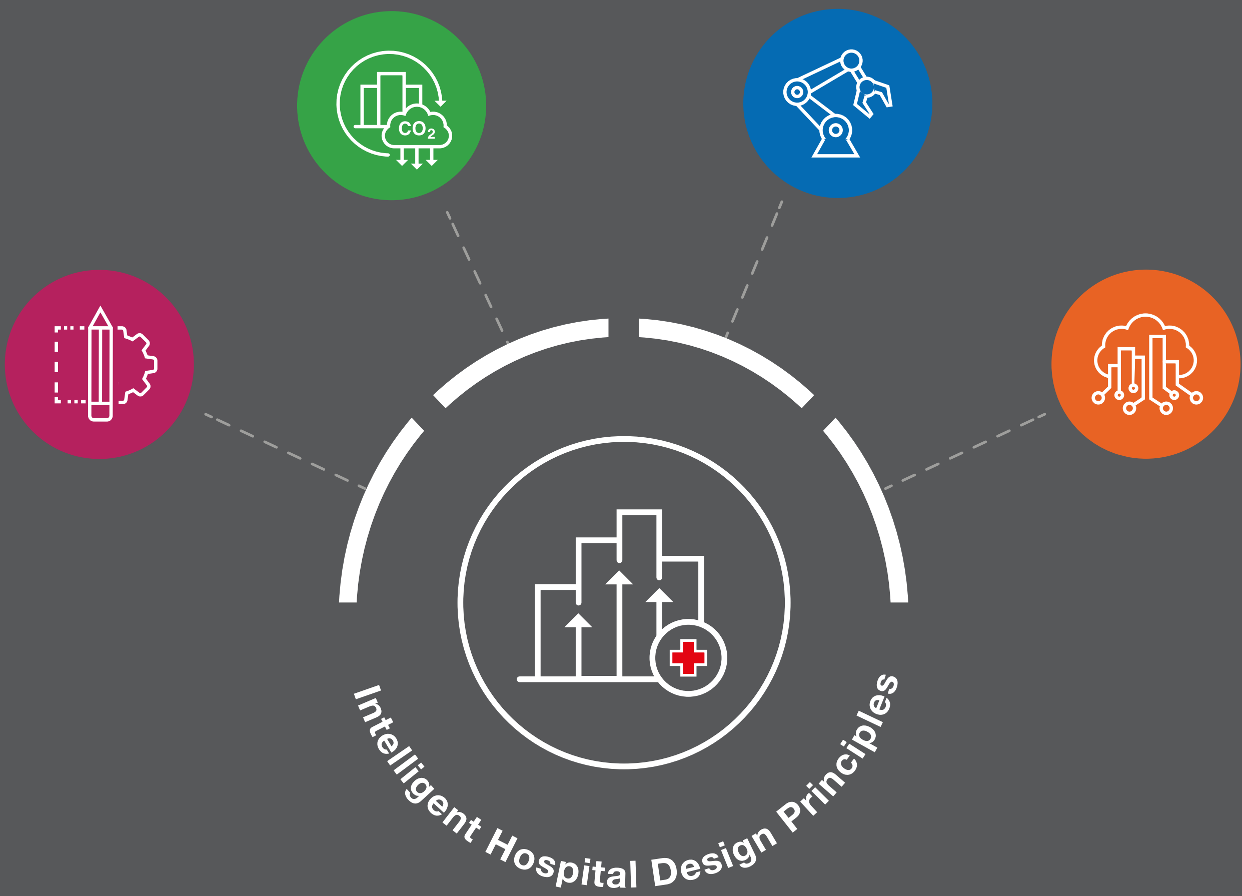

Intelligent Hospital Design Principles

Whipps Cross Hospital Redevelopment

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Contents

Ryder Architecture Limited, June 2021

Our Approach
Intelligent Hospital Design

The New Hospital Programme (NHP) is a significant opportunity to create a more efficient, more responsive healthcare estate. It requires a flexible approach based on intelligent principles of design and construction. An approach that supports shared learning and is adaptable to the particular needs of each project.

Coming back from the brink

The NHS in England is looking to come back from the brink of the pressures of COVID-19 with £3.7bn of investment currently allocated for major rebuilding projects across over 40 estates by 2030.

The importance of our health systems and estates has been brought into sharp focus by the COVID-19 pandemic, the effects of which continue to apply significant pressure on the NHS and highlight shortcomings in the responsiveness of the physical estate.

New hospitals and care systems must be able to respond more effectively. This requires delivery of more effective care away from acute settings and greater flexibility of acute estates to ensure capacity for surge and continuity of all care pathways.

The NHP

The NHP is part of the **Government's Health Infrastructure Plan,**[1] a rolling five year programme of investment published in September 2019. It is aimed at modernising the NHS estate in England, improving mental health facilities, investing in diagnostics and technology, and eradicating critical safety issues.[1]

Key principles to be addressed by the NHP include: A commitment to Net Zero Carbon (NZC), implementation of the NHS Digital Strategy, realisation of the benefits of Modern Methods of Construction (MMC) and ensuring our hospital estates provide the resilience to respond to any future pandemic situation with minimal impact on ongoing patient needs.

A collaborative approach

Building on our successful collaboration on complex hospital projects and harnessing significant global healthcare experience, Ryder Architecture, WSP, Hoare Lea and BIM Academy have developed an approach to the Principles of Intelligent Hospital Design to respond to the key drivers of the NHP.

Ryder and WSP were part of the team for Royal Stoke University Hospital that **pioneered the extensive use of MMC technologies on major hospital projects** in the early 2000s.

We built on our knowledge and experience alongside Hoare Lea in the development of the design for the multi award winning **Dumfries and Galloway Royal Infirmary (DGRI).** Ryder led the DGRI design team collaborating to develop extensive utilisation of MMC. The hospital was completed six months ahead of contract programme.

Our advanced understanding and application of digital design enables a direct workflow from design to manufacture, testing and optimising alternative scenarios, and coordinating components. Our digital design models are used directly as a base for supply chain fabrication information and to inform the programme of component installation, reducing time and risk. Our approach to clinical design is to create a flexible standard platform framework that supports the efficient planning of technical departments such as theatres and imaging, outpatient clusters and inpatient modules using a series of repeatable standard rooms across the hospital.

Our NZC approach addresses five factors to develop a project specific Sustainability Charter in conjunction with stakeholders, **to consolidate the vision and set key sustainability targets** for each project in response to its particular environment.

A blueprint for better healthcare

The NHP investment is a significant opportunity to create a blueprint for the development of a better, more responsive healthcare estate in England.

It requires a response that is flexible and adaptable, providing a framework to ensure each project can capture lessons from those preceding. The physical, social and healthcare context of each project across the programme will present unique challenges and opportunities. Rather than developing a standard hospital design, a system of principles that address the key drivers of the programme will create a **flexible framework to support the efficient design and effective delivery of projects** across each phase, allowing continuous development and learning from project to project.

In this way, each project contributes to the ongoing development of the Principles of Intelligent Hospital Design, sharing lessons openly for the good of the programme rather than seeking to create a fixed rule book.

This publication captures our progress, to share our approach. Providing a series of key principles across four themes: Design, NZC, MMC and digital. This provides the basis for a standard platform that has inherent flexibility and adaptability to respond to changing needs of individual projects across the programme and over the lifetime of each project.

Whipps Cross Hospital Redevelopment

Delivering a brighter future for Whipps Cross requires a sustainable response and a commitment to delivering NZC, developing a hospital that is flexible and adaptable that will transform clinical outcomes for its patient cohort, in an ever changing social and healthcare context.

A pathfinder project

The redevelopment of Whipps Cross Hospital has been identified as a **pathfinder project for the Government's NHP**. The objective is to create a flexible, modern, digital hospital for the future.

It is a highly complex site which has evolved incrementally for more than a century. Throughout the redevelopment process the existing hospital must remain fully operational.

Whipps Cross Hospital is part of Barts Health NHS Trust and sits within a large site on the edge of Epping Forest. We have a once in a lifetime opportunity to build a new state of the art hospital and to **transform the wider Whipps Cross site to benefit the local community.**

Whipps Cross aspirations

This is a unique opportunity to re imagine Whipps Cross as a new London neighbourhood next to Epping Forest to benefit both residents and the wider community including staff, visitors and patients within the new hospital.

The key aspiration is to create a **brighter future for Whipps Cross,** leading the way as a local hospital of the future and creating an exemplar for care of the frail and elderly. Realising that brighter future requires an environment that engages the senses, reduces stress and promotes wellness.

In response to a rapidly shifting healthcare environment, the new Whipps Cross Hospital will be flexible and adaptable, supporting effective integration of new models of care that transform clinical outcomes for the local patient cohort.

The garden hospital

The overarching project vision is to create a hospital in a garden / garden in a hospital.

Our vision connects Whipps Cross more successfully to the local area, **drawing the surrounding landscape of Epping Forest into the site.** New accessible and attractive public green spaces will create a health and wellbeing setting for the new hospital. Reconnecting the hospital to the forest will provide therapeutic and healing benefits for patients and an uplifting environment for staff, visitors and the wider community.

The redevelopment of Whipps Cross Hospital offers an unprecedented opportunity to regenerate a unique site and create an integrated health, care and wellbeing campus. It will bring together a wide range of services designed around the needs of the local population, including housing, leisure and culture.

Platform systems

The new hospital is designed using a standardised platform approach. This enables the delivery of better care, a better experience for patients and a better environment for staff to provide care in. The approach provides an efficient and functional framework with **flexibility and adaptability to respond to changing healthcare needs in the future.**

The standardised platform integrates key structural and building services engineering principles to design in flexibility for a range of MMC delivery options. Our standardised platform approach will be discussed in more detail later.

Our commitment to deliver on NZC targets has informed the design from first principles, looking at the form factor of typology options to an assessment of embodied carbon in structural frame options and the optimisation of grid dimensions.

A pioneering health campus

Pioneering an approach to the Principles of Intelligent Hospital Design alongside excellence in residential design and placemaking will deliver a health and wellbeing setting to support the local community to **start well, live well, stay well and age well**. This is a unique opportunity to create London's first neighbourhood defined by a holistic approach to health and wellbeing to the benefit of all communities in this part of East London.

Recognising the value that Whipps Cross has within the hearts and minds of its community, the new Whipps Cross will be more than a hospital. It will be a clear and easily understood **health campus** organised around a series of uplifting spaces and routes, connecting people within a legible and effective masterplan that is responsive to change as the implementation of the new Whipps Cross develops.

Our Sustainability Charter encompasses new clinical pathways realising operational efficiencies within an integrated care system, together with the wider opportunities for economic regeneration and growth in North East London.

The garden hospital

Intelligent Clinical Design
A Standardised Platform Approach

Our approach to intelligent clinical design is to create a flexible framework based on the key principles of NZC, MMC and digital strategy. This framework, a standardised platform, must support the delivery of efficient, effective, safe and uplifting environments for patients, staff and visitors.

Responding to NHP priorities

The NHP seeks to "create an infrastructure ecosystem that owns, learns from and improves healthcare design iteratively – specifically through centralised standards with limited scope for variation, centralised design, modelling, and assumptions, with repeatable learning and efficiencies applied to the pipeline of hospital builds in the programme."[2]

We share this approach, proposing a series of key principles from which we have developed a standardised platform that has inherent flexibility and adaptability to respond to the changing needs of each project over its lifetime. Considerations have also been given to the NHP priorities around digital infrastructure and the future use of technology within the clinical environment.

Remaining flexible while limiting variations

A key challenge in realising the NHP priorities is to facilitate the flexibility required to respond to the needs of each project whilst adhering to the demand for limited scope for variation.

Rather than setting a definitive standard grid and fixed templates for clinical settings, our approach is to study the alternatives for typical rooms and spaces. By studying how these can be stacked to respond to particular site, massing, scale, land take, typology and brief constraints. **We have developed a series of intelligent clinical design principles that can be implemented to inform but not limit other projects.**

The NHP proposal of a kit of parts is a valid approach and our Standardised Platform based on the principles of intelligent clinical design responds to this.

The flexible framework approach

Our approach is to create a flexible framework to support the efficient planning of technical departments such as theatres and imaging, outpatient clusters and inpatient modules using a series of repeatable standard rooms across the hospital.

This approach builds on **our knowledge of standardised platforms from other projects,** our contribution to the P22 repeatable room program, our lean design development of an HBN15-01 exemplar emergency department, and our collective expertise in the delivery of MMC for healthcare.

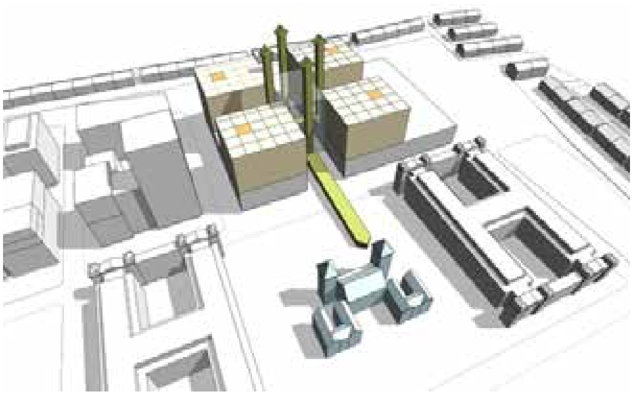
The design allows for a standard structural grid between technical and ward levels which removes the need for transfer structures which can be costly, both in financial terms and carbon content.

Technical levels have been designed with a simple structural grid and carefully positioned cores to support effective planning for today while **allowing flexibility and adaptability for the future.**

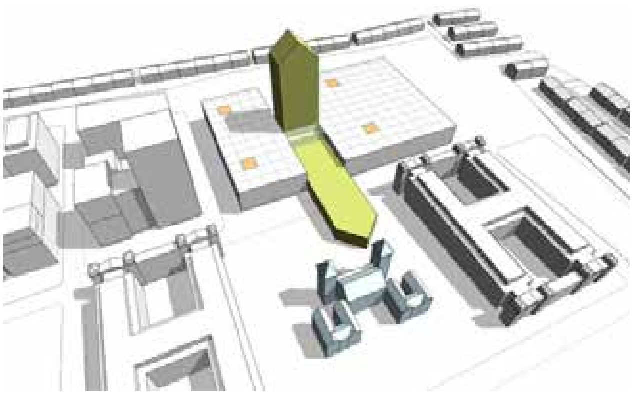
The standard platform should provide flexibility to adapt between off stage / on stage models for outpatients. This approach will support the provision of generic suites of flexible outpatient clusters or the development of more specific clusters relevant to particular needs. In either scenario, clusters should be based on standard room types.

In response to the physical constraints of the site footprint, Whipps Cross is a mid rise hospital that requires vertical stacking of departments and functions. This presents challenges in the development of a standard grid that avoids transfer structures between levels.

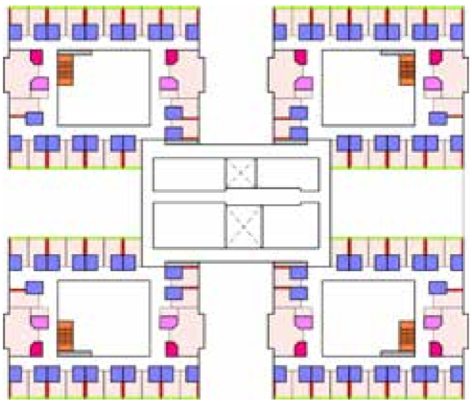
The grid dimensions at Whipps Cross have been developed to coordinate with both the standard inpatient template of the upper levels and the constraints of a standard theatre template within the lower technical levels. In addition to the spatial demands of typical rooms and workflows associated with each function, grid dimensions and structural solutions were considered holistically alongside embodied carbon calculations and cost efficiency.



Flexible and repeatable design - inpatient levels



Flexible and repeatable design - technical levels



Repeatable floor template

Key considerations

Inpatient accommodation is designed as a series of standard ward modules around a central circulation and support hub. This arrangement is informed by **a series of typology studies** that considered the particular challenges and opportunities of the available site for the new hospital, alongside a response to the aspiration for an exemplar hospital with a special interest in the frail and elderly.

The pinwheel typology minimises horizontal travel distances to wards, in response to the frail and elderly patient cohort. It also brings **efficiency to staff workflow, allows effective sharing of support space and provides resilience for separation and isolation.**

Ward modules are 28 beds with repetition of a single room module which defined the grid taken through to the lower floors. The bedrooms are clustered into sevens, each half of the ward has a four bed bay, to maintain balance, with staff bases distributed to provide optimum observation. The layout of the single room and en suite was tested to ensure the visibility and observation of the room from the corridor was optimal.

At Whipps Cross, particular consideration of the frail and elderly patient cohort informed the design of enlarged en suites to allow for **improved patient assistance** and ease of movement to reduce the risk of falls.

Options for the en suite location were tested looking at inboard, outboard and nested alternatives considering ease of movement, observation, quality of patient environment and overall area efficiency.

An inboard position was preferred. This maximises opportunities for natural light and the quality of views out from the patient bed, optimising the environment within the patient room. Recessing the bedroom doors from the corridor line allows for effective bed turning while maintaining a narrower corridor width which, from our studies, resulted in an overall more efficient area allocation per bedroom.

Defining an early strategy in relation to flexibility and adaptability was key to the process. The standardisation of inpatient ward templates and the ability to pair ward templates on a typical floor, improves efficiency of shared support accommodation and **provides resilience in managing surge capacity** during winter months or in the case of a pandemic situation.

Connected and vibrant streets

Connected and vibrant streets

Factory to Frame
From Digital Design to Construction

At the heart of our factory to frame approach is a commitment to collaborative project working, embracing digital technology to move seamlessly from concept to construction, reducing risk and optimising cost and programme.

Reinvention

Delivering the NHP alongside other major infrastructure projects, and in the context of both a post Brexit workforce and post pandemic material supply, is a challenge that requires fresh thinking.

In 2018, Ryder Architecture published **Reinvention for an Exceptional Construction Industry.**[3] Receiving wide acclaim, it called on the whole project team to unite behind a single goal to place the project ahead of each team member's commercial priorities.

At the heart of this is a commitment to **collaborative project working,** and breaking down the historic silos of the built environment professions and industry, embracing and developing digital design technology to provide a synergy from concept to construction.

National and local challenges

In response to the Government's paper, **Introducing the MMC Definition Framework,**[4] and subsequent Government announcement of a presumption in favour of MMC by 2019, we are targeting a minimum of 70 percent MMC with the majority coming from high pre manufactured value. To achieve this requires effective collaboration across design and supply partners.

Whipps Cross is a tightly constrained live hospital site that must remain fully operational throughout construction of the new hospital. The proposed design must therefore not only provide excellent clinical functionality and deliver an exemplar wellbeing environment, but also consider effective construction logistics from the outset.

Focussed on optimisation

Our approach to MMC, described in more detail later in this document, is fundamental to how we have approached construction logistics.

The use of digital technology included parametric design tools, energy analysis and sequencing analysis, providing significant added value in design efficiency, project risk, energy efficiency and material usage, as well as the intelligent operation of buildings and buildability. We utilised a digital twin to resolve complex issues in a fully coordinated manner, testing construction sequencing and logistics in addition to designing out coordination clashes.

Our approach at OBC stage was to design in flexibility for a range of MMC options, such as **volumetric and componentised approaches** for standard rooms, assemblies, building services modules, structural elements and envelope panels.

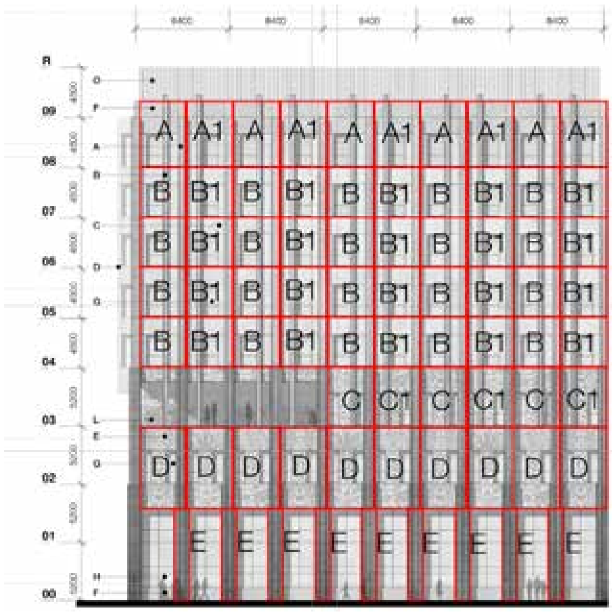
A number of envelope panellisation options are being developed considering efficiency of connection strategy, structural frame deflections, transportation (maximising loads and minimising trips) and repetition to optimise cost and programme.

Access to and within the Whipps Cross site is challenging. The logistics strategy is to minimise disruption to both neighbours and the live hospital. We have designed in **a construction racetrack to allow delivery of components to all faces of the building with a landing stage,** carefully considering crane positions to enable MMC components to be lifted directly from delivery vehicles onto the building frame.

The position of the building on the site responds to early logistics planning in addition to the key masterplan principles. By optimising the construction logistics we optimise cost and time, reducing the implications of site constraints and adding value to the public investment in health.

Building on lessons learnt

Our approach builds on lessons learned from our collective experience, particularly at DGRI. Whilst DGRI embraced extensive use of MMC, the number of external envelope panel types grew from a small number of generics to a large number of bespoke panels with varying structural thickness levels and connection details.

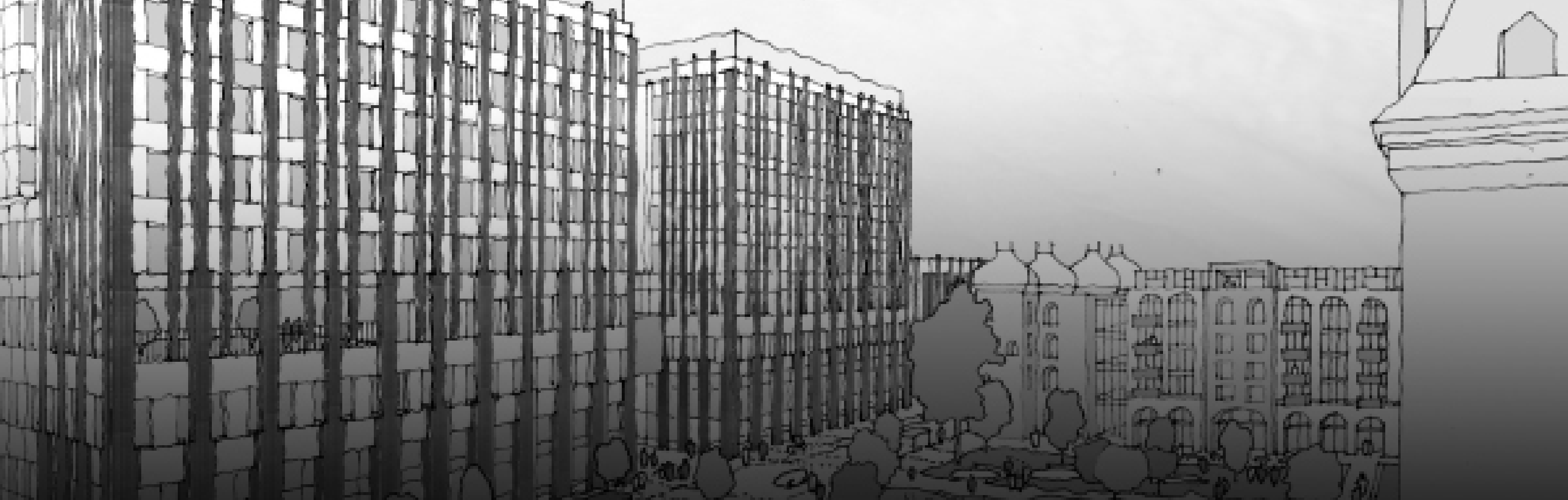


Early study for standard external envelope panel types on a typical elevation

To improve standardisation and optimise sequencing where construction progress is not reliant on a number of bespoke panels, we have developed the modularity of the external design.

Panel design ensures that window modules can be installed off site, with suitable minimum chord widths below and to the side of windows. Feature piers and fins are designed as separate panels to avoid increasing the number of panels through handing and to design out asymmetric loading of panels. **These design considerations will optimise the lifting operations and improve programme efficiency.**

This factory to frame approach recognises that if MMC programme and cost benefits are to be realised on a tightly constrained site, then crane hook time and just in time delivery are key design considerations from early concept stage.



Design for Wellbeing Placemaking and Community

The importance of healthy placemaking and creating a sense of community is key to the wellbeing of patients, staff and visitors. The design of the new Whipps Cross celebrates the uniqueness of its setting on the edge of Epping Forest, its special place in the hearts and minds of its community, and creates a new social hub.

Creating a connection to nature

We propose a Whipps Cross Hospital organised around a series of uplifting spaces and routes, connecting people to the wider forest setting to provide a legible and effective caring environment that minimises patient and staff workflow travel distances.

Our approach is to ensure patient safety, clinical effectiveness and the quality of experience for patients and staff in an environment that engages the senses, reduces stress, and promotes wellness, compassion and friendliness.

Whipps Cross Hospital will provide a health and wellbeing setting to support the community to **start well, live well, stay well and age well.**

Enabling a health focussed community

The vision is for a brighter future for Whipps Cross, leading the way as a local hospital of the future and creating an exemplar, with a special interest in the care of the frail and elderly.

Whipps Cross has a special place in the hearts and minds of its community but the quality of care that can be provided is hampered by the outdated hospital estate and this in turn impacts staff recruitment, retention and absence.

Whilst the original West Ham Infirmary set the hospital on the edge of Epping Forest, capturing the forest's biophilic benefits, the current hospital has turned its back on the forest setting. **The new hospital must recapture the relationship with the forest and improve connectivity to the wider landscape and the community.**

Hospital in a garden, garden in a hospital

The overarching concept is to extend the landscape of Epping Forest into Whipps Cross, providing **access to nature and green spaces for therapy, exercise, relaxation and contemplative escape.**

The development of the new Whipps Cross masterplan has been underpinned by detailed analysis of the site and the constraints which exist within its curtilage and the immediate context. At the heart of our spatial concept is a **public realm strategy** which seeks to improve existing connections through the site as well as create new ones, stitching the new neighbourhood with its wider context to maximise the uniqueness of the place.

The landscape provides a common thread that runs throughout the development and supports the key principles of the masterplan. The woodland of the adjacent Epping Forest will permeate through the whole site to provide connections to the wider landscape context.

This landscape led approach will provide **a rich mosaic of parkland spaces** which respect the local setting, connecting local residents and the future community with nature. This approach will enable all to benefit from the health and wellbeing opportunities within the proposed landscape.

Access to green spaces

The principal objective of the landscape design has been to create a network of green spaces which respond to the built form and maximise the opportunities for public open space.

A focus on NHS staff wellbeing

Connection and access to the wider landscape has been a key design driver – not just for patients and visitors, but also for staff.

Staff wellbeing has been brought into sharp focus through the pressures of COVID-19. **Access to separate wellbeing areas including external spaces where staff can find escape from the pressures of providing care is critical in all new hospitals.** We provide this at every level of the hospital, meaning staff have immediate access for effective short respite.

A focus on wellbeing

A range of spaces are needed – opportunities for supported therapy, space to take a critical care bed into a garden setting, spaces for children to let off steam, space for quiet contemplation both within and outside the hospital and places for staff to exercise, socialise and make their own.

These spaces need to be welcoming, manageable and accessible. There is an established link between nature and improved clinical outcomes. Improving the wellbeing environment for staff will bring significant added value through better recruitment, better retention and reduced staff absence.

Building a healthy community

A series of hospital typologies were developed to address the masterplan principles – connection with nature, improving connectivity with the wider community, delivering a NZC environment and reframing the heritage of the original hospital to create a unique response to place. Each option aimed to optimise clinical adjacencies, flows, stacking and fit within the constraints of the hospital site.

A **pinwheel typology** around a central hub that reduced travel was developed as the preferred option. This benefits the frail and elderly cohort, optimising adjacencies and compared to other typologies minimised corridors and travel distances to and from departments.

The upper floor templates are eased apart to allow natural light to enter the central social hub and all four sides of each template to accommodate perimeter bedrooms. Accessible pocket gardens connect to the central hub and social heart, each with its own character to create a mental map of the building and promote **intuitive natural wayfinding** for patients.

These gardens provide access to external spaces at every level of the hospital and benefit from desirable views to the park, forest and longer range views to the city. The pinwheel central hub would be a social heart, easy to navigate, benefiting wayfinding whilst having the potential to foster community spirit and encourage social interaction amongst all users.

The pinwheel offers a high quality user experience, with **positive impact on wellbeing** through easy access to pocket gardens and excellent daylight penetration to bedrooms and the social hub between wards.

Improving connectivity

Promoting biodiversity and green landscapes

Reframing heritage

Creating a new identity

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Whipps Cross Hospital masterplan approach

Key considerations

The existing Whipps Cross is known for having one of the longest corridors in Europe – not great for the care of the frail and the elderly, but **the corridor is also seen as the social heart of the hospital.**

The design response and arrangement of the new hospital has been informed by the clinical and functional brief and regularly tested with the Trust, through **a series of stakeholder engagements.**

A range of different typology studies were assessed with the Trust against a variety of factors, including clinical adjacencies, functionality, flexibility, standardisation, environmental aspects, urban design, massing principles and cost.

The pinwheel with its central hub and social heart stacked vertically above the entrance foyer provides a strong vertical connection that consolidates primary circulation cores for visitors, patients, service and staff in a central location. This minimises travel distances, eases wayfinding, and facilitates pairing of upper wards for future pandemic scenarios.

This typology also allows effective use of a tightly constrained site supporting the concept of **hospital in a garden, garden in a hospital.**

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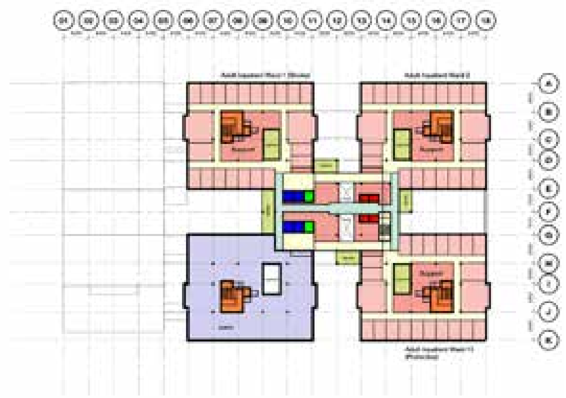
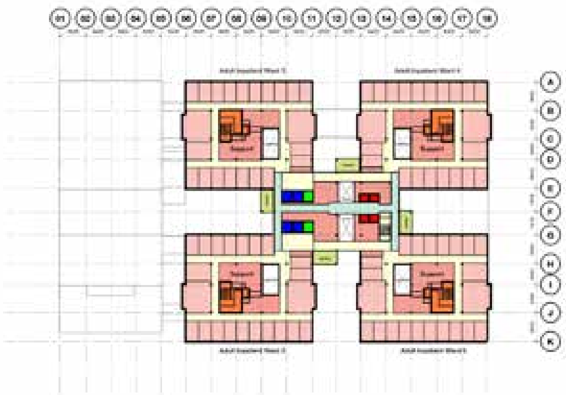
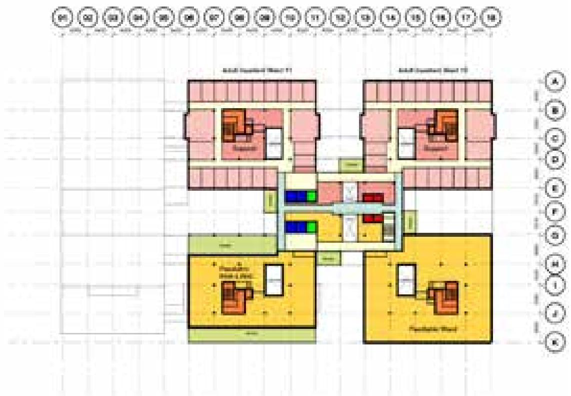


Level 5 - Inpatients and Admin



Level 6 and 7 - Inpatients



Level 8 - Inpatients and Paediatrics

Roof plan

Whipps Cross Hospital
Meeting the Sustainability Challenge

The NHP is one of the most ambitious hospital construction programmes ever seen. The challenge has been set by the Government to design hospitals with NZC emissions over the lifetime of the building. Including the construction, operation and eventual end of life, and disassembly of the building. However, net zero is only part of a much needed, wider holistic sustainability strategy.

The national and international context for net zero buildings could not be clearer. If left unchecked, the alarming current increases in global warming due to human related carbon emissions are set to cause widespread destruction of ecosystems, habitats, wildlife and human settlement.

The UK has committed to achieving NZC by 2050 through an unprecedented interest in renewable energy and carbon reduction measures.

The NHP is one of the most ambitious hospital construction programmes ever seen. It's mission is to bring the UK health service up to modern standards **to provide fit for purpose healthcare and wellbeing for our population for generations to come.** However, construction carries a heavy price in carbon emissions, which poses a significant challenge to achieving our 2050 net zero goal.

The challenge has been set by the UK Government to design hospitals through the NHP, with NZC emissions over the lifetime of the building. This includes the construction, operation and eventual end of life / disassembly of the building being zero.

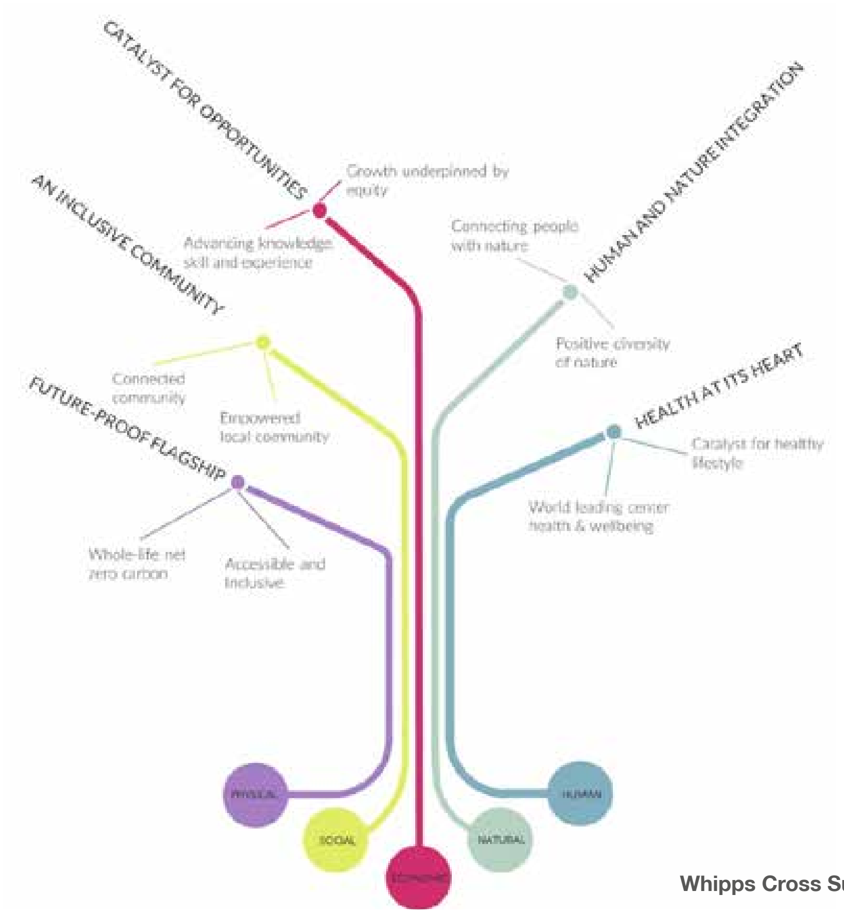
NZC is one major part of a holistic sustainability strategy that needs to be developed for each of our new hospitals. For Whipps Cross Hospital, our Sustainability Charter was developed involving stakeholders from the Hospital Trust, Council and local community.

The aim of the Charter was to capture the most significant factors for both the hospital and wider community, and to make sure these are championed throughout the design and construction phases of the hospital, along with the wider masterplan development.

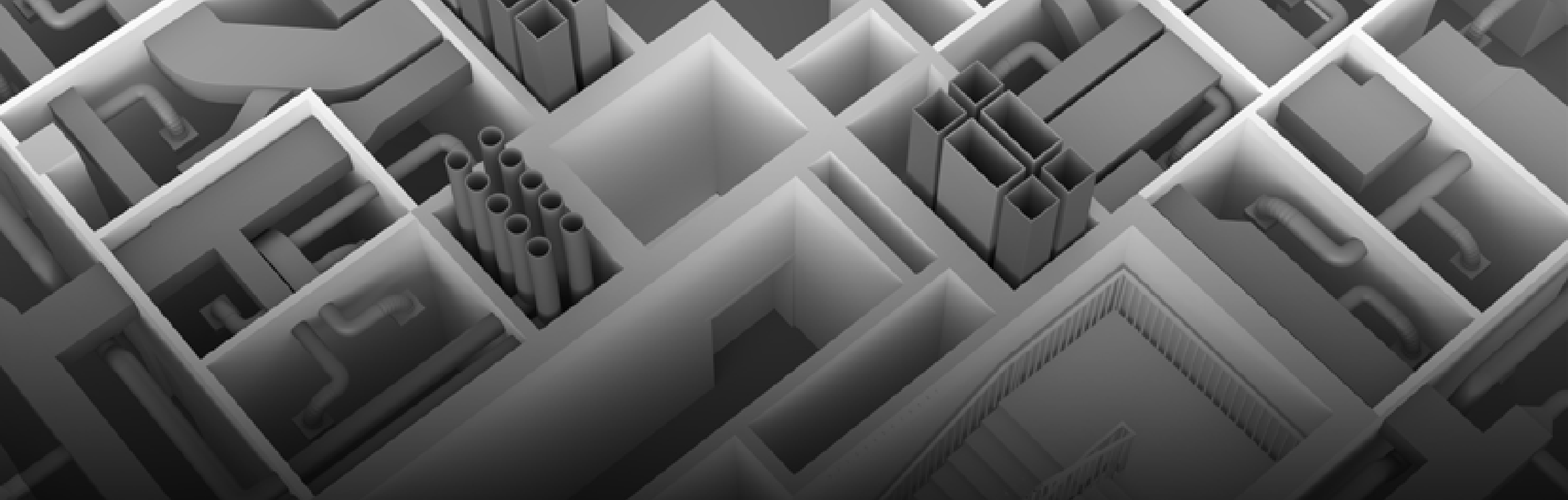
The hospital is also targeting a "BREEAM Excellent" sustainability benchmark which provides multiple further metrics by which the development will be monitored.

NZC is a hugely important part of the Sustainability Charter and **goes well beyond the BREEAM metrics for low energy.** It involves a radically different approach to hospital design.

That approach has been initiated by the NHP programme in the form of the Net Zero Carbon Brief published in 2020.[5] The Brief is currently being advanced in collaboration with industry contributors including members of the Whipps



Whipps Cross Sustainability Charter



Net Zero Hospitals
A Focus on Whole Life Carbon

The NHS is aiming to become net zero a decade ahead of the national legal requirement. For new hospitals to meet this ambition we must understand the implications of reducing both embodied and operational carbon. Here we define what we mean by NZC and set out the principles that need to be considered to achieve a NZC hospital.

Carbon emissions

Whole life carbon emissions associated with the construction and operation a new hospital can broadly be divided into two key categories: Operational carbon and embodied carbon. Plus additional smaller allowances made for end of use / demolition.

Operational carbon

This is the energy used in heating, hot water, ventilation, cooling, lighting, and running of hospital equipment. It is not possible to reduce this energy consumption to zero, but **it can be minimised by efficient design.** If the residual energy is supplied from zero carbon energy sources (either on site or off site) or an investment is made in offsetting this carbon through equal and additional renewable generation elsewhere, then we can achieve net zero operational carbon.

Embodied carbon

The energy used in the construction of a building and the manufacture of the materials used over the lifetime of the building. Again, at this time, it is not possible to reduce this energy use to zero but it can be minimised by careful design and selection of sustainable materials and construction techniques. It is possible to offset the residual carbon used by investing in recognised **carbon offset schemes,** where the same amount of carbon emissions can be reduced or mitigated elsewhere.

The aim of a NZC design is therefore to **minimise operational and embodied energy and associated carbon emissions,** which then minimises the cost of offsetting the associated carbon through zero carbon energy generation, zero carbon energy tariffs or recognised energy offsetting schemes.

Regulations and Policies

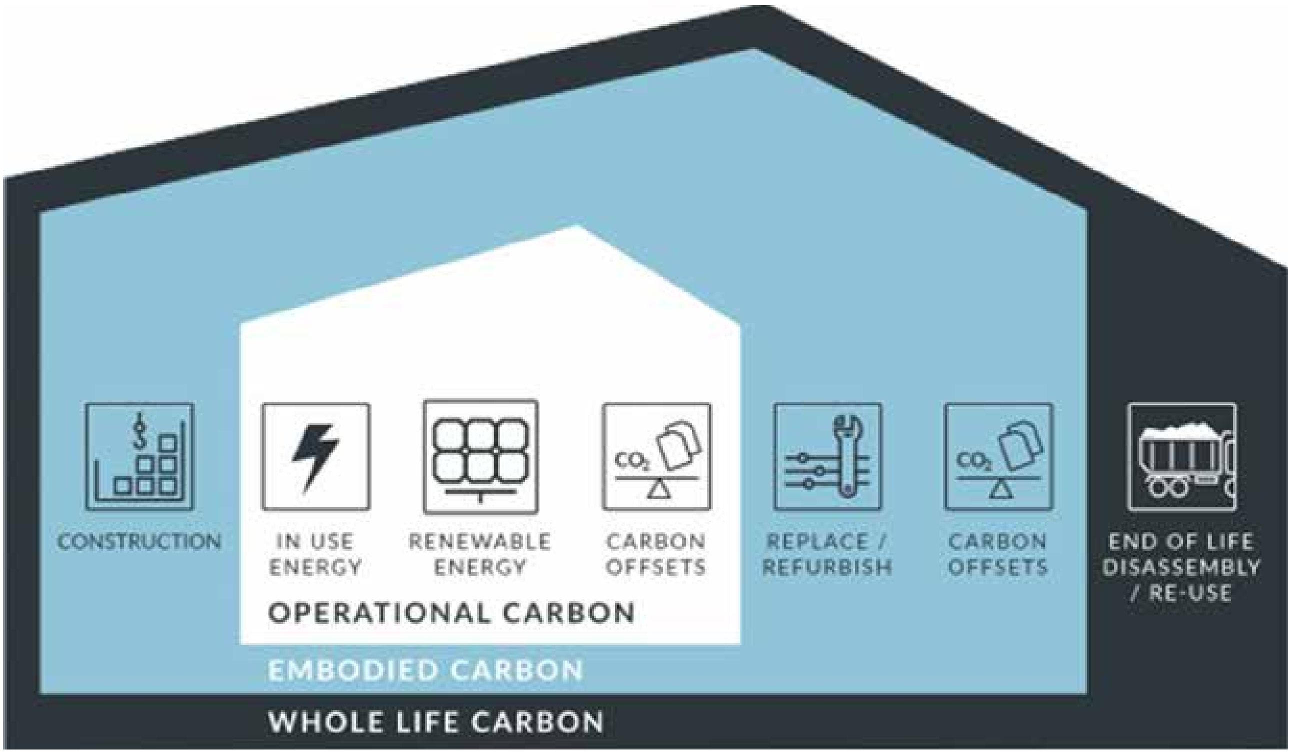
At the time of writing, the UK Building Regulations do not require non domestic buildings to be NZC. However, projects within London are required to make an operational carbon offset payment to cover 100 percent of regulated emissions.

The NHS has published policy documents showing how it is aiming to become a net zero organisation by 2040[5] - ten years ahead of the UK's legal deadline.

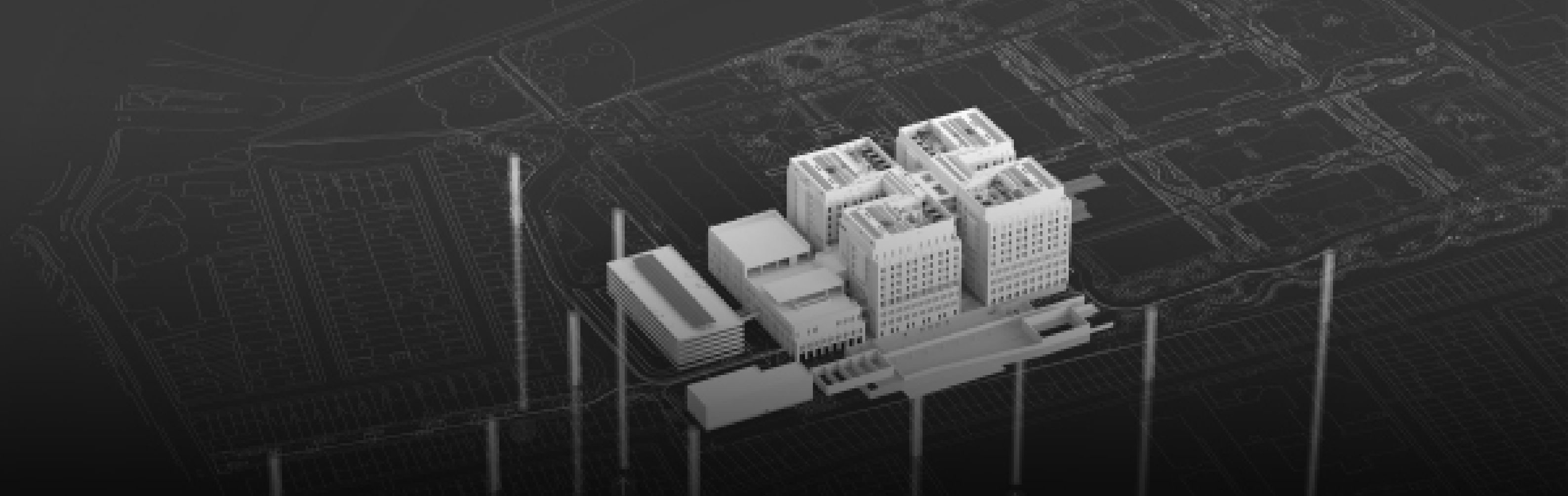
The front running NHP hospitals are currently following the NHS England and Improvement (NHSE/I) Net Zero Carbon Brief in their designs to achieve reduced embodied and operational carbon, **ensuring residual offsetting can be minimised.** This document sets out a number of minimum standards for building fabric and engineering systems performance, which requires a consistent method of calculation.

The NHS brief does not stipulate a whole life carbon assessment method to be used but references the **UK Green Building Council[6] (UKGBC)** and **the London Energy Transformation Initiative[7] (LETI)** guidance. These follow the British Standard BS EN 15978:2011[8] definitions of embodied, operational and whole life carbon.

Local authorities also have planning policies with regards to carbon emissions. Whipps Cross Hospital is based in the Greater London Authority (GLA) area which has a policy requiring new non domestic buildings to achieve a 15 percent carbon reduction via passive design measures, and overall on site reduction of 35 percent. They also require any shortfall (up to 100 percent) to be compensated by a cash contribution to a central carbon offset fund.



NZC components of the UKGBC whole life carbon assessment method



Reducing Operational Carbon Designing for Energy Performance

In the drive to reduce operational energy of a hospital, the most important factor to be considered is how decisions impact internal environment quality and the comfort and recovery of building occupants. Significant modelling and analysis has been undertaken to minimise energy consumption, reduce associated carbon emissions and maintain occupant comfort.

Operational energy consumption

Reducing operational energy demand reduces a hospital's dependence on imported energy and the associated carbon emissions of that energy. By minimising the energy consumed we minimise the carbon emissions.

There are **two main areas** of operational energy consumption:

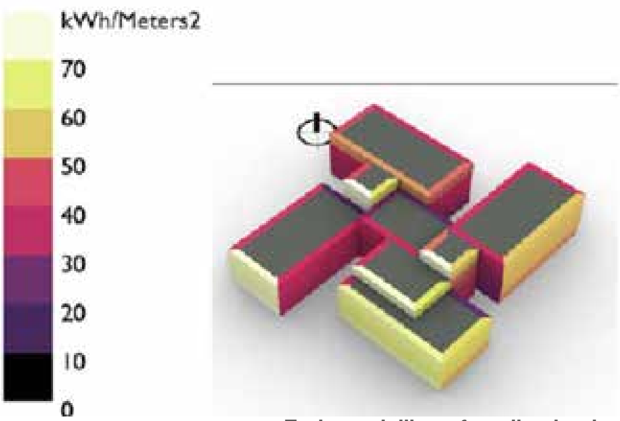
Human comfort
Providing heating, cooling, lighting, ventilation, and sanitation (hot and cold water and drainage)

Hospital operational processes
Medical equipment, ICT systems, medical gases, catering, lifts, FM systems.

Orientation and form factor

The performance of the building fabric has a key influence on the ability to provide human comfort and wellbeing. On Whipps Cross, **early thermal modelling studies** highlighted the difficulties of optimising orientation and form on a constrained urban site. The orientation was eventually driven by the site footprint with localised solar shading on the south west and south east façades.

The challenge of a constrained footprint required a compact building design that minimises the surface area to volume ratio. This allows reduced thermal losses and gains, but involves a trade off with reduced daylight leading to increased lighting energy demand. This is overcome by breaking up the façade with indentations and provision of courtyards. The resulting compact form is efficient in terms of net to gross floor area and also minimises travel distances.



Early modelling of cooling loads for different building orientations

Thermal envelope

The NHSE/I Brief and other current best practice guidance is pushing towards near Passivhaus standards for building fabric. The thermal modelling at Whipps Cross has shown that there are diminishing returns in highly insulated façades and that cooling is more dominant than heating. Modelling showed that **meeting the minimum requirements of the GLA was optimal** and helped lower costs and embodied carbon of the façade.

Lighting

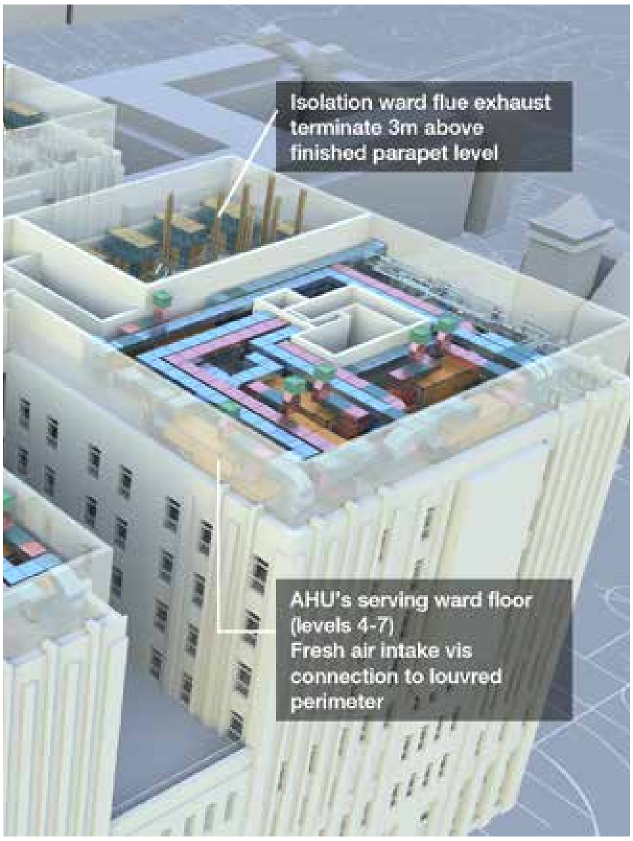
The availability of daylight will be maximised whilst **minimising unwanted solar heat gain** through careful window and shading design, and materials selection. Artificial lighting energy will be minimised using LED luminaires with daylight and occupancy sensor controls.

Ventilation

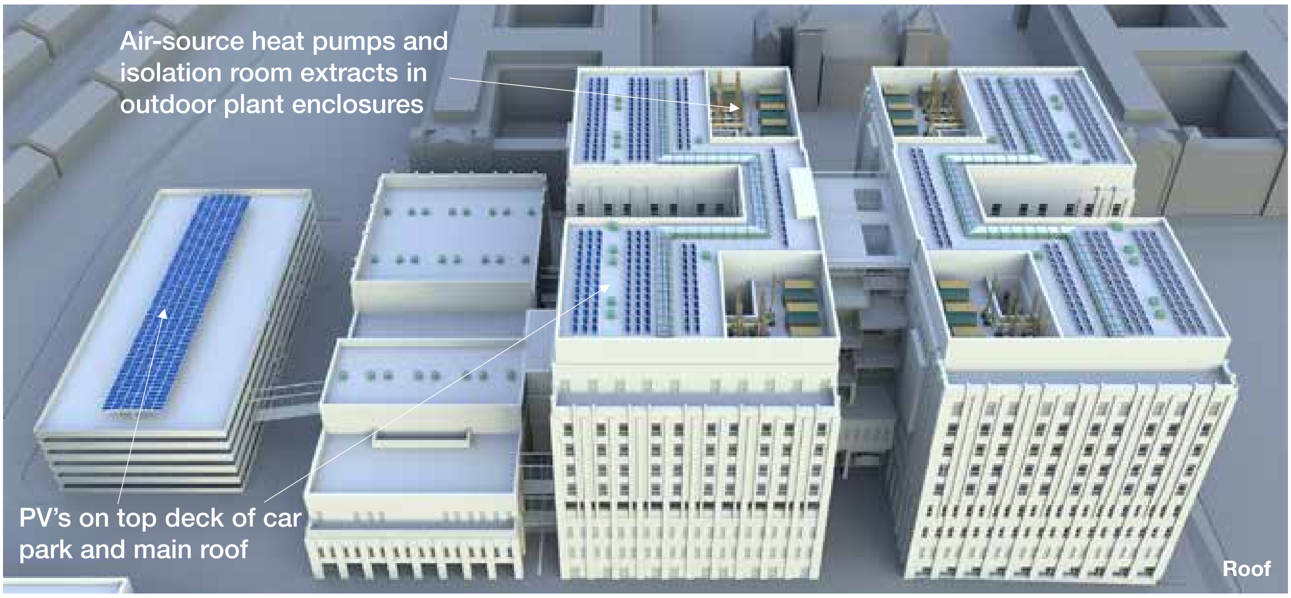
It has become increasingly difficult to justify reliance on opening windows in a hospital to provide the required levels of human comfort. Yet the idea of not being able to open a window to connect with outside environment seems alien to most people, as it is believed to have a positive therapeutic effect. However, when a window is opened, safety, security and privacy must be considered, the ventilation rate is highly variable, the outdoor air pollution is often unacceptable, and the high temperatures in summer and low temperatures in winter mean that comfort standards cannot be maintained.

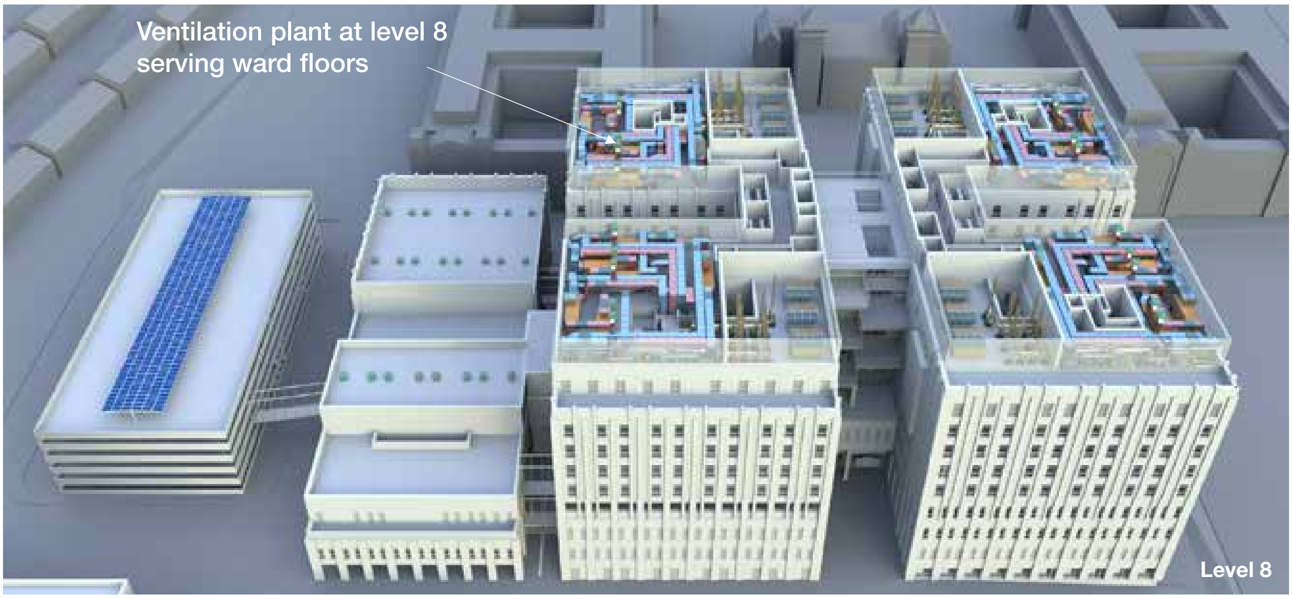
The solution at Whipps Cross is to design all spaces to **meet healthcare criteria using mechanical ventilation** – this can provide controlled levels of filtered fresh air and thermal comfort with minimal energy use, due to the availability of heat recovery between supply and exhaust air streams. Openable windows have been included where appropriate so that it will be **possible to override the air conditioning systems** and with appropriate measures in place to ensure windows are closed as the norm.

