Resilient Hospital Refurbishment

Pamela M. Garthwaite, B.Sc. (hons).

Thesis submitted for the degree of Doctor of Philosophy

School of Engineering and Innovation
Faculty of Science, Technology, Engineering and Mathematics
The Open University

This work was supported by the UK Engineering and Physical Sciences Research Council (EPSRC) grant EP/G061327/1, for the University of Cambridge research project “Design and Delivery of Robust Hospital Environments in a Changing Climate”.

December, 2016.
Abstract

Resilient Hospital Refurbishment

Despite periodical refurbishments, hospital buildings appear to become less resilient over the long term. This thesis considers the underlying reasons for this loss of resilience and examines the implications for the wider hospital system. Decisions made during a project can radically alter its course, resulting in highly successful outcomes or alternatively, in projects facing budget overruns, delays, partially or wholly unfulfilled objectives, disappointed end-users, and inadequate buildings. Refurbishment change is examined through the lens of resilience at three levels of magnification; initially, the focus is on refurbishment projects in hospitals; this is followed by an examination of the wider refurbished hospital building; and finally, consideration is directed towards the NHS Estate.

Project changes may be particularly challenging when they relate to measures aimed at adapting buildings to future climate change. Specifically, there may be little enthusiasm for expenditure devoted to future needs, when funding is insufficient to meet today’s urgent priorities. Where Trusts have large portfolios of property, pre-emptive climate adaptation measures will take considerable time to realise, and accordingly, necessary measures must be in place before any climate-related risk to vulnerable patients becomes life-threatening.

Hospitals are extremely intricate buildings, both in terms of function and of the services that underpin the care process. Relatively small changes, either temporary or permanent, made during the course of a project can have significant repercussions for the hospital. A systems approach has been adopted to explore the relationships and connectivities that may be affected by the hospital refurbishment process. The research findings include the identification of change and resilience mechanisms in refurbishment projects. A framework for mapping change trajectories is presented, to assist in the analysis of propagating changes that affect refurbishment processes. The thesis also makes recommendations for what should be considered in hospital refurbishment projects to improve their overall resilience and reduce vulnerability to major impacts, particularly those that may arise as the UK climate changes.

Pam Garthwaite, 2016.
Declaration

This thesis is the result of my own research and does not include the outcome of collaborative work, except where stated otherwise. This dissertation has not been submitted in whole or in part for consideration for any other degree.

Pam Garthwaite
The Open University
December 2016

This PhD thesis was sponsored by the EPSRC funded research project “Design and Delivery of Robust Hospitals in a Changing Climate” (DeDeRHECC), led by Professor CA Short, Professor of Architecture, University of Cambridge.
Acknowledgements

I am deeply grateful to my main supervisor Professor Claudia Eckert for her continuing guidance, advice, support and kindness during the preparation of this thesis. I am also indebted to my co-supervisor Professor Jeff Johnson for his help, counsel, infectious enthusiasm and encouragement.

I would also like to thank the EPSRC and the DeDeRHECC project team, Professor Alan Short, Professor John Clarkson, Professor Cath Noakes, Dr Alistair Fair, and Dr Labi Ariyo for their valuable advice and encouragement, and also to the wider DeDeRHECC team for many enjoyable discussions.

Finally, I am beholden to the NHS Trust staff, along with the Open University Nursing lecturers, and the specialist consultants who participated in the research and contributed their valuable time and expertise.
To my wonderful family, with grateful thanks for their support and understanding.
# Table of Contents

Chapter 1 Resilient Hospital Refurbishment ................................................................. 13
  1.1 NHS Hospital Buildings: Risk and Resilience ......................................................... 13
  1.1.1 Constraints and Responsibilities ........................................................................ 14
  1.1.2 Hospital Buildings: Robust, Reliable or Resilient? ............................................. 16
  1.1.3 Major Incident Risks and NHS Resilience ......................................................... 19
  1.1.4 Less Immediate but Equally Serious “Creeping Onset” Risks .............................. 20
  1.2 The Research Aim ................................................................................................. 22
    1.2.1 The Research Questions .................................................................................... 23
  1.3 Overview of the Research Approach for this Thesis ................................................. 25
  1.4 The Structure of the Thesis ..................................................................................... 26

Chapter 2 Review of Relevant Literature ......................................................................... 29
  2.1 Backcloth to this Research ..................................................................................... 29
    2.1.1 The NHS is changing ......................................................................................... 29
    2.1.2 Research Themes ............................................................................................... 30
  2.2 A Brief Description of Risk, Complexity, and Connectivity ................................. 32
    2.2.1 Risk .................................................................................................................... 32
    2.2.2 Justifiable Risk .................................................................................................. 35
    2.2.3 Systems and Complexity ................................................................................... 36
    2.2.4 Wicked Problems and Complexity .................................................................... 37
    2.2.5 Connectivity and Coupling .............................................................................. 39
    2.2.6 The Advantages of a Systems Perspective ......................................................... 40
    2.2.7 Risk and Patient Safety ..................................................................................... 42
  2.3 The Precautionary Principle .................................................................................... 47
  2.4 Accident Theory and High Reliability Organizations .............................................. 50
    2.4.1 How Accidents Occur ......................................................................................... 51
    2.4.2 High Reliability Organisations ........................................................................... 53
  2.5 Interpretations of Resilience ................................................................................... 58
    2.5.1 Resilience in the Ecological Literature ............................................................. 59
    2.5.2 Resilience in the Psychology Literature ............................................................ 60
    2.5.3 Engineering and Resilience .............................................................................. 60
2.5.4 Resilience in the Business Environment .......................................................... 62
2.6 Interpretation of Building Refurbishment .............................................................. 65
2.7 Refurbishment in the NHS ..................................................................................... 66
  2.7.1 The Aging NHS Estate ....................................................................................... 66
  2.7.2 The NHS Refurbishment Process ....................................................................... 69
  2.7.3 Adaptation of Hospitals to Climate Change ....................................................... 72
  2.7.4 Successful Projects in the NHS ......................................................................... 73
2.8 NHS Contractual Issues ......................................................................................... 76
  2.8.1 Public-Private Partnerships ............................................................................... 76
  2.8.2 Framework Agreements and Procure 21 (superseded by Procure 21+ and
       more recently by Procure 22). ............................................................................. 76
  2.8.3 Partnering ....................................................................................................... 79
  2.8.4 Scrutiny ........................................................................................................... 81
2.9 Refurbishment Process Improvement ..................................................................... 83
2.10 Change .................................................................................................................. 86
  2.10.1 Change in Construction .................................................................................. 86
  2.10.2 Change Propagation in Engineering ................................................................. 87
  2.10.3 Mechanisms of Change .................................................................................. 88
  2.10.4 Options for Managing Change ....................................................................... 89
2.11 Conclusion ............................................................................................................. 90
Chapter 3 The National Health Service ...................................................................... 93
3.1 Overview of the UK National Health Service (NHS) ............................................. 93
3.2 Historical Context .................................................................................................. 94
3.3 Changes in Government Policy ............................................................................. 95
3.4 NHS Trusts and NHS Organisational Structure ................................................. 98
  3.4.1 Trust Status ..................................................................................................... 98
  3.4.2 NHS Organisational Structure ....................................................................... 98
3.5 Challenges for the NHS ....................................................................................... 101
  3.5.1 The Aging Demographic ................................................................................. 101
  3.5.2 Co-morbidities ............................................................................................... 102
  3.5.3 The Pace of Change ....................................................................................... 102
  3.5.4 Options for the NHS Estate: Where will patients be treated? ...................... 103
Chapter 4 Methodology ..................................................................................... 107

4.1 Introduction ......................................................................................... 107

4.2 Research Philosophy ....................................................................... 110
  4.2.1 Ontology and Epistemology ............................................................. 110
  4.2.2 Methodology Adopted for this Research ........................................ 114

4.3 The DeDeRHECC Project ................................................................ 116
  4.3.1 Context ......................................................................................... 116
  4.3.2 The Design and Delivery of Robust Hospital Environments in a Changing Climate project (DDRHECC) ................................................................. 117
  4.3.3 Project Partners ........................................................................... 119
  4.3.3 Organisation, Communication and Objectives ............................. 121

4.4 Overview of the Case Studies .............................................................. 122
  4.4.1 Case Study 1: The Neo-Natal Project (NNU) .................................. 124

4.5 Ethics Approval .................................................................................. 126

4.6 The Preliminary Study ...................................................................... 127
  4.6.1 Open-ended Semi-structured Questionnaires .............................. 129
  4.6.2 Analysis and Implications from the Preliminary Study ................. 132
  4.6.3 Study Outcomes ......................................................................... 139

4.7 Conducting and Analysing the Case Studies ....................................... 141
  4.7.1 Analysis Method for the Case Study 1 “Post-Project Review” ....... 141
  4.7.2 Analysing Case Studies 1 to 4 ...................................................... 142
  4.7.3 Analysis Methods ....................................................................... 143
  4.7.4 Case Study Modelling ................................................................. 145
  4.7.5 Supporting Documentation .......................................................... 149

4.8 Additional Expert Interviews ............................................................... 150

4.9 Validation ........................................................................................... 151
  4.9.1 General ....................................................................................... 151
  4.9.2 Credibility Validation ................................................................. 152
  4.9.3 Validation for Research in this Thesis ......................................... 153

Chapter 5 Empirical Studies ................................................................. 155

5.1 Structure of the Chapter ................................................................. 155
10.2.3 How is hospital building resilience affected by refurbishment? ............ 307

10.2.4 Can partial hospital refurbishments compromise the resilience of NHS hospital buildings over the long term? ................................................................. 310

10.3 Key Contributions .................................................................................. 312

10.4 Limitations of the Work ....................................................................... 313

10.5 Conclusions ............................................................................................ 313

10.6 Further Work: Create Tools and Make Recommendations for the NHS .... 314

References .................................................................................................... 321
Chapter 1 Resilient Hospital Refurbishment

“The short and long term consequences from hospital failure not only include loss of life, financial implications and challenges in providing health services, particularly if facilities require rebuilding following the event, but also cause intangible far-reaching effects on the community through loss of their ‘safe haven’.” (NHS London, 2009).

1.1 NHS Hospital Buildings: Risk and Resilience

Despite undergoing numerous partial refurbishments during their life-cycle, older hospital buildings may become less, rather than more resilient, over time. This thesis attempts to determine the possible reasons for this and to identify the influences and underlying mechanisms that contribute to this loss. The thesis looks at the partial refurbishment of hospital buildings in the NHS, at different levels of magnification (Figure 1.1). At the micro level the refurbishment project is considered through the lens of change and examines how changes to projects can cause delay and cost increases, and generate cascades of change in other connected systems, resulting in unfulfilled aspirations (Chapters 6 and 8). At the meso level, hospital buildings are examined, particularly with respect to the refurbishment process and how this process may conflict with the needs of the existing building (Chapter 7). At the macro level, the thesis looks at the NHS organisation and considers where decisions about building refurbishments have had an impact on overall resilience and considers the implications for resilience within NHS Trusts and for the NHS estate generally (Chapters 9 and 10).

![Figure 1.1. Thesis Levels](image-url)
1.1.1 Constraints and Responsibilities

The recent “high profile” fire at the National Trust’s historic Clandon Park, illustrates some of the problems that beset organisations attempting to maintain or refurbish their elderly or historic buildings. The report by the investigators acknowledged that older buildings, with a long history of changes or refurbishments become increasingly vulnerable to serious outbreaks of fire (Strudwick, 2015). This poses real risks for building occupants, especially those that may be frail or unwell. Unfortunately, on NHS hospital sites throughout the UK, there are many examples of ageing, hospital buildings that have undergone numerous “piecemeal” refurbishments over time. Picture 1.1 depicts the devastating fire that destroyed the roof and almost all of the historically significant interior of Clandon Park.

![Image 1.1 National Trust Clandon Park Fire (2015)](image)

Links to further images of the Clandon Park fire:


“....buildings of this construction and age (some 290 years old) would have been adapted and/or changed for different uses and to add more modern amenities, for example: heating, water supplies, electricity etc., many hidden
voids in the building construction are produced. Some of these voids may be known and others may, due to loss of buildings plans and records, not be known. It is the hidden voids in this type of building that allow unpredictable and uncontrollable fire spread and cause problems when trying to effectively protect the building from fire.”


Many older NHS hospital buildings share similar histories of little or no documentation, unrecorded changes and poor management of their fire protection systems. In January 2008, an intense fire broke out in London’s world renowned Royal Marsden Cancer Hospital, engulfing large areas of the hospital’s Chelsea Wing. The fire’s rapid spread led to the complete evacuation of 198 patients and almost 200 staff. Two patients were anaesthetised and undergoing surgery at the time and six were in intensive care.

“the entire hospital had to be rapidly evacuated, with the fire spreading unpredictably via oxygen ducts and falling roof timbers from the attic to the first floor of the ICU.” (Murphy and Foot, 2011)

Fortunately on this occasion there were no fatalities. However the hospital’s Chelsea Wing was severely damaged and adjoining areas suffered extensive smoke and water damage. The roof, plant room, two wards, five operating theatres, a restaurant and ancillary accommodation, were all destroyed in the blaze. It appears likely that successive refurbishments and intermittent maintenance had gradually eroded the integrity of the fire barriers, reducing the building’s ability to contain the spread of fire. Consequently, despite necessary refurbishments, system upgrades, and regular maintenance, the building had become less resilient over time.

“if you can get such a dramatic and dangerous fire in what is regarded as a relatively safe and well-managed hospital, what would happen in an institution which was in an older or less well-managed building?” (Valerie Shawcross, Chair of the London Fire and Emergency Planning Authority, 2008).

The NHS Trust was able to call on its available resources, including the expertise of staff, the good-will of the local community and uncommitted financial resources. These
resources were initially used to ensure the safety of patients, secure temporary mobile facilities and to reschedule patient appointments. Consequently patient care did not suffer unduly, and the hospital was able to reorganise and return to full capacity. Hence, although the fire resistance of the building had become compromised, and over time the resilience of the building had been eroded, the hospital as a whole remained resilient. Hence, the extra resources that were available to the Royal Marsden allowed it to resume normal functioning. If a hospital with significant financial difficulties (that is, less resilient) suffered a fire involving a similar level of disruption, the recovery process might be considerably more difficult, or uncertain. Moreover, serious fires are not restricted to elderly buildings and fire containment systems can become compromised in buildings of any age during the repair or refurbishment process. The links below identify examples of serious fires in a range of NHS hospital building types, including some buildings of more recent construction.

Strathmore Hospital Dundee Fire (2015)

http://www.bbc.co.uk/news/uk-scotland-tayside-central-32288172

Chase Farm Hospital Fire (2008)


Chesterfield Royal Hospital (2011)


1.1.2 Hospital Buildings: Robust, Reliable or Resilient?

The essential function of a hospital building is to support the care process. Consequently both the buildings and the care processes carried out within them, must be resilient if services to patients are to be provided without interruption. In effect, hospital buildings represent only one system within the complex web of the healthcare process.
Robustness and reliability

For a building to be “robust” to a specific threat, such as a fire outbreak, every effort must be made to ensure that a fire does not occur. Subsequently, in the event of a fire event developing, the necessary fire equipment and containment systems (e.g., alarms, sprinkler systems, fire dampers, fire-safe compartments and smoke control systems etc.) must have been regularly inspected, tested and maintained. Although the risk of fire at any one time may be relatively low, the consequences can be completely devastating and accordingly, a high level of preparedness is essential.

A building protected as described above can be expected to be safe for patients in the event of a serious outbreak of fire and can be considered to be robust to the threat of fire. However such a building should not be considered “reliable”, as the likelihood of failure in an emergency from other less robust hospital systems may be high. For example, a power outage or a flood event could still overwhelm a facility. For a building to be considered reliable (within defined limits), there must be a range of systems in place to ensure that expected threats can be managed, and normal activities can continue, without danger to the occupants, or significant damage to the buildings structure or fabric, or to the services provided by the facility.

“Resilient” buildings, on the other hand must, be able to function, even where the type of threat is unanticipated or surprising. This means that the hospital’s critical systems must function in the event of unpredictable incidents or combinations of incidents so that the building’s functionality is maintained, even if at a somewhat reduced capacity. Resilience in such circumstances, requires that experienced staff are on hand and able to make immediate responses to complex situations: and that spare or flexible resources are available to provide additional options for managing unexpected situations or impacts.

For buildings to function in situations where cascades of failures are conceivable, such as floods that result in power and/or transport failures, then alternative, duplicated or redundant systems for key services provide continuity options for critical systems.
Resilience Resources

Resilience, is a complex consideration for NHS hospitals and has wide-ranging organisational implications. Resilience, for NHS staff may involve high level, educational input and significant situational training, whereas technological system resilience may depend on such factors as system diversity (i.e., having alternative methods or systems for providing services), redundancy (having spare systems or components in the event of a failure) and flexibility (providing shared or adaptable resources). Maintaining resilience during periods of change, such as during short-term refurbishment projects, may require that Trusts or hospitals make additional resources available, so that it is possible to meet the project goals, without detriment to existing hospital systems.

Resilience Definition for This Thesis

Central to the development of this thesis is the distinction between a building’s robustness to specific threats, such as fire, weather events or power outages; and a hospital’s overall resilience, which allows it to continue functioning, reorganising and adapting, as required, despite the very broad range of threats that may arise. Consequently resilience is seen as a way of “keeping going” and maintaining functionality.

For this thesis, a definition of resilience suitable for NHS hospitals can be considered as:

Ensuring sufficient continuous functionality to protect patients and sustain their care, whilst safeguarding staff and visitors, and maintaining existing systems as far as possible, in the event of a serious threat (or threats) arising. (See Chapter 2.5 for a more detailed consideration of resilience definitions).

However resilience has both short-term and long-term perspectives. The short-term perspective identified in the above definition, focuses on maintaining safety and providing essential patient-care support systems during, or in the immediate aftermath of a hazardous event. A range of perspectives on resilience is presented in Chapter 2.5 and a resilience definition suitable for the long-term, is developed in Section 9.3.2.
1.1.3 Major Incident Risks and NHS Resilience

The Royal Marsden Fire was not an isolated event for the NHS. Indeed, it was just one of five serious fires in London in the 14 months between January 2008 and March 2009 (NHS London, 2009). Until 2011, when the reporting of NHS fires ceased to be mandatory, there were an average of 500 hospital fires annually, resulting in 65 injuries and one or two fatalities each year (Murphy and Foot, 2011). Unfortunately, the situation does not appear to be improving. Recent statistics confirm that there were 1,364 NHS fire incidents recorded in 2014/2015, resulting in one fatality and 47 injuries. It is also possible that the figures do not provide the full picture, as there may be some level of underreporting.

The NHS Retained Estate has a number of buildings that may be equally vulnerable and the Royal Marsden fire illustrates just one area of concern for NHS Trusts (Edwards et al, 2004; Aldridge, 2016; Coleman, 2015). Since the Royal Marsden fire (widely regarded as a “wake-up call” to NHS Estates), ensuring the integrity of hospital fire barriers has become a priority.

Typically, major incidents or unexpected serious events trigger protocols that can result in the cancellation of elective treatments, patient transfers, large-scale disruptions or even full-scale evacuation. The possible consequences of such events include anxiety or harm to patients and damage and loss to buildings and equipment; the after-effects of which may persist for months or years after the event.

Risks such as fire, heatwaves, flooding, severe snow storms, infrastructure breaks, chemical and gas escapes, etc., are all considered within NHS Trust incident plans along with detailed risk registers and major incident training events. During NHS training events there are frequent examples of critical planning failures, shortages of essential resources, equipment breakdowns and instances of non-compliance with safety advice or legislation (Aldridge, 2016; Urry, 2008; NHS London, 2009; Murphy and Foot, 2011). Moreover when real incidents arise, it is not unknown for backup systems to fail; or for there to be a collapse in communication; obstructed access to key resources such as pharmacy; and essential spare equipment found to be inoperative.
Modern acute hospitals operate at, or near, full capacity and can rapidly become overstretched or unable to maintain the full range of essential services. In such cases, the risks for acute or seriously ill patients can be significant.

The links below also illustrate flooding caused by leaking service pipes 2015).

Flood at Queen Elizabeth Hospital (2015),
http://www.bbc.co.uk/news/uk-england-birmingham-33800654

Redcar Hospital (2015),

These ever-present continuity risks, feature prominently on NHS estate manager’s priority lists. Nevertheless, immediate budget pressures may mean that fire-protection or other essential resilience resources become progressively eroded.

“I think it does show that we do have a particular problem dealing with the Health service when people are distracted by so many other pressing issues and financial demands.” Valerie Shawcross (Chair of the London Fire and Emergency Planning Authority, 2008).

1.1.4 Less Immediate but Equally Serious “Creeping Onset” Risks

A gradual change in a population’s susceptibility to disease, increasing antibiotic resistance, or a change in the public’s health care preferences could eventually overwhelm vulnerable healthcare services. A rapidly increasing need for out-patient services has been one consequence of the rise in diabetes-related diseases (Clement et al., 2004). Diabetes has risen by 58.9% in the last decade and is now estimated to affect four million people (Diabetes UK, 2016).
Similarly, the growing pressure on A&E services has stretched many acute hospitals in the UK. This rising demand for A&E treatment was considered by the UK coalition government (2010-2015) to result from people’s changing preferences for care, which, they suggested, led many to by-pass the primary care referral process (Simpson et al., 2015). In response, a £50 million “Challenge Fund” was set up in 2013 to support wider access to GPs in the hope of alleviating the pressure on A&E Departments. Increased access to GP services remains a key goal of the present government’s primary healthcare policy, although as yet, there appears to be little hard evidence to support the view that this will halt the rising demand for A&E services.

A gradual escalation in demand for specific types of health care may result from population changes. For example, the growing tendency of UK pensioners to retire to Britain’s south coast has severely stressed the services provided by hospitals in the UK’s southern half, and this pressure has been exacerbated by the high levels of co-morbidities suffered by elderly people, as they become vulnerable to other health issues over time.

Some risks, such as those posed by climate change, may affect large areas of the NHS retained estate within the same time-frame. Hence, preparation for such a large-scale risk must begin long before any expected outcomes materialise. Adapting the vast acreage of the existing NHS estate to perform adequately in a changing climate will require significant and co-ordinated prior planning, owing to the considerable construction time involved. As climate change progresses, predicted weather effects, such as severe storms, flooding and high summer temperatures, will become increasingly common. However, the process of adapting the existing estate to function appropriately in these extremes has barely begun.

Critically ill patients, those in mental health units, and patients recovering from surgery, are extremely vulnerable to overheating. Indeed many hospital buildings are already finding it difficult to protect patients from overheating during warm summers. Equally, at least 7% of UK hospitals are located in flood prone areas (Bagaria et al., 2009) and particular problems exist where access tunnels, plant rooms and service equipment/infrastructure are located at ground level or below, giving them increased risk of being inundated by contaminated flood water. Furthermore, many hospitals have
envelopes that were not designed to withstand the more aggressive storms, wind-loads or summer temperatures predicted for the UK.

1.2 The Research Aim

The DeDeRHECC project, which sponsored this research, was tasked with investigating the possibility of increasing the resilience of hospitals to climate change, particularly to heatwaves, through the process of building adaptation or refurbishment.

This PhD specifically addresses the partial refurbishment process in the NHS and considers how the process may affect the resilience of hospital buildings. Partial refurbishment involves the refurbishment of specific areas of a building, typically a ward or group of wards, a department, specific floors or an entire block. Four NHS Trusts were project partners and provided access to four completed refurbishment projects, one from each Trust. The Trusts facilitated interviews with people who were key to the refurbishment projects, gave access to hospital buildings, and provided much helpful documentation. In this thesis, each refurbishment project is the basis of a case study and these case studies underpin the work reported here.

Essentially, from the climate-change perspective, it may be important to understand the constraints and barriers to refurbishment, as refurbishment is the essential mechanism for adapting hospitals, to make them less vulnerable to climate impacts.

Hence, the overall aim for the research is:

To explore the hospital refurbishment process through a systems perspective and to determine how refurbishment might affect the realisation of long-term resilience in the NHS, particularly where changes may be required within constrained refurbishment boundaries.

A series of elaborating research questions is presented below (Section 1.2.1).
1.2.1 The Research Questions

It is usually necessary to understand the constraints and barriers that might affect the processes involved, which for this research, include those factors that affect the process of refurbishing hospitals. As the research progressed, the data analysis from each phase suggested or contributed to the subsequent phases.

A variety of issues fed into the formation of the research approach, including those identified below.

1. In practice, there were no preconceived assumptions as to how resilience or change would operate in partial refurbishment projects. Indeed, at the outset of the research there appeared to be very few recent peer-reviewed research papers relating to either refurbishment in the built environment, organisational resilience, or to the mechanisms involved in the change process in refurbishments. The previous experience of the team researchers suggested that changes required during projects appeared to affect their outcomes. Hence change was thought to be a useful area of research when considering hospital refurbishment and resilience.

2. It was thought useful to apply an approach to the problems of change that had been successful in another domain. In product engineering, changes to projects during the design process can be very problematic and result in the loss of desired qualities or goals, or at worst, if managed poorly the project may end in outright failure (Eckert et al, 2004). If this approach could be considered as transferable to the built environment, it suggests that there is a risk that changes to refurbishment projects could present a potential barrier to the process of refurbishing and adapting hospitals to climate change.

3. It was also considered necessary to capture issues related to the working hospital environment, and staff perspectives about the purpose/value of refurbishment and their perspective on resilience (estates, doctors, nurses, etc).

4. Further uncertainties included the process of NHS decision making in refurbishment, and how climate related decisions would impact on hospital refurbishment in the short or long term.
To address these issues, this thesis will focus on the research questions in Table 1.1.

**Table 1.1 Research questions addressed in this thesis**

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| 1 How are refurbishment projects carried out in the NHS?                         | • What are the main drivers, barriers and constraints to hospital refurbishment?  
• How do changes impact the refurbishment process?  
• How does the change process unfold and what mechanisms underlie the refurbishment change process?  
• How do changes to refurbishment projects impact on stakeholders? Are some refurbishment objectives less likely than others to survive the design/construction process?  
• Is there convergence or mismatch in the priorities of the contractor, user and client? |
| 2 How does scope change impact refurbishment projects?                            | • How does strict adherence to refurbishment project boundaries; or alternatively accepting some degree of scope expansion or “scope creep”, influence project/building/hospital/NHS resilience?  
• Are there benefits that could be achieved by permitting specific scope changes? How could such benefits be re-interpreted in terms of project success? |
| 3 How is hospital building resilience affected by refurbishment?                  | • How and why do project changes impact connected hospital systems?  
• How does the building refurbishment process affect resilience in NHS Trust hospitals, and/or the NHS organisation?  
• Can partial hospital refurbishments compromise the resilience of NHS hospital buildings over the long term? |
There appeared to be a distinct gap within the literature in the area of the relationship between refurbishment and resilience. It might be considered a logical assumption that as more areas of a hospital building are refurbished, the hospital building as a whole should become more resilient. However it was not possible to locate research that had either suggested, negated or confirmed this. It was also considered important to identify how resilience could be improved for refurbishment projects, for NHS hospitals and for the wider NHS estate.

1.3 Overview of the Research Approach for this Thesis

The thesis adopted a qualitative approach drawing principally on four case studies of refurbishments in NHS Trusts geographically dispersed across England, and supported by additional expert interviews. Following the selection of the topic area, the research progressed through a largely linear, staged process as shown below in Figure 1.2. Although the stages were sequential, they overlapped considerably, especially in the case of an on-going literature review, which continued throughout the research process. In practice, the major part of the work was focussed towards identifying the research gap and research questions, and developing the knowledge base for planning and carrying out the research studies. The case study planning was carried out with the guidance of the DeDeRHECC project team, however the preliminary study, the research analysis, the development of the conclusions and validity considerations were all informed by the literature study.
1.4 The Structure of the Thesis

The thesis is organised in 10 chapters. The current chapter has introduced the research area and the aims of this thesis. Chapter 2 presents a review of the relevant literature. Background research related to the specific area of UK construction change is comparatively sparse, but the research themes developed within the thesis draw from number of disciplines, including product engineering, ecology, risk management, reliability and complexity theory. Hence the review is necessarily broad and wide-ranging rather than focussed and deep. Chapter 3 describes the structure of the NHS in England and considers the critical issues that are particularly relevant to this study. Chapter 4 explains the research perspective taken and describes the methodology adopted for this study. Chapter 5 describes the empirical studies undertaken for the research.
Chapter 6 looks at how the change process operates in refurbishment applications, and compares this with the change process in product engineering. It presents a framework for conceptualising the refurbishment process that can also be used for mapping refurbishment changes. The consequences of change propagation are considered in some detail. Chapter 7 considers the refurbishment process within the NHS context and examines the barriers, constraints and implications associated with refurbishment changes. Chapter 8 looks at the process of mapping refurbishment project changes and considers whether it is possible to identify commonly occurring groups of change, or change motifs to aid project planning and analysis. Chapter 9 considers systematic issues within different NHS organisational levels and the implications for resilience. Chapter 10 presents the conclusions from the study and considers possible options for future research.

Output from the DeDeRHECC project includes the following papers that I co-authored: Ariyo, Garthwaite, Eckert and Clarkson (2012); Eckert, Stacey, Wyatt and Garthwaite (2012); Garthwaite and Eckert (2012a); Garthwaite and Eckert (2012b). Garthwaite and Eckert (2012b) forms the basis of Chapter 6 and Garthwaite and Eckert (2012a) forms the basis of Chapter 7.
Figure 1.3 The structure of the thesis
Chapter 2 Review of Relevant Literature

Mach’s dictum: “Erkenntnis und Irrtum fließen aus derselben psychischen Quellen; nur der Erfolg vermag beide zu scheiden.”

(Knowledge and error flow from the same psychic sources; only the success can separate both).

2.1 Backcloth to this Research

2.1.1 The NHS is changing

Many aspects of hospital practice in the UK are undergoing considerable upheaval and this is largely, though not exclusively, due to a combination of political changes, the global economic downturn and escalating healthcare costs (Majeed, 2013; Maynard, 2013; Bosanquet, 2013; Reeves et al., 2013). Issues such as the introduction of General Practitioner (GP) healthcare commissioning; Sustainability and Transformation Plans; the ageing national demographic; changing patterns of disease, along with concerns regarding quality of care particularly in response to the Francis Report (Francis, 2013) are impacting on the way the NHS provides its healthcare services. Major efforts at restructuring the NHS have been ongoing over its history in response to various government priorities (Webster, 2002; Tallis, 2004). Sir David Nicholson, the Chief Executive of the NHS (2006-2014) commented that the recent reforms (GP commissioning) were ‘so big you can see them from space’ (The King’s Fund, 2015).

Clearly, the ability of the NHS to continue to provide high level healthcare services, continuously, over a very long period in a constantly changing environment, suggests
that the organisation has been fundamentally resilient. However, there are many challenges facing the NHS and one such relates to ensuring that the NHS estate is fit for purpose for the coming decades. Indeed the NHS estate must continue to support the delivery of services during a period of rapid clinical and technological development, with an aging population, a changing climate and restrained funding. Hence, this research is situated within the wider general context of the external risks facing the NHS and the consequent need to improve resilience and efficiency and reduce dependence on fossil fuels.

2.1.2 Research Themes

This research considers the impacts for NHS hospitals, related to uncertainties such as the predicted rising summer temperatures, altered funding for hospital estates, or changing healthcare priorities etc. Hence a broad review of the literature has been necessary to understand both the internal and external stresses that affect NHS hospital systems, such as the risks associated with climate change and the consequences for patients, staff and hospital buildings required clarification. Other external influences include government priorities and their initiatives related to rising fuel costs; demographics and changing patterns of disease; the “Urban Heat Island” effect (UHI) and air quality issues, amongst many other factors. The core context for the research relates to the NHS’s significant portfolio of ageing hospitals, which struggle to provide “year-round” comfortable environments for staff and patients; along with the numerous constraints that affect the design and refurbishment process; and the ongoing radical changes within the NHS organisation resulting from the “Health and Social Care Act” of 2012 and the impending changes that will result from the recently completed NHS Sustainability and Transformation Plans (2016), that have been designed to improve NHS healthcare efficiency and sharing of services across Trusts in local areas and reduce the potential for budget deficits for regions of NHS England.

Several themes such as change, refurbishment, and resilience, interweave throughout the research and underpin the logic of the thesis, (Figure 2.1). However these themes are more specifically addressed in Chapters 6, 7, 8 and 9. Initially, the focus is on how organizations manage their risk to improve their functional reliability under stress, and consequently, develop their resilience. Section 2.2 considers the evaluation of risk
factors and the influences that determine how risks are managed/mitigated or considered acceptable. This is significant because, it is the *predicted* risk of serious local climate/weather changes that the NHS must address now, if it is to minimise the future risk to patients. Hence the question as to whether the NHS should spend very large sums to adapt hospitals to mitigate against an uncertain future, is relevant here, particularly as the opportunity cost associated with this choice means that less funding is available for new treatments and research for today’s problems. For this reason, Section 2.3 gives a review of the precautionary principle in the context of both the NHS and medical practice, and legislation related to it.

![Logic of the thesis](image)

**Figure 2.1 Logic of the thesis**

A consideration of how other critical organisations manage to operate reliably and avoid disruption over very long periods is included, and is particularly relevant to the climate challenges facing the NHS. Typically, for most organisations, including the NHS, accidents and disruptions are the clearest outcomes of risks that materialise, and literature about how these occur is reviewed in Section 2.4, where an organisational approach to reducing the risk of accidents or disruption is discussed. In Section 2.5 the focus is explicitly on resilience, and discusses the distinct views of resilience taken by different disciplines. The review then concentrates on topics relevant to the
refurbishment. In Section 2.6, it briefly considers the meaning of building refurbishment before a longer section (Section 2.7) considers maintenance and refurbishment issues associated with NHS hospitals. The pressing need for hospital adaptation is also considered. Section 2.8 describes the background to the contractual issues associated with such refurbishment. Section 2.9 considers the process of refurbishment and Section 2.10 looks at the problems associated with changes to projects and how this can impact on overall success.

The review draws primarily on academic peer reviewed journals, although where necessary, “grey sources” are consulted, such as government reports and legislation; reports from charitable trusts (such as the King’s Fund); the national meteorological service (Met Office) advice; Department of Health (DoH) and NHS guidelines and documents; along with industry and international standards. On occasion, reports from the national press have been included to provide examples of the specific issues under study.

2.2 A Brief Description of Risk, Complexity, and Connectivity

2.2.1 Risk

The Oxford English Dictionary (OED) defines risk as “a situation involving exposure to danger”, however this interpretation is somewhat limited and provides little useful characterisation. Lowrance’s definition of risk below improves the description by including the notion of the possible consequences along with an idea of quantification,

“Risk is a measure of the probability and severity of adverse effects.”

Lowrance (1976, p.94)

In their seminal paper on risk, Kaplan and Garrick (1981) distinguished between the constructs of “uncertainty” and “risk”. They suggest that uncertainty about an event does not necessarily entail danger or injury and might simply relate to which of various outcomes might be preferable, whereas the notion of risk does include the perception of damage and considers whether or not a damaging event will occur. Hence they describe risk as
“Risk = uncertainty + damage”


In epidemiology, risk is considered as “the probability that a particular outcome will occur following a particular exposure” This introduces the suggestion of “sequence” or “timing” into the definition. Furthermore, Haimes (2009), points out that “the time frame plays a central role in risk assessment” and he argues that the question “what can go wrong?” is fundamentally related to the consideration of the timing.

Kaplan and Garrick (1981) maintain that the optimised combination of cost, benefit and risk, provide the only means of evaluation to achieve an “acceptable” level of risk.

Whittingham (2004), considers that,

“It is frequently stated that the risk of an activity can never be reduced to zero, but can hopefully be reduced to a level which is considered acceptable when weighed against the benefits of the activity.”

Whittingham (2004)

In engineering, risk is most usually defined as the combination of likelihood and impact (Clarkson et al, 2004a). Similarly, the product of these two parameters is generally used to provide risk rankings in risk registers used by organisations to assess and prioritise their risks. However, Williams (1996) argued that such a risk ranking can give a seriously inaccurate view of an organisation’s risk position. He pointed out that the risk register is used to support decisions about which risks are included or excluded from contracts and that a single ranking does not provide enough information for such critical decisions. He suggests that it is “obvious that a 10⁻⁸ probability of a loss of £10⁹ is not the same as a probability of 10⁻¹ of a loss of £100”. Nevertheless, he identified that very simplistic risk estimations figure strongly in determining risk priorities for many organisations, and this is also true for the NHS.

The International Standards Organisation (ISO) risk standard (ISO 31000, 2009) describes “risk” as the “effect of uncertainty on objectives” and explains that this effect can be “a positive or negative deviation from what is expected”. The standard should help to
improve the way risks are considered and assessed by developing a more holistic perspective. ISO 31000 does not prescribe the method of determining risk, but encourages an integrated approach that is sensitive to the assumptions that may be made about a risk (Purdy, 2010). Essentially, ISO 31000 maintains that how risks are viewed will depend on the risk criteria. According to the standard, these risk criteria (derived from standards, laws, policies, etc.) should be carefully considered in relation to the organisation’s values, policies and objectives, whilst also taking account of the organisation’s external and internal context.

The external context typically might include the “views of external stakeholders, the local, national, and international environment, key drivers and the trends that influence its objectives”. The internal context would relate to the organisation’s “governance, its contractual relationships, and its capabilities, culture, and standards.” These criteria can help to provide a clearer perception of the risks and whether a specified level of risk is acceptable or tolerable. The standard recommends that to be effective, it should be incorporated within an organisation’s decision-making processes, although Purdy (2010) suggests that many organisations find this difficult in practice.

In healthcare all risks (organisational and operational) ultimately impact, to some extent, on patient-care, either through the risk event occurring, or through the costs of analysis and mitigation. According to Sheridan, (2008), most patients and their families (who are also stakeholders) tend to be exceptionally risk averse, particularly with regard to their children’s health, where the level of acceptable risk tends towards zero (Sheridan, 2008). Nevertheless risk is present in various forms in all healthcare systems and the onus is always to identify and minimise these risks as far as possible. Sheridan (2008) also noted that where there are multiple outcomes associated with a risk, this can add a significant level of complexity to the evaluation of consequences.

The level of risk posed by a threat may depend on the context. Risks can be classified in various ways, such as “external” as mentioned above, (e.g., demographic changes, severe climate events, earthquake etc.), or “internal” (e.g., changes in funding, failure of infection control policy). Alternatively, risks can be classified as “immediate” and obvious, such as major accidents or acts of war; or they may be subtle and “slow to register”. The Intergovernmental Panel on Climate Change (IPCC) notes, in the final
chapter of the Fourth Assessment Report (Confalonieri et al., 2007), that disaster risk reduction is most commonly associated with large-impact high-risk studies and perhaps there is a failure to recognise that “creeping onset disasters” such as slowly rising temperatures, may be more significant and greater in effect in the long-term. Calman (1996) classified risks as “avoidable or unavoidable; known or unknown; or justifiable or unjustifiable”. Avoidable risks, for the NHS, could be considered as those that can be prevented or mitigated in some way, for example by careful design of systems or equipment to eliminate the possibility of error, injury or mishap. Unavoidable risks include those risks whose timing cannot be easily anticipated such as national strikes; insolvency of supply chain partner; or they may be associated with sudden infrastructure failure; a severe weather event; or a terrorist act. Known risks can be evaluated within a range of likelihoods and consequences, (Calman, 1996).

2.2.2 Justifiable Risk

Classifying a risk as “justifiable” presumes a particular perspective and depends on the perception of the risk and the qualifying circumstances. What may be a justifiable risk for a patient with an incurable illness, may be totally inappropriate for a patient with alternative options. Unknown risks, however, can on occasion be the cause of serious danger to patients or disruption to systems, as their nature, likelihood or consequences may be unimaginable or unquantifiable.

Bovaird and Quirk (2013) looked at risk and resilience in public institutions, and suggested that risk management approaches such as risk tools, frameworks, registers, matrices, spreadsheets, guidance and software and elegant risk registers, local risk champions and ‘traffic-light dashboards’ are a response to the requirement for accountability, fiscal prudence or operational reliability. They considered that such tools are focused towards limiting a public organisation’s own internal risks, rather than reducing the hazards that might be experienced by service users (Bovaird and Quirk, 2013). Hence these tools may be considered to support self-preservation strategies and the “blame and shame” approach to risk management, rather than making an earnest effort to reduce public risk and improve community resilience. Bovaird and Quirk (2013) also argued that such approaches can even be counter-productive as risk registers have little “theoretical underpinning” and may mislead institutions regarding their actual
risks, leading to an inaccurate view of the risk backdrop and thus presenting decision makers with the misconception that they may have some control over the risks that may present. In actuality, decision-makers using such tools may have little understanding of the scale of the risks they face, or of their capacity to control or remedy greatly underestimated consequences (Bovaird and Quirk, 2013).

2.2.3 Systems and Complexity

Russell Ackoff (Ackoff, 1994), characterised a system as “a whole that is made up of two or more parts” and considered that system problems result, not from the actions of the parts of a system, but from the interactions between the parts (Ackoff, 1994). He suggested a thought experiment (Ackoff, 1995) involving the 457 different brands of automobiles available in the United States of America. He proposed that hypothetically, the best performing example of each type of car part, should be selected from among the 457 brands of cars. He then asked that, once the best possible performing car parts have been selected, would these, when assembled together, make the very best possible car? Clearly, the answer, he suggested, would be in the negative, as the parts would not fit together, and therefore the system could not work (Ackoff, 1995).

Ackoff (1995) proposed that parts of systems have three properties:

1. Each part can affect the properties of the system as a whole.
2. The way that each part affects the whole depends on what at least one other part is doing (i.e. no part acts independently).
3. If parts are grouped together into sub-systems, each sub-system has the same properties as the original parts.

He described systems as “a whole that cannot be divided into independent parts” and, as an example, he pointed out that the human body, as a system, cannot be sub-divided into parts, i.e., if a hand is removed from the body, the hand ceases to work. He further posited that since the parts interact, the properties of the system are a product of the interactions of the parts (not of the parts themselves). Hence when managing systems, it is not the activities of the individual parts that must be considered, but the interactions between the parts, (and he suggested this is both surprising and counter-intuitive). Crucially, he stated that “when you improve the performance of the parts separately,
you do not improve the performance of the whole, and you may actually reduce system performance” (Ackoff, 1995).

Herbert A. Simon, (Simon, 1991) described decomposable systems as those that could be reduced to simple components. For example he clarified that a bicycle can be disassembled to its basic components and then reassembled without any loss of functionality. Hence, he proposed that the bicycle can be considered to be a 

*complicated* system, but not a *complex* one. Large complex systems, he argued, are those systems that cannot be disassembled without losing functionality. Such systems develop emergent properties which cannot be found within any of the separate components. When disassembled, emergent properties cease to exist, such as “life” or “intelligence” in biological systems. For complex systems, it appears that the end product is greater than the combination of the individual component systems. Consequently it is not possible to reduce such complex systems to their individual components (Simon, 1991).

2.2.4 Wicked Problems and Complexity

“We can't solve problems by using the same kind of thinking we used when we created them.”

*Albert Einstein*

The term “wicked problem” was coined by Rittel, and first documented by Churchman (1967) and later expanded (Rittel and Webber, 1973) to describe problems in social policy planning that are particularly difficult to solve due to their complex and changing dependencies. This is opposed to the largely “tame” problems of science and engineering, where problems can be solved by unilinear thinking. They later elaborated on this idea, describing wicked problems as those with incomplete, contradictory, fuzzy or changing requirements that may be difficult to capture or even to recognise. Wicked problems are typical of complex dynamic systems like the NHS, where there are multiple interlinked systems with many levels of connectivity. Solving a problem anywhere in the system will, either marginally or profoundly, have an effect on the NHS, either locally or extensively (Rittel and Webber, 1973).
According to Rittel and Webber (1973), wicked problems are problems that are more than just complicated. He suggests that complicated problems (or “tame” problems) can be reduced to manageable parts, resolved and then reassembled. However with very complex or wicked problems, such as managing the UK economy or eliminating poverty, it is not possible or practical to isolate problematic areas for consideration. In effect, it may not be possible to actually define the problem or even detect the boundaries of the problem or of the contributing elements. Moreover, if a possible solution is considered for implementation, whatever its efficacy, it cannot simply be introduced back into the system without affecting the environment or system with which it interacts.

Rittel and Webber (1973) identified characteristics of wicked problems:

1. Each wicked problem is different. “Poverty”, for example, may be related to very different drivers in different countries.
2. There are no clear boundaries for wicked problems. One problem may be the precursor or consequence of another.
3. Solutions to wicked problems can be only good or bad, not true or false.
4. There is no template to follow when tackling a wicked problem.
5. There may be multiple solutions to wicked problems or alternatively, no possible solution and it is impossible to determine the range, as there are no criteria that can determine that all possible solutions have been identified.
6. There is always more than one explanation for a wicked problem, with the appropriateness of the explanation depending greatly on the individual perspective of the designer.
7. Every wicked problem is a symptom of another problem. This is due to the interdependencies between systems.
8. Each "solution" to a wicked problem is a "one-off" opportunity because a significant intervention changes the problem.
9. Every wicked problem is unique. The description or explanation of the problem will direct the approach to its solutions, however there can be many explanation for the same problem and there are no criteria to determine which is correct.
10. A solution can have serious consequences.
Hence solutions to current problems must accommodate or coordinate with changes that may be ongoing elsewhere within the wider system. Where communication between connected systems is poor, changes may proliferate unexpectedly, especially where connections between components of the system are relatively tenuous or obscure.

Changes made to any connected part of the NHS system may have a surprising impact on other parts of the NHS’s connected systems. Such changes may affect patients, or their care-team, or support systems such as the NHS buildings and equipment essential for their treatment. Indeed relatively minor system changes may inadvertently affect any of the other connected systems that underpin the healthcare process.

As solutions to wicked problems have no obvious end-point, interventions usually last until the available resource is depleted.

2.2.5 Connectivity and Coupling

The connections between systems or groups may be strong. That is, individuals or groups may be part of the same hierarchical team and work together on a range of many projects, or they may be co-located, working together. Conversely, connections or links may be tenuous, where there is only an occasional requirement for brief communication between groups. However, the fact that such connections exist, suggests that changes to one system may affect the other. Weick (1976) emphasised the importance of developing a language to understand the interactions between sub-units or parts of a larger system and introduced the idea of “loose coupling”. He considered that possible advantages and disadvantages of loose coupling between systems or parts of systems might include persistence, sensitivity, local adaptation, diversity, problem isolation, self-determination and loose coordination. The disadvantages that would most likely result from this type of organisation might include a lack of overall control and high levels of variability. However he stressed the difficulty of correctly identifying the interactions and the risks of misinterpretation (Weick, 1976).

Glassman (1973) suggested that systems or units could be considered as loosely coupled or tightly coupled depending on the number and strength of the variables they shared. A sub-system having few shared variables or weakly acting variables, compared to other
strong influencing factors, would give rise to loosely coupled systems acting with relative independence (Glassman, 1973). Orton and Weick (1990), were concerned that research was suffering from a lack of clarity in understanding and use of the concept, and suggested that only a one-dimensional view would envisage that organisations are made up of systems that display a range of connectedness from “loosely coupled” to “tightly coupled”. They described a more developed or dialectic image of loosely coupled systems as follows,

“If there is neither responsiveness nor distinctiveness, the system is not really a system, and it can be defined as a non-coupled system. If there is responsiveness without distinctiveness, the system is tightly coupled. If there is distinctiveness without responsiveness, the system is decoupled. If there is both distinctiveness and responsiveness, the system is loosely coupled.” (Orton and Weick, 1990).

This perspective might support a view that hospital clinical systems, which aim to reduce error by tightly controlling response and reducing distinctiveness, may display a large proportion of tightly coupled attributes. Conversely, according to Dubois and Gadde (2002), construction systems overall act as loosely coupled systems in their “pattern of tight and loose couplings (which) can be interpreted as a means of coping with the prevailing complexity in construction operations”, thus providing the necessary “ease” to reduce the pressures of tight couplings. In consequence, the way in which organisations or systems respond to outside stimuli and change may depend on the degree of interdependence (tight or loose coupling) and the overall prevalent pattern of relationships between sub-systems (Dubois and Gadde, 2002).

2.2.6 The Advantages of a Systems Perspective

Systems Theory (see Reynolds and Holwell, 2010) in effect envisages a world made up of a group or groups of interacting elements, and that those groups (or sets) of interacting components have emergent properties that form part of the wider combined system set, but that are not found in any of the individual groups.

A systems perspective (Moe and Smith, 2012) involves:

- a methodical approach to organisation
• a way of thinking about relationships between objects and processes
• a language for describing parts of a system
• and a way of envisaging the system activity

General systems theory provides an opportunity to view the built environment from various perspectives and helps in identifying basic characteristics common to all building systems. These include (Moe and Smith, 2012),

• Boundaries: a building’s electrical system will connect to the main supply infrastructure for an area and these two systems interact, usually at some distance from the actual building. Hence the boundary for any specific building system may exist within or well outside of the building.
• Feedbacks and control: Positive (reinforcing) or negative (stabilising) feedbacks may control building functions (Brager and deDear, 1998).
• Flows, sources and sinks: occupants, energy, water, waste, and communications are examples of the flows that circulate within a building. Sources and sinks identify the origins and destinations of these flows (Rees, 1999).
• Transformations: Buildings change during their life-cycle. From construction handover they become operational space. Eventually they become less effective as technology, processes, or fashions change, until functional obsolescence is reached. The process of refurbishment or adaptation may provide prolonged period/s of operation. Finally senescence and decay ensue, followed by demolition and in some cases, redevelopment (Mansfield, 2008).
• A resilience perspective: Buildings exist for long periods (60 – 250 years or more), although the various components may have very short lives, (Windows for example might need to be replaced every 15-20 years). Indeed, failure to manage these multiple scales of building components threatens the survivability of the whole. External influences or catastrophic events may also compromise buildings or building systems, and there must be the capability to respond or adapt appropriately.

Building systems involve interactions between the primary elements of the system:

• The building enclosure (envelope: fabric and structure);
• The inhabitants (humans, animals, and/or plants, etc.);
• Building services (electrical/mechanical/communications systems);
• Finishes, fittings, furnishing and equipment
• The site, with its orientation, landscape and services infrastructure; and
• External environment (access, location, weather and micro-climate).

Consideration of these elements through a systems perspective allows a holistic approach to building design, construction and management that fully values the various inputs and outputs over the building life-cycle.

2.2.7 Risk and Patient Safety

“Risk is the price we expect to pay when, in an uncertain world, things go badly. More precisely, risk is how we measure today the adverse impact or losses we think may happen in the future”.

Knight (1921).

Sheridan considered that, as risks are partly subjective, it may be possible to evaluate risk in terms of indifference. That is, for example, how much one would be willing to pay to avoid the consequences of a risk (Sheridan, 2008). This type of evaluation forms the basis of actuarial decisions. As might be expected, statisticians have developed a variety of probabilistic approaches to evaluating uncertainty and risk. Probabilistic approaches present results as distributions, which can include a variety of factors such as utility, variability or effectiveness, and which provide additional insight for decision-makers. However in research for her PhD thesis, Montgomery (2009) identified that many decision-makers find statistical reports opaque and difficult to interpret. Haimes (2009), suggests that a universally accepted definition of risk has been hard to achieve “as the concept is multidimensional and nuanced”. He argues that risk is ultimately a function of the state of a system, of the system environment, and of the initiating event.

For the NHS, this poses a significant challenge, as a risk assessment would need to consider multiple factors, and require whole system evaluation i.e., organisational, clinical, service, and estate monitoring along with an assessment of the wider environment i.e., catchment populations, competing service suppliers, changing funding priorities, and other risks. These assessments need to be ongoing, so that changing patterns of risk can be captured. In consequence, a much more integrated risk management system than is generally undertaken would have clear benefits for acute
hospital Trusts, although in practice, it might be a very expensive undertaking and/or extremely difficult to achieve. In practice, NHS risks tend to be assessed for their direct impact on specific risk areas, such as direct patient-related risks, estate risks, business risks, H&S staff risks etc, without the benefit of an holistic framework. A more inclusive model has been suggested by Hogan et al. (Hogan et al., 2008), which recommends a thoroughly integrated risk management methodology. However, their approach still remains heavily biased towards direct patient related risk monitoring with very limited attention to organisational and other risks.

A key aspect of managing risk relates to determining appropriate strategies for eliminating or controlling the risk. Such strategies would be directly related to the type of risk but often include design changes to equipment or processes, improved training and education, administrative changes, or improved monitoring and evaluation. Where patient safety issues are concerned, most mitigation strategies can be considered as either administrative or engineering-design strategies. Administrative strategies typically include signs, labels or protocols and provide advice or instruction (e.g., of the type “oral administration only - do not inject intravenously”). Engineering strategies involve actual design changes to processes or equipment which preclude or minimise options for improper or unsafe use.

Card et al. (2012) reviewed the literature on patient safety incidents and near misses that have been investigated using Root Cause Analysis (RCA), a methodological approach frequently used to promote learning from such incidents. Although the techniques and application vary across organisations and regulatory regimes, RCA is a commonly adopted approach to identifying and correcting the root cause of events rather than tackling just the symptoms. Card et al., (2012) concluded that there has been little systematic research to find the most appropriate way of managing the risks identified through RCA. Worryingly, they also discovered, from the two largest studies they reviewed, that risk control measures based on training and education “rather than improve the situation, generally made things worse”. According to Mills et al. (2008), this may be because when an adverse event occurs, the response is generally to introduce a new policy addressing or prohibiting the contributing factor/s. However the task of ensuring that all staff are aware of the new policy (including its rationale and
requirements) through effective training and education, may be patchy in execution and poorly monitored.

Similarly, in a personal communication from Bagian to Caird (Caird et al., 2012), regarding Bagian’s analysis of a series of historic surveys, that engineering strategies and administrative strategies appeared equally effective in managing specific risks when advance notice of a health and safety survey was provided (Caird et al., 2012). However Bagian (in Caird et al., 2012) found that this was not the case for unplanned surveys, where hospitals were much less likely to be compliant with administrative controls. Card et al. (2012) suggest, “the implication being that engineering controls work even when no one is watching; administrative controls often do not”.

Risks for the NHS eventually impact on patient treatment, comfort or safety to a greater or lesser extent as, ultimately, they either directly affect patient care or reduce the resources available for patients, either in their mitigation or consequences.

“It is often hard to judge the level of risk that can be tolerated. This is because the risk is balanced against the benefit and whether there is a better alternative to accepting the risk. It is reasonable to accept a level of risk if the risk from all the other alternatives, including doing nothing, is even greater. A risk is not acceptable if there is a reasonable alternative that offers the same benefit but avoids the risk. Acceptable risk may become unacceptable over time or because circumstances change.”

The National Patient Safety Agency.

Typically, risks within NHS acute hospitals are monitored and assessed by individual departments and reviewed periodically by the Board of Directors. In this way, trust managers seek to identify their strategic risks in relation to their objectives and planning horizons; governors monitor their risks of non-compliance under their legal, ethical and regulatory obligations and address identified system risks; clinical directors try to minimise their operational and patient safety risks; financial managers assess their business risks; estates managers regularly review their buildings, equipment, infrastructure and CRC Energy Efficiency Scheme risks; and ITC teams constantly monitor
the risks or threats to hospital communications and the confidentiality of patient information.

Healthcare risks may be considered in terms of their threat to overall system-wide reliability for each NHS Trust, where their magnitude and likelihood is evaluated in terms of their impact and in their consequences (which may be delayed) for connected systems. Risk registers that identify these risks are key elements of the risk control process and Boards are required to have robust risk control procedures. Clearly it is not possible to eliminate all risks, but identifying and minimising risk wherever possible and as far as is “reasonably practicable” is an NHS priority. Notionally, Foundation Trusts enable both providers (through their management structure and governing bodies), and users of the system (through their elected representatives) to play a part in making shared determinations of the level of risks they feel are acceptable. However this depends largely on the commitment of the Board towards participation and their ability to meet the expectations of users within the available resources.

In practice, English hospitals generally consider only the range of risks that they can actually envisage and healthcare workers may be working beyond their expertise when adopting sophisticated Risk assessment tools such as Root Cause Analysis (RCA) or Failure Mode and Effects Analysis (FMEA) (Card et al, 2014). In those hospitals where risk is treated systematically, once a risk is assessed, it is included within a set of risk matrices. The risk is then prioritised and a strategic action plan developed, for the avoidance, reduction, mitigation or elimination of the risk. Very obvious contingent risks may also be included in risk matrices, that is, where the failure of one element directly impacts on another closely connected element. Following from the results of Bovaird and Quick (2013) in Section 2.2.2, this suggests that Trust Boards may be making decisions without fully appreciating the extent of the risks involved.

However, the complex and significant dependencies that arise within an organisation or its environment cannot always be predicted and, in some cases, critical links may be missed as there is only distant or “loose” connectivity. An example of “loose” connectivity between system elements can be seen in the case of a major Australian public hospital, where a significant fracture in the fire detection /sprinkler system caused water to leak into the medical records archive. Although the major leak was
dealt with rapidly, a residual leak continued for some months. As addressing this residual leak would involve shutting down the hospital’s laundry operations, the leak was allowed to continue. A very heavy mould infestation developed which eventually cross-contaminated the entire medical records system, across multiple sites. The upshot of this unexpected connectivity resulted in multi-million dollar legal and remedial costs for the hospital. Critically, it was the physical proximity to the laundry operations that escalated a relatively minor problem into a serious incident. It would be very difficult to detect such weak linkages without employing a detailed systematic risk evaluation process such as a Design Structure Matrix (described in Section 4.7.4), to identify critical linkages.

Regrettably, the process of risk assessment and mitigation planning does not, of itself, provide resilience as it simply develops an organisation’s robustness to known threats. To build resilience, there must be the capacity to respond appropriately, not only to known or expected threats, but also to unexpected or “surprising” events, for which there will be no pre-prepared protocols or practiced scenarios.

At present, Foundation Trust status requires Boards to consider their risks appropriately (Clarkson et al, 2013). Predictable risks can be either external or internal and as these are foreseeable risks, they are generally included in hospital emergency plans and disaster training events. However even predictable threats can present in unexpected ways. For example, hospital overheating during a heatwave may be exacerbated by infrastructure failures, particularly as power and transport systems are vulnerable to heat.

Power generation is less efficient during hot weather and very high temperatures (40°C or more) may cause power stations to cut-out completely (Heatwave plan for England, 2011) and this has clear implications for hospitals. During the European heatwave of 2003, the water level in France’s rivers dropped alarmingly, and temperatures were so high, that it was impossible to ensure adequate cooling for the river-cooled nuclear power stations. In consequence, 16 power plants operated at a much reduced capacity, and there were concerns that supplies to hospitals might be affected. However the heatwave ended before hospital power supplies were compromised (Poumadere et al., 2005).
In the hot summer of 2006, electricity prices trebled as the rise in demand for air conditioning and refrigeration caused the UK National Grid to issue an “insufficient margin” warning. In the event, out-of-service power stations had to be brought online to maintain the supply. Few power stations have been built since the 2006 event and similar conditions could result in significant power outages, particularly if interconnector supplies from continental Europe were to be affected, as they were in the heatwave of 2003 (Ofgem, 2013). Even if power outages were to be avoided, electricity price fluctuations could result in severe stress for a Trust’s energy budget, in the event of the above scenario.

2.3 The Precautionary Principle

If an action is suspected of having harmful consequences to the public or environment, the precautionary principle states that the burden of proof that it is not harmful falls on those taking the action. This principle might normally be expected to provide an appropriate approach for managing the situation where there is uncertain information or evidence regarding the nature of a risk but where the impact may be significant. Typically, such situations arise in connection with threats to the natural environment, although there are situations where public health risks may require a precautionary approach.

Climate change may pose a significant burden on hospital environmental systems in the future and there is a clear choice to consider: whether to prioritise spending towards future mitigation of unknown local weather effects, or direct scarce resources towards existing patients. The precautionary approach is included within the United Nations Rio Declaration on Environment and Development (United Nations, 1992) to which the UK Government is a signatory.

Principle 15 of the Declaration states:

“In order to protect the environment, the precautionary approach shall be widely applied by States, according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”
The notion of cost-effectiveness is particularly significant as it differs from the "no-regrets" perspective, advocated by various political or environmental pressure groups such as Greenpeace, which focus on minimising or averting risk or mitigating possible consequences, regardless of cost (Greenpeace UK, 2013; D’Argo, 1995).

Although the Rio Declaration did not strictly define the precautionary principle, it has since become a statutory feature of European Law, again without a precise definition, although advice is given regarding its application. European law includes a legal requirement for a “high level of protection” and decisions based on the precautionary principle must ensure that damage is rectified and that the “polluter” must pay (European Union, 2010).

The precautionary principle appears, on the surface, to be a prudent approach to dealing with risks that may result in serious consequences and where there is little information about the likelihood or nature of the risk. However it is an extremely contentious precept. Its use is commonly associated with issues related either to health or the natural environment, and in Europe it can be invoked where there is only tentative evidence that future harm may result from an activity. Rather than acting precipitously, decision-makers may require a cost-benefit analysis to assess the opportunity costs associated with the available options: adopting the principle; taking no action; or waiting for further information. Essentially, the principle is aimed at encouraging decision makers to act to prevent the possibility of future irreparable harm, even when evidence is inconclusive. To some extent this should encourage prudent decisions and a “prevention is better than cure” attitude.

Critics claim however, that such “prudence” can seriously limit technological or scientific progress. For example, the UK’s controls on the research and cultivation of transgenic or genetically modified (GM) crops may have caused significant disruption to research efforts aimed at alleviating the lot of the world’s poorest people, who would benefit significantly from the improved yields and disease resistance of genetically modified crops (Levidow, 2001; Raybold and Poppy, 2012). Hence it may be that the opportunity
costs resulting from adopting the precautionary principle could be considered of greater environmental significance than the consequences of the original risk.

In the context of health, the consequences from inappropriately applying the precautionary principle can have serious adverse consequences. This is illustrated by the situation that arose with the Measles, Mumps and Rubella (MMR) triple vaccine. In a small uncorroborated study by Wakefield et al. in 1998 (as mentioned in Farrington, 2001) a possible link was suggested between the MMR vaccine and the medical condition Autistic Spectrum Disorder (known as ASD or autism). Although considerable previous research had shown the vaccine to be safe, the authors were unwilling to wait for corroboration and publicised their results in the popular press. The suggested link was later found to be unsound (Farrington et al., 2001), but the wide publicity afforded to Wakefield’s study had far reaching consequences and engendered serious concerns in the general population regarding the safety of the triple vaccine, greatly reducing uptake of the vaccine – in case of serious adverse side-effects, many took the precaution of refusing to have their children vaccinated.

The precautionary principle was designed to provide guidance in just such a difficult situation, but in this case there were confounding issues. If the NHS had invoked the principle and withdrawn the triple vaccine, this would, in all likelihood, have led to a significant drop in the overall population immunity (as adequate supplies of single vaccines require long lead times). Instead, the NHS continued to make the triple vaccine routinely available, but many people thought it safer not to have their child/children vaccinated, so that the overall level of immunity in the population fell. This decline in immunity can be directly attributed to the attention given by the popular press to poor quality research (Jacob and Hellstrom, 2000).

The MMR vaccine illustrates that issues involving risk are complex. Professor David Salisbury, Director of Immunisation at the World Health Organisation, in a presentation to the University of Cambridge Centre for Science and Policy (Salisbury, 2012), impugned the precautionary principle for precipitating a serious decline in population immunity (also known as “herd immunity”) in relation to the triple vaccine (even though the principle was not actually implemented by the UK Government Department of Health). The 2013 Swansea measles outbreak has been directly attributed to this failure to
maintain herd immunity through wide-spread MMR vaccine uptake (Ramsay, 2013). This lack of immunity resulted from the intense local publicity given to Wakefield’s misleading results coupled with the community distrust of government advice. Salisbury argued that the public should be protected from research of poor quality. However, Richard Horton, editor-in-chief of the Lancet, (Horton, 1998; Horton, 2004), maintains that it is essential to ensure support for research that might provide an early indication of a problem related to an accepted treatment or activity. He concluded that it was not the precautionary principle or the conflicting research that was problematic, but rather it was the lack of independence of the investigating bodies and distrust of government advice that should be addressed. Salisbury, however, emphasised that there is an onus on government to ensure that decisions are evidence-based, in the event of the principle being invoked. However in practice, one might question what level of evidence would be required? And if this level of evidence is very significant, would this in actuality, make the precautionary principle redundant?

The MRM vaccination example demonstrates the special case in healthcare; that even when the mitigation of a risk is neither appropriate, nor ultimately required, a government’s decision to refuse to mitigate an alarming risk, cannot prevent very serious consequences.

2.4 Accident Theory and High Reliability Organizations

One purpose for improving reliability is to reduce the risk of accidents. Reliability has a variety of definitions, depending on the systems that it describes. In facilities management, reliability has been defined as “the maintenance of capacity and function over time” or alternatively, in product engineering, “reliability” is defined as “the probability that a device or system will perform its intended function for a given interval of time under specified operating conditions” (Blank, 2004). Psychologists consider reliability as “the degree to which measures are free from errors and as such yield consistent results” (Paul,1979) and in research, the term reliability means the "repeatability" or "consistency" of results (Trochim, 2006).

Weick et al. (1999), suggest that the idea of repeatability is fundamental to the traditional understanding of reliability. Hence, they reason that, for organisations, this
notion of reliability based on an “engineering” definition or perspective has become ultimately linked with standardised routines and protocols. Over time, these may increase an organisation’s inertia and consequently reduce their adaptive capability. Weick et al. (1999), explains that focusing on repeatability through standardised routines to achieve reliable outcomes, fails to allow for variability. This is because set routines cannot cope with eventualities for which they were not designed. Weick et al. (1999) considers that achieving reliable outcomes requires the ability to deal with the unexpected, and they suggest that this can be realised through “stable cognition” or an understanding of how the system must respond to individual variations, or errors, in order to maintain its reliability.

2.4.1 How Accidents Occur

Human error is often quoted as the contributing or sole cause of tragic events. However, Sheridan (2008) defines human error as “an action that fails to meet some implicit or explicit criterion”, although he cautions that the nature of risk criteria can be somewhat arbitrary. According to Whittingham (2004) “...the cause of about 80 per cent of all accidents can be attributed to human error”. He notes that between 1988 and 2000, 66 people died and 434 people were injured in three separate British train crashes, and the cause of each crash was attributed to human error (Whittingham, 2004). However it is the view of Hollnagel et al. (2011) that a more comprehensive perspective looks, not so much at which individual parts have failed, but considers what system pressures led to either maintenance failures or faulty working practices. Hence it is the safety of the whole system that must be considered (Hollnagel et al., 2011). Nevertheless, accident investigations continue to search for a single causal event or broken part. This may be a natural reaction to search for a single cause for a failure event and hence it can be regarded as a “reactive mechanism”, but this type of “blame culture” may hinder the identification of the underlying causes such as maintenance failures, budget cuts and staff shortages. An alternative is FMEA (Failure Mode Effects Analysis), which is a systematic process designed originally to inductively assess the consequences of the failure of military components in the 1950’s, and which aims to prevent failures by looking at the outcome of each type of component failure to
Determine what the consequences would be (Tahera et al., 2012), hence this may be considered a protective or “pro-active mechanism”.

Dekker (2011, p.89), considered that accidents develop from system failures, as systems drift from safe operating conditions, towards greater and greater risk or vulnerability, through “the unintended and complex interactions between seemingly normal organisational, managerial and administrative features”. He suggests that, in this age of complex systems with inexplicable emergent properties, the “Newtonian-Cartesian logic” behind the idea that it is possible to understand this complexity by deconstructing the system and analysing the constituent parts is overly simplistic. Rasmussen and Svedung (2000) also view accidents as the result of inexorable management pressures within an organisation (in this case, focused on reducing costs) and they propose that, “Accidents are the effect of a systematic migration of organisational behaviour under the influence of pressure toward cost-effectiveness in an aggressive, competitive environment”.

Dijkstra (2011) explains that in the early days of technological innovation, systems were unreliable and technical difficulties were usually cited as the cause of accidents. Over time, systems became more reliable and the most likely cause of accidents then switched to human error. However, Dijkstra suggests that this phase is also coming to an end with the growing realisation that organisational factors make a significant contribution to accidents.

“Each year about 850,000 patients in England are harmed, or nearly harmed, by their hospital care.” Sir Liam Donaldson, in his introduction to “Medical Error”, NPSA, 2005.

Where a serious failure results in harm to patients, human error may be the immediate cause, but systemic organisational pressures, such as cost-cutting or efficiency drives, which result in staff shortages, mismatch of skills, faulty equipment, or deviations from normal procedures, may be the underlying problem source. Governmental pressure on NHS management to achieve ill-conceived targets; or continual “improvements” may produce “change fatigue”, (Meyer and Stensaker, 2006) which could ultimately lead to an erosion of safety margins and may already have done so (Francis, 2013).
2.4.2 High Reliability Organisations

“Every successful organization has to make the transition from a world defined primarily by repetition to one primarily defined by change. This is the biggest transformation in the structure of how humans work together since the Agricultural Revolution.” Bill Drayton (2012)

The NHS aims to operate dependably over the long term, and consequently, it is useful to look at research relating to reliable organisations. Some organisations require particularly high levels of reliability, termed High Reliability Organisations (HROs), such as nuclear power plants, international banks, infrastructure and communications systems. Beginning in the 1980’s, a group of researchers from the University of California’s Berkley campus identified that research relating to organisations that had suffered disasters and failed was plentiful, but research into organisations that should have failed but did not, was very limited. They considered that such HROs could provide useful operational models. They defined HRO’s as hazardous systems that produce “nearly accident-free performance” (La Porte, 1996), such as nuclear power generation, air traffic control, naval air-craft carriers, and rail systems.

Weick et al., (1999) considered that HRO’s

“all operate in an unforgiving social and political environment, an environment rich with the potential for error, where the scale of consequences precludes learning through experimentation, and where to avoid failures in the face of shifting sources of vulnerability, complex processes are used to manage complex technology”

The analysis of HRO case studies, including those mentioned above, led to the development of High Reliability Theory (HRT). The theory proposes that such HROs operating in high-risk environments can function reliably and safely despite the complexities of their technologies and the uncertainties of their environment. Weick et al. (1999) suggest that successful HRO’s have a predisposition towards “mindfulness”.
This, he explains, is related to their worries about failing (Weick et al., 1999). They also identified specific attributes common to successful HROs which contributed to an organisational “mindfulness” and these are:

- A preoccupation with failure and constant watchfulness
- A reluctance to simplify
- A sensitivity to operations
- A commitment to resilience
- An under-specification of structure

Greater detail of these qualities is provided below.

**Preoccupation with failure**

As HRO’s have few opportunities to learn from past failures, they have instead developed an acute sensitivity to vague clues or unusual or unexpected data or occurrences. Such clues are given very considered attention and, coupled with a willingness to take appropriate action, this enable HRO’s to manage variations. Any minor failure is not localised but regarded as a possible step in a chain of failures and hence the whole system is closely scrutinised.

**A reluctance to simplify**

Weick et al. (1999) explain that HROs resist the temptation to ignore specific data or possibilities that might be considered “unlikely” or make issues/problems manageable by simplification. They constantly try to see the “larger picture” and adopt very wide and varied perspectives so that the unknowns do not become unpleasant surprises.

**Sensitivity to operations**

This refers to the necessity for operators to have an understanding or “cognitive map” of their system as it stands, within a particular time frame, including a “situational” awareness of the performance and capability of the diverse systems that make up the organisation and an ability to predict short-term responses.

**Commitment to resilience**

Weick et al. (1999) suggested that High Reliability Organisations focus on strategies for anticipation or avoidance of disturbance, adopting methods that improve resilience.
However they emphasised that they use the term *resilience*, not in the sense of rebounding or bouncing back from an event, but more specifically in the sense of “managing” with the aim of controlling or containing an unfolding problem. Weick et al. (1999) found that HROs carefully and purposefully develop the management skills of their employees, whilst continually extending the range of options available to them for managing events or “fluctuations.” They explained that as there is no way of predicting all future problems, employees are encouraged to innovate and combine possible actions to produce still further management options, thus multiplying their choices for containing or controlling surprises. Somewhat surprisingly, they noted that a further contributor to organisational resilience comes from a lack of dependence on past experience. This, they explained, is because there is a keen appreciation that new and surprising problems are to be expected and that the capability to manage unanticipated events is critical.

*Underspecification of structure*

Weick et al. (1999), identified the need to “under-specify structures” and explained why this is helpful by considering the example of a firm that had a very organised and efficient distribution system (Turner, 1978). They found that a faulty batch of the firm’s product (a contaminated dextrose infusion) was thus very efficiently and reliably delivered to a very wide group of hospital customers, thus demonstrating how an orderly hierarchy can amplify errors. They suggest that a more flexible organisational structure with wider access to the decision-making process reduces the options for such amplification. Schulman (1993) identified that in HROs, knowledge and experience are considered as valuable or “important” as hierarchical rank, and the resulting array of perspectives that experienced individuals bring (“conceptual slack”) permeates the organisation, enabling decisions to be made quickly, by the most knowledgeable, and often on the spot. This is supported by an ease of access to top management who, by making themselves available at all times, promote rapid resolution of impending problems (Weick et al, 1999).
How long must organisations remain event-free to be classed as an HRO?

Roberts (1990) posed a question to decide if HRT applies to an organisation, “how many times could this organization have failed resulting in catastrophic consequences that it did not?” She advises that “if the answer is in the order of tens of thousands of times”, then the organization is a “high reliability organisation” (Roberts, 1990, p160).

According to de Bruijne and van Eeten, (2007), healthcare organisations can be considered High Reliability Organisations (HRO’s), as their vital function requires that they exist “not just to provide critical services to society, but reliable critical services”. According to Schulman et al. (2004), reliability is needed regardless of the turbulence of their operating environment. Indeed critical infrastructures, such as healthcare, transport, banking, water, energy and telecommunications, all aspire to achieve reliable service provision, as large-scale failure of any of these systems could result in disastrous consequences for society (Schulman et al., 2004)

Resilient Organisations

The above research into high reliability organisations has highlighted that there are crucial perspectives that help to ensure an organisation remains functional despite frequent threats to its core processes.

The pioneering work of Hollnagel et al. (2006) on resilience engineering suggests that to achieve resilience, management must be “mindful”, listening for the “weak signals” that may suggest system problems. Essentially, they suggest that management must monitor what is happening in their systems and anticipate change and respond appropriately. Rankin (2014) advised that managers must be cognisant of “work-arounds” that enable their systems to function under pressure, but to be prepared to intervene when systems are operating close to safety boundaries. As an example, NASA’s funding cuts and their flawed reasoning suggested that work could be done “faster, cheaper, better” but failed to identify that the eventual outcome of such an approach would result in seriously compromising systems. The pressure to speed the design, and innovate and reduce costs, meant that the organisation became increasingly brittle and blinded to the
eroding margins and unsafe practices that led to the high-profile failures of six of their sixteen missions in the 1990s (Woods, 2006).

Clearly, an organisation cannot be fully impervious to all threats, and unforeseeable events will inevitably occur from time to time. Most such events will have only minor impacts, but occasionally an unlikely or unpredictable event has the potential to cause very serious or catastrophic disruption. Where such risks are known to exist, mitigation measures are usually considered as part of an organisation’s risk planning. Unforeseeable events, however, must be managed without the benefit of prior training and resource planning. Similarly, for an expected but unlikely event, a risk evaluation may be carried out, but the extent of the problem may be underestimated. A relatively minor under-spend on resources can result in disastrous consequences. This was illustrated during the 12m high tsunami following the Tohoku earthquake of 2011 (Lipscy, et al 2013). The sea walls protecting the generators at the Fukushima nuclear plant (10m high), were breached, whereas the sea walls at the Onagawa Nuclear Power Plant, actually closest to the earthquake epicentre, built to a more prudent 14m high, remained largely undamaged, and successfully withstood the tsunami (Yamaguchi, 2012).

The serious damage resulting from a catastrophic event may be exacerbated by associated or contingent effects, such as the environmental and economic after-effects of the oil spill from the British Petroleum Deepwater Horizon oil rig in April 2010. An estimated 4.9 billion barrels of oil was released into the Gulf of Mexico affecting wildlife and marine habitats, fishing, tourism and human health and the effects of these impacts were devastating to the local communities.

**Tipping Points**

Risks that result in adverse effects may be urgent (as mentioned above) or they may be subtle in nature, only slowly impinging on an organisation’s consciousness. These slow to develop or “creeping onset” risks, perhaps best illustrated by our progressively changing climate, can be much more damaging to the natural, social or economic environment in the long term, depending on whether there is a timely and appropriate response.
The term “tipping point” was originally coined in physics to describe the point at which the smallest additional increment of load causes a balanced weight to tip. The term has been adopted widely to describe similar critical points at which change occurs. In climate science, the “tipping element” has been appropriated to describe large-scale subsystems (or components) of the Earth system that can alternate between qualitatively different states, and which may be “forced” in a changed state by a relatively minor external influence. Lenton (2011) describes the tipping point as “the critical point at which the future state of the system is qualitatively altered”.

Public preferences or perceptions can alter over time; populations may grow, shrink or change their ethnic mix; disease or vector patterns can mutate; or environmental changes may accumulate imperceptibly for long periods. Gladwell (2000) argued that when a “tipping-point” is reached, a change to a qualitatively different state occurs. He suggested that in social systems, a relatively small pressure can spark a major system change, be it social, organisational or political.

2.5 Interpretations of Resilience

It has been suggested that the UK Built Environment generally, and hospitals in particular, tend to display relatively low levels of resilience, despite the high priority of hospital funding prior to the 2015 Conservative government and the considerable sums devoted to the NHS Retained Estate (Bosher et al, 2007; Lomas and Giridharan, 2012). Despite this funding, many NHS Trusts neglected to prioritise maintenance during this period, and for some Trusts a significant proportion of their buildings deteriorated. For example, Epsom and St. Helier University NHS Hospitals Trust estimate that 43% of their estate is “not fit for purpose” and acts as a significant constraint on their care activities (Epsom and St. Helier University NHS Hospitals HUHT Estates Review, 2016). Clearly, where the estate is acting as a brake on the Trust’s ability to perform their central function, i.e., caring for patients, it is very likely that the estate may be lacking resilience.

In consequence, one of the objectives for this research has been to consider how “resilience” could be framed within the built environment and, additionally, how “resilience” relates to the practice of adapting or refurbishing the NHS retained estate. This process of disentangling the rich concept of “resilience” has involved teasing out
assumptions, meanings and nuances that have become associated with “resilience” to allow a clearer understanding of how it might best be used to apply to buildings, to the NHS and to construction practice.

The term resilience has evolved significantly, over its long history of common usage. Its first recorded use was in 1626, when it implied “the ability to rebound”, (Oxford English Dictionary, 2010). More recently, following its adoption by government and large commercial interests, the term has developed further to characterise the UK’s crisis response systems (e.g. in local Resilience forums). In addition through its relevance to various academic domains, its meaning has evolved substantially. Many disciplines have developed their own distinct definitions which, from their perspective encapsulate attributes or characteristics of “resilience” that are specific to their field of interest. A preliminary approach to understanding what is meant by “resilience” has been to review how the term is applied within other domains. Examples of various domain definitions are presented below.

2.5.1 Resilience in the Ecological Literature

“In the game of life, less diversity means fewer options for change. Wild or domesticated, panda or pea, adaptation is the requirement for survival.”

Cary Fowler, Executive Director, Global Crop Diversity Trust (2010)

The construct of resilience was promoted extensively by the ecologist C.S. Holling (Holling, 1973), as a means to describe the way in which ecological systems respond to disturbance. Theorists, particularly those involved with the Resilience Alliance (http://www.resalliance.org/), have long since been developing and extending his understanding of resilience and how it relates to natural and managed systems (social ecological systems). Consequently the literature relating to ecological resilience is both rich and diverse, with definitions that are continually evolving.

Ecologists have developed an understanding of resilience that has resonances for the managed building environment, which shares some similar system characteristics (long life-cycles, a need for learning and adaptation, obsolescence and decay, renewal, etc.), and which functions across similar composite time-scales.
2.5.2 Resilience in the Psychology Literature

One key psychological component of resilience for the purposes of this research appears to be related to emotional stability or resilience, and appears particularly relevant to the caring professions, who care for the very sick and dying in addition to supporting their close relatives. Hammond (2004) suggested that competences (developed through learning) play an important role in coping. Tugade et al. (2004) further demonstrated that positive emotions play a crucial role in enhancing coping resources in the face of negative events. Hence emotional resilience appears to be partly a learned competence that can be developed by care-givers, such as clinicians and nurses, to support their practice.

2.5.3 Engineering and Resilience

In the engineering domain, the main focus of resilience is to ensure that systems perform predictably and within specified tolerances. Here “resilience” is a term used to describe systems that work around a closely defined equilibrium. Hence resilience is measured by the speed and ability of the system to return to its desired equilibrium state, following an external disturbance (Dieter, 1989). This is a much more restricted and specific description of resilience than that produced by ecologists or organizational researchers, reflecting a need for clarity and simplicity in describing a precise phenomenon in very explicit circumstances. This differs significantly from the previous descriptions of resilience and demonstrates how the different context alters both the form and complexity of the definition. In engineering resilience, the focus is not a system’s adaptation to change, but on its being impervious to a changing environment. The concern is more with inherent variability than with a rare external disruptive event.

Resilience of Materials

In technological applications, this form of resilience is a particularly useful because it is amenable to very specific definition and relevance. It is primarily concerned with the performance or function of the materials and structures on which we depend. In materials science, “resilience” has been defined as the “ability of a strained body, by virtue of its high yield strength and low elastic modulus, to recover its size and form
following deformation” (Parker, 2003). The modulus of resilience (that is, the maximum amount of energy that can be absorbed for a unit volume before the material permanently deforms) can be determined by integrating the stress-strain curve from zero to the elastic limit. When in tension (along a single axis), the modulus of resilience can be calculated from the strength of the material and Young's modulus (Campbell, 2008, p206).

Here the property of “resilience” has been very precisely defined as characteristics associated with a physical phenomenon and, significantly, parameters for materials resilience are clearly identified, allowing the analysis, design, specification or comparison of materials.

**Resilience Engineering**

Resilience Engineering, on the other hand, has a very different perspective and has developed largely from studies relating to safety, i.e., major accident analyses and systems failures. Research in this area tends to view resilience not so much as a property of a system but more as a characteristic of how a system performs. Hollnagel et al. (2011, p. 348) suggests that “resilience cannot be engineered by introducing more safeguards, procedures and barriers but requires a continuous monitoring of system performance”. He defines a resilient organisation as one that in the event of a disruption, “does not lose control of what it does but is able to continue and rebound” (Hollnagel et al., 2006, p348). Crucially, he also implies that resilience, like safety, is never complete or absolute and hence, for organisations, it is only possible to measure its potential. He contends that a system is in control if it is able to eradicate either its own or the environment’s variability. He further argues that knowledge of the past, present and future predictions are essential for control, together with the resources, competencies and knowledge to manage any arising contingency.

Dekker (2011), suggested that organisations can “drift into failure” and that this is a metaphor for the unheeding shift towards unsafe practice and that such “drift” may be the end result of the regular toll of sacrificing or trade-off decisions, necessary in the face of difficult operating conditions. Weick et al. (1999) suggest that a preoccupation with failure and constant watchfulness can assist in preventing complacency and failure
to perceive changes in the environment. Dekker (2011), argues that when trade-offs and compromises become routine, they can easily be forgotten and consequently, the underlying reasons for decisions become lost. In this way, a company’s processes and protocols become infused with out-dated assumptions and rationales. He suggests that to be resilient, a system requires continual scrutiny, so as to avoid the accepted norms becoming implicitly embedded and thereby inhibiting future change (Dekker, 2011).

2.5.4 Resilience in the Business Environment

Business operates in an uncertain world and a key feature of successfully managing potential risks is to develop resilient organisations, with correspondingly resilient supply chains. It is this appreciation of uncertainty in business that has led to the development of the international standards ISO 22301 Business Continuity Management (2012) and ISO 22313 (2013), Societal Security and Business Continuity Management which provide guidance and specifications towards developing resilience to disruptions and their effects on business activity. ISO 22301 does not define resilience, although it discusses aspects of resilience in relation to organisations. The pre-cursor British Standard BS 25999 however did define resilience very broadly, stating briefly that resilience is the “ability of an organization to resist being affected by an incident”. The British Standard also identified the difference between a continuity plan (which focuses on recovery) and continuity management (which focuses on maintaining continuous operation in an uncertain environment). However the British Standard (BS 25999-2:2007 2.33 Part 1) is now withdrawn.

The Cabinet Office’s use of “Resilience” as an umbrella concept to frame its continuity planning for communities and business (Cabinet Office, 2013a; Cabinet Office, 2013b), highlights the suitability of the term “resilience” when considering disruption and recovery. Although the site does not provide a definition of resilience, there is an emphasis on planning to avoid disaster by assessing risk and vulnerability.

In the final chapter of the IPCC Fourth Assessment Report (Confalonieri et al., 2007), it is noted that disaster risk is usually associated with large-impact high-risk disruptions, such as earthquakes or floods, and perhaps there may be a failure in recognising that
“creeping onset disasters” such as slowly rising temperatures may be more significant and greater in effect in the long-term.

Table 2.1 Summary of resilience definitions

<table>
<thead>
<tr>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
</table>
| General definition         | 1. The action or an act of rebounding or springing back; rebound, recoil.  
2. The action of going back upon one's word.  
3. The action of revolting or recoiling from something; an instance of this. Repugnance, antagonism. |
| *OED on line*              |                                                                                                                                                                                                          |
| Engineering Resilience     | “The degree of system resilience is measured by the speed and ability of the system to return to the desired equilibrium in response to some form of external disturbance”. (Pimm, 1991)                                  |
| Resilience Engineering     | ”The essence of resilience is therefore the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress.” Hollnagel et al., (2011). |
| Materials Science          | “the ability of a material to absorb energy when deformed elastically and to return it when unloaded”. *(Dieter, 1989).*                                                                                     |
| Ecology                    | Ecosystem Resilience: ”Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks”. (Walker et al., 2004) |
| Socio-ecologic systems     | Human social systems are interrelated with natural systems and have the added capacity of planning and preparing for future events. (Resilience Alliance, 2009)                                                 |
| Business                   | “ability of an organization to resist being affected by an incident”. BS 25999:2006                                                                                                                     |
| Psychology                 | “the maintenance of positive adaptation by individuals within the context of significant adversity”, (Luthar et al., 2000).                                                                                   |
| ICT                        | “a general ability to improve network fault tolerance and, as a result, its reliability”. (Cholda, et al., 2009)                                                                                           |
Figure 2.2 Development of resilience in different literatures

Figure 2.2 provides a loose comparison of the resilience definitions from the various disciplines based on the breadth, or range of the literature and the quality or suitability for purpose of the descriptors. Engineering and materials resilience definitions generally have narrowly defined attributes and are focused towards maintaining an optimum equilibrium or a specific set of properties. Resilience in psychology, ecology, system safety, management and organisations appears to be more concerned with complex emergent qualities that may be less amenable to capture. Hence, in these areas many alternative definitions may be suggested, as resilience becomes better understood within a particular field.

Interestingly, Brand and Jax (2007) identified that when there is a loose description of a construct, it may be relatively easy to share ideas and terms across discipline boundaries. However, they noted that where descriptions become closely tailored and
more explicitly designed to suit a particular purpose, the resultant specificity provides precision and clarity, but the usage becomes limited to within particular contexts. Such has been the case with the emerging use of the term resilience; over time it has been co-opted by various disciplines, becoming defined with greater precision to suit particular purposes.

2.6 Interpretation of Building Refurbishment

How “refurbishment” should be defined for construction applications has been an issue of considerable debate, particularly since the late 1980’s. Quah (1988), commented that many common construction terms lack precise meanings and he considered that “refurbishment” had become a generic or umbrella term, encompassing almost all aspects of post construction work and that the term has become “multi-faceted and contextually fluid”. Mansfield, in his detailed critical review of refurbishment definitions (Mansfield, 2002), agreed that many refurbishment-related terms appear to be used interchangeably and identified more than twenty terms commonly used to describe the process remedying degeneration in buildings.

The OED define “refurbishment” as originally meaning “to brighten or clean up”. Later connotations included “restoring to good condition, to renovate”. The OED adds that in modern usage, to refurbish suggests “to repair and redecorate.”

Egbu (1996) and Highfield (2000) both considered that “refurbishment” can include extensions to an original building, whereas Hardcastle (1997) argued that “rebuilding behind the façade, or other new building works, should be excluded”. Similarly, Mansfield (2002) considered that façade retention was primarily done to placate planners and that behind the façade, the new building is almost entirely unrelated to the original building, so the building should be considered as new work.

The RICS definition of 1987 provides greater clarity (in Mansfield, 2002),

“……the extensive repair, renewal and modification of a building to meet economic and/or functional criteria equivalent to those required of a new building for the same purpose. This may involve the installation of current
standards of building services, access, natural lighting, equipment and finishes using historic fabric as the carcass of what is, effectively a new building”

Genre et al., (1999), agreed that Building refurbishment mainly concerns physical and functional building components, but in addition they considered that the definition should also include consideration of energy consumption, polluting emissions and operational waste reduction, as well as air quality and spatial comfort.

Mansfield considered building lifespan in terms of a cyclical process, consisting of a number of successive phases, including maintenance, repair, replacement, refurbishment, and eventually redevelopment (Mansfield, 2002). He believed that precision is needed in defining the refurbishment process, as the extent and timing of refurbishment work can have significant implications, particularly for investment and taxation purposes (Mansfield, 2002).

Difficulties in producing an adequate definition include:

- identifying the boundaries between the different building life-cycle phases;
- determining what level of change can be encompassed by the term “refurbishment”;
- distinguishing the rationale or criteria;
- identifying benchmarks for performance.

The definition developed for use in this thesis is presented in Chapter 7 (Section 1) and describes “refurbishment” from the perspective of NHS Estates.

2.7 Refurbishment in the NHS

2.7.1 The Aging NHS Estate

When the NHS was formed in 1948, it assimilated most of the existing hospital buildings, the earliest of which dated back to 1732 (St Bartholomew’s in London) and many hospital buildings were considered to be unsuited to “modern” clinical practice.

A major NHS hospital building programme was planned in the 1950’s and began in the 1960’s with the aim of improving the service (Francis, 1999). Hence a large majority of the UK’s hospitals were built in the latter half of the 20th Century, often employing
standardised building forms and novel construction systems and with only limited consideration of site and orientation. Until relatively recently, ward refurbishments tended to be carried out informally, using the hospital’s own estates tradesmen; and records tended to be sketchy or non-existent. However, as the collective estates workforce held an extensive and detailed knowledge of the hospital site, this was not considered to be problematic.

Buildings had large areas of single glazing and were heavily reliant on relatively inefficient heating systems for thermal comfort. Many hospitals were prone to overheating in summer and are now showing signs of serious deterioration. Since the latter half of the last century, medical technology and models of care have changed dramatically. For example, patient safety considerations now limit the opening of all windows to just 100mm, which tends to exacerbate problems of overheating and poor ventilation.

Extensive refurbishment will be required if the NHS current portfolio of 27.3 million square-metres of occupied healthcare accommodation is to remain functionally effective for the coming decades. Clearly, patients are subjected to increased levels of risk when a hospital building environment is seriously compromised and, as such, this would be an infringement of the NHS Constitution (DoH, 2013b).

Until recently, Individual Trusts managed their own property portfolios with guidance from the Department of Health. In 2004 DoH guidance, (DoH, 2004), suggested that Trusts adopted a ‘risk based methodology’ to establish and manage their estates backlog of building maintenance which would both, identify the cost of bringing substandard buildings up to an acceptable condition, and in addition, provide an assessment of the risk of failing to take the appropriate action. Categories of risk were identified, related to the cost to bring below standard assets (in terms of their physical condition, or compliance with mandatory fire safety requirements and statutory safety legislation) up to an acceptable condition. Hence an NHS backlog maintenance reporting grid was developed to provide a 5x5 “risk” matrix that required estates managers to rank a specific maintenance impact as: insignificant, minor, moderate, major, catastrophic; against the probability of failure, identified as: rare, unlikely, possible, likely, certain. These scales were ordinal scales so the difference between categories was vague (much
like television ratings – where it is clear which programs are most popular but not which is better or by how much). Hence the real risk to patients may be very different to the reported risk.

Table 2.2 Comparison of backlog maintenance (DoH, 2014)

<table>
<thead>
<tr>
<th>Risk level</th>
<th>Cost to eradicate (£)</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012-13 £ million</td>
<td>2013-14 £ million</td>
</tr>
<tr>
<td>High risk level</td>
<td>353.1</td>
<td>356.6</td>
</tr>
<tr>
<td>Significant risk level</td>
<td>1,002.0</td>
<td>1,016.7</td>
</tr>
<tr>
<td>Critical Infrastructure Risk (= High + Significant Risk)</td>
<td>1,355.1</td>
<td>1,373.3</td>
</tr>
<tr>
<td>Moderate risk</td>
<td>1,476.5</td>
<td>1,426.6</td>
</tr>
<tr>
<td>Low risk</td>
<td>1,204.3</td>
<td>1,241.8</td>
</tr>
<tr>
<td>Total</td>
<td>4,035.9</td>
<td>4,041.7</td>
</tr>
</tbody>
</table>

In April 2013, large sections of the NHS Estate were transferred to a new private limited company wholly owned by the Department of Health (NHS Property Services). The Primary Care and community property portfolios were transