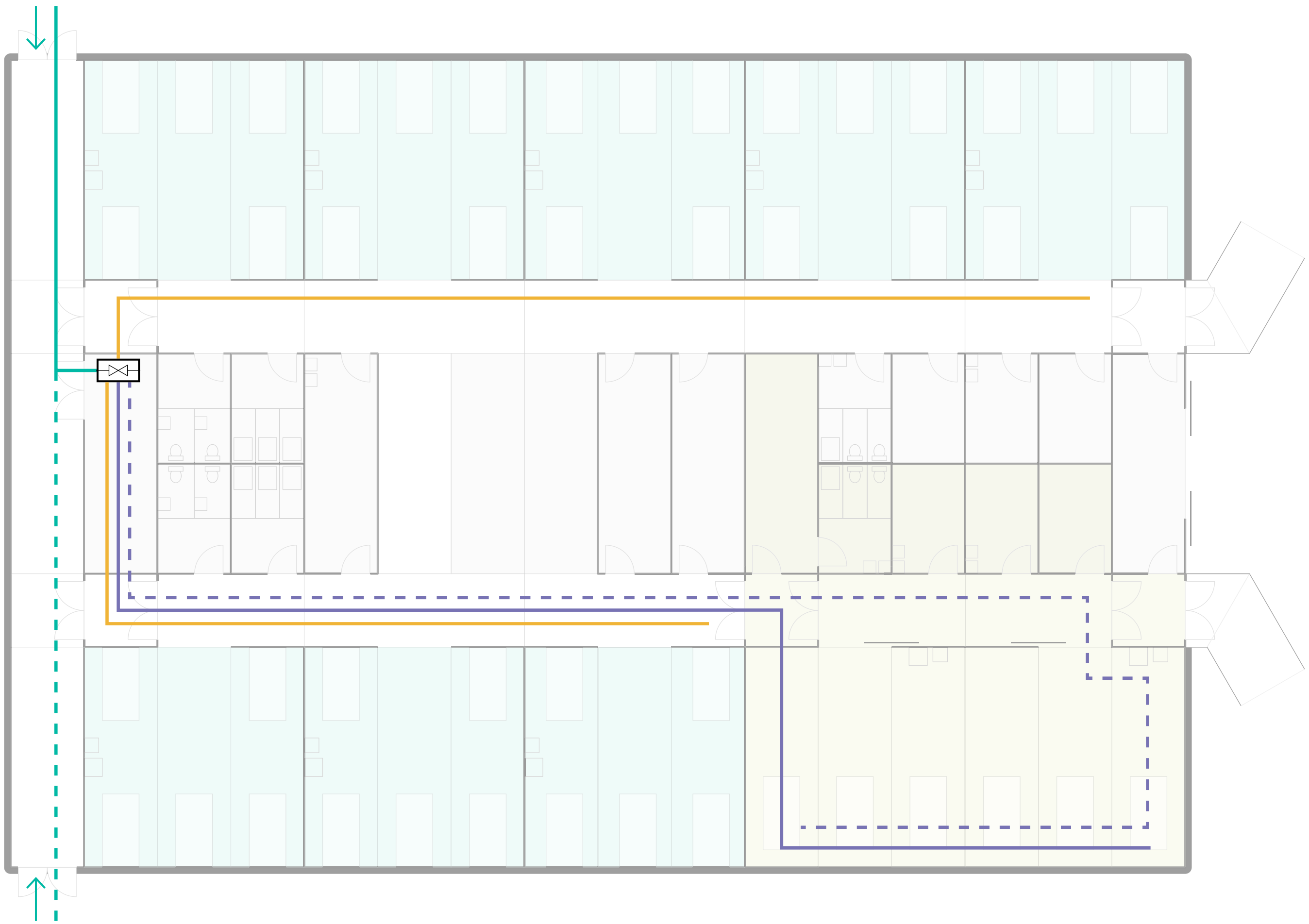
## DIVERSITY FACTORS

| | |
|---|---|
| Oxygen | Wards. 50% of diversity |
| | ICU. No diviesity |
| Medical Air (4 bar) | Wards. 50% of diversity |
| | ICU. No diviesity |
| Vacuum | To be provided by portable suction units not from a piped supply. |

## NUMBER OF OUTLETS PER BED

| | **Wards** | **ICU** |
|---|---|---|
| Oxygen | 1 | 2 |
| Medical Air (4 bar) | 1 | 1 |
| Medical Vacuum | 1 | 1 |

# Medical gases



## MEDICAL GASES

| Typology | O2 flow (l/min) | MA4 flow (l/min) |
|---|---|---|
| 50 Wards | 250 | 500 |
| 40 Wards + 6 ICU | 440 | 640 |
| 25 Wards + 15 ICU | 720 | 840 |
| 30 ICUs | 1200 | 1200 |

Medical gas supply from existing infrastructure

Optional medical gas supply from temporary infra.

Ward medical gas circuit

ICU medical gas circuit 2

ICU medical gas circuit 2

Valves

# Electricity

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

The electrical service is essential for the operation of any building. This installation becomes critical when feeding clinical spaces or air locks systems to contain the virus spread. The electrical supply to the CareBox will be carried out in Low Voltage, either from the existing infrastructure of the hospital itself or from auxiliary installations installed for this purpose. Each module of the CareBox will have a main board. All main boards will have a double power supply. Hence, all loads will be 100% backed up by an alternative energy source.

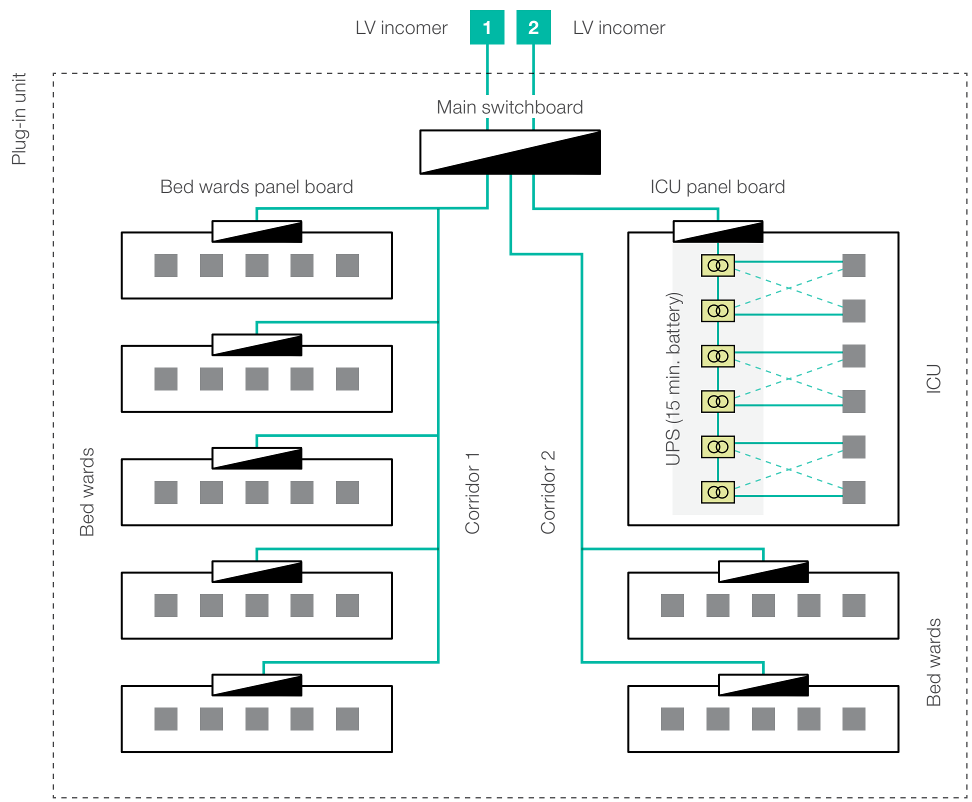
**The options are:**

- Network LV 1 / Electric generator 1
- LV network 1/ LV network 2
- Electric generator 1 / Electric generator 2

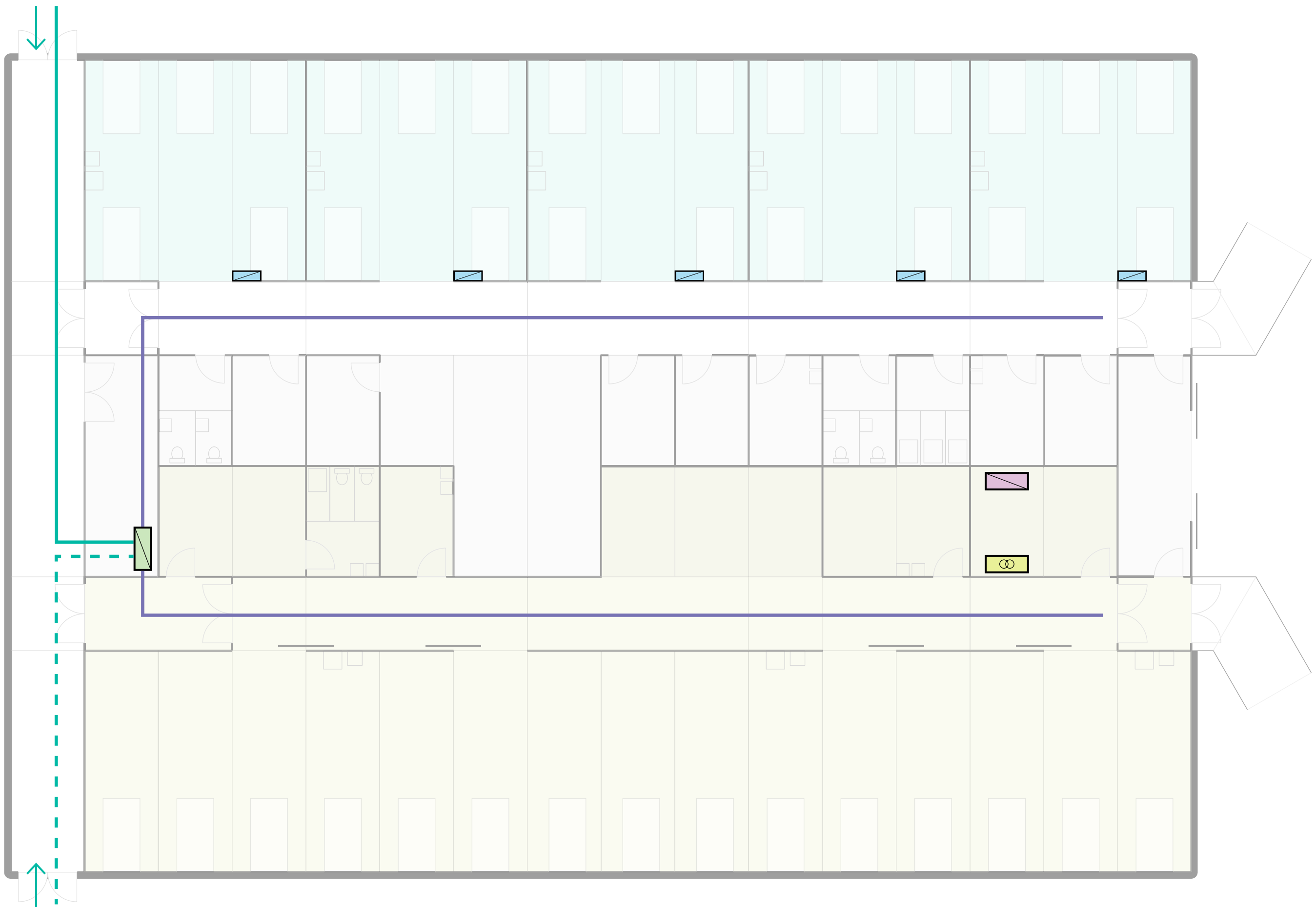
In addition, the power supply to vital services such as respiratory support systems and medical monitoring systems will be backed-up by UPS. An isolated power supply (IPS) system will provide extra resilience and patient protection to the ICU beds. The intensive care power outlets will be fed from individual supplies deriving from interleaved circuits of 2 individual UPS-backed IPS system. Each IPS will have 3kW of capacity to fully feed 2 ICU beds in case of need.

### POWER DENSITY CRITERIA

| | |
|---|---|
| Lighting | 8 W/m² |
| Small Power | 10 W/m² |
| HVAC / Ventilation | 75/20 W/m² |
| Ward bed | 0.75 kW/each |
| Ward bed | 1.5 kW/each |
| Radiography | 80 / 35 kW |
| Others | + 25% |



# Electricity



## ELECTRICAL SUPPLY

| Plug-in Tipology | LV Incomer 1 | LV Incomer 2 | UPS |
|---|---|---|---|
| 50 Wards | 113 kVA | 113 kVA | – |
| 40 Wards + 6 ICU | 130 kVA | 130 kVA | 15 kVA - 15 min |
| 25 Wards + 15 ICU | 133 kVA | 133 kVA | 30 kVA - 15 min |
| 30 ICUs | 153 kVA | 153 kVA | 60 kVA - 15 min |

External LV Supply 1

External LV Supply 2

Distribution

Main distribution board

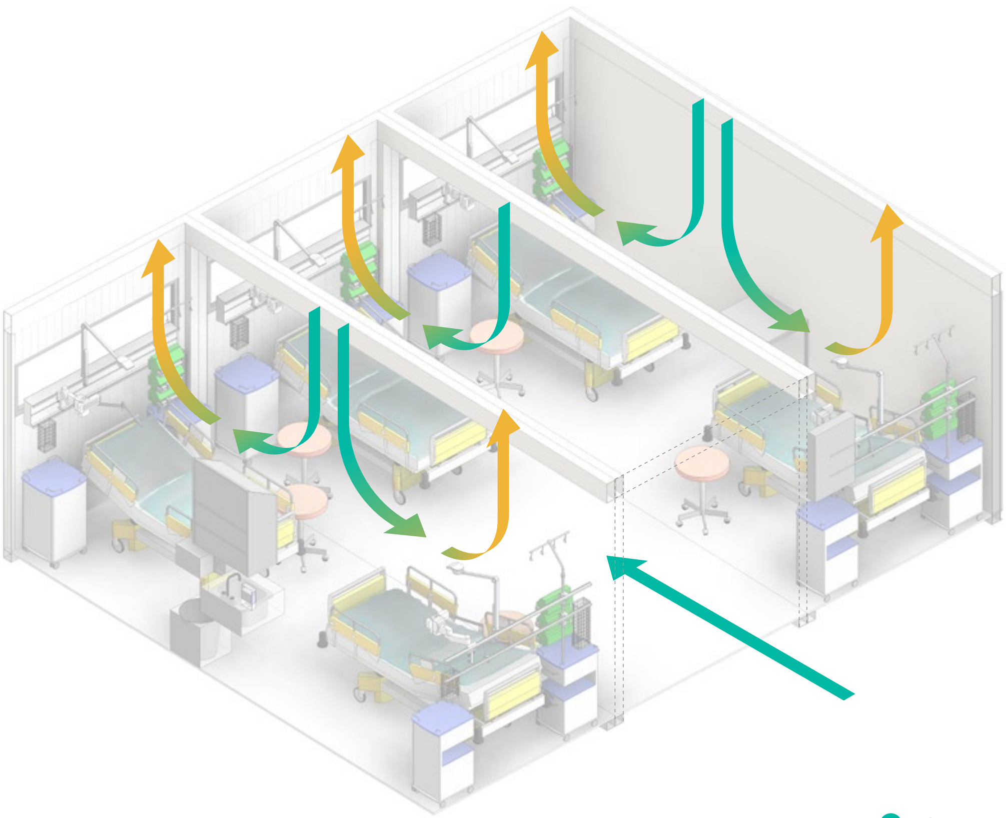
Ward dedicated board

ICU DB + IPS's

UPS

# HVAC

Mechanical Ventilation provided at a rate of 12 air changes per hour. This high rate of ventilation is critical to reduce the virus levels in the space, reducing the risk of infection to staff.

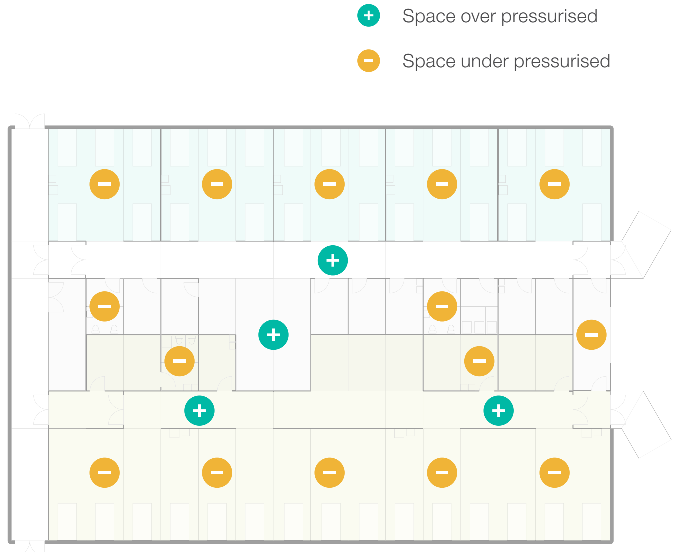


The placing of supply and extract points is also critical to infection control. The air will be supplied in such a way that the flow goes from the feet to the heads of the beds, being extracted over each patient, generating a cross flow to remove pathogens from the room. System will be sized for 12 air changes per hour and will ensure negative-pressure into the room. As corridor will be over pressurised, there will be an air flow moving from corridors to rooms, keeping contaminated air confined into the rooms.

The extracted air should be filtered through a HEPA filter, with a 'safe change' bag-in bag-out facility, to remove pathogens before being discharged to atmosphere.

To reduce the risk of the the spread of COVID-19, there should be an airflow from the clean spaces to the contaminated spaces. Air pressure strategy has been implemented to create airlocks between spaces, under pressurizing patient, dirty and waste spaces.

The ward is kept to temperature by the ventilation system, which will include direct expansion coils to heat or cool the fresh air so that internal conditions are maintained. Individual ventilation equipment will be provided for each ward and ICU unit avoiding ductwork distribution. The equipment will be placed on the roof over the spaces to be served, avoiding the need of fire dampers.



# Water & Sewage

## Water is indispensable in a hospital environment, where water consumption is also very high.

The "Care Box" has been designed with one water supply point per module. This supply may be established from the hospital's own infrastructure or from temporary facilities.

In the case of temporary facilities, in addition to the booster set needed to guarantee the necessary pressure at the end points, it will be necessary to install accumulation tanks and water treatment systems.

Allow for water consumes of 150 litres per bed-day in wards and 200 litres per bed-day in ICU. Allow storage for 1 day of water consume which can be increased in case of non resilient water supply or local code requirements. All water to be treated adequately.

Hot water will be generated by local electric water heaters and clinical wash hand basins are provided with cold water only.

### CRITERIA

**150**
litres per bed and per day in wards

**200**
litres per bed and per day in ICU

### DAILY CONSUME

| Care Box Tipology | Water Consume | * Days of Storage | Storage capacity |
|---|---|---|---|
| 50 Beds Ward | 8 $m^3$/day | 1 day | 8 $m^3$ |
| 40 Beds Ward + 6 ICU's | 8 $m^3$/day | 1 day | 8 $m^3$ |
| 25 Beds Ward + 15 ICU's | 7 $m^3$/day | 1 day | 7 $m^3$ |
| 30 ICU's | 6 $m^3$/day | 1 day | 6 $m^3$ |

* Days of autonomy to be increased in case of non resilient water supply.

# 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.

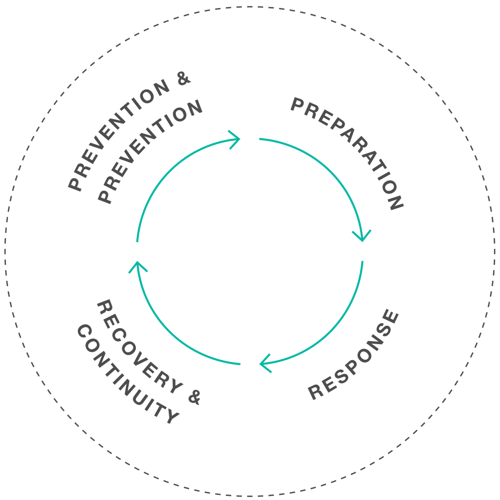
Many or all patients are likely to be high-dependency, bedbound and served by fixed O2 feeds. ICU patients will likely be intubated on ventilators and sedated. Relocation of a patient is usually protracted, requiring connection of a portable O2 bottle and multiple staff to move their bed and all associated 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 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.

Should a fire occur, early intervention to tackle the fire will be key. Prior to arrival of the local fire brigade, intervention will be via dedicated fire teams on site, preferably by retained firefighters or alternatively non-clinical staff trained in firefighting. 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.

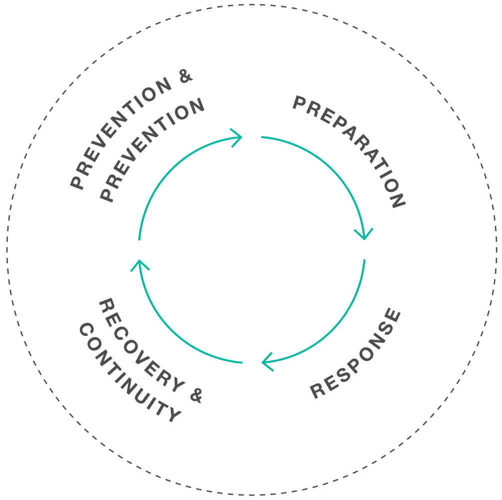





THE NEED · THE ANSWER · PLUG-IN · MODULES · REQUIREMENTS · NEXT STEPS

REQUIREMENTS

# Fire safety




## PREVENTION & MITIGATION

- **Electrical fires:** qualified electrical installers, robust residual circuit breakers, certified installations and portable appliances.
- **Stored combustibles & waste:** minimise and remove from wards ASAP.
- **Oxygen-enriched fire risk:** provide adequate ventilation; install oxygen enrichment sensors and alarms; train staff to cap all O2 feeds when connecting temporary O2 bottles (for daily movement and evacuation).
- **Ignition risk from static:** consider checkpoints for testing / discharging static from people / equipment; avoid clothing / PPE prone to static.
- **Construction:** non-combustible walls and ceilings (e.g. gypsum board, metal frame, mineral wool infill – avoid foam insulation, chipboard partitions, plastic canopies, etc.)
- **Linings:** non-combustible wall and ceiling linings.
- **Containment of fire & smoke:** separate wards from the spine corridor by 30-minute fire-resisting walls with fire doors (including smoke seals, door closers), fire-stopping (at joints, pipes, cables) & fire dampers (at grills, ductwork).

## PREPARATION

- **Early warning:** smoke detection throughout; manual call points; linked to nurses' monitoring stations; avoid widespread alarm which can cause panic and hinder healthcare.
- **Exits from rooms / bays:** doors / openings to be suitably sized for movement of beds + all required equipment, as well as space for staff re-entry simultaneously.
- **Exits from wards:** at least 2 exits to another ward / protected corridor / outside; exits to be remotely located to minimise single-direction travel distances; avoid dead-end corridors.
- **Fire exit doors:** double-doors, outward-opening to allow bed movement.
- **Signage:** clear, conspicuous, graphical emergency signage (back-lit or by lights).
- **Temporary O2:** keep sufficient bottles available to support patient relocation.
- **External exit routes:** weather protected; avoid steps (use ramps).
- **Emergency lighting:** all internal areas & external escape routes.
- **Fire extinguishers:** provide throughout (type appropriate to fire class and occupancy).
- **Fire blankets:** provide throughout.
- **On-site fire teams:** retained professional firefighters (preferably) or trained non-clinical staff.
- **Facilities for firefighters:** assess and retain / adapt existing hydrant network or alternatively deploy fire water truck continuously on site; temporary fire mains; hoses out and ready.
- **Information for firefighters:** 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: move all occupants out of the room / bay of fire origin to the circulation outside the room; mobilise as many staff as possible to assist.
  - Phase 2: relocate the above occupants to another ward / protected corridor / outside.
  - Phase 3: if fire is not extinguished, relocate all other occupants of the fire-affected ward to another ward / protected corridor / outside.
- **ICU patients:** should be relocated only as absolute last resort.
- **Contamination:** avoid relocating 'dirty' Covid-19 ward to 'clean' areas.

## RECOVERY & CONTINUITY

- **Continuity:** relocate patients to other wards / areas with fixed O2.
- **Ward / building separation:** fire engineering assessment should be undertaken to take account of site-specific conditions.
- **Overflow capacity:** provide sufficient space and O2 provisions, etc. in other temporary wards to house relocated patients + beds + equipment.
- **Ongoing care of ICU patients:** separate ICU from wards by 30-minute fire-resisting walls with fire doors, fire-stopping and fire dampers; avoid routing ICU services through fire-resisting walls.
- **Post-fire smoke clearance:** via doors, vents and portable fans.

# Fire safety

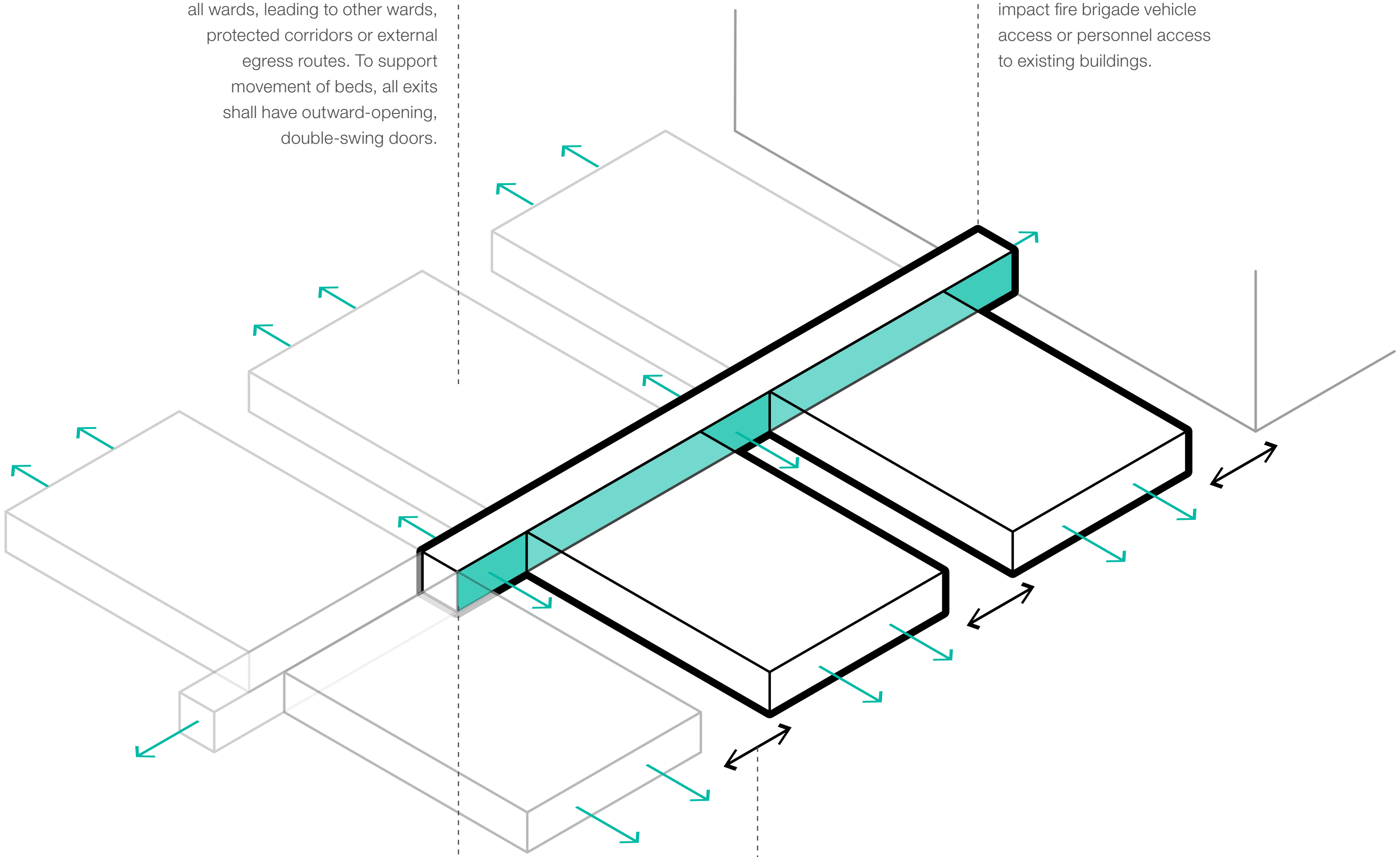
Some of the key fire strategy principles and features are presented here. To establish effective and suitable measures for a particular temporary hospital facility, the fire safety strategy must be developed in partnership with relevant stakeholders including the hospital operators and the local fire and rescue service.

### MEANS OF EGRESS FROM WARDS

Multiple exits are required from all wards, leading to other wards, protected corridors or external egress routes. To support movement of beds, all exits shall have outward-opening, double-swing doors.

### EXISTING FIRE BRIGADE ACCESS

Plug-in hospitals shall not impact fire brigade vehicle access or personnel access to existing buildings.



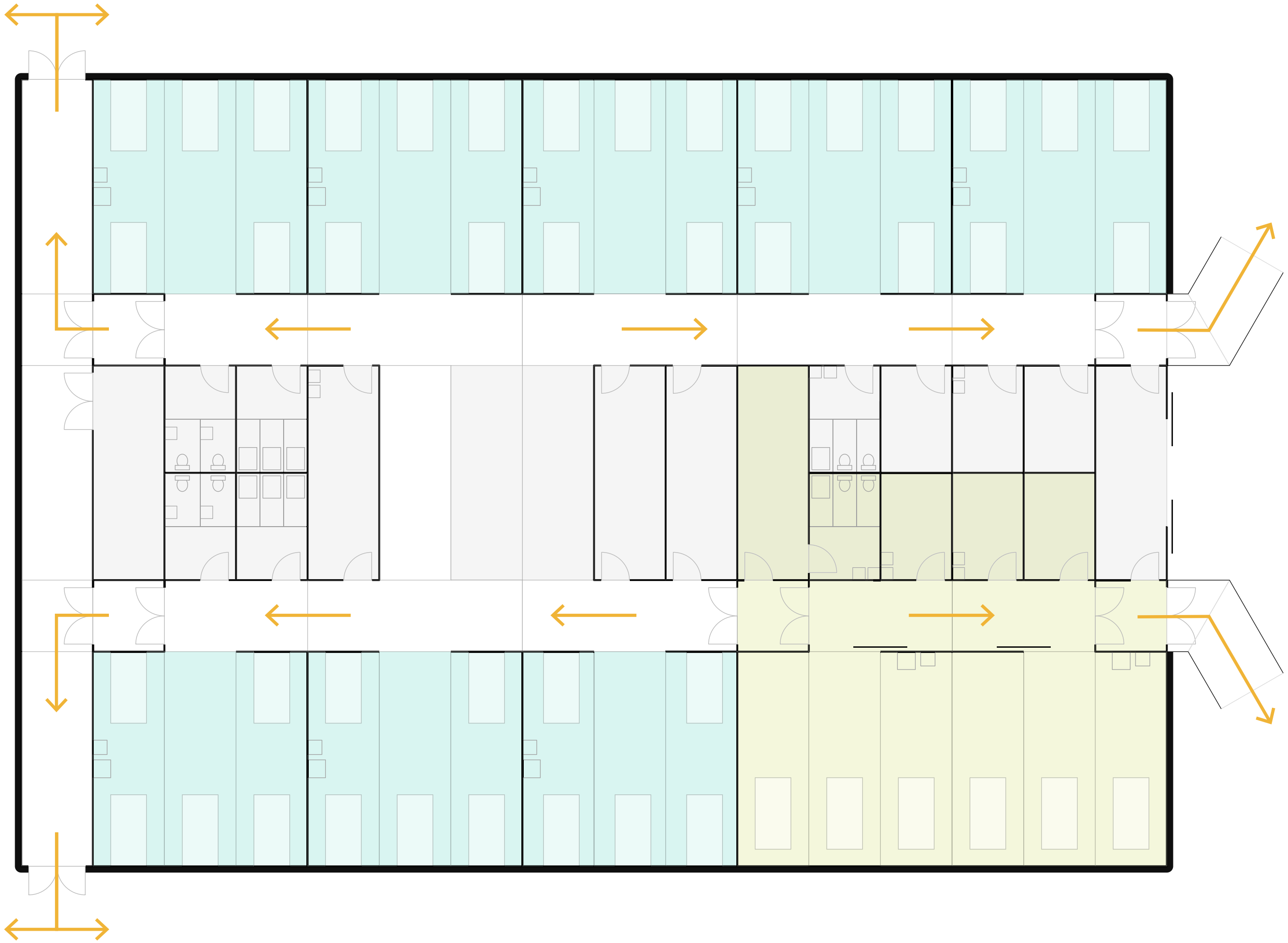
### FIRE RESISTANCE WALLS

Walls of the spine corridor should achieve 30 minutesfire resistance (integrity + insulation, from both sides), including the external walls of the corridor (as shown). The walls should include FD30S fire doors (with self-closers and smoke seals), fire-stopping at all joints and penetrations (cables, pipes), and fire dampers on any grills or ductwork passing through the walls (motorised dampers recommended where feasible; fusible link dampers otherwise).

### SEPARATION DISTANCE BETWEEN UNITS AND TO EXISTING BUILDINGS

To mitigate the risk of fire spread to / from wards, or to / from existing buildings, spatial separation is required. Fire engineering assessment should be undertaken to take account of site-specific conditions. As an indication of separation required between wards, preliminary radiation analyses for a 2.8 m high x 36 m long ward, suggest a minimum separation of 8.5 m would be appropriate.

# Fire safety



Evacuation in case of fire is based on horizontal flow, to the left or to the right depending on the fire-starting point. Each ward has been designed as a central spine with support areas, serving both sides of the spine.

Evacuation routes

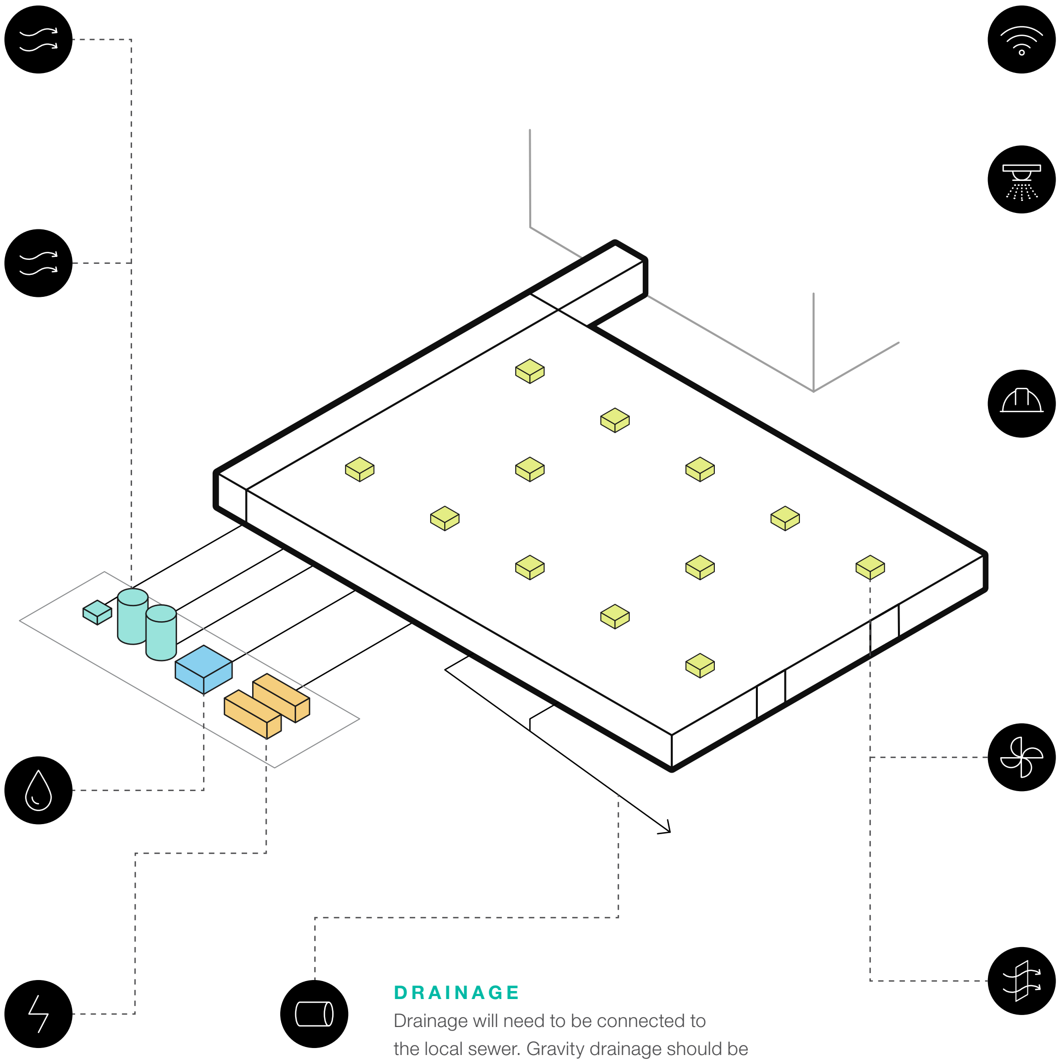
# Plant & Utilities

### MEDICAL OXYGEN
When possible, Oxygen will be provided from the existing hospital infrastructure. However, when connection is not feasible an oxygen plant will be provided, which will need to be accessed for regular deliveries.

### MEDICAL AIR
When possible, medical air will be provided from the existing hospital infrastructure. However, when connection is not feasible a specialist air compressor system and/or gas cylinder system will need to be provided for medical air.

### WATER
When possible, water will be provided from the existing hospital infrastructure. However, when connection is not feasible a connection to the local potable water main is needed, feeding a water storage tank.

### POWER
When possible, power will be provided from the existing hospital infrastructure. However, when connection is not feasible dual incoming supplies will be provided via LV network, generators or combination of both.



### DRAINAGE
Drainage will need to be connected to the local sewer. Gravity drainage should be provided wherever possible. Wet areas that require drainage should be grouped together to limit the number of connections needed.

### DATA
A data connection is needed for communications and connectivity with existing hospital systems.

### FIRE SUPRESSION
Depending on country code and building-specific requirements, a fire suppression system (e.g. sprinklers or water-mist) may be required. The system and water supplies should be designed and installed by competent and certified parties.

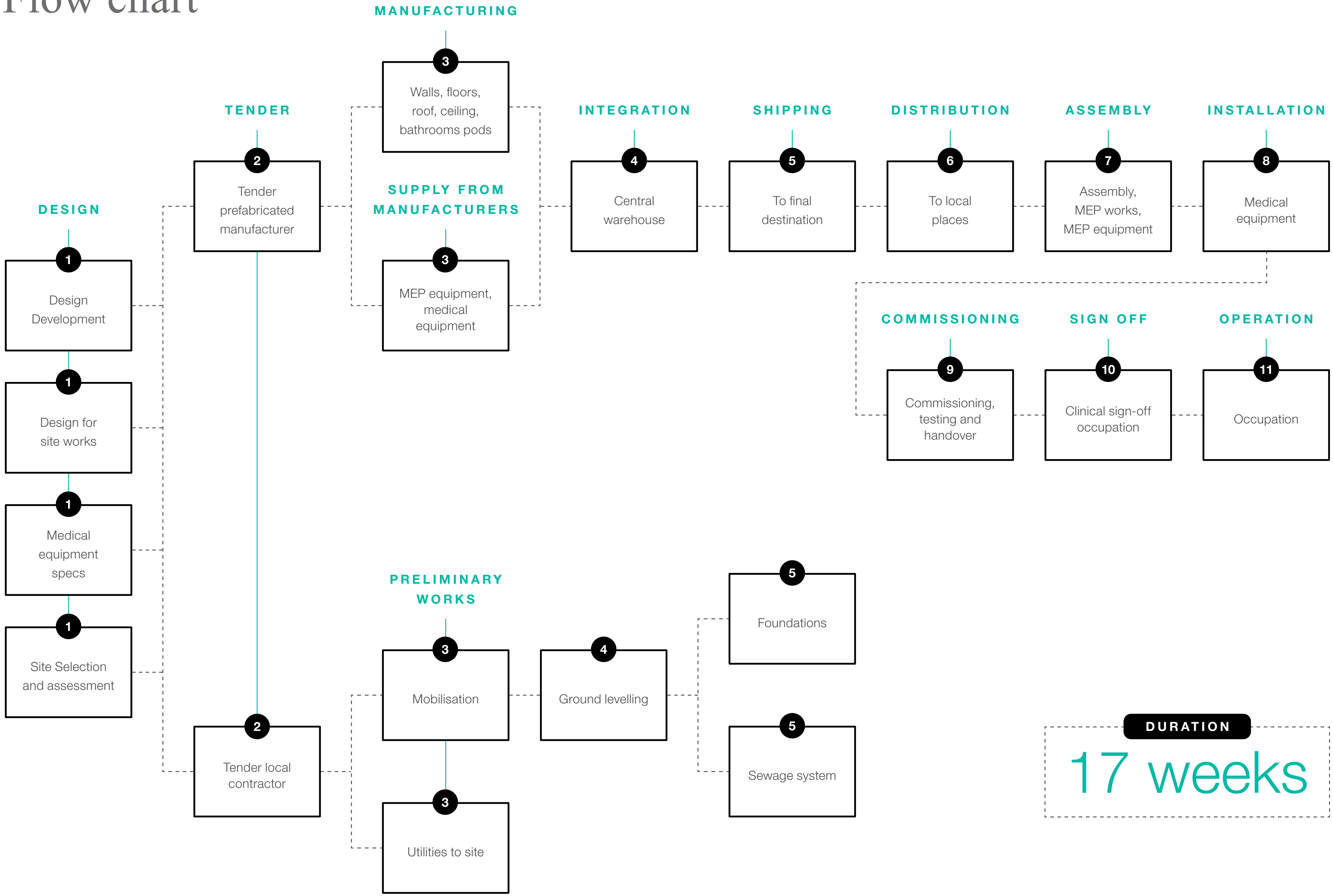
### CIVIL ENGINEER
A certified civil engineer will need to be consulted on the ground capacity and associated loadings of modules. Also consideration of other hazards such as flooding should be noted during site selection.

### VENTILATION
Packaged air handling units are used to ventilate, heat and cool the new ward. They should include direct expansion coils connected to condenser units, which will provide the necessary heating and cooling to the air stream.

### FILTRATION
Extract air is HEPA filtered by central HEPA filter units on each ventilation system. Filters should be located upstream of any equipment such as fire dampers. Filter replacement should be bag in bag out which makes them safe change, as they will be heavily contaminated.

NEXT STEPS

# Flow chart



# Assumptions

**Main considerations:**

- This approach is recommended when there is enough time for planning.
- There are other less planned approaches but with shorter delivery time.
- Prior shipping and storage of prefab elements is the basis of this approach.
- Local construction instead of prefab can be considered for certain elements depending on the market.

**The following team members are assumed to be part of a global response (no tenders are needed):**

- Design Consultant.
- MEP equipment supplier.
- Medical equipment supplier.

**Key stakeholders subject to tender:**

- Prefabricated manufacturer.
- Local contractor for preliminary works.

**Logistics:**

The following manufacturers / suppliers are expected to ship their elements to a central warehouse (hub), where full integration takes place.

- Prefab manufacturer.
- MEP equipment supplier.
- Medical equipment supplier.

After this, containers will be shipped to final destination.

Certain not technological elements could be locally sourced when this is considered as a way to speed the process.

Suppliers' supervisors are sent to site to guide local workforce in the installation of prefab components.

Once pandemic is over, prefab components are dismantled and stored again for future reuse.

# Post-lockdown

### LOOKING FORWARD

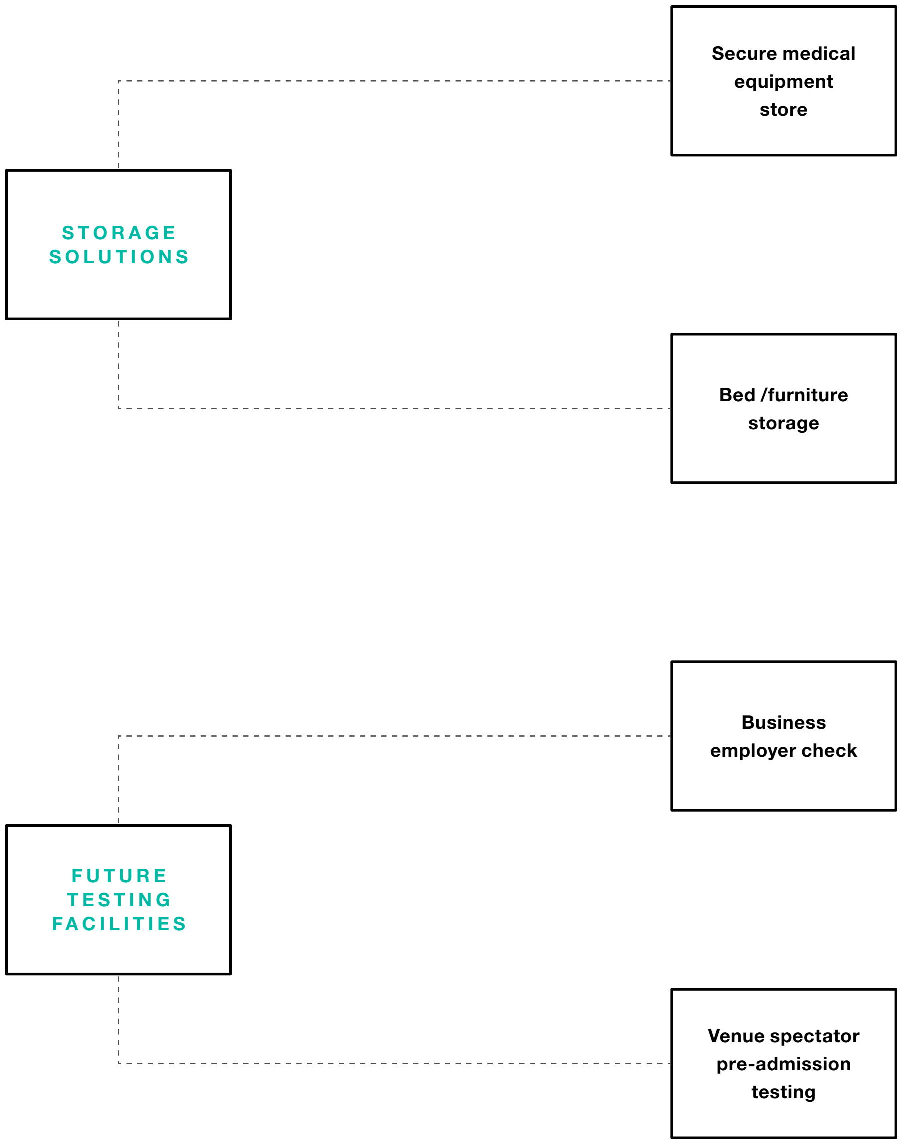
As normal life resumes (post lockdown), it is likely temporary facilities will be required for checking and storage.

### EVIDENCE SUGGESTS

The virus is likely to spread again and further lockdowns will be required. Having secure storage near previous hospital sites would enable these facilities to be quickly deployed and operational with minimal delay.

### AS RESTRICTIONS ARE LIFTED

On people movement, it is likely that entry checks will be carried out, monitoring the health of people entering work and leisure facilities. These could be temporary 'check in' security points, outside of the buildings secure perimeter.



# CareBox PLUG-IN

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IMPORTANT NOTE