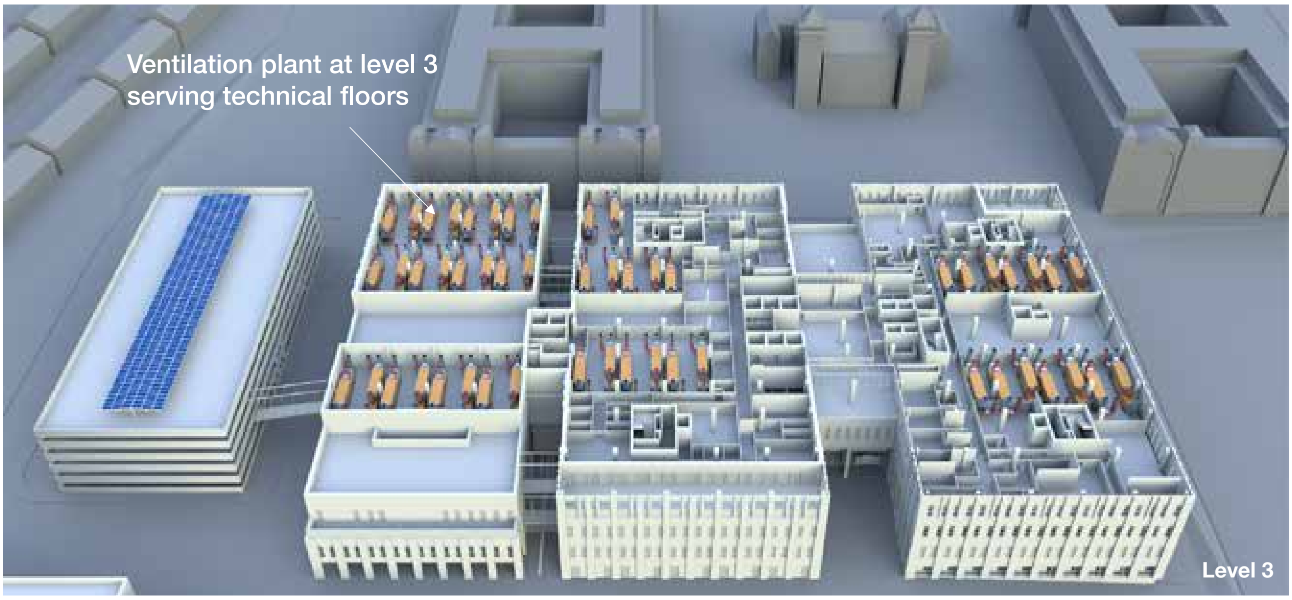
Fan energy is reduced by using larger (lower air resistance) air handling units and ducts, however there is a compromise in greater plant space and riser capacity required.



Ward ventilation strategy


Air-source heat pumps and isolation room extracts in outdoor plant enclosures
PV's on top deck of car park and main roof
Roof


Ventilation plant at level 8 serving ward floors
Level 8


Ventilation plant at level 3 serving technical floors
Level 3

Heating, cooling and hot water

With the ongoing decarbonising of grid electricity, it is now more carbon efficient to use electrically driven heat pumps to provide heating, cooling and hot water to hospitals. **Heat pump systems use low grade heat sources** including ambient air or ground temperatures to generate heating or cooling using, typically, only a third of the input energy compared to a gas based heating plant.

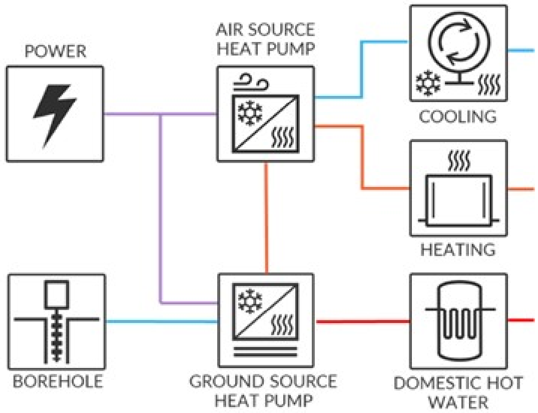
Heat pump networks allow thermal energy to be efficiently transferred between simultaneous heating and cooling demands, as well as reclaiming waste heat from server rooms, medical gas plant and electrical transformers / switch rooms. This has been called a **Heat Wrap** principle.

Heating water is circulated at a lower temperature, 50 degrees Celsius, than with traditional heating systems but with a well insulated building the low heat losses mean heating can be delivered using **terminal heater coils** in the ventilation systems to each room.

Domestic hot water at a higher, sterilisation temperature, around 60 to 70 degrees Celsius, is achievable through water to water heat pumps linked to waste heat circuits, chiller heat rejection and ground source heat pumps.

Air source and ground source heat pumps

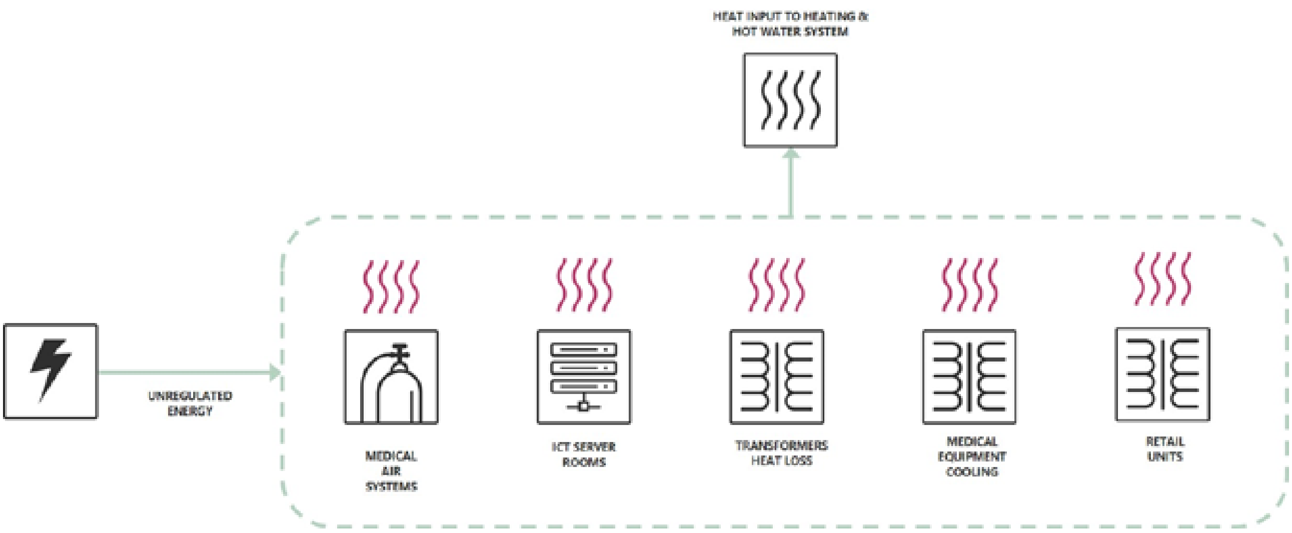
A ground source heat pump desk top feasibility study was carried out. It was found that the presence of a suitable aquifer under the site is predicted to allow sufficient energy exchange to feed the base load of heating and hot water in winter and cooling in the summer, using ground source heat pumps.



Ground and air source heat pumps

Hospital operational processes

The energy used by hospital equipment, medical gas plant, catering equipment and much more, are all difficult to control as part of a design process. Low energy plant will be specified where feasible and Barts Health Trust are committed to purchasing low energy, A-rated equipment wherever possible. However, it will take time for the supply chain to adjust and make significant inroads into equipment energy reduction.



The Heat Wrap principle

Renewables, Heat Networks, Offsetting Minimising Incoming Grid Energy

Once operational energy has been reduced the feasibility of on site and off site renewables and the need for resilient power supplies and stand by energy sources has to be considered. Many available technologies do not currently represent economically viable solutions across large scale sites. Designs should regularly assess viability and plan for future adaptability and compatibility with renewable sources.

Renewables

Once operational energy has been reduced to an acceptable minimum, we have to look at ways to reduce the energy intake using on site and off site renewable energy systems. However, this also has to be considered in conjunction with the strategy for standby energy sources to ensure the hospital can continue to run autonomously in the event of an energy supply failure.

On Whipps Cross Hospital, a review of potential renewables resulted in a section of approximately 1500sqm of roof mounted photovoltaics. **This will mitigate approximately three percent of the total annual energy.**

Electrical supplies

One of the drawbacks of an all electric solution is the increased incoming power supply needed for the site. At Whipps Cross an increased power supply, four times the existing site supply, was needed and moves have been made to reserve a suitable 11kv supply sized to service the hospital and future masterplan area.

Consideration was given to a smaller secondary back up supply but the cost of reserving the additional capacity made this uneconomic. The possibility of a **private wire connection** to a local renewable supply was reviewed but was unavailable in this high density urban area.

Resilience

In a traditional hospital two incoming power supplies and an essential systems generator back up are required under HTM 06-01.[9] At Whipps Cross, the decision was taken to provide a single incoming power supply and 100 percent generator back up. It is expected that a **suitable e-fuel or biofuel drop in will be available for the generators** at the time of completion for the hospital. The feasibility of battery back up of the scale and duration needed was discounted as currently uneconomic.

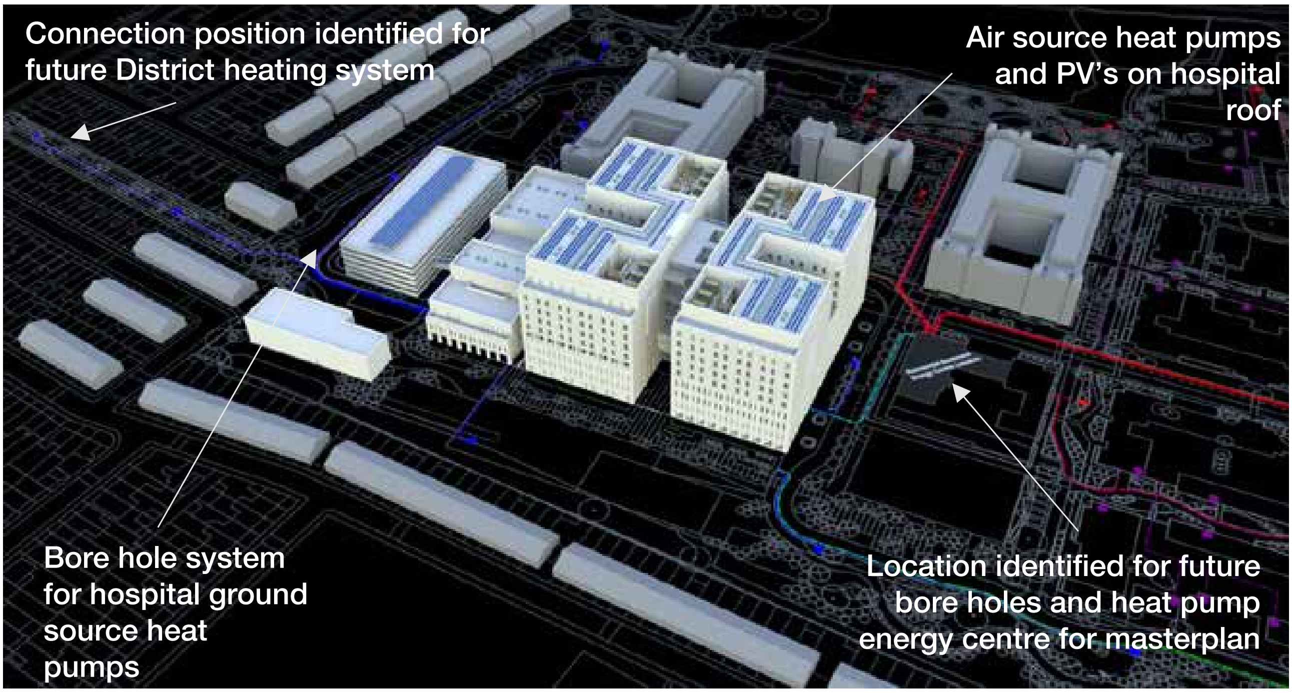
The car park photovoltaic system will include batteries to store solar power for use in car charging. A further assessment of larger scale partial battery storage will be reviewed at the next stage.

Heat networks

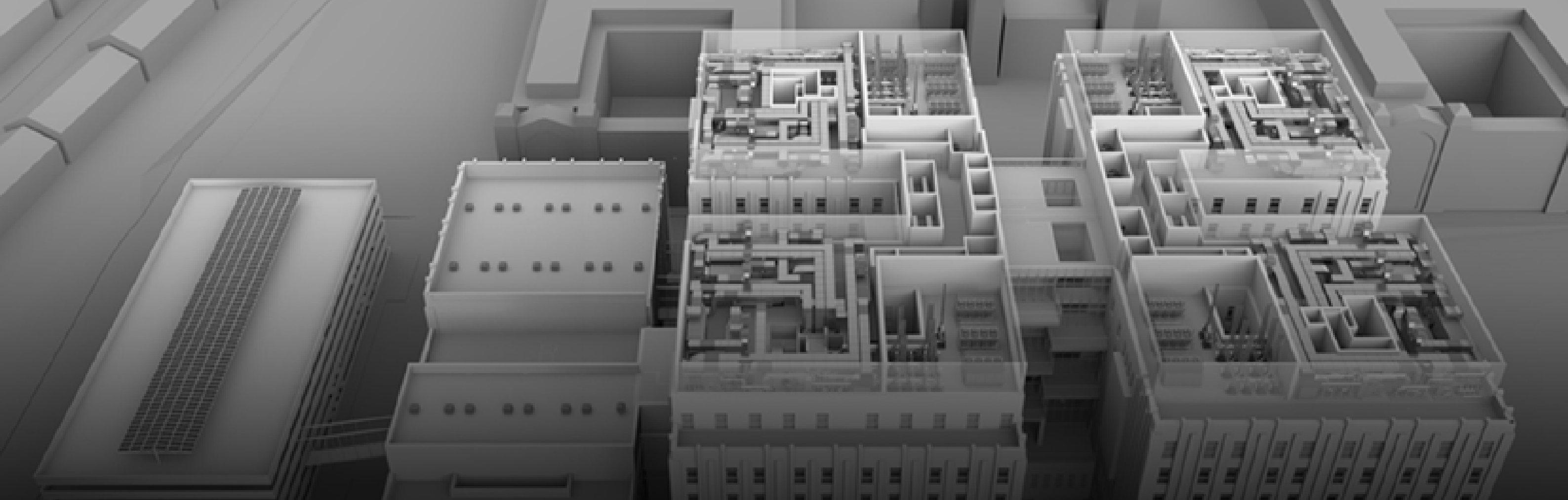
The hospital will include connections ready for a future **ambient loop** interface with the masterplan. An ambient loop is a pipe circuit typically operating between 20 to 30 degrees Celsius that can be used by both heating and cooling heat pump systems simultaneously, thereby sharing energy between buildings. Space for a future ground source heat pump energy centre for the masterplan has been identified along with the potential to connect to a future local authority district heat network.

Operational carbon offset

The GLA has a requirement for offset payments for any residual regulated operational carbon emissions. This has been considerably reduced by the low energy design. The NHS is calling for all operational carbon to be offset but the mechanism for this has not yet been determined. An initial CIBSE TM54[10] real world energy assessment has been carried out to demonstrate the low energy benchmark for the scheme.



Whipps Cross Hospital renewable energy and heat networks



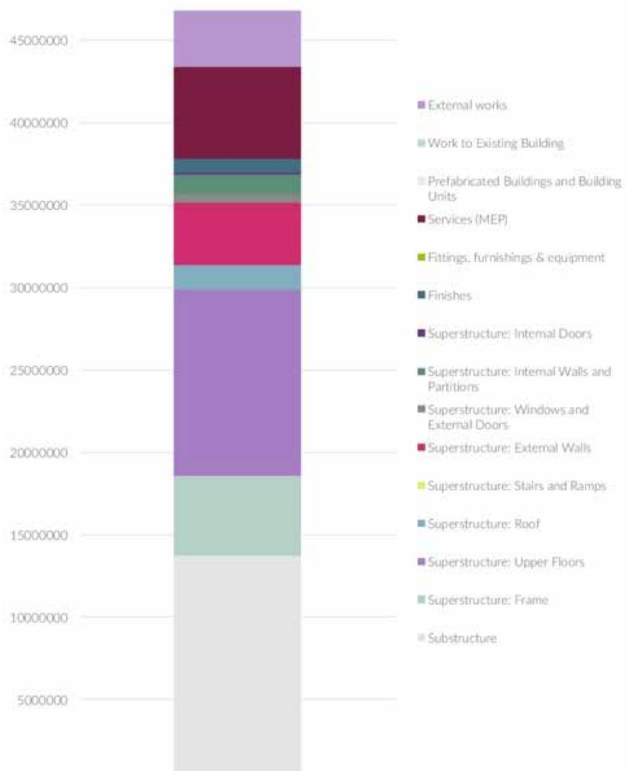
Reducing Embodied Carbon
Intelligent Structural and Fabric Choices

In reaching for net zero we have adopted a whole life carbon approach and utilised early whole life carbon assessments. Here we discuss the way that embodied carbon is calculated, the benchmarks that are used and how the design for Whipps Cross has reviewed and incorporated best practice to date.

Whole life carbon assessment

The embodied carbon is one part of a whole life carbon assessment that needs to be carried out to allow the designers and installers to optimise the design and material selection for a hospital, including the lifecycle maintenance, replacement and eventual disassembly of the building.

At Whipps Cross, an **early whole life carbon assessment was carried out** using the RICS standard method of calculation.[11] The initial results for embodied carbon, as displayed in the corresponding diagram, show that the structural frame is the major component of the calculation.



Whipps Cross Hospital embodied carbon assessment

Embodied carbon analysis

With structure being the largest component, an in depth analysis of the building design was undertaken to compare quantities and carbon content of concrete and steel. An in situ flat slab was identified as the best solution, due to the lower levels of embodied carbon used in the process.

The full carbon assessment uses quantities for materials provided by the project quantity surveyor at the end of the concept design stage. At the technical design stage, and in conjunction with the installation partners, a further analysis will be completed to **optimise materials selection.**

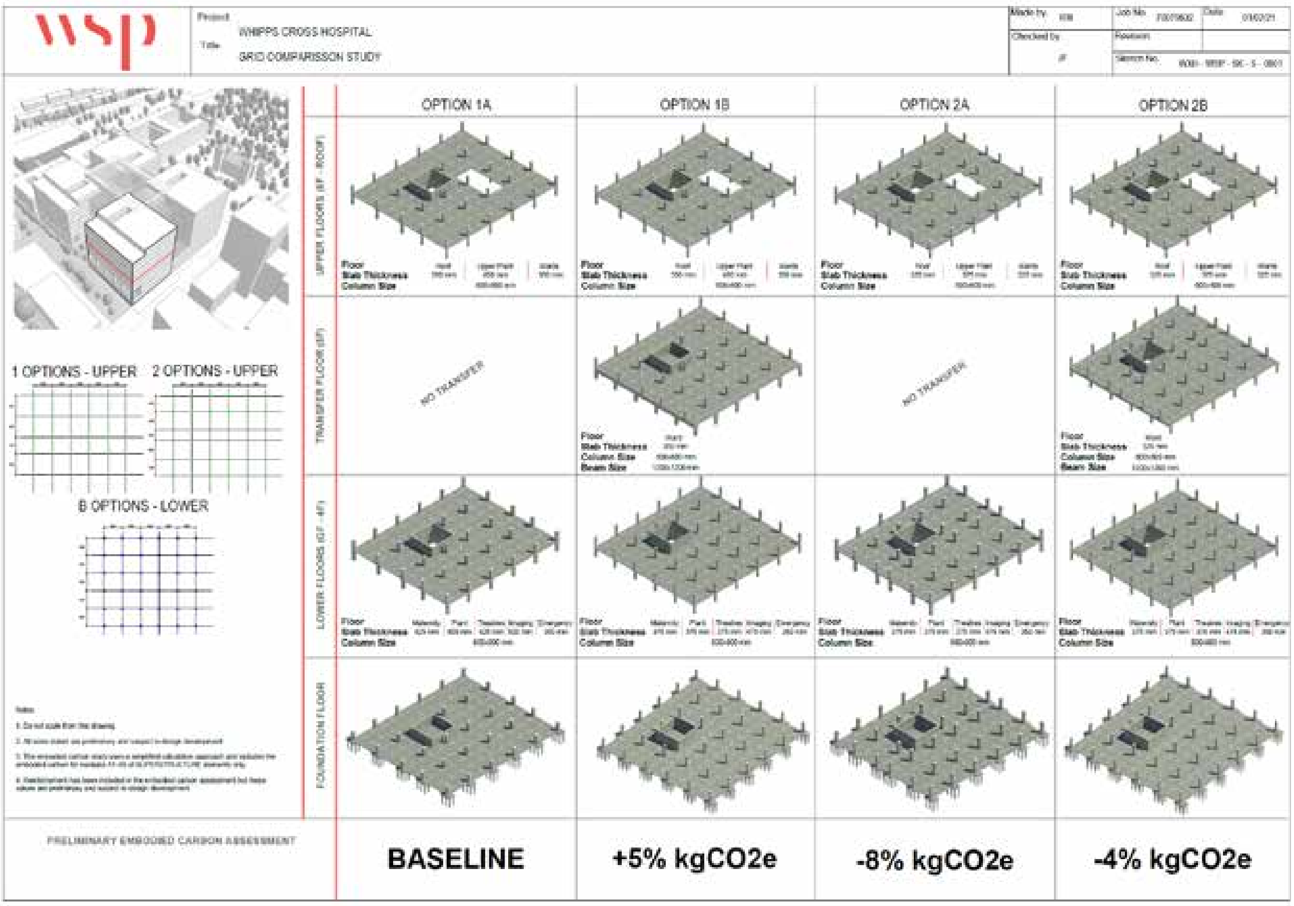
Embodied carbon reduction

The key will be to employ circular economy principles – where the planning and construction is carried out with future recycling and reuse in mind.

The building has been **designed for a long life** by selection of robust materials and using a modular layout, and floor to floor heights that allow future re purposing.

Embodied carbon offsetting

Once the whole life assessment has been optimised the residual carbon associated with the building can be offset through investment in registered carbon offsetting schemes. The exact mechanism for the NHP programme is yet to be finalised.



Whipps Cross Hospital structural embodied carbon options appraisal

Modern Methods of Construction
The NHP and MMC

As we begin to Build Back Better, the NHP is poised to capitalise on the value that can be generated from MMC. We look at the Government's framework for MMC and how as Trust design advisers we can help unlock this value.

Increase value, reduce carbon

The Government's white paper on the MMC definition framework and subsequent announcement of a presumption in favour of MMC across all construction programmes, has created the agenda for unprecedented change to the way we design and construct public sector buildings.

The UK Government policy, **Build Back Better: Our Plan for Growth,**[12] further strengthens the desire for change and growth in the construction industry. The demand for greater use of cutting edge construction technology and the billion pounds of investment set the scene for significant industry opportunities.

MMC and the NHP

The NHP, as part **The Health Infrastructure Plan (HIP),**[1] is one of the centre pieces of the Build Back Better policy.

The HIP creates a clear framework to invest in MMC for the long term benefit across the programme of investment – "A multi year capital settlement will provide greater certainty to develop capacity, plan effectively, get better value for money".

In 2020, NHSE/I issued an interim statement as part of The NHP stating: "In line with the Government 2019 statement – 'Presumption in Favour of MMC' Department of Health and Social Care (DHSC) and NHSE/I assume that all schemes start out as MMC."[1]

The value of MMC to healthcare environments

The NHP creates the opportunity to transform the construction industry serving the healthcare sector over a consistent and transparent decade long investment programme.

The value that can be derived from a maturing MMC healthcare market is clear.

Healthcare is one of the most complex and dynamic environments, having to continuously evolve with:

- A changing population and demographic
- Ever improving clinical pathways and models of care
- Enhancements of research and equipment used
- A digital revolution and embracing smart technology
- Building resilience against future pandemics

All of these create a constant environment of change, not only throughout the lifetime of a hospital, but also **during the design and construction time frame.**

Traditional bespoke hospital designs can struggle to flex and quickly adapt to this change. By creating designs based on a **standardised platform approach** we can begin to realise the opportunities of pre manufactured value, the measure of the extent of off site construction used on a project.

We can create standardised design components that are directly compatible with efficient off site manufacturing. This platform approach can be combined in a number of configurations to meet the bespoke needs and demands of any given NHS Trust.

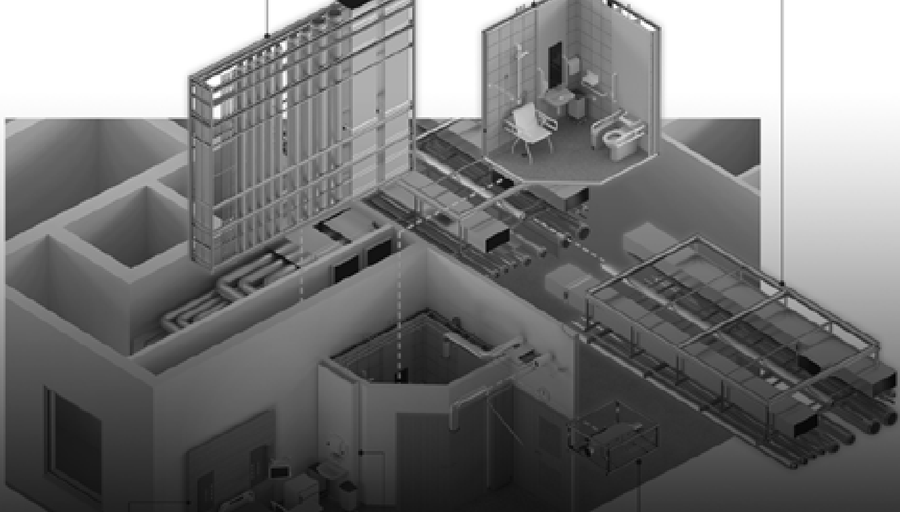
MMC at DGRI

Trusted advisers

In the context of a complex large scale build programme, there are significant opportunities as described, but also significant challenges and barriers.

As a design team and Trust advisers we have to provide support in navigating these challenges to ensure we **maximise the value that MMC will bring to the individual NHS Trusts,** as well as achieving the long term ambitions of the HIP to create a mature and highly efficient MMC sector to serve the healthcare market.

The following articles describe how we as a unified team helped to define and deliver the objectives of MMC within the Whipps Cross Hospital redevelopment; the approach we took to begin to realise these objectives; as well as discussing one of the challenges that faces all healthcare facilities and how to determine an optimal structural grid that will provide a flexible and adaptable building well into the future.



Developing an MMC strategy Whipps Cross Hospital Redevelopment

Whipps Cross Hospital redevelopment is a significant midrise new build hospital. We have developed a clear approach to maximise the value that MMC can bring to healthcare environments of the future.

Understanding the MMC landscape

The Government are placing renewed emphasis on MMC and the role it plays in the NHP's vision for delivering healthcare environments of the future. Setting a robust approach to realise this vision is essential.

This starts by drawing from the Government's Infrastructure and Projects Authority (IPA) guidance, which defines three categories of MMC:[13]

Manufactured – High levels of standardisation of both process and components
Volumetric – Fully fitted modules
Components – Standardised design elements

With the highest value to be gained from a manufactured approach; a high pre manufactured value.

Our team used extensive MMC experience from past projects, such as Dumfries and Galloway Royal Infirmary, which used a Design for Manufacture and Assembly (DfMA) approach to set MMC objectives.

The Whipps Cross development is targeting **70 percent MMC**, at OBC stage, with the majority coming from high pre manufactured value.

With the drive to net zero, creating 100 percent MMC is not carbon efficient. An example of this is large buildings requiring large foundations, as such carbon efficient concrete mixes that are delivered direct to site offer a more carbon sensitive solution. Although even in the ground, there are still **opportunities to use advanced construction technologies** to enhance traditional approaches.

MMC strategy development

A summary of our approach is included here with more detail of specific MMC selection in the following article.

To drive maximum pre manufactured value each possible hospital typology was assessed for its ability to maximise MMC potential. The results of which were a significant factor in the overall assessment and selection. From this analysis a typology was selected that could efficiently accommodate a range of MMC solutions.

A secondary review was then undertaken to assess the ability of each available solution to respond to the key criteria within each functional area of the hospital. Taking into account:

- Structural requirements
- Clinical planning
- MEP
- Façade
- Finishes

A detailed score based assessment was then used to narrow the options down to the most appropriate for this type and scale of development. Once complete, this provided a framework for decision making moving through the OBC stage.

Key to our strategy at this point was keeping as many MMC options available for as long as possible. When decisions were made, they were tested against which MMC options and associated opportunities might be ruled out. **Iteratively evaluating the impact of decisions made to optimise our solution.**

This introduces the concept of informed decision making, which we touch on in more detail later in this document. This informed iterative approach allowed us to maintain a core of MMC options open.

This mitigates the risk of potential supply chain delivery issues until further testing can be completed alongside a main contractor's supply chain.

Crucially, the planning height of the building was determined to allow for a range of structural zones moving into the FBC stage.

Summary of our approach

SOC / Start OBC

Hospital typology selected from the start, based on its ability to maximise the use of all MMC opportunities.

Start OBC

Assessment of all MMC options against key Trust specific criteria and selection of the most appropriate options to proceed.

During OBC

Refine the assessment to a selection. Test all decisions against the framework of options to keep as many open as possible as long as possible.

End OBC

Final selection of narrowed MMC options. Keep a number of options viable until contractor involvement.

FBC

Contractor involvement to help directly with a supply chain and finalise option selection.

Our approach was not to close down to a single preferred option at the end of the OBC process. This approach has ensured that the Whipps Cross Hospital redevelopment is poised to capitalise on the growing capacity and **expertise of the MMC industry** into the FBC. stage.

The Flexible Framework Approach
A Process of Informed Decision Making

Selecting the right MMC solution for the project can be challenging and potentially constrictive with broader unintended consequences. Our flexible framework process created for Whipps Cross Hospital provides a clear auditable approach to informed decision making, enabling us to maximise the value MMC can deliver to large scale hospital programmes.

Realising MMC ambitions

We have touched upon the MMC ambitions of the Government, NHP and Whipps Cross, and discussed our approach to developing an MMC strategy on the project. Here we describe in greater detail the flexible framework approach that was developed to realise these ambitions.

Our approach was set out in a dedicated MMC strategy document which provided a clear auditable approach to the decisions made and set the project framework for iteratively evaluating the impact of decisions made on the project.

To maximise the success of MMC it is critical to get all decision makers on board from an early stage. **Our collaborative, workshop approach helped define a clear strategy whilst taking the whole team on that journey.**

A core part of the strategy was to select a range of MMC solutions to take forward through the OBC process. Our selection process started at the review SOC stage, prior to the start of OBC.

Upon review, four functional areas of the hospital were assessed:

- Wards
- Highly serviced areas
- Low serviced areas
- Plant

The impacts and benefits to each area were assessed independently with a focus on maintaining flexibility of different MMC options. For example for the ward towers and the more highly serviced podium areas.

The flexible framework approach

While this process was used on the delivery of a large scale complex hospital, it is equally appropriate for a range of building typologies and programmes of work.

Define

Define the functional areas of the hospital that are each fundamentally different.

Define a wide array of characteristics, such as acoustics, fire, adaptability, cost, carbon and logistics.

Define all available forms of construction, traditional and modern.

Score

Score each functional area against the importance of each characteristic for that area.

Score each form of construction against the ease of which that characteristic can be delivered by that form.

Combine

Combine the two scoring matrices.

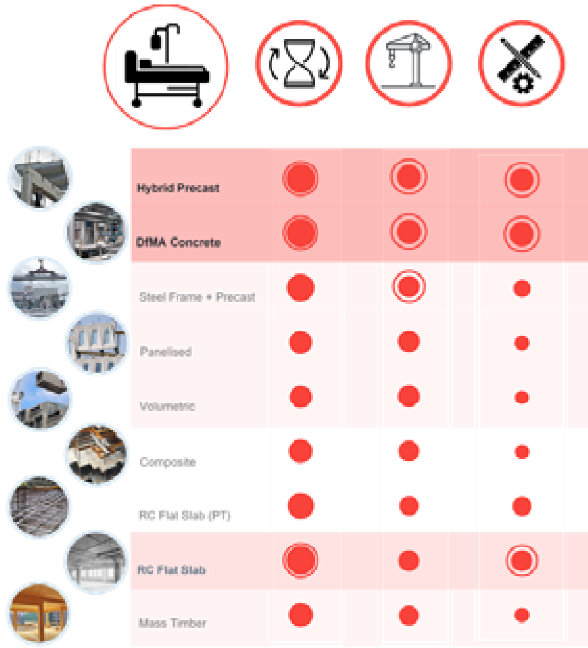
Combine similar characteristics into focus areas to help inform decision making, such as flexibility, adaptability, constructibility, design, carbon and cost.

Assess

For each functional area, the top scoring MMC solutions within each focus areas were then used by the team to help refine the available options.

Recommend

The resulting top options were then taken through into the start of the OBC stage.



Flexible framework approach

At the concept design stage, **all MMC opportunities were considered against the developed architectural typology**. The strategy was to create the spatial arrangements of the developing hospital plan to allow for the maximum number of MMC opportunities moving into the FBC stage. Or, alternatively to minimise the number of MMC opportunities that are ruled out as the design development progressed through OBC.

> A key consideration was to set the planning height of the building to allow for **a range of structural zones** to broaden the supply chain opportunities.

The midrise height of the hospital coupled with the stacked content ultimately drove the selection of DfMA concrete frame approach throughout, with the opportunity for alternative forms of construction for the ward towers and plant. For the DfMA concrete elements a large structural zone was incorporated to accommodate a range of solutions and to include more carbon efficient solutions such as downstand beams and slabs.

Key considerations

Early engagement at SOC stage to maximise the opportunities through the selection of the most effective hospital typology to accommodate MMC solutions efficiently.

Create a process to **take all members of the Trust team and key stakeholders on the journey** by creating a clearly defined project strategy, to assess the impact and benefit of decisions made. Provide a clear demonstration of the approach and solutions to the NHP team.

The impact of material availability and specialist contractor capacity on public sector projects has become a well documented challenge to project viability and deliverability. **Our flexible framework approach is ready to leverage a principal contractor's supply chain** options to achieve the ambitions as set out by the Government, NHP and Whipps Cross Hospital redevelopment team.


DGRI © Paul McMullin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A Generative Parametric Approach Advanced Structural Optimisation

The structural grid is a decision made early on in the project lifecycle which is likely to remain unchanged through to construction. It is a critical decision with a wider impact on the whole lifecycle of the hospital. Getting it right is key to future proofing and ensuring optimal building performance. Ensuring operational success of the hospital and enabling the project to achieve strict cost and carbon objectives.

Structural grids

The ideal structural grid size has long been a subject of lively debate. Historically governed predominantly by flexibility versus cost, the equation in recent years has become a far more complex one to solve.

Whichever form of construction is selected on a project, **structural grid optimisation is paramount.** It minimises embodied energy and creates maximum efficiency in clinical space, that can flex and adapt to accommodate change over time.

The following article looks at the approach taken to enhance the information available at an early stage to inform the critical decision making process in relation to the structural grid.

Our approach

Incorporating MMC on a significant scale on a mid rise hospital development will to an extent be determined by the chosen structural form and structural grid. This was important to tackle as early as possible on the project.

Collaborative working and informed decision making were at the heart of developing and enabling optimal solutions. The more informed the decision making process, the more optimised the solutions.

To respond to this challenge, we developed an **advanced structural optimisation tool** to help optimise each type of end use as a single floor plate, and to identify where the differing end uses could be stacked across multiple floor plates. For example, wards over theatres.

Advanced structural optimisation

Determining an efficient structural grid when considering the effects of loading and deflection is relatively straightforward. Generally, the shorter the span, the more efficient the structure but the less flexible the space. However, for healthcare design, **vibration response is often the governing factor.** Vibration performance has a non linear relationship to the span and detailed calculations are often completed late in the design process as a cross check due to its time intensive requirements. Historically the time taken to process detailed checks on multiple options has been prohibitive. There is a risk therefore optimum solutions are not selected, leading potentially to an increased carbon content or inflexible space.

To address this, we developed an advanced grid optimising tool that is used right at the start of the project to complete **detailed analysis across hundreds of potential options.** Crucially this optimisation process includes detailed vibration analysis.

The output of the tool is a structural design optimised around embodied carbon for each possible span across a range of forms of construction. This includes complex interdependences such as the optimum carbon balance between slab thickness and reinforcement quantities. It also takes into account the extra foundation carbon for heavier thicker slabs arriving at the optimum design. The results then provide **highly accurate information to the wider project team to make much more informed decisions.**

As an example, looking at two different areas: general areas and theatres. For general areas, where vibration is a lesser requirement, the assessment shows that embodied carbon for concrete flat slab construction over a nine metre span has a 15 percent carbon premium over a seven metre span.

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For a theatre area, which has an enhanced vibration performance requirement, there is **a 50 percent carbon premium** at a nine metre span when compared to a seven metre span.

Stacking these competing spaces on top of each other you can then start to consider the effects of inserting transfer structures between two different optimised structural grids. This can then be compared with taking a larger clinically compatible structural grid top to bottom.

On Whipps Cross, with wards above theatres and other uses such as imaging, a mid level transfer structure was found to increase the carbon content across all potential solutions and hence focus was turned to **achieving the most efficient clinically compatible grid, top to bottom.**

Determining the optimal grid size is one of the most complex decisions of any healthcare project. This multi objective optimisation includes some mutually exclusive interrelationships such as embodied carbon, operational carbon, clinical efficiency and cost. The varying efficiencies, and inefficiencies, of MMC then adds a further layer of complexity. Hence the need to develop the flexible framework process discussed to analyse the wider impact and benefit of differing MMC solutions.

Advanced and accurate early stage studies of these key objectives is paramount in making high quality decisions.

Where larger spans are required which are beyond structurally optimal, understanding the exact cost and carbon trade offs and what that means to the project, for example what is compromised elsewhere, will drive the holistically optimum solution. Our approach has ensured that informed decision making focused on optimising building performance is at the heart of these critically important early stage project choices.

The Value of Digital for the NHP

Intelligent hospitals require a digital strategy that takes into account how future healthcare environments will interrelate with data, software and technology. Considerations within the strategy include estate management through digital twins, forecasting future trends through Artificial Intelligence (AI), the integration of wearable sensors, monitoring building performance with sensor technology and a robust, future proofed infrastructure layer to support future innovations.

Future hospitals

The NHP includes significant considerations for a digital strategy which will underpin patient care in future healthcare environments.

Future hospitals will process patients differently to the hospitals of today. Technology will aid the clinical patient lifecycle as well as enabling virtual consultations to take place.

Digital technologies will help the hospital move from **episodic to collaborative and longitudinal care.**

Emerging technologies will create new ways to continually monitor patients and to integrate patient and facility data.

Digital strategy

To realise optimal value an intelligent hospital must consider from the outset how data and digital technologies can bring value to the design, construction and operation of the new facility.

The digital strategy should support the management of NHP estates. Utilising a digital twin to manage asset information during the capital phase, that will also continue to be used during the operation phase of the hospital.

Data and digital technologies can assist in evolving traditional information management processes. For instance, data lakes and AI could, via big data analytics, review archived data to create trends which can be used to inform future patient care, and facilities management. **Driving the information and learning experiences directly to caregivers and building operators.** Data insights could also be directly passed to the command centres and ward monitoring stations therefore increasing patient monitoring efficiencies and capabilities.

New technology will play a huge role in the **future of healthcare environments** both in patient care and building performance optimisation. Examples of new and emerging digital technologies for people include wearables and microfluidic sensors that can be placed either on or near patients to track vital measurements. Building performance and efficiencies will be vastly improved via technologies such as Internet of Things (IoT), Radio Frequency Identification (RFID) and sensing solutions.

The digital strategy also needs to ensure that there is a **robust, future proofed infrastructure layer** providing significant uptime which allows hardware and software layers to function appropriately.

The case studies that follow detail the key considerations that should be considered to produce a digital first approach. Focussing on creating the digital foundations through the capital phase and the use of digital twins during the operation of a hospital. Finally taking a look at **how information can be utilised to create an intelligent building.**

Tangible benefits of an intelligent hospital

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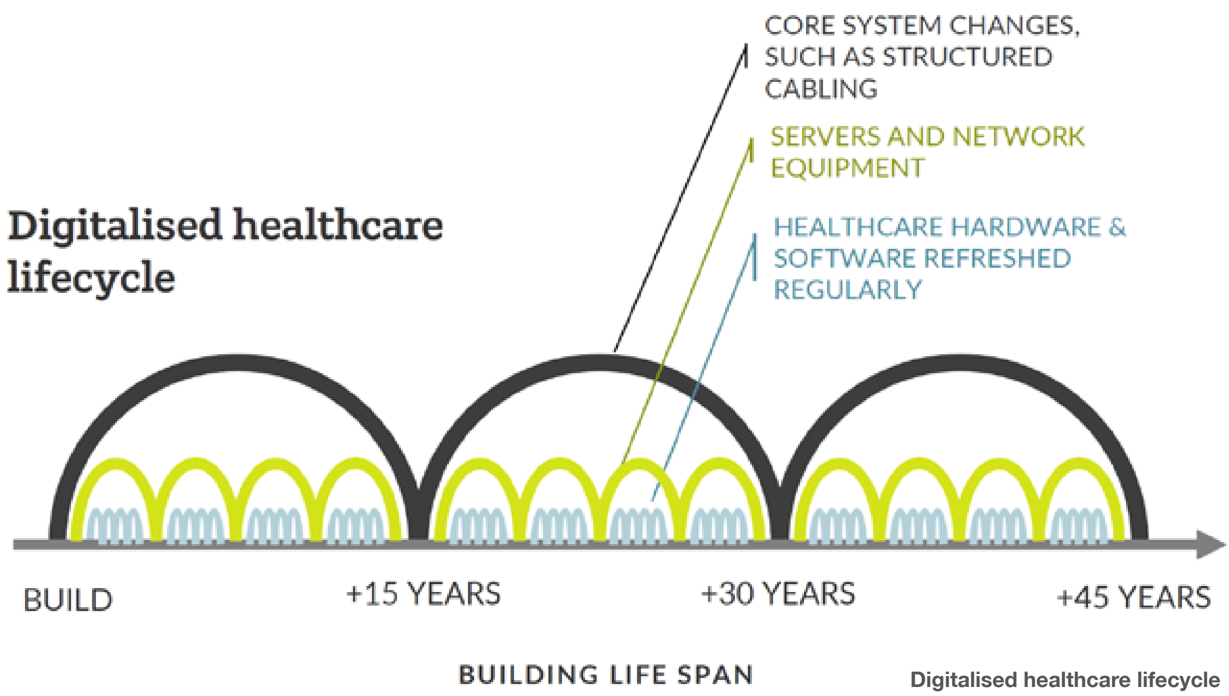


Digitalised healthcare lifecycle

Digital by Default
Establishing a Digital Culture

The NHP digital as default approach outlines that a BIM process should be utilised for the entire lifecycle of the project to support decision making, coordination and collaboration. Here we discuss the process to deliver key digital information that can be used to optimise the delivery and operation of intelligent hospitals.

The steps below outline the process **to deliver key digital information** that can be used in the delivery and operation of an intelligent hospital.

1 It is critical that the project starts with the end in mind and develops a comprehensive list of client requirements. These requirements will establish what information needs to be delivered through the capital phase to support operation.

2 Once the client has established the requirements, the project team will develop a BIM Execution Plan (BEP) which sets out the process for implementing and delivering the BIM process and client requirements.

3 Based on the BEP the project team will set up the models so that they can deliver the client requirements alongside industry best practice in terms of design development and construction.

4 Throughout the project until handover, the project team will be responsible for creating the geometry and data that supports the design and construction of the hospital. This process is set out in the BEP including how information is coordinated, verified and validated.

5 At the handover of the project, the Trust will be delivered a validated as built model of the hospital alongside the information associated to the building. This then needs to be managed in operation to ensure that it is kept up to date.

6 The data handed over at the completion of the project will be delivered in a standardised format. This ensures that it can be seamlessly transferred into the hospitals operational system, and will utilise existing nomenclature where available.

Added value with digital as default

By defining a digital as default approach and a core BIM process starting with the end result in mind, there is considerable potential to add value in a number of key areas.

Engagement

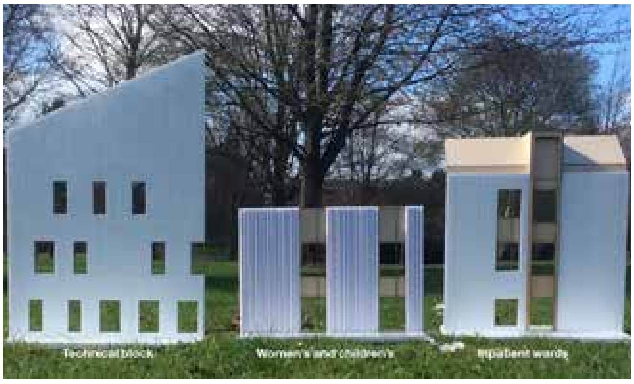
Ryder Architecture have been pioneering digital engagement tools long before the pandemic made it a necessity. This meant that we were able to run **in depth, interactive engagement sessions and design reviews** through a digital medium, Miro, without getting everyone in the same physical space. This approach has proved incredibly successful, capturing more view points than ever before whilst reducing travel, cost and carbon footprint.

Collaboration

Alongside video conferencing, other platforms can be utilised to improve collaboration on NHP projects. One tool that has been successfully implemented on Whipps Cross is the use of **BIM360 as a common data environment and collaboration tool**. The platform has been set up to share all models, drawings and documentation on the project with the project and client team. All communication can be captured within the platform and it acts as the one source of truth for the project moving forward. Improving transparency, accountability and communication along the way.

Standardisation

A digital as default approach, lends itself well to standardised platform design and delivery. This approach was initiated by Ryder on DGRI, where most of the off site panels were rationalised into a set of standard sizes, supporting quality control and speed of delivery. **The use of the digital model to plan and manage this was paramount.**

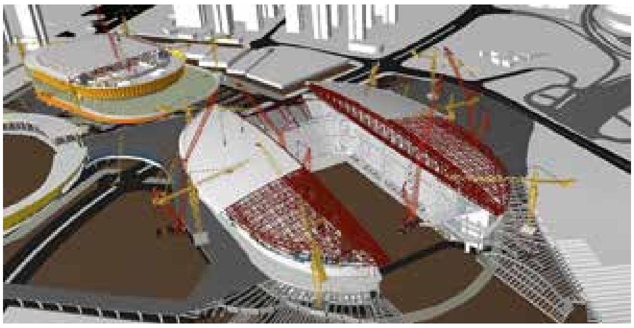


Standardised MMC panels for DGRI

Logistics optimisation

Much of the work within the NHP is going to be undertaken on live hospital sites, meaning that the coordination of the logistics during construction will be critical. BIM Academy have utilised 4D construction logistics planning on **construction sites throughout the world on complex projects**. 4D planning combines the 3D model with the project programme, communicating to all stakeholders the build sequence. It also allows for in depth planning of complicated elements of the build.

BIM360 environment



4D planning environment

Aquila

BIM Academy have recently pioneered a new 4D planning system on project Aquila, a new digital tool for monitoring, managing, and predicting the performance of plant equipment on site. By combining BIM and 4D scheduling, Aquila works to improve project productivity and sustainability in realtime.

Live planning environment

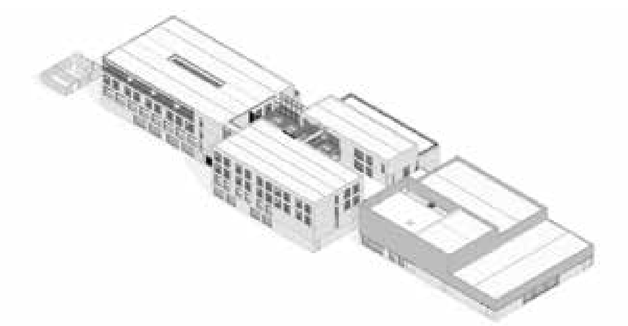
Coordination

The coordination of design work on complex hospitals is a significant task, however, digital tools can simplify this process and improve the efficiency of tasks having a direct impact. This improves productivity during the design stages. BIM Academy and Ryder have implemented **BIM Track** on all major projects to support this process. BIM Track hosts all of the coordination activity and provides a portal to the project team to **collaborate and resolve all clashes in coordination.**

Sustainability

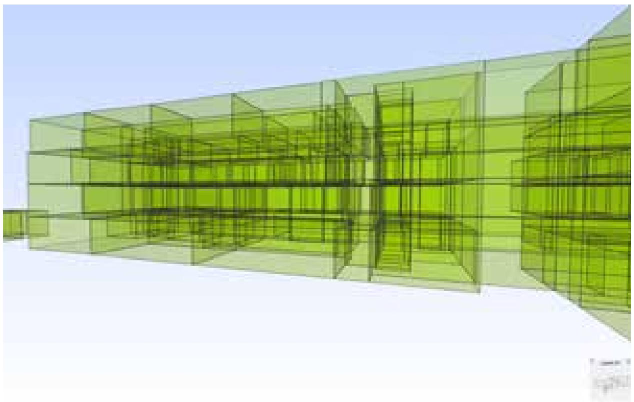
Digital tools play a fundamental role in supporting the delivery of sustainability targets and the monitoring and evaluation of building performance over time. BIM Academy and Ryder have worked extensively with the **Scottish Futures Trust (SFT)** in developing a dynamic energy modelling process in order to lower a buildings energy consumption to predicted levels, offering solutions on how to better match predicted levels with realtime levels.

Collecting and evaluating data on building performance is necessary to ensure we are collecting **comparable performance related data sets from each of the new hospitals** in order to demonstrate each new hospital being built can learn from the last.



Queensferry High School

BIM Track



Energy modelling at Queensferry High School

Key considerations

Data and digital technologies can be used to continually benchmark and optimise the design, construction and operation of intelligent hospitals.

The key to a digital as default approach is to ensure that the base requirements are captured at the start of the project. This means that the project team can **develop the digital information in a standardised format** that can be utilised by the best technology available at the time.

Whipps Cross Hospital

Digitise to Optimise
NHP Intelligent Building Considerations

An intelligent hospital can be achieved by using a digital twin to manage the operation of the hospital. The NHP digital as default approach outlines that a BIM process should be utilised for the entire lifecycle of the project, delivering key standardised information that can be utilised in operation, supporting an intelligent building and digital twin.

Intelligent buildings

Intelligent buildings can bring increased efficiencies, system visibility and automation. These benefits can be harnessed by both the hospital and the Trust across its building estate. Examples of intelligent building initiatives include using asset data to create predictive maintenance, building performance optimisation, disaster planning and simulation.

Intelligent building is a term which is used interchangeably with smart building, offering a tailored solution based on the weighting of specific drivers for user and patient experience, productivity, profitability and efficiency outcomes. It is not a technology driven building, but one that is digitally enabled to achieve the strategic goals of the organisation, building operators and occupants.

Software for intelligent buildings typically brings together siloed systems, allowing machine learning and business intelligence to enable the systems to operate together.

Digital twins

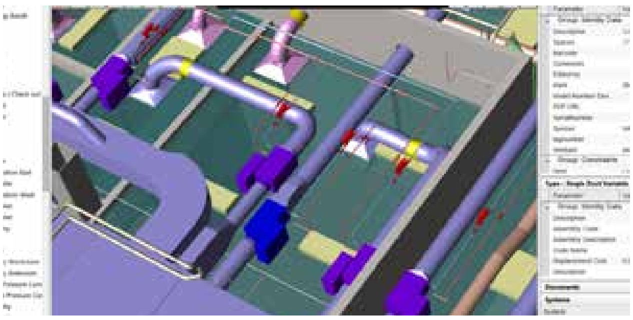
One approach to supporting an intelligent building is to develop a digital twin to manage the operation of a hospital through an integration platform that connects several disparate systems with the 3D model, providing a front end viewer so that all operational information can be viewed in place, providing one source of the truth. The BIM process during the capital phase of the project should build the foundations for the delivery of a digital twin for use in the operation phase.

The technology to develop a digital twin already exists. BIM Academy developed an early example of a digital twin with the Sydney Opera House in 2015 to **improve the facilities management, maintenance, logistics and planning across the site.**

Smart Connected Buildings

An example of this is **Ryder's Smart Connected Buildings initiative,** which aims to bring together live data from various sources, typically sensor technology, and present it on an intuitive dashboard where users can make more informed decisions about how they manage or use the building to minimise energy, improve occupant wellbeing and reduce transmission of viruses.

This system has also been utilised to provide actionable predictive maintenance alerts to building operators and health and wellbeing alerts related to internal environment quality to building occupants.



Digital twins

Individual components of a building can also be considered intelligent as they are upgraded from **typical functionality to advanced functionality and introduced to the ecosystem.**

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Intelligent building initiatives
Other example of intelligent building initiatives utilising a digital twin may include:

1 Predictive maintenance, utilising data to predict when assets need maintaining rather than running to failure.

2 Performance optimisation, constant measurement and adjustment of resource intensive services to improve the sustainability and performance of the hospital.

3 Disaster simulation analysis, virtual simulation planning, preparing staff for unusual events that require adaptation of the hospital in a short space of time.

4 Smart portering services, showing porters where the nearest free bed is.

5 Smart bathrooms which allow the cleaning team to proactively know which consumables require servicing and general bathroom cleaning based upon footfall traffic rather than timing.

An intelligent building relies being able to interact with robust, reliable digital building information. The BIM process during the capital phase will support this ambition alongside the base ICT requirements. The exact requirements of Whipps Cross Hospital in terms of intelligent buildings, will evolve over the project and will be based on the needs of the user through the use of user journeys.

By focussing on user journeys, we can envision the data and **technologies needed to realise the experiences we want to deliver,** as well as the procedural benefit, this provides a platform that enables design teams and stake holders to be part of the process and understand the vision and benefits of such an approach.

Enhance patient user journey

Clinical staff user journey

Principles of Intelligent Hospital Design

1 Digital as Default

Start with the end in mind, establish the base digital foundations required by the design and construction teams as well as the client. Build on this digital foundation with services that add value to the project, including logistics optimisation, engagement, collaboration, coordination and standardisation of MMC components to support quality control and speed of delivery. The ultimate aim of a digital as default approach is to hand over an intelligent building and digital twin to support the operation of the hospital for years to come.

2 Early Engagement

Early and meaningful engagement with key stakeholders underpins many of these principles, allowing each to be tailored to the specific context of each hospital. Input from both clinical and non clinical staff is used to understand technical requirements as well as their aspirations for wellbeing, environment and ways of working. Engagement with staff, patients and the wider community builds a sense of ownership and familiarity with the project. Stakeholders often provide the insights that transform the user experience and create a stronger community.

3 Collaborative Project Working

Successful collaboration can only be achieved with strong leadership, skills development, a keen eye on the economic context, design which is fit for purpose, and an emphasis on technology and production. Intelligent hospital design relies on an ethos of collaboration between design disciplines, client team and the contractor supply chain developing trusted design processes and promoting continuous learning from one project to the next.

4 The Sustainability Charter

Developing a holistic sustainability charter in collaboration with key stakeholders creates shared ownership and adds the necessary structure to deliver the ambitious environmental aspirations of each project. It should be developed to encompass new clinical pathways and realise operational efficiencies within an integrated care system, together with the wider opportunities for economic regeneration and growth in the local area.

5 The Flexible Framework

Informed decision making in MMC will maximise pre manufactured value. Developing an MMC strategy in collaboration with the whole project team to review the impact and benefits of differing MMC solutions, in relation to the delivery of key areas of the hospital, is key. A flexible framework approach does just this, allowing for the maximum number of MMC opportunities to be carried forward into the FBC stage.

6 Standardised Platforms

A standardised platform approach, based on a suite of standard room types, will facilitate the flexible planning of departments in response to the needs and opportunities of each individual project brief and site. The aim is to develop a platform that adopts a standard grid arrangement allowing stacking of technical, outpatient and inpatient accommodation where site constraints dictate. The standardised platform will promote the use of pre manufactured components and assemblies that can be shared across projects.

7 Factory to Frame

This can only be realised through a commitment to collaborative project working from the outset. Embracing digital technologies is critical to move seamlessly from concept to construction. Enabling energy and environmental analysis, as well as sequencing analysis, to provide significant added value, improving design and energy efficiencies while reducing project risk and material waste. The factory to frame approach recognises that if standardisation, MMC and programme cost benefits are to be realised on constrained live hospital sites then construction logistics need to be key design considerations from the early concept stage.

8 Reducing Emissions

New hospitals should be designed to reduce operational energy demand in order to reduce dependence on imported energy as well as minimising embodied energy, through iterative whole life carbon assessments, modelling and analysis. Sustainability strategies should not adversely impact internal environment quality and the comfort of building occupants. They should incorporate lifecycle maintenance, replacement and the eventual disassembly of the building. Adhering to circular economy principles, taking future recycling and reuse into account. Only once the project has been optimised should we offset through investment in registered carbon offsetting schemes.

9 Resilience with Renewables

Once operational energy has been reduced to an acceptable minimum, then ways to reduce the energy intake using on site and off site renewables should be considered. Many renewable alternatives are not currently economically viable for deployment across large scale sites. Viability should be assessed throughout the project. Projects should be designed to facilitate change to future energy sources where appropriate.

10 People Centred Environments

The pandemic has highlighted the importance for hospitals to provide an environment that not only supports the delivery of efficient, effective and safe care but also provide an environment that offers opportunity for respite and contemplation – supporting the wellbeing of the full hospital community. Connections with, and access to, external spaces that bring nature and landscape through the hospital environment create the optimal health and wellbeing setting for a new hospital. This provides therapeutic and healing benefits for patients, staff, visitors and the wider community.

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