



Design and Decision Making to Improve Healthcare Infrastructure

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Design and Decision Making
to Improve Healthcare Infrastructure

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HaCIRIC has developed the world's largest research programme in healthcare infrastructure.

About HaCIRIC

The Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) aims to improve people's health and wellbeing by supporting the development of better health and care infrastructures. Until recently, healthcare research concentrated mainly on how clinical interventions impact on health outcomes or on how services can be improved. So our emphasis on the impact of infrastructure represents a significant widening in thinking.

Since it was founded with core funding from the Engineering and Physical Science Research Council (EPSRC) just five years ago, HaCIRIC has become the largest centre of its kind. In a relatively short time, we have pioneered a wide-ranging and integrated programme of research to transform and embed understanding of how buildings, systems, services and health outcomes interact. We are building a global reputation, with an approach that is collaborative, strategic, change-focussed and outcome-orientated. We have successfully forged a single purpose from the cultural and disciplinary diversity of our four parent institutions: Imperial College London and the Universities of Loughborough, Reading and Salford.

The capacities developed in HaCIRIC's critical mass of 23 directly supported researchers, the majority starting out on their careers, promises enduring value to the UK healthcare sector.

HaCIRIC's research is providing vital help in achieving the Government's priorities: to maximise health outcomes; to improve quality in healthcare; to shift patterns of care between the acute and community sectors; and to bring the benefits of innovation to patients more rapidly.

Our research areas – involving 40 interconnected projects underway or recently completed – reflect the expressed needs of the NHS, its users and other stakeholders. These range, for example, from the immediate demand to tackle healthcare associated infections in a systematic manner to understanding the potential benefits of telecare for those with long-term conditions.

The Centre's unique capability is particularly important, given the current economic recession, weakness in public expenditure and the drive for efficiency and productivity gains in healthcare. Innovation to deliver infrastructure and redesign is needed now more than ever. It will also help keep the UK competitive in the provision of healthcare services to overseas markets. Our action research philosophy and our strategy to engage international research collaborators around common priority issues will offer significant benefits to the UK care system. It will lead to improved value for money, better outcomes for patients and staff, and creation of infrastructure that addresses emerging needs.

Executive Summary

Aim of this report

This report presents summary and key findings of research projects undertaken within the Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) by Loughborough University. These projects develop new knowledge and theory on how the built environment adds value to the healthcare delivery process and mainly relate to: 'Theme 3, Innovative Design and Construction' undertaken during HaCIRIC Phase 1; and provide an excellent foundation for the work to be undertaken within the Optimising Healthcare Infrastructure Value (OHIV) project during HaCIRIC Phase 2.

The projects presented in this report cover a wide range of issues associated with healthcare infrastructure design and contribute to a better understanding of: stakeholder consultation and engagement; and healthcare infrastructure planning, design, construction and operational process.

Depending on the main focus of the research undertaken, these projects have been divided into four major sections, as summarised below.

- **Therapeutic Healthcare Environments.**
- **Operational Efficiency of Healthcare Space.**
- **Healthcare Infrastructure Planning.**
- **Sustainable Healthcare Infrastructure.**

Therapeutic Healthcare Environments

The concept of designing therapeutic environments is not new. However, relationships between environmental stimulus and response are complex and not fully understood. The reported projects identify exemplar cases and good/best practice in healthcare building design and performance. The report contributes to an ever increasing evidence base of environmental impacts on healthcare building performance, patient wellbeing and medical outcomes. It also identifies key environmental parameters and their multiple variables, as well as identifying topical healthcare building interior and exterior environmental-related issues for further study in new and emerging HaCIRIC projects.

Key findings:

- Facility design quality can significantly impact on staff and patients' health and wellbeing: empirical studies have shown that design attributes such as the ambient environment (e.g. sound, light and art) and physical features (e.g. windows, spatial layout, interior design corridors and circulation) can all influence patient recovery and staff performance.
- The application of advanced computer simulation approaches (e.g. the use of evolutionary computation in optimising lighting design) has been demonstrated to be highly effective during the design of healthcare spaces.
- An evidence-based relationship between daylight and clinical recovery has been established.
- A study of ventilation design has established that, compared to multi-bed wards, single-bed wards could better protect patients from cross-infection and the risk of infection within a smaller ward may be higher due to its smaller volume and hence lower dilution. This problem can be counteracted by increasing airflow without energy penalties, through natural ventilation.

Future agenda:

Many of the projects under this topic have highlighted key issues that require further attention/research targeted at improving the healthcare facility planning and processes; thus delivering more therapeutic healthcare spaces/environments which in turn leads to increased staff performance and better patient outcomes. These issues include: the advanced use of building performance simulation tools to support the evaluation and optimisation of therapeutic healthcare environments; developing more robust evidence that establishes an intrinsic link between the built healthcare environment and health outcomes (efficiency, quality and safety); improved evaluation of existing facility performance; and improved design guidelines for the elderly.

Operational Efficiency of Healthcare Space

The healthcare sector is currently going through one of its most challenging phases. In 2008, the then Chancellor of the Exchequer identified improvements to NHS estate utilisation as a key saving area in 2010/11, potentially reducing the need for new hospital space by up to £3bn and saving up to £100m per annum of estate costs. Alan Milburn, the former Secretary of State for Health, pointed out in a speech to the Building a Better Patient Environment NHS/Prince's Foundation conference that flexible space designs can provide good opportunities for staff to deliver the best quality care. This suggests that both the design of new healthcare facilities and refurbishment of existing buildings need to be flexible enough to cope with changing patient expectations, new treatments and medical advances.

Meanwhile, it is acknowledged that an optimally sized and configured clinical room or space is critically important for reasons of both safety and efficiency. There is also evidence suggesting that one of the main factors that impacts on hospital productivity is how the design of the hospital deals with access and circulation of the people inside the building.

Key findings:

- The best opportunity to achieve space flexibility lies at both the levels of a room and a ward / department.
- The best opportunity to achieve space standardisation lies at the level of a room / space.
- It is feasible to quantify and characterize the qualitative aspects of the working environment for care providers using standardized instrument development methodologies.
- The layout of a hospital is one of the main factors that could influence nursing staff productivity. There are other environmental factors to consider (e.g. natural light, view, thermal comfort, etc.).

Future agenda:

Several key issues emerged throughout the course of the research and have been used for the basis of future research, for example, the value of operational analysis, post project evaluation (PPE) and post occupancy evaluation (POE) to space planning and design.

Summary continued

Healthcare Infrastructure Planning

These projects address the changing context of healthcare infrastructure planning. They highlight the importance of reconfiguring infrastructure to improve value through improved efficiency and performance. Action-based research has been used to help improve the Strategic Asset Management of healthcare infrastructure and explore the various implications on local Primary Care Trusts (PCTs). Effective links have been established with local Primary Care Trusts in order to follow their multi-intuitive and multi-agency process for Master Planning and Strategic Asset Management.

Key findings:

- The research has identified Healthcare Planning Evidence that supports the relationship between clinical experience/volume and clinical outcomes/quality. This evidence needs to be applied to projects to understand the scale and distribution of healthcare infrastructure and to link capacity and demand.
- The importance of combining strong quantitative activity, space, time, cost and quality tools so that they can dynamically respond to changing clinical technologies and enable infrastructures to be scale based on varied demands has been demonstrated.
- A better understanding has been developed of how population distributions, demographics and prevalence data can inform the equitable distribution of care models that meet patient access and care needs, and how these can in turn inform investment decision making.
- We have established the need to improve service-life building value to ensure that infrastructure capital investment has been assessed against a complex set of competing multi-disciplinary value measures, metrics and evidence throughout an integrated planning and design process.
- The need has been demonstrated to incorporate a dynamic and open approach to long-term investment appraisal and scenario planning that enables investment decision-making based on a balance between investment opportunities and effective service provision. It has been established that improved adaptability and open and flexible decision-making can respond to changing social, economic, political, technological and environmental factors.

Future agenda:

This research has identified the following, as priority areas for further research and action.

- Application of advanced modelling and simulation approaches to improve the integration of multi-parameter building and service performance data and inform whole system optimisation in infrastructure sustainable planning and design.
- Explore and assess the interdependency and integration between levels of care, estates and transport infrastructures and their impact on whole-system and whole-life value.
- Development of an approach to stakeholder consultation which can be utilised within an estates planning strategy and includes: a tool to address the gap between healthcare infrastructure investment appraisals and its impact on health outcomes.
- Investigate the cost implications of alternative models for reconfiguring healthcare services and its built infrastructure and develop scenarios and modelling tools that can support efficiency-improving and cost-saving service reconfigurations over various time periods.
- Explore and determine how lessons can be learned and evidence maintained from previous healthcare buildings to maximise infrastructure's contribution to health gain, healing and patient or staff satisfaction.

Sustainability of Healthcare Infrastructure

The UK healthcare service is going through a significant number of challenges due to the performance of its infrastructure and the new strategies and targets set by the Government. Most healthcare sustainability projects deal with a single aspect of sustainability and fail to take into consideration the broader sense of sustainability. This project is the outcome of a multi-disciplinary research team which has been working to mitigate these risks with a view to improving the sustainability of healthcare infrastructure in the areas of: whole life value, travel plans, construction waste minimisation, refurbishment and resilience to natural hazards.

Key findings:

- During briefing, there is an indication pointing towards a desire for selective involvement of stakeholders in what they use and what affects them directly.
- A mechanism is needed to enable varied communication methods for different stakeholder groups and guidance on who to engage with, what to engage about and how.
- There is disparate research evidence on the healthcare impact of scale and distribution of infrastructure reorganisation on healthcare quality and no common integrated framework for understanding these issues.
- Healthcare facilities have complex functional and operation features that increase construction waste generation throughout the lifecycle of the facility.
- The main causes of waste in healthcare facilities are: incomplete documentation; ineffective communication and coordination between project partners; lack of waste awareness among project stakeholders; poor buildability; inappropriate materials selection; and procurement.
- A successful refurbishment can significantly improve a building's life cycle.
- Significant energy savings are easily achievable with more sophisticated planning and mechanical systems by reducing air volumes and using appropriate energy features.
- Resilience is a major element for sustainable development and needs to be involved in strategic planning to maintain the quality of life.
- The resilience of healthcare facilities depends on the degree of internal preparedness, but it can extend to include external issues such as accessibility, performance of suppliers, ability to cope with sudden surges in service demand, and future challenges.

Future agenda:

Further research is needed into the stages of the healthcare planning process and the approach to engaging various stakeholders in decision making.

- How can stakeholder commitment in healthcare facility definition processes be improved?
- There is a need to develop tools to be used as a spatial decision support system (SDSS) to support decision makers and stakeholders to measure accessibility to healthcare facilities.
- Simulation of emergency response that reflects the complexity and interconnectivity of medical care delivery and relevant stakeholders and provides a tool for decision-making process.



Therapeutic healthcare environments



Operational efficiency of healthcare space



Healthcare infrastructure planning



Sustainable healthcare infrastructure

1. Introduction

Current NHS priorities and funding

The delivery of health and social care in the UK is undergoing profound change and being redesigned to improve capacity and performance through the provision of high quality, patient-centred services. In 2000, the NHS announced one of the biggest building programmes in the world – funded by over £5 billion from the private sector – with hospital building at the heart of the investment programme. In such major investment programmes, where new opportunities are also being created as a result of scientific and technological innovation, costs tend to escalate and best value is not always achieved. However, economic pressures are now beginning to bite and costs accelerate.

Aim of this report

This report presents brief summaries and key findings of research projects undertaken within Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) by Loughborough University. These projects develop new knowledge and theory on how the built environment adds value to the healthcare delivery process and mainly relate to: 'Theme 3: Innovative Design and Construction' undertaken during HaCIRIC Phase 1. They also provide a foundation for the work now being undertaken within the Optimising Healthcare Infrastructure Value (OHIV) project during HaCIRIC Phase 2. The projects presented in this report cover a wide range of issues associated with healthcare infrastructure design and contribute to a better understanding of: stakeholder consultation and engagement; and healthcare infrastructure planning, design, construction and operation. Depending on the main focus of the research undertaken, these projects have been divided into four major sections, as summarised below.

- **Design of Therapeutic Healthcare Environments**
- **Increasing the Operational Efficiency of Healthcare Space**
- **Healthcare Infrastructure Planning**
- **Sustainability of Healthcare Infrastructure**

Structure of the report

This report comprises the following section.

- Section 2 **introduces the context** of this report.
- Section 3 covers the research projects under the topic of **Design of Therapeutic Healthcare Environments**. This section aims to identify key design considerations to promote the therapeutic performance of healthcare space and covers various topics such as, evidence based design, lighting, ventilation, modelling and simulation.
- Section 4 discusses the research projects related to the **Operational Efficiency of Healthcare Space**. The research focuses on: improving the design of healthcare space; producing flexible layouts; and optimising people access and people circulation in order to improve patient safety, cost effectiveness and operational efficiency.
- Section 5 discusses the changing context of **Healthcare Infrastructure Planning** and raises the importance of reconfiguring infrastructure to save money and improve efficiency. This action-based research aims to help improve the Strategic Asset Management of healthcare infrastructure and explore the various implications for local Primary Care Trusts (PCTs). Very effective links have been established with local PCTs in order to follow their multi intuitive and multi agency process for Master Planning and Strategic Asset Management.
- Section 6 summarises projects associated with **Sustainability of Healthcare Infrastructure**, which has been defined as: providing comfort and enhancing the safety and wellbeing of hospital occupants; being physically and socially resilient to adverse disruptions resulting from nature or technologies; environmentally friendly; and being financially efficient without compromising gained values to taxpayers.

Also included at the end of the document are a list of references, publications emerging from this research, key collaborators, plus details of the researchers and PhD students associated with HaCIRIC Loughborough projects.

2. Context

Design and decision-making

The provision of high quality healing environments very much depends upon the selection of appropriate planning, design, construction and operational processes that contribute to the quality of care and recovery process by promoting therapeutic goals and enhancing operational efficiency. Previous research has linked quality of care, patient health and wellbeing with the physical characteristics of the healthcare environment (Douglas and Douglas 2004). More specifically, there is clear evidence that the physical environment of hospitals can affect the healing process, for example by: reducing the level of anxiety and stress (Beauchemin and Hays, 1998; Pattison and Robertson, 1996); shortening recovery periods following surgery through improved views of the external environment (Ulrich, 1984); increasing social interaction through improved building layout; positioning of furniture to increase patients' wellbeing (Somner and Ross, 1958; Baldwin, 1985); significantly diminishing pathological behaviours by creating supportive building environments; establishing links between built environments and patients' recovery (Gabb, et al, 1992); and by the provision of appropriate space and conditions to decrease patients' recovery time and maximise the benefits from therapeutic environments (Ewing, 2005).

Evidence-based design

One of the main problems associated with healthcare infrastructure design is the difficulty associated with demonstrating and comparing the costs and benefits of different solutions. The construction costs associated with single rooms compared to multiple bed rooms are relatively easy to determine. However, the benefits from the associated recovery rates are more difficult to quantify. Action based research has an important role to play in providing the evidence that supports decision-making during the design planning, investment appraisal and design processes. Ulrich (2004), in his report *The Role of the Physical Environment in the Hospital of the 21st Century*, provided an excellent starting point and has highlighted the importance of the physical environment in relation to patient care. According to Ulrich (2000), healthcare building design has traditionally been based on decisions focused on achieving efficiency in relation to operational cost, clinical and technological aspects. However, they have seemingly overlooked key aspects related to creating conducive healthcare environments capable of facilitating good patient wellbeing, experiences, and positive outcomes. Ulrich (1992) and Horsburgh (1995) further stated that the emphasis on erecting hospital edifices portraying profiles of formality does appear to unduly limit the development of calm, enabling healthcare environments for effective therapeutic impacts on patients.

The Centre for Health Design (2011) defines evidence-based design as the process of basing decisions for the development of effective built healthcare environments on credible research in order to achieve the best possible outcomes. Hamilton (2003) identifies that this approach appears to be similar to that adopted by medicine itself, which has progressively leaned in favour of evidence-based medicine where clinical choices rely on knowledge derived from robust research. Similarly, the relationship between the healthcare environment, patients' wellbeing, staff productivity and positive outcomes is progressively being informed by research – such as that being undertaken by HaCIRIC – for the provision of knowledge about how best to achieve harmony in such a complex relationship. It appears that evidence can be informative about what has occurred, but, more importantly, it should be reflective of what is reoccurring.

Modelling and simulation

Action based research and physical mock ups have traditionally been used to elicit stakeholders' perceptions and enhance the evidence base. Recent information technology (IT) advances offer newer simulation and visualisation tools, which provide opportunities for applying improved computing capability in modelling and solving complex problems. The use of simulation tools is increasingly being used to support: the design of indoor environments and evaluation of existing building performance; and the assessment of different options during planning and service redesign. However, their integration and full application within the decision-making process of healthcare facilities is yet to be achieved. Based on the evidence emerging from the reviewed studies, it is apparent that the application of simulation and visualisation during the design of healthcare environments facilitates is being increasingly used to develop innovative solutions; strengthen the evidence base; build consensus; and support collective decision-making with multiple stakeholders.

There are four significant factors that characterise high quality healthcare facilities and need to be considered during the design process. These are: clinical efficiency; integration within the local community; accessibility to consumers and the public; and promotion of patient and staff wellbeing (NHS Confederation 2004). The importance of good design was, in the NHS Estates' (2005, p.8) publication, 'Better Health Building', expressed as:

“ Good design is not an optional extra, it has to combine fitness for purpose with whole-life costs to deliver value for money.”

“ Good quality design will contribute to providing an environment in which patients will be safe and secure. Well designed buildings, capable of adaptation to meet rapidly evolving medical and technological advances and social change, are more likely to help staff deliver their objectives and long-term best value. Good design will also ensure a reduction in defects and more sustainable solutions. ”

Galvanised by this thinking, the NHS set out what it called its vision, which outlined ten key design principles: Uses; Access; Spaces; Character and Innovation; Citizen Satisfaction; Internal Environment; Urban and Social Integration; Performance; and Engineering; and Construction (NHS Estates, 2005, p.6).

The benefits of appropriately designed environments, though implicit, are far reaching and can: improve medical outcomes; reduce work related stress, reduce infections and the intake of costly analgesics; and improve job satisfaction thus resulting in less staff absenteeism and lower staff turnover. According to Gesler et al (2004), the therapeutic value of hospitals relates to their physical, social and symbolic design.

The contribution of the physical environment to the performance (hence value) of any healthcare facility is highly complex as many qualitative and quantitative factors need to be taken into account. Several studies have investigated the influence of building layout, ward location and views on the performance of healthcare facilities (Vogt, 1990, Touran and Lopez, 2005). However, as highlighted by Toole (2001), performance is not only affected by physical characteristics, but also by the behaviour of users and surroundings. Although previous research has emphasised the potential influences of design characteristics (such as vision, building layout and lighting), there are also many claims that better healing environments can also have a positive influence on staff (doctors and nurses) productivity.

There is a growing need for healthcare infrastructure to be more sustainable. Sustainable built environments which offer green surroundings can also help improve: the healing environment and patients' rate of recovery (CICA 2002, SDC 2005 and Shelbourn et al. 2006); the overall performance of healthcare service through reduced running costs; and user satisfaction through more occupant-friendly facilities (Bosch and Pearce 2003). Designing, constructing and managing a hospital in accordance with principles of sustainable development can also benefit the local community, the economy and the environment. It can also improve public health as well as reduce the demand for health services (Kats and Capital, 2003). However, there have been many missed opportunities regarding the integration and advancement of sustainability to reduce long-term costs of healthcare services (NAO, 2005).

It is not only important to produce good designs, but it is also important to demonstrate the value being achieved. The National Audit Office (NAO, 2003, p.6) warned that “value for money was particularly important because of the Government's plans to spend £19 billion over three years on schools, hospitals and transport infrastructure”. It suggested that savings of up to £2 billion could be achieved if government departments and construction companies improved their working relationships (BBC 2001). The Department of Health identified Local Improvement Finance Trust (LIFT) as “a vehicle for improving and developing frontline primary and community care facilities. It is allowing Primary Care Trusts (PCTs) to invest in new premises in new locations, not merely reproduce existing types of service. It is providing patients with modern integrated health services in high quality, fit for purpose primary care premises” (DH, 2004). The DH concluded that the bidding process was an unequal struggle between large consortia and inexperienced clients, which had resulted in a wasted opportunity to optimise benefits and costs.



Natural light and good ventilation impact on patient recovery and need to be engineered into the design of healthcare facilities.

3. Design of Therapeutic Healthcare Environments

3.1. Introduction

The provision of innovative healing environments very much depends upon the design and construction of healthcare facilities that contribute to the quality of care and recovery process while promoting therapeutic goals and enhancing operational efficiency. Previous research has linked quality of care, patient health and wellbeing with the physical characteristics of the healthcare environment. More specifically, there is clear evidence that the physical environment of hospitals can affect the healing process, for example: reducing the level of anxiety and stress; shortening recovery periods following surgery through better views of the surrounding environment; increasing social interaction through improved building layout; positioning of furniture to increase patients' wellbeing; significantly diminishing pathological behaviours through the creation of supportive building environments; establishing links between built environments and patients' recovery; and providing appropriate space and conditions to decrease patients' recovery time and maximise the use of therapeutic environment.

The concept of designing therapeutic environments is not new, however, the relationships between environmental stimulus and response are complex and not fully understood. According to Gesler et al (2004 pp.117-128): the therapeutic environment of hospitals relates to their physical, social and symbolic design; and the aim should be to produce facilities that are: "clinically efficient; well integrated within the community; accessible to consumers and the public; and encourage patient and staff well-being".

The section presents a range of projects that studied various environmental design aspects (e.g. lighting, thermal and ventilation) associated with increases in the therapeutic value of healthcare spaces. In addition, modelling and simulation approaches to improving the quality of environmental design and tools associated with the quality assurance are also investigated.

3.2. Project: Evidence Based Learning Environment (EBLE)

Researcher: Grant Mills

Project start and end date: April 2009 to May 2011

Overview

This work studied the relationship between evidence and design in its broadest sense, in order to deliver principles, processes and tools to ensure that design directs the needs for research and in turn that the research supports evidence-based design. This work is developing an understanding of how a new quality assurance system could be developed that integrates existing quality and evidence tools. It aims to review best practice both within regulators, commissioners, providers and constructors and to develop new systems for delivering multi-stakeholder quality assurance.

This project has completed a comprehensive systematic literature review and an online survey relating to Activity Data Base and has held several single theme quality assurance workshops with industrial partners. This work has updated the existing evidence on the impact of the built environment on outcomes, evaluated tools and created a best practice framework. Seven case studies have been identified to validate this framework and ethics approval for further studies (as part of HaCIRIC Phase 2) is ongoing. The following three one day workshops were also conducted.

Workshop 1

To examine the options and issues for meeting the challenges of the changing needs or requirements for dementia and mental health through the provision of efficient and therapeutic healthcare environments (Medical Architecture).

Workshop 2

To consider the options and issues of refurbishing NHS healthcare buildings in order to increase the proportion of single rooms within the Trust estate (Nightingale Associates). Related to this are several issues, notably: single sex accommodation and the requirements for isolation beds; environmental improvements including energy saving measures and future flexibility.

Workshop 3

To examine the options and issues around the provision of carbon neutral NHS healthcare environments for the treatment of sick children (WSP Group/ Llewelyn Davies Yeang).

These workshops are contributing to the development of an understanding of the role of Department of Health guidance and healthcare sector standards along with the need to create a system of value and quality assurance that is able to respond to changing policy and organisational structures.

Methodologies

The review of quality assurance tools and organisations has led to the development of a strong relationship with the Department of Health who are currently developing a new quality assurance approach which this research is critically appraising. As part of the tool review, an ADB (Activity Database) workshop that explored the future of the ADB approach and how this could be developed into an advanced BIM environment has been facilitated. The NHS health planning standards (i.e. Health Building Notes) have been reviewed and their relationship to value criteria has been mapped in relation to stakeholders and the project process. The aim has been to support the development of efficient and effective stakeholder consultation and compliance processes. Further work is underway to compare the UK and Swedish situations, as significant lessons can be learned from each (as they are at opposite ends of the stakeholder consultation and quality compliance spectrum).

Findings

The gap between estates and facilities and healthcare delivery services is a cause for concern across EU countries. However, those countries that have been most successful in bridging these domains have also put in place strong collaborative research and development (R&D) relationships. Many countries share similarities in how they structure quality assurance. However, there is no common framework for assessing quality standards and guidance. Further research must address this need and define a number of successful quality assurance measures that can be applied by researchers and regulators alike. Other findings from this work include the following.

- There is no single source which establishes, at a global level, evidence of an intrinsic link between the healthcare built environment and health outcomes (efficiency, quality and safety). Intuitively, however, the healthcare system must use its physical assets as a core production asset.
- Facility design affects health: empirical studies have shown that design attributes such as the ambient environment (e.g. sound, light and art) and features (e.g. windows, spatial layout, interior design corridors and circulation) have impacts on behaviour, performance and wellbeing.

- Negative harmful impacts of poor design on health are clearly evident: there are clear links between poor quality healthcare design and poor outcomes. Inadequate lighting, protection against hospital acquired infection, ventilation, temperature control and acoustics all have negative impacts on healing, performance, behaviour and ultimately health. The evidence supports the cost effectiveness of bringing poor environments up to an adequate level.
- The application of health gain and evidence for cost benefit analysis and business case investment appraisal requires further investigation to frame health system evidence against national and local differences in: healthcare resource allocation and distribution (e.g. tariffs, spending); economic variances (exchange rate, varying inflations); and research evidence quality and availability.
- Many tools that support design excellence are not well aligned with evidence based design. An integrated approach is needed to delivering and demonstrating the impact of the built environment on outcomes.

3.3. Project: The feasibility of natural ventilation strategies in healthcare building

Researcher: Zulfikar Adamu

Project start and end date: July 2009 to February 2012

Overview

It is also common for functional (comfort) requirements of indoor air to be misconstrued as being the same as the clinical (health) requirements, but distinction between these issues is critical in healthcare spaces. Healthcare acquired infections (HCAIs) are of major concern and the role of ventilation in the dispersal of airborne pathogens has long been established. Currently, the problem of airborne infections is being complicated for many reasons. First, there is the emergence of drug-resistant strains of airborne diseases such as multi-drug resistant tuberculosis (MDRTB) and Methicillin-resistant *Staphylococcus aureus* (MRSA). Second, there is the issue of global airborne pandemics like SARS and H1N1 which have strained and challenged healthcare facilities. Third, hospitals in the UK allocate over 40 per cent of their energy for ventilation and thermal comfort needs, which cannot be sustained in the long term.

Due to the need to minimise the health and energy issues of such buildings, natural ventilation presents an opportunity to deliver comfort and acceptable air quality through low-energy, simple or advanced techniques. However, existing healthcare ventilation standards are lacking in specific guidance on how to utilise natural ventilation strategies for health facilities. Additionally, there is a need for ventilation metrics or indices that are requisites for evaluating the performance of ventilation systems. Their absence can be attributed to the prescriptive nature of current guidelines.



“

The concept of designing therapeutic environments is not new, but the relationships between environmental stimulus and response are complex.

”

3. Design of Therapeutic Healthcare Environments (continued)

While the provisions made in such standards/guidelines are quantitative e.g. number of air change rates, research shows that other qualitative features such as the direction of airflow and the pattern of air movement also have impact on bio-aerosol control. This suggests that current standards have focused on the efficiency and not the effectiveness of healthcare ventilation.

This research is aimed at providing proofs of concept on the performance of specific natural ventilation strategies on the quality of air as well as on their thermal and energy performances within healthcare facilities. The specific objectives of the research cover analysis of natural ventilation strategies for healthcare buildings through the following.

- Evaluation of airflow rates and room air distribution techniques and their impact on migration of airborne pathogens.
- Assessment of the thermal comfort and energy implications of selected ventilation strategies.
- Optimisation of the design of natural ventilation components for ADB wards through innovative airflow configurations.
- Development of guidelines and framework for the use of natural ventilation in hospital wards.
- Results are expected to provide new insights and practical guidelines for use on both refurbished and new healthcare facilities.

Methodologies

Based on the initial findings, this research uses the single bed ward as defined through the Department of Health's Activity Database (ADB) guidelines. Various natural ventilation strategies are represented as schemes which are investigated through dynamic thermal simulation (DTS) to demonstrate their long-term airflow, comfort and energy implications. Simultaneously, computational fluid dynamics simulations (CFD) are then used to provide an in-depth steady-state prediction of airflow rates, pattern and direction as well as pathogen dispersal for the selected strategies.

Key Findings

- Compared with multi-bed wards, single-bed wards would protect patients from cross-infection, but the risk of infection within a smaller ward is higher due to its smaller volume and hence lower dilution. This problem can be countered by increasing airflow without energy penalties, through natural ventilation.
- Factorial simulations can provide singular and combinatorial effects of the variables at work in ward ventilation, thereby providing objective insight on what to emphasise as per research effort and design/operational resources.
- The main ventilation variables which determine comfort, energy and air quality in hospital wards include: airflow rates, pattern and direction; source strength and location; and contaminant removal efficiency (CRE) of a given ventilation strategy.

Recommendations

- Single occupancy hospital wards should not be expected to deliver the same level of ventilation performance. Grouping them into categories (e.g. using bio-aerosol control and comfort criteria) will assist energy efficiency and better management of their ventilation systems. This will also aid the standardisation (e.g. through ADB) of such ward spaces. Examples of such categorisation include two cases which can be considered as follows:
 - When patients are the potential source of bio-aerosol, meaning care workers and visitors require protection
 - When patients are considered vulnerable to bio-aerosol from workers or visitors.
- The direction and pattern of airflow in single-occupancy wards, which is critical in achieving the above recommendation, should also consider the pressurisation or depressurisation of such spaces, because, in reality, door openings can lead to cross-flows of contaminated air into and out of the wards. When buoyancy-driven ventilation is to be used as a primary strategy, it may be necessary (depending on site location) to supplement the system with auxiliary fans for those times of the year when weaker temperature differentials lead to stagnation of airflow or reversal of airflow across openings with undesirable results for contaminant control.

3.4. Project: Innovative daylight design for clinical recovery

Researcher: Ashikur Joarder

Project start and end date: April 2008 to June 2011

Overview

The biological need for lighting by an individual differs from merely the visual need. Lack of adequate daylight for biological stimulation can lead to health problems. The importance of daylight is vital for hospital patients who are already physically and/or psychologically stressed. As many patients stay indoors for 24 hours, they are more vulnerable to the lack of daylight which is necessary for health reasons. In the case of hospital patients, daylight can be a strong therapeutic environmental design element that supports good health and accelerates clinical recovery. This research is aimed at developing strategies for architects and designers to incorporate therapeutic daylight into the architectural design of hospital buildings to improve patient health, comfort and recovery. To achieve this aim the following objectives were adopted.

- To understand the impact of daylight (positive and negative) on patient health and wellbeing.
- To establish statistical relationships between daylight intensities and patient Length of Stay (LoS) in a general hospital environment.
- To identify the range of daylight intensities within which positive health outcomes are expected.
- To develop and implement a therapeutic daylight design concept in the architectural design of a hospital building.
- To conceptualise the impact of climate change on indoor daylight levels and its contributions to therapeutic lighting environment.

Methodologies

The research started with a literature review that aimed to develop evidence-based methodologies for field investigations and simulation studies. Using the therapeutic daylight goal highlighted in literature and confirmed from real-world patients' data (263 samples) by multiple linear regression (MLR) analysis, the (Sky Window) concept was explored by simulation studies and was found to be more effective than traditional standard hospital windows in relation to therapeutic daylight inside patient rooms under present and future climate change scenarios (UKCIP02). Finally, the findings from the literature review, retrospective field investigation and simulation study were compiled. This resulted in recommendations and architectural strategies for therapeutic daylight hospital building design. The main objectives have been summarised here.

- To correlate daylight with patients' clinical recovery rate, a MLR model was developed.
- To develop and evaluate the therapeutic potential of hospital rooms through computer simulation.
- In this research, innovative design solutions have been developed by simulating the introduction of new architectural forms into hospital building design. The methodology demonstrated in this research and the concept of inclined windows are also applicable to other types of commercial buildings and ensure better distribution of daylight inside the rooms as well as supporting the physiological health of occupants/users.

Key Findings

- The coefficient estimates of MLR models derived from real-world field data suggest that, while holding other explanatory variables constant, the provision of outdoor views reduced patients' stay time by, on average, 13.5 hours; a 100 lux increase of daylight reduced patients' stay time by 4 hours.
- The coefficient estimates of the MLR model derived from the principal study show that while holding the other explanatory variables constant, the provision of outdoor views reduces patients' stay time by, on average, 18 hour and reduces stay time by 7 hours per 100lux increase in daylight intensity near a point above the patient's head.
- The simulation analysis shows that a specially designed 450 inclined high window (Sky Window) performed better than traditional standard hospital windows with respect to therapeutic daylight inside patients' rooms.

Recommendations

- The impact of daylight on patients needs to be better established, based on sound evidence.
- A complete therapeutic daylight model (characteristic of daylight that may support patients' health) should be developed as a reference for hospital environment/ buildings' design.
- More evidence or examples need to be developed to show possible ways to incorporate therapeutic daylight into the design of hospital buildings.

3. Design of Therapeutic Healthcare Environments (continued)

3.5. Project: Optimisation of luminous environments in healthcare spaces

Researcher: Shariful Shikder

Project start and end date: December 2008 to June 2012

Overview

The design of a lighting environment is a complex task because of the need to satisfy multiple objectives. For example, an adequate level of illumination is required to ensure task visualisation while not introducing glare or discomfort. Although the impact on physical health needs to be explored further, recent studies have established strong relationships between lighting and mental health. Specified and controlled implementation of lighting has been successful in reducing mood disorders and improving sleep wake patterns among the elderly. Lighting is also associated with energy and sustainability measures, where the maximum use of daylight with optimised use of artificial light can help in minimising energy consumption as well delivering more resilient systems.

To meet this various criteria, an integrated approach is necessary to deliver high quality lighting design for healthcare spaces. The use of building performance simulation tools is an established methodology for predicting and evaluating building performance considering various criteria. This project has extended the use of computer simulation through integrating prospective multi-objective optimisation techniques in developing a better decision-making process for healthcare lighting.

The aim of the project is to develop a decision support system through modelling and simulation to optimise lighting design of healthcare spaces; and suggest innovative/ alternative design strategies for existing and new facilities. The following objectives were set to achieve the following aims.

- To develop a knowledge base about the impact of lighting in therapeutic performance, safe navigation and clinical outcomes.
- To identify daylight and artificial lighting design criteria and evaluate design guidelines.
- To identify and evaluate existing simulation tools and optimisation methodologies that generate design decisions.
- To develop integrated optimisation methodology and decision support system to manipulate evidence based design data.
- To explore innovative solutions/ methodologies through modelling and simulation which complement desired lighting environment of healthcare spaces.

Methodologies

The project is ongoing and uses various methods to achieve the stated objectives. A literature review has developed the knowledge base on the role lighting in therapeutic performance, safe navigation, clinical outcomes and energy use. A questionnaire survey as well as structured interviews will explore the current design process and use of modelling and simulation among professionals. Computer simulation and object-oriented programming will be used to develop an optimisation methodology that can support the decision-making process considering multiple objectives.

The project has completed a state-of-art review on lighting requirements for the elderly and the partially sighted, which has identified lighting design requirements to promote the therapeutic performance in terms for photometric units. A computer simulation based optimisation framework has been proposed and applied in a senior living space and a hospital patient room. Future studies will be aimed at developing a dynamic activity based simulation approach to enhance the process of therapeutic lighting design. The project also intends to develop an integrated natural and artificial lighting optimisation approach to deliver better energy efficient and resilient solutions for healthcare environments.

Key Findings

- There is a growing body of evidence that is more robustly quantifying the therapeutic benefits of lighting in treating psychophysical problems particularly among the elderly, most of which emanate from clinical experiments as a therapy process. This evidence has contributed to the improved understanding of the underlying theories behind light as a therapeutic element. However, they are yet to be fully integrated within the lighting design process.
- Increasing the visual performance was found to be crucial to ensuring health and safety in healthcare environments, which is positively associated with the reduction in falls among the elderly.
- Further improvements to the guides could include detailed recommendations for vertical illumination, luminance and contrast thresholds considering various psychophysical conditions prevalent among the elderly and partially sighted.
- Building performance simulation can contribute to designing high quality healthcare lighting. However, there is a need to identify specific design parameters in photometric units.

Recommendations

- Along with the general visual and lighting design parameters (e.g. illumination level, luminance contrast and distribution of illuminance), time of day and duration of exposure to light are also key to improving the therapeutic performance of the environment.
- Further studies are required to identify detail photometric parameters to develop recommendations for therapeutic lighting, vertical illumination and luminance contrast design.

3.6. Project: What strains of *Clostridium difficile* are dominant in UK hospitals and why?

Researcher: Krusha Patel

Project start and end date: October 2008 to September 2011

Overview

Clostridium difficile is a pathogenic bacterium, and is the dominant causal agent of infectious diseases and gastro-intestinal complications, particularly in the elderly and immuno-compromised. In 2008, there were over 34,000 reported cases in patients aged 65 and over in the UK. Screening for *C. difficile* positive patients often uses a diagnostic presence/absence test, providing no further information on the disease severity. PCR ribotyping is a molecular method which is often used to categorise the different strains. *C. difficile* also produces spores which are able to persist on environmental surfaces for long periods of time and are very hardy.

The key aims and objectives of this project are: to classify strains that are carried by patients and exist in their surrounding environments and determine whether abundant strains are more resistant to hospital cleaning techniques than those found less frequently.

Methodologies

This study utilises a combination of approaches including: literature reviews, sample collecting (both clinically and environmentally from the field), as well as modelling within the laboratory. The University Hospitals of Leicester is used as a case study. Collaborators assisted in this work, recognising areas of strengths and potential development.

Key Findings

- Current methods of screening do not provide information with respect to the strains present in the healthcare facilities. Identification of the *C. difficile* PCR ribotypes is important for monitoring disease outbreaks.
- *C. difficile* strains can potentially possess different spatial and temporal abundance patterns, which can correlate to severity of disease.
- Resistance to cleaning depends on particular strains, and their ability to persist on an environmental surface.

Recommendations

- Typing techniques are not conducted routinely due to factors such as time, costs and labour of isolation, culturing, extraction, and amplification of bacterial DNA. Insights into the presence of strains can be useful in the observation of outbreaks within healthcare facilities in NHS Trusts, and investigating methods to type strains from the patient sample would aid in difficulties faced.
- Cleaning regimes of healthcare facilities need to incorporate methods to minimise persistence and subsequent spread of spores.
- Methods need to be developed for routinely sampling high-contact environmental surfaces in practices whilst maintaining respect and protecting the privacy of patients and healthcare staff.



Our research uses modelling, simulation and visualisation techniques to improve the design of healthcare space.

4. Increasing the Operational Efficiency of Healthcare Space

4.1. Introduction

The design of healthcare facilities is highly complex and needs to take account of changing patient expectations, new treatments and medical advances. A wide range of stakeholders such as staff, patients, visitors, delivery personnel and volunteers use healthcare facilities, thus driving the need for multi-use and multi-functional healthcare space. It is acknowledged that an optimally sized and configured clinical room or space is critically important for reasons of both safety and efficiency. Evidence also suggests that one of the main factors that impacts on hospital productivity is how the design of the hospital deals with access and circulation of the people inside the building.

This research uses a variety of modelling, simulation and visualisation (MSV) techniques to improve the design of healthcare space, produce flexible layouts, optimise people access and people circulation in order to achieve patient safety, cost effectiveness and operational efficiency. The research is exploring potential solutions to the evidence-based design of healthcare space. The main objectives are as follows.

- To establish state-of-the-art understanding relating to the design of healthcare space, and identify, understand and collate evidence of current UK and international best practice, innovative design solutions and lessons learnt.
- To identify the main priorities for the design of high quality hospital space in relation to future needs.
- To develop a flexible design approach to improve the quality of multi-functional hospital space at a ward/department level that accommodates and reflects day-to-day changes and future demands.
- To develop flexible solutions for high quality of spatial layouts at a ward / department level that optimise people flow.
- To develop a framework for the integration of environmental performance assessment in RSR decision-making process through the use of automated space layout planning and mathematical optimisation methods.
- The research outputs will include evidence-based strategies, practical guidance, good practice and tools for improving the design of healthcare space and layout.

4.2. Project: Hospital space layout optimisation

Researcher: Yisong Zhao

Project start and end date: June 2008 to May 2011

Overview

Compared with traditional hospital design concepts, fundamental shifts are taking place in the way we design and evaluate healthcare buildings. Conventional ways of designing hospitals around the delivery of service are moving towards creating a healing environment that can accelerate patient recovery and enhance staff productivity and morale. The understanding of different stakeholders' perspectives on the healthcare environment is providing an effective evidence-base for informed decision making in healthcare planning and design.

This project aims to develop methodologies to optimise the space layout of healthcare facilities as an evidence based design by quantitative and qualitative research, considering the factors influencing the spatial layout planning in the context of hospital design and integrate automated SLP (spatial layout planning) method and mathematical optimisation techniques in the decision making process. The research has conducted questionnaire surveys with both patients and care providers to explore their perceptions of the physical environments. Analysis of survey results and in-depth interviews provide possibilities to integrate the survey findings with mathematical modelling and simulations in the way of assisting layout plan and healthcare design. The main objectives are as follows.

- To establish the principles of hospital design in the healthcare facilities through literature review.
- To explore the perceptions of healthcare environment from different stakeholders via questionnaire surveys and interviews.
- To establish a state-of-the-art literature review relating to the design of healthcare space and methods for space layout planning.
- To investigate the factors that affect decision making during layout planning of healthcare facilities.
- To develop a framework in decision making process through the use of automated space layout planning and mathematical optimisation methods.
- To test the developed framework in solving realistic hospital spatial layout problems

Methodologies

The study adopted a pluralistic approach including: a literature review, questionnaire survey, interviews, modelling and simulation. The involvement of national and international collaborators helped in identifying key concerns and strengths and provided an important source taken directly from practice.

Key findings

- Perceptions of both care providers and patients are indicators of quality of healthcare.
- It is feasible to quantify and characterize the qualitative aspects of the working environment for care providers using standardized instrument development methodologies.
- Space layout planning at the starting point of hospital design needs to consider the benefits from the users' perspective in addition to geometrical and topological requirements.

Recommendations

- Consideration of the influencing factors for healthcare users is essential in the process of hospital design or refurbishment.
- Review practices related to access to layout design while respecting and protecting the privacy of patients and staff.
- Investigate the perception of either care providers or patients to identify how space layout design can be influenced.
- Applications are needed in various sustainability scenarios and in development of automated space layout planning methods with less computational time.

4.3. Project: Hospital ward productivity: the role of layout and people circulation

Researcher: Masoumeh Nazarian

Project start and end date: April 2009 to March 2012

Overview

There are many factors that could contribute to the design of a more effective healthcare environment for patients. It is understandable that supportive built environments with high quality internal layouts and circulation can create an overall inviting, calming, engaging, and more hygienic and productive healthcare environment for staff, patients and their families. The ongoing increase in population in addition to the increase in average age of the populace means that the need for expanding public healthcare services will continue to increase for the foreseeable future. This expansion is normally sought through the:

- construction of new hospitals;
- physical extension of existing hospitals; or
- optimising the productivity of existing hospitals.

Hospitals are among the most expensive building projects that are used by all members of the public on a daily basis. The finance needed for building new hospitals or extending old ones as well as the need for constant and uninterrupted access to these facilities has led health authorities to put more emphasis on improving the productivity of the existing facilities through less intrusive and less expensive strategies.

This project aims to identify different systems of access and people circulation and determine their impact on staff productivity. MSV will be used to develop a productivity-oriented circulation system which will: improve staff performance; enhance patients' safety, privacy and rate of recovery; minimise the risk of cross-infection; reduce the delay time of external service delivery; create a more welcoming environment for visitors; and reduce evacuation time in emergency situations.

The main objectives are as follows.

- To explore and demonstrate the importance of good access and circulation in hospitals.
- To gain a clear idea of the current status of productivity in hospitals and its relationship with people circulation and establish the quantitative impacts of circulation design in improving the productivity of hospitals.
- To review and compare the current domestic and international standards and guidelines related to access and circulation in hospitals.
- To identify and demonstrate the specific factors that can enable and improve access and circulation levels in different hospital designs in terms of improving productivity.
- To review relevant existing MSV tools in order to select and use the most suitable tool to fulfil this research's aim.
- To develop a framework for improved people circulation in hospitals.

Methodologies

This study aims to develop an integrated approach to the design of more productive hospital layouts using state-of-the-art methods and tools, including modelling, simulation and visualisation tools. The research will consider the design of new and the redesign of existing facilities. It will also: develop new knowledge on how the built environment adds value to healthcare delivery; and improve understanding of how a well-designed access and circulation system affects patient care, safety, privacy, clinical recovery, staff effectiveness and operational efficiency.

Key findings

- Supportive built environments with good internal layouts, accessibility and circulation can create a more inviting, calming, engaging, hygienic and productive healthcare environment for staff, patients and their families.

4. Increasing the Operational Efficiency of Healthcare Space (continued)

- The layout and design of a hospital are factors that can significantly impact on nursing staff productivity. However, there are also other environmental factors that need to be considered, such as natural light, view and thermal comfort.
- Existing approaches and layouts have been identified. A comparative study of different categories of people circulation designs is being conducted to compare and contrast their advantages and disadvantages with respect to access and people circulation.

4.4. Project: The Value of Standards in the Healthcare Environment

Researcher: Erica Ricks

Project start and end date: April 2009 to March 2012

Overview

A study of Department of Health (DH) standards reveals a logical focus on clinical patient-oriented care. However, studies on the impact of the physical healthcare environment have established clear inter-relationships between the quality of their surroundings and the experiences of staff and patients. The fundamental premise of the National Health Service (NHS) is to provide healthcare “free at the point of delivery”. Where this “point” is located is rarely mentioned, nor is its suitability as an environment from which to deliver healthcare. By contrast, the public’s view of a good NHS service seems closely linked to physical environmental and vocational factors such as pleasant accommodation, cleanliness and ease of access.

The DH produces guidance and tools to assist with the briefing, design and procurement of the healthcare environment. Guidance is largely driven by policy emanating from the government of the day, making a clear link between the standards and policy. Today’s guidance is regarded as providing baseline recommendations or standards to which the design of healthcare facilities should conform.

The aim of this research is to establish the costs and benefits of standards in the healthcare environment in England. Standards are currently delivered in the form of tools, datasets and processes that have evolved over time and have variable status. The principal focus of the research is the users of the buildings, i.e. staff and patients, but will necessarily also include the wider audience of healthcare stakeholders. Standards affect many aspects of healthcare environments, and in this project will include those relating to visual criteria, patient outcomes, safety in the healthcare environment, and the status, purpose and relevance of standards.

The objectives of the research are to:

- establish how the historical background to the NHS has led to the current standards and how they relate to the NHS healthcare estate;
- identify the political drivers and how they affect the NHS estate and compare them those of other countries;
- define and explore the costs and benefits of standards in the procurement and management of healthcare facilities;
- track where and how the accountability for development and management of the healthcare environment is applied, and establish whether it is considered adequate;
- deduce how the recent policy changes will affect the estate and therefore healthcare delivery; and
- identify the role of DH guidance in the new environment following the May 2010 General Election.

Methodologies

The research has been divided into three strands: policy; standards; and practice and process. A literature search has included electronic methods of accessing references to healthcare infrastructure in legislation, as well as an assessment of the guidance and tools currently available. An action research methodology has been used where possible, using experiences gained in providing training in the use of DH guidance and tools. Interviews have been conducted with acknowledged experts in the field, and workshops run. A comparison with international practices is proposed.

Key findings

- A view of the development of healthcare infrastructure-related policy and how this has affected the development of standards and guidance.
- An exploration of the costs and benefits of standards and guidance to patients and staff in the procurement and management of healthcare facilities.
- An assessment of the effect of recent political changes (post the May 2010 election) on the use and application of standards and guidance for all stakeholder groups.
- An understanding on the healthcare estate of the practices and processes related to DH guidance and standards.
- An overview of policy and processes in other countries relating to healthcare infrastructure and the application of their standards and guidance.

Recommendations

- A framework for the use of levels of standards and guidance for the DH has been proposed.
- Development of a process to encourage the sharing of knowledge, and gathering learning/feedback from post project and post occupancy evaluations as well as generation of innovative solutions for new technologies and clinical practices.
- An investigation of how other industry sectors might provide learning for healthcare.



Due to the huge costs associated with asset management, healthcare organisations must ensure they achieve value for money in managing their estate.

5. Healthcare Infrastructure Planning

5.1. Introduction

With the advent of the Darzi review in 2008 and more recently the White Paper 'Equity and Excellence; Liberating the NHS' (2010), the delivery of health and social care in the UK is undergoing profound change and being redesigned to provide high quality, person-centred services and improved capacity and performance. In 2008 and again in 2010, the Chancellor of the Exchequer identified improvements to NHS estate utilisation as a key saving area in 2010/11-2012/13, potentially reducing in 2010/11 the need for new hospital space by up to £3bn and saving up to £100m per annum of estate costs.

The Department of Health is now moving towards a system focussed on 'outcomes and quality standards' rather than operational targets. About 60 per cent of the NHS estate is more than 25 years old and due to the huge costs associated with asset management, the NHS needs to ensure that it achieves value for money in managing its estate. In this change-oriented scenario, the importance of stakeholder consultation and public participation is highly topical with widespread advocacy in government policy literature and healthcare literature; along with systematic management of all decision-making processes taken throughout the life of physical assets.

5.2. Project: Strategic Asset Management and Integrated Service Provision within the Healthcare Sector

Researcher: Grant Mills, Sameedha Mahadkar

Project start and end date: January 2008 to May 2011

Overview

Stakeholder consultation is a complex process that emerges alongside the infrastructure planning and design process. It is needed both at the strategic programme and estates project levels, and must be delivered in a coordinated and efficient way to achieve best value. As such, an action research methodology was adopted in order to understand the specific details of the interrelation of the planning and consultation processes.

The research team worked collaboratively with the local NHS Leicestershire and Rutland County Primary Care Trust to investigate the multi-intuitive and multi-stakeholder approach to infrastructure planning. They worked dynamically with the communications and engagement team at the PCT which was also involved in the development of a live public consultation and service review. Furthermore, a web based review was conducted in order to investigate the consultation exercises carried out with regards to significant estates and service changes within 149 Primary Care

Trusts in England. A conceptual framework was developed based on a literature review in order to understand how decision making and stakeholder consultation can drive value in the infrastructure decision-making in line with Section 242 of the NHS Act 2007.

Key findings

This study concluded that all Primary Care Trusts have conducted public consultation which appears to be in line with legislation. However, there have been wide and varied interpretations of how this should be done. There is a lack of a clear definition and guidance to determine when care, estates or transport structural change consultation should be conducted and also a definitive approach should be introduced to determine at what point of the infrastructure planning process should these be conducted.

Studies evaluating the involvement of stakeholders in the definition and assessment of value, suggest that the public are uncomfortable making resource allocation choices. However, others state that this is not the case when stakeholders are given sufficient time and adequate support and information. Very few trusts are using the most advanced approaches to priority setting. Instead they are selecting to use measurement methods that may bias outcomes or samples that may be inadequate.

Few trusts appear to use modeling, simulation or visualisation tools (e.g. GIS) although the stakeholder consultation practice would benefit from the utilisation of these tools and will also help to improve stakeholder judgment making. There is a lack of understanding within trusts on how stakeholder involvement should integrate with the business planning process. Further detailed guidance is required to ensure that consultation is integrated into the decision making process and that the public are provided with enough information to make effective judgments.

5.3. Project: Strategic Asset Management

Researcher: Sameedha Mahadkar

Project start and end date: April 2008 to September 2011

Overview

Planning needs to address critical capacity gaps and establish appropriate demands for accessible service models. With the ever-changing healthcare services environment within the NHS, trusts have to deliver sustainable services that can accommodate increased patient volumes in their existing facilities, while others may need to refurbish or build new facilities to maximise flow. Within the UK, the UK public sector estate is the largest land owner and its largest tenant, with assets worth £370 billion and annual maintenance costs of up to £25 billion.

Even a modest improvement of 15 per cent savings in facilities management costs would result overall across the NHS in savings of £533 million (EC Harris, 2010). There is a clear need for efficient management of NHS estate and huge savings can be achieved through better management of assets.

There is a growing trend within the NHS is to move towards an increasingly community based service with integration between generalist, specialist and social care; but this needs to be underpinned by robust demand data. This work involves the development of a framework which will be outcomes orientated, underpinned by effective stakeholder consultation for improving strategic asset management which can be utilised by practitioners and decision makers to facilitate the planning process.

This is an action-based research project and effective links have been established with local Primary Care Trusts in order to follow their multi intuitive and multi agency process for estates strategic planning and strategic asset management. Strategic asset management can be viewed as a tool for achieving efficient performance of estates and service delivery outcomes through optimum asset management.

Approach and key findings

A literature review has been conducted and some of the key findings include the following.

- There is no clear definition of asset management and its integration into the healthcare planning process.
- Existing tools, while underpinned by robust baseline data, lack a practical estates decision-making and consultation framework that integrates care service, estates and access planning.
- Transport and access is a major factor in healthcare planning. However, there is little supporting guidance and the benefits of GIS are only just starting to be exploited.
- Existing care, estates and access data, models and assessment methods are too rigid, inflexible and not integrated into a whole infrastructure planning approach.
- There is a need for improved scenario planning approaches.
- Technical specialists in care, estates and transport planning lack an integrated understanding to make optimum value judgements.
- The distribution of a trust's user population should be a large factor in determining care model design.
- Regional and local estates strategy formation must be bespoke to respond to changing local needs and other baseline data.

The research also included a collaborative project with the Prince's Foundation which involved exploring various care models (based on the six recommended specialities by DH) and co-location of facilities. A literature review along with the development of the conceptual framework has been completed. We were also provided

with access to an estates reconfiguration tool 'SHAPE' designed by the Department of Health Estates and Facilities, and a desk study has been completed.

The research team also collaborated with teams at The Bartlett, University College London and have conducted a number of workshops with the following Primary Care Trusts: Milton Keynes, Southampton, Salford Royal, Taunton, St Thomas's and Guys and Brighton. These workshops explored decision-making processes and enabled thinking of new environments and impact of commissioning and the implications on estates projects and the ability of the assets to respond to service re-design. They also provided a platform to examine tools for reconfiguration of service and estate along with multiple stakeholder perspectives (estates and clinicians) to map individual attitudes and understand decision-making networks.

Workshops on Capacity Planning and Lean Healthcare Infrastructure Planning were also conducted at Loughborough University, which informed key aspects of this research. The workshop on 'Lean Healthcare: delivering Value in Planning and Design' was conducted in collaboration with European Construction Institute and Lean Healthcare Institute. This enabled us to define future directions for lean healthcare estates planning and design and its role in achieving reconfiguration, space rationalisation and clinical productivity.

The Capacity Planning workshop was jointly conducted with ECHAA (European Centre for Health Assets and Architecture). It was centred on how flow is accurately modelled to understand both systematic well defined procedures (that account for about 80 per cent of activity) and those more complex, ill-defined and individualised pathways. It further explored how buildings could translate these various care pathways into efficient and unconstrained patient flows.

5.4. Project: Evidence-based design of healthcare built environment to improve quality and safety

Researcher: Nadeeshani Wanigarathna

Project start and end date: July 2010 to June 2013

Overview

With the findings that better designed buildings contribute to a built healing environment, the concept of Evidence Based Design (EBD) - the process of basing decisions about the built environment on credible research to achieve the best possible outcomes-has gained a wider acceptance by stakeholders including the UK Government.

There have been several studies that present opportunities for EBD to strategically inform design and thereby increase healthcare outcomes. Ulrich (2005) identified design to increase safety, reduce infections, falls, medical errors, staff fatigue, eliminate environmental stressors etc as the main opportunities of EBD through specific

5. Healthcare infrastructure planning (continued)

strategies, such as: single instead of shared patient rooms; rooms with natural light and nature views; using acoustical materials and creating sight lines; decentralised nurses stations; and large scale art projects. At a macro scale, Webster and Steinke (2009) established that EBD can assist in addressing issues of an aging population and workforce, labour shortage, high incidences of workplace injury and increasing absenteeism.

It is timely, especially in the UK, to research extensively into EBD considering the country's specific characteristics and the National Health Service's future requirements. This research aims to investigate how an Evidence Based Learning Environment (EBLE) can be created within the healthcare built environment through evidence-informed design standards, guidance to improve quality and safety. The specific objectives are as follows.

- To review existing quality standards, guidance and evaluation tools to identify their quality and safety realization mechanism.
- To investigate the current healthcare built environment design process to identify how design process manages quality and safety of its products.
- To identify the changing future requirements of the healthcare built environment and its design process locally and internationally.
- To explore the opportunities to improve quality and safety through evidence-based guidance to healthcare built environment design process.
- To identify how to create an EBLE within the healthcare built environment design process to improve health and safety.

Methodologies

This research will review literature of standards, guidance and tools and the healthcare built environment design process. Further selected books, journals, newspapers, reports, television programmes etc. to partially identify the foresight of the healthcare built environment and its design process. This will be further investigated by a questionnaire survey followed by further rounds to achieve fourth and fifth objectives using Delphi technique.

Anticipated/planned outcomes

- How existing design standards, guidance and tools contribute to quality and safety of the healthcare buildings.
- Future requirements of the healthcare built environment and building design process.
- Opportunities to improve quality and safety of the healthcare built environment through evidence-based guidance to the people involved in their design process.

5.5. Project: Open Scenario Planning: Enabling Service Transformation with Change-Ready Infrastructure

Researcher: Phil Astley

Project start and end date: October 2009 to June 2011

Overview

The development of research currently undertaken at the Bartlett, University College London with the HaCIRIC team at Loughborough University Department focuses on the development of: Open Scenario Planning for Healthcare Infrastructure (OPHI). The study has proposed Open Scenario Planning approaches to support the front end stage of planning to enable service transformation with insights drawn from A&E and Urgent Care and how it connects to space and infrastructure.

We have generated a method using scenario building techniques driven by operational innovation for a range of possible futures that will have an impact on the future configuration of A&E/ Urgent care (and other associated) pathways. They test strategic scenario options for clinical effectiveness rather than traditional functional relationships.

The ideas and direction of the research are underpinned by concepts of Open Building with case studies from England, Switzerland and the Netherlands. The research has investigated current approaches to master planning of hospital sites. It proposes a new framework that directs the future development of the hospital and partner organisations as a set of high level objectives driven by clinical priorities. This framework incorporates planning and design innovation through the mapping of divergent operational scenarios. It is a non-linear planning process that provides for a range of change-ready scenarios and the potential for rationalisation of existing property and buildings, whilst improving decision making for healthcare pathways across locations and settings.

Research Questions

The research addresses some key questions. What new approaches need to be developed for service and spatial strategies that respond to uncertainty and change for effective planning, design and project management at the inception of projects? What are the multi-disciplinary decision-making networks, structures and competencies required? How can we determine Open Scenario Planning approaches that understand the need for 'preparedness' for constant clinical change and capacity? What are the range of tools and techniques available to facilitate the implementation of new infrastructure investment strategies?

Methodologies

Evidence and analysis has been drawn from workshops in the field of A&E/trauma and urgent care service (re)organisation within seven English Trusts. These workshops set out a process to determine scenarios of a shifting pattern of patient-centred requirements and clinical priorities by testing strategic options for clinical effectiveness rather than functional arrangements. The ideas and direction of the research are also supported by our engagement with case studies from Switzerland and the Netherlands that have applied open building methods for the scenario planning of infrastructure and built assets.

Findings

The findings of our study with the acute hospital trusts in England respond to emerging radical solutions in A&E and Urgent Care to control demand and the potential of identifying key savings from the efficient planning of space. We have investigated the appropriateness of their introduction within the context of UK service reorganisation for patient-centred, integrated care. Findings are suggesting clinically-led units supported by mobile multi-disciplinary teams for on and off-site planning of admission avoidance, referral patterns and long-term care of chronic conditions. This is informing scenarios of community driven social care models, the virtual management of care, and the infrastructure requirements to support this activity.

Conclusions

This work has informed principles and strategies for an 'Open Scenario Framework', the purpose of which is to direct scenario building methods for the future development of the hospital as a set of high level objectives driven by service transformations. The Framework incorporates planning and design principles for change-ready infrastructure aligned to open building concepts for the organisation of projects. The outcome illustrates an Open Scenario Planning approach to enable decisions based on stakeholder values made against these principles.

5.6. Project: The development of a knowledge feedback loop between design and construction within healthcare infrastructure projects

Researcher: James Henderson

Start and end date: October 2009 – September 2012

Overview

The built environment is directly related to the quality of service that is provided and therefore linked to positive health outcomes. However, the construction industry as a whole is viewed as providing suboptimal facilities due to the lack of learning from previous experiences. For many years the need has been constantly raised for the construction industry to better manage and share knowledge that resides within the supply chain, with their clients and internally within construction firms themselves. This is due mainly to the cited efficiency and effectiveness benefits that can be gained. However, interest surrounding organisational learning and knowledge management within construction has seen a disproportionate degree of focus concentrated on post occupancy evaluations.

The aim of this research is to investigate the application of a feedback loop framework between the phases of design and construction to facilitate closer integration and learning. The main objectives have been listed below:

- To identify the need/drivers for and barriers against the design-construction feedback loop
- To investigate current practices (if any) designed to improve the feedback of poor design quality
- To investigate what knowledge is currently being captured and assess its usefulness if fed back to the design stage
- To identify the relevant techniques and technologies that assist the delivery of a design-construction quality loop
- To identify the makeup of an enhanced or innovative design-construction quality loop framework

5. Healthcare infrastructure planning (continued)

Methodology

A whole to parts process has been adopted in order to narrow the focus of this broad topic. Firstly, an extensive literature review concentrated on establishing a holistic view of related research. This subsequently shaped the formulation of further interest areas. In particular, the identification of the need to concentrate effort on cross-phase knowledge sharing and learning between the phases of design and construction was recognised. This led to the development of an electronic survey which aimed to: validate the need for further research in this area; further focus the key research areas; and highlight the challenges faced in developing the proposed feedback loop within healthcare infrastructure projects. In order to move towards the concentrated investigation of how a feedback loop can be devised within this context, more in-depth case study research is planned.

Findings

- Most formal feedback and learning for designers is generated from post occupancy evaluations. However, very little is gained regarding how the facility's design can be improved to be built more effectively and efficiently.
- Many project and industry level barriers exist which hinder learning from past projects to take place.
- There is a greater appreciation now than in the past regarding the need for early integration of construction personnel in the design stage in order for the industry to provide better value end products.
- The issues of buildability problems are discovered as being reoccurring but avoidable. Therefore, a lack of value is currently being experienced.
- Current knowledge management procedures are insufficient in providing effective learning outcomes to be applied to future projects.

Recommendations

- The current lack of integration and/or feedback between design and construction is severely restricting the extent to which learning and continuous improvement can be achieved from previous healthcare infrastructure projects to the next.
- At present, a lack of value is being experienced due to the repetition of inefficiencies such as rework, delays and cost overruns due to a lack of learning.
- In order to share knowledge between phases, current knowledge management procedures need to move away from text based explicit knowledge, towards attempting to capture tacit knowledge.
- Furthermore, for the knowledge capture to be of the highest quality, greater efforts are needed to capture knowledge live.



Our research aims to help the NHS deliver care to people that is accessible, convenient and in the most appropriate setting.

6. Sustainability of Healthcare Infrastructure

6.1. Introduction

The relationship between healthcare infrastructure and sustainability is very strong in terms of impact on whole life value, health and wellbeing. Delivering a sustainable health system, with sustainable healthcare facilities, requires a good appreciation of the value of sustainable design solutions in relation to the environment, economy, policy and strategy. Most healthcare sustainability projects deal with a single aspect of sustainability (reduction of CO₂ emission) and fail to take into consideration the broader sense of sustainability. This research focusses on four aspects of sustainable healthcare infrastructure: comfort, safety and wellbeing of hospital occupants (patients, visitors and staff); physical and social resilience to adverse disruptions resulting from nature or technologies; environmental friendliness; and financial efficiency that does not compromise gained values to taxpayers (e.g. low or free cost of treatment).

The UK healthcare service is going through a significant number of challenges due to the performance of its infrastructure and the new strategies and targets set by the Government. High CO₂ emission, natural hazards, infectious diseases and indoor air quality are examples of the challenges that this report addresses. It is the product of a multi-disciplinary research team which has been working to mitigate these risks with the view to improving the sustainability of healthcare infrastructure.

6.2 Project: Improving Whole Life Value of healthcare facilities through better briefing and optioneering

Researcher: Ruth Sengozi

Project start and end date: April 2008 to June 2011

Overview

Recent years have seen the NHS undergo a massive multi-billion pound building programme. However, hospital costs (construction, operation, maintenance) are generally high. Moreover, they need to demonstrate value for money. The planning and designing of healthcare facilities have responded to a range of complexities associated with: complicated and yet ever-changing technologies that are usually associated with healthcare infrastructure; disparate stakeholders with different needs and expectations; changing global and national priorities such as sustainability and value for money; changing demographics. There is a need for improved briefing and option selection implying capturing and accounting for several factors in selecting suitable project/ decision choice, consequently better mechanisms for enabling informed decision-making for better Whole Life Value delivery.

The aim of this project is to investigate better ways through which Whole Life Value of healthcare infrastructure may be enhanced and delivered by focusing on: front-end processes; improved briefing; and strategic options selection. The key objectives are as follows.

To explore the concepts of construction briefing, optioneering theory and Whole Life Value and their linkages with reference to healthcare projects.

To identify gaps and areas for improvement in order to design a best practice framework for effective process improvement towards better Whole Life Value.

Methodologies

The study involved a multiple approach including an extensive literature survey, interviews and workshop observations, and a longitudinal case study.

Key findings

- In order to clarify clinical needs and requirements, clinical service modelling is an important first step in the briefing process.
- The role of the healthcare planner in defining and planning for whole life delivery cannot be over-emphasised.
- During briefing, there is an indication pointing towards a desire for selective involvement of stakeholders in what they use and what affects them directly.
- A mechanism is needed, to enable varied communication methods for different stakeholder groups and guidance on who to engage with, what to engage about and how.
- Most important WLV criteria include: modern, therapeutic and inclusive environments; location; waiting areas; adjacency; artwork; sense of place; and personalisation to community.

Recommendations

- A clinical output specification is included as one of the key documents, alongside the briefs and this document is prepared as the first step before embarking on design.
- Integrating the healthcare planning role as standard members of the project team, along with the architects and engineering consultants.
- The NHS needs to improve its decision-making process to enhance capital spending by proactively spending more on original building and by investing in training of its personnel in business case preparation skills.

6.3 Project: Planning Healthcare & Infrastructure: Assessing Transport Implications of Healthcare Facility Reconfiguration using GIS

Researcher: Omid Titidezh

Project start and end date: Dec 2008- Dec 2011

Overview

The aim of this research is to establish a refined vision for the NHS, centred around patient choice, that is responsive to families and local communities. Core objectives are putting clinical decision-making at the heart of the NHS, improving patient care with joined-up services, and delivering accessible and convenient care in the most appropriate setting. The goal is to develop practical ways to strategically plan for this while also meeting the NHS commitment to reduce carbon.

In this broad context, the integration or co-location of services is viewed as part of a strategic framework that should account for the broader issues of health, social care and general well-being as part of the community setting. It is significant that, in parallel to the Climate Change Act, with a target to cut greenhouse gas emissions by at least 80 per cent by 2050, the NHS has set its own Carbon Reduction Strategy. This mandates all commercial and public sector organisations to promptly restructure and devise plans to reduce greenhouse gas emissions and improve care accordingly.

Methodologies

Healthcare is a highly complex field that involves the interaction of three very different types of infrastructure. These are: healthcare service design; estates planning; and accessibility planning. Each must be understood and analysed to reduce the carbon emissions from the process as a whole while maintaining improved care standards. Information and data were collected through:

- multidisciplinary workshops and steering group meetings;
- specialist care pathway (Dermatology) co-design questionnaire and workshops;
- literature and tool review desk studies;
- process modelling and observations;
- action research;
- small pilot studies; and
- data analysis of census population and demographics.

Key findings

- Poor approach to establishing existing and future healthcare demands and match of capacity to these figures.

- Disparate research evidence on the healthcare impact of scale and distribution of infrastructure reorganisation on healthcare quality and no common integrated framework for understanding these issues.
- Whole healthcare system data not readily available, integrated or transparent, and existing tools have limitations.
- Further research is needed about the stages of the healthcare planning process and the approach to engaging various stakeholders in decision making.

Recommendations

- Primary and Community Care Commissioners must work together to build a unified whole system approach to healthcare infrastructure planning.
- Healthcare planners need to have a clear definition of scale and type of care, estates and travel response to define clear distribution scenarios and a whole system carbon strategy.
- Easily assessable and integrated data management system for use in all PCTs.
- A broader decision-making framework and human process needs to be defined.

6.4 Project: Reducing construction waste in healthcare facilities: A project lifecycle approach

Researcher: Niluka Domingo

Project start and end date: April 2008 to June 2011

Overview

The construction industry is responsible for producing a wide variety of different waste streams and, according to the recent figures published by the UK government, construction activities produce 120 million tonnes of waste every year. As one of the UK's biggest responsibilities, the NHS has a considerable role in supporting the government in minimising construction waste. The aim of this project was to reduce the construction waste generation from healthcare projects through a lifecycle approach. The key objectives were as follows.

- To identify characteristics in healthcare facilities effect on waste generation.
- To identify causes and origins of waste particular to healthcare facilities.
- To explore good waste minimisation practices to implement throughout the project lifecycle.
- To provide recommendations on how to embed waste minimisation practices in the healthcare project lifecycle.

6. Sustainability of Healthcare Infrastructure (continued)

Methodologies

The study adopted an interpretive approach to collecting data for the study through a literature review, interviews and case studies. Clients, architects and contractors who were experts in the healthcare industry provided details of healthcare waste generation; causes and origins of waste and best waste minimisation practices.

Key findings

- Healthcare buildings produce high quantities of construction waste compared to other building types.
- Healthcare facilities have complex functional and operation features which increase construction waste generation throughout the lifecycle of the facility.
- The main causes of waste in healthcare facilities are: incomplete documentation; ineffective communication and coordination between project partners; lack of waste awareness among project stakeholders; poor buildability; inappropriate materials selection and procurement.

Recommendations

- Participation of all the parties (clients, designers, contractors and product manufactures) in the project from the very beginning to capture all the building needs.
- Timely completion of documents during brief, design, project plan, etc.
- Good communication to improve information sharing between project partners.
- Standardisation of building elements wherever possible.
- Maintain quality standards as stated in NHS guidelines to reduce lifecycle waste generation.
- Use modern technologies such as modular constructions, offsite pre fabrications etc.
- Early planning and organising of all the project activities.
- Keep allocations for future expansions and changes in the design (i.e. keep more service connections, large flexible spaces etc.).

6.5 Project: A framework for refurbishment of healthcare facilities

Researcher: Amey Sheth

Project start and end date: April 2008 to June 2011

Overview

The NHS has one of the largest property portfolios in the UK, which is raising a significant number of environmental concerns and challenges that need to be addressed in the reduction of resource (energy, water, etc.) consumption. The aim of this research project was to develop a framework to support and facilitate refurbishment of existing healthcare facilities and improve their energy performance. The key objectives were as follows.

- To develop a framework to support refurbishment of existing healthcare facilities.
- To identify the components for management, design team to be included within the framework.

Methodologies

The study adopted a pluralistic approach including: literature review, face-to-face interviews, questionnaire survey, and case studies. The involvement of national and international experts and collaborators helped to identify key concerns and strengths and provided an important source taken directly from practice.

Key Findings

- Research in the area of refurbishment of existing hospitals has been neglected.
- There is a need to develop approaches for the existing healthcare facilities to achieve overall sustainability.
- A successful refurbishment can significantly improve a building's life cycle.
- Significant energy savings are easily achievable with more sophisticated planning and mechanical systems by reducing air volumes and using appropriate energy features.
- Modelling and simulation tools are not only for new buildings and should be used with refurbishment projects as well.

Recommendations

- Pre and post refurbishment evaluation of existing facilities to examine success of refurbishment proposals. This will help in future to improve and speed up refurbishment process.
- Make use of modelling and simulation tools to assess and predict energy and carbon emissions.

- Explore modern concepts such as the built healing environment, evidence-based design and sustainability during the refurbishment of existing hospitals.
- Incorporate concepts related to planning of new healthcare facilities layout such as nucleus, decentralised, open, flexible, or adaptable hospital design during major refurbishment projects to reduce the complexities in existing layouts if needed. Reduced energy consumption should not be achieved by compromising user and especially patient comfort.
- Conduct in-depth surveys of existing facilities before refurbishment can elicit various details related to operational hours, number of visitors, staff and patients occupancy, existing indoor environmental quality, need for lighting, etc., which can help plan vital role in developing a refurbishment proposal.
- Post refurbishment evaluation to generate knowledge for refurbishment.

6.6 Project: Healthcare Resilience Tool (HeaRT)

Researcher: Nebil Achour

Project start and end date: Sept 2008-May 2011

Overview

The number of natural hazards has increased in the last decade. These have adversely affected a significant number of people including healthcare workers, who are supposed to treat injuries, but in many cases could not operate as they were themselves “victims”. The aim of this project is to help improve the resilience of healthcare facilities to natural hazards. The key objectives are as follows.

- To identify the key priorities in terms of hazards and risks.
- To compare the performance of different types of healthcare facilities during different types of disaster.
- To benchmark UK practice against international healthcare resilience strategies.

Methodologies

The research adopted a pluralistic approach including: a literature review, interviews, case studies, field investigations and modelling and simulation. The involvement of national and international collaborators helped to identify key concerns and strengths and provide an important source taken directly from practice.

Key Findings

- Resilience is a major element for sustainable development and needs to be involved in strategic planning to maintain quality of life.
- Healthcare facilities structural and architectural components respond differently to earthquakes due to the diversity of causes and the specification of each building; equipment and utility supplies’ damage is similar because facilities are often equipped with similar equipment and installations that are not protected by codes.
- The resilience of healthcare facilities depends on the degree of internal preparedness, but it can extend to include external issues such as accessibility, performance of suppliers, ability to cope with sudden surges in service demand, and future challenges.

Recommendations

- Healthcare facilities resilience needs to integrate physical and social issues and reflect particular features of societies (such as ageing).
- Review practices regarding access to information while respecting and protecting the privacy of patients and staff.
- Investigate the impact of extreme weather events on healthcare facilities (by independent research groups) to identify faced difficulties.
- Benefit from scenarios to identify potential risks and set the necessary solutions to mitigate the risk.
- Develop more accurate scenarios to predict the impact of natural hazards..



Tackling the vulnerability of healthcare infrastructure to climate change is key to achieving sustainability.

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Titidez O., Price A.D.F., Ison S., Quddus M.A. and Mills, G. (2009) "Accessibility Modelling for Healthcare Facilities Development: A Case of Reconfiguration Using GIS Tools", *Health GIS Conference*, 21-23 Sep., Nashville, USA.

Zhao, Y., Mourshed, M. and Wright, J. (2009) "Factors influencing the design of spatial layouts in healthcare buildings." In: Dainty, A. (Ed) *Procs 25th Annual ARCOM Conference*, 7-9 September 2009, 1041-49, Nottingham, UK.

Invited presentations

Mills, G., R., W (2011) "Appraising Healthcare Infrastructure at Various Levels of a Hospital's Acuity System", Nohr-Con Conference on Planning and Designing Hospitals of the Future. *International Debate Conference on Future Patient Pathways and Operation of Super Hospitals*, 10-12 May, København (Copenhagen).

Price, A.D.F and Harty, C (2011) "NHS Estate: Is there too much old and too much new? Possible answers to this dilemma", *Healthcare Infrastructure 2011, Procurement-Refurbishment- Disposal, Building Better Healthcare, Conventus Healthcare Communications*, 2 March, Birmingham, United Kingdom.

Mahadkar, S., Mills, G., and Price, A.D.F. (2009) "Exploring the Relationship between Public Health Service Planning and Effective Stakeholder Consultation" (presentation), *Australian College of Health Service Executives (ACHSE) in partnership with CHAA-2009 National Congress: Building Our HealthCare System around People and their Needs*, 4-7 August, Queensland, Australia.

Shikder, S. and Osaji, E. (2009) "HaCIRIC: Current Research Portfolio", CogWorks Workshop, *The Influence of the Built Environment on Cognitive Decline and Wellbeing*. 5 November, University of Warwick, UK.

Price, A.D.F. and Shikder, S. (2009) "Lighting and the Elderly", Ambient Assisted Living (AAL) event, De Montfort University, Leicester, UK.

9. Key collaborators

Academics

- Ball State University, Indiana
- Coventry University, UK
- Health Environments Research and Design Journal (HERD)
- Kanazawa University, Japan
- Karlsruhe Institute of Technology, Germany
- London Southbank University, UK
- Medical Architecture Research Unit (MARU), UK
- National Chen Kung University, Taiwan
- National Graduate Institute for Policy Studies (GRIPS), Japan
- Purdue University, USA
- Sheffield University, UK
- The Bartlett, University College London, UK
- University of Abertay, Dundee, UK
- University of Liverpool, UK
- University of New South Wales (Centre for Health Assets Australia (CHAA), Australia
- University of Southampton, UK

Designers, contractors and consultants

- Active Plan
- Arup
- Assura
- Avanti Architects
- BAM construction
- BDP
- Blue Skies
- BWB Consulting
- Cannon Design
- Community Health Partnership
- CPMG Architects
- Davis Design
- DLA Freemanwhite
- Equity Solutions
- Freemanwhite Architects
- Hockerton Housing Project, Nottinghamshire
- HOK Architects
- Integra
- JSR Associates Inc.
- Laing O'Rourke
- Mace
- MJ Medical
- Nightingale Associates
- NK Architects
- Parallel
- Perkins + Wills
- RSP Group
- Sedgwick Igoe,
- Simons Group
- SIMUL8 Corporation
- Skanska
- Space Syntax
- Willmott Dixon

Organisations, institutions and health providers

- Babbington Court Care Home, Leicestershire, UK
- Barts and the Royal London NHS Trust
- Birmingham Children Hospital NHS Trust
- Cambridge University Hospitals Foundation Trust
- Cambridge University Hospitals Foundation Trust and NHS Brighton PCT
- Charnwood Neighbourhood Housing (CNH), UK
- Circle HPML
- Community Health Partnerships
- Department of Health (DH) Estates and Facilities
- European Centre for Health Assets and Architecture (ECHAA)
- European Health Property Network (EuHPN)
- European Investment Bank (EIB)
- Great Ormond Street Hospital (GOSH)
- Health Facilities Ireland
- Healthy Urban Development Unit (HUDU)
- HF Scotland
- Institute of Civil Engineers (ICE)
- Institute of Structural Engineers (IStructE)
- Intelligent Building Institute, HUST, China
- Kaohsiung Municipal Hospital (Taiwan)
- Leicestershire & Rutland PCT
- Milton Keynes NHS Foundation Trust
- Multidisciplinary Center for Earthquake Engineering Research (MCEER)
- NHS Innovation, East Midlands, UK
- NHS Leicester City PCT
- NHS Leicestershire and Rutland PCT
- NHS Milton Keynes PCT
- NHS Nottinghamshire County Estate Department
- NHS Salford Royal PCT
- NHS Southampton PCT
- NHS St Thomas's and Guys PCT
- NHS Taunton and Somerset Foundation Trust
- Northern Lincolnshire & Goole Hospitals NHS Foundation Trust
- Nottingham University Hospitals
- Ove Arup
- Prince's Foundation for the Built Environment
- Rotherham NHS Foundation Trust
- SINTEF
- Southampton University NHS Foundation Trust
- Square Hospitals Ltd., Dhaka, Bangladesh
- Surrey Borders Mental Health Foundation Trust
- Taunton and Somerset NHS Foundation Trust
- University Hospital Leicester
- Welsh Health Estates
- World Agency for Planetary Monitoring and Earthquake Risk Reduction (WAPMERR)
- World Health Organisation (WHO)

10. Our team

10.1 Researchers

Following is the list of researchers who are involved in reported research projects.



Amey Sheth

Amey is a research student at the Civil and Building Engineering Department of Loughborough University, UK. His current research includes refurbishment of existing healthcare facilities, and modelling and simulation tools for healthcare facilities. Amey is an architect by profession, and has worked on various architectural projects.

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Ashikur Rahman Joarder

Md. Ashikur Rahman Joarder is an Assistant Professor in the Department of Architecture, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh and PhD Researcher, HaCIRIC, Dept. of Civil and Building Engineering, Loughborough University, UK. His research interests include evidence based therapeutic environment design, daylight modelling and simulation and innovative healthcare design with daylighting.

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Emeka Efe Osaji

Emeka Efe Osaji is a Qualified Architect and Chartered Environmentalist. For over ten years he has been involved in the sustainable design and development projects.



Erica Ricks

Having worked in architectural, engineering private practices, and in the NHS during the 1980s and 1990s, I joined the Department of Health in 1996 and moved progressively to my present position of ADB Project Manager in 2003. I currently research the value of standards in healthcare environments as a PhD student.

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Masoumeh Nazarian

Masoumeh Nazarian is a PhD student at Loughborough University. Her current research includes hospital productivity and people flow. She is an architect by background and holding a M.Sc. in architecture with the title of "Female Students' Dormitory: Al-Zahra University".

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Grant R. Mills

A Research Associate at Loughborough University since July 2002, as part of the Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), a unique collaboration between existing research centres at Imperial College London and the universities of Loughborough, Reading and Salford. He has a growing healthcare research portfolio investigating: evidence based design, open scenario planning, integrated strategic asset management and master planning, and sustainable infrastructure planning. His areas of specialisation are value, process and quality management, capacity planning, lean healthcare, advanced organisational and project stakeholder consultation approaches, strategic asset management, master planning and decision support.

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Jun Lu

Jun Lu is a post-doctoral researcher at Loughborough University. She has been working in the field of healthcare facility design and research over the last seven years. Her current research develops an integrated approach to design of high quality healthcare space and flexible spatial layouts through modelling, simulation and visualisation.



Krusha Vasanti Patel

Krusha Vasanti Patel is a PhD researcher in the Department of Chemical Engineering, Loughborough University. She attended the University of Leicester and received a BSc (Hons) in Biological Sciences. Her current area of research is classifying what strains of *Clostridium difficile* reside in UK hospitals, and investigating whether abundant strains are more resistant to hospital cleaning techniques.

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James Henderson

James Henderson is a PhD student with HaCIRIC at Loughborough University. His current research is in the area of knowledge management and organisational learning within healthcare infrastructure projects in order to deliver heightened value solutions. Prior to James joining the HaCIRIC research team, he completed his BSc in Management Sciences at Loughborough University. He then continued his studies at Loughborough in completing an MSc in Construction Management.

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10. The Team (continued)



Nadeeshani Wanigarathna

Nadeeshani Wanigarathna is a PhD student studying in the Loughborough University and a member of HaCIRIC. Her research interests include Construction Management and Facilities Management. Her PhD research is focused on creation of Evidence Based Learning Environment (EBLE) within the healthcare built environment through evidence informed design standards, guidance.

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Dr. Nebil Achour

Dr Nebil Achour, Research Associate, Loughborough University, with expertise in the resilience of infrastructure applied to healthcare. He has developed an approach to assess hospital physical performance to earthquakes and has joined several international investigation teams. Currently, his research deals with improving the performance of healthcare infrastructure in crisis related emergencies through better planning, coordination and collaboration with the different stakeholders. Also he has experience in working with a team of researchers on improving the sustainability of infrastructure to reduce energy consumption through refurbishment and minimisation of construction waste.

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Niluka Domingo

Niluka Domingo is a Quantity Surveyor, who worked as a University Lecturer in the Department of Building Economics, University of Moratuwa, Sri Lanka. She is currently a PhD student in the Department of Civil and Building Engineering in Loughborough University. Her research interests include construction waste minimisation in the sustainable construction arena.

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Shariful Shikder

Shariful Shikder is a Research Associate and PhD candidate at Loughborough University. His research interest includes lighting in healthcare facilities, healthcare layout planning, building performance simulation, and computer aided architectural design. Shariful's background is from architecture and had worked on various architectural projects. He has expertise in building performance simulation and lighting design. His current research project is 'Optimisation of luminous environments of healthcare spaces'.

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Phil Astley

Phil Astley, Senior Research Fellow, the Bartlett, Principal Investigator for 'Open Planning for Healthcare Infrastructure: a multi-factorial framework', 2011 for HaCIRIC with Loughborough University. Phil has worked on planning healthcare facilities for 20 years with multi-disciplinary architecture and urban planning teams for the development and front-end project intermediary for integrated primary and community resources, mostly in deprived communities within London. A visiting lecturer in the UK and internationally, previously, EPSRC Principal Investigator 'Controlling Hospital Infection: Design and Management Guidelines', 'Adaptable Homes for Care', Shaping Future Healthcare Infrastructure: An Access and Carbon Study for Department of Health and the Prince's Foundation. Previously Senior Research Fellow and Course Director at Medical Architecture Research Unit 2002-2010, an architect in practice since 1992-2002 he developed methods for the planning of integrated health and community resources with input into many strategic frameworks as well as realising individual built projects across London.

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Sameedha Mahadkar

Sameedha Mahadkar graduated with a first class in degree in Civil Engineering from the University of Pune, India. She briefly worked as an assistant project manager on a building project in India and further went on to pursue her Masters in Construction Management at Loughborough University. She has been working as a Research Assistant within the EPSRC funded HaCIRIC project for the last two and a half years. Her core research area has been 'Strategic Asset Management and Integrated Service Provision within the Healthcare Sector' which deals with planning, designing and operations of healthcare facilities. She has also been pursuing her doctoral studies in the same area.

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Omid Titidezh

Omid Titidezh is PhD Researcher, HaCIRIC, Dept. of Civil and Building Engineering, Loughborough University, UK. Omid was lecturer in Shomal University, Iran and has been involved in construction and GIS projects for more than ten years. His MSc and BSc degrees were in Civil Engineering. His current research is 'assessing transport implications of healthcare facility reconfiguration using GIS'.

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Yisong Zhao

Yisong Zhao is a PhD student at HaCIRIC, Department of Civil and Building Engineering in Loughborough University. Prior to joining Loughborough, Yisong studied his MSc program in Sweden and he completed his undergraduate courses China. His current research is concerned with the spatial optimisation of healthcare facility with regards to people's perception of different environmental aspects

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Zulfikar Adamu

Zulfikar A. Adamu is a PhD researcher with HaCIRIC, Department of Civil and Building Engineering in Loughborough University. Prior to joining Loughborough, Zulfikar obtained an MSc degree in Architectural Engineering from KFUPM, Saudi Arabia, where he also lectured for 4 years. He initially studied Architecture (BTech and MTech) from FUT Minna, Nigeria. His current research focuses on natural ventilation of hospital wards for comfort, low energy and bio-aerosol control.

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10.2 Academics

Following is the list of the academics who are involved as investigators and/or supervisors in reported research projects.

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The HaCIRIC online library (www.haciric.org/library/haciric-publications)

The HaCIRIC website provides access to all publications developed as a result of our research work, as well as links to material developed by others in the field.

These include the following:



Better Health Through Better Infrastructure

This report reviews the Centre's current projects and sets out a vision for the future of HaCIRIC.



How should we create 21st century healthcare infrastructure to deliver best value?

Our HaCIRIC Insights document, published in September 2011, sets out key findings and expertise developed during Phase 1 of the HaCIRIC programme. The document details how HaCIRIC is expanding the evidence base linking infrastructure and health outcomes, improving decision-making and helping to future-proof healthcare infrastructure.



Adaptability and innovation in healthcare facilities: lessons from the past for future developments

James Barlow, Martina Köberle-Gaiser, Ray Moss, Ann Noble, Peter Scher, Derek Stow: HaCIRIC, The Howard Goodman Fellowship. September 2009
Reviews capacity for innovation in PFI hospital building programme, contrasts it with earlier NHS hospital building programmes and suggests lessons for the future.



Meeting Tomorrow's Healthcare Challenges Today:

HaCIRIC September 2010. Sets out the four big issues on which HaCIRIC is focussing – safer patients, home not hospital, smarter purchasing and better decision-making.

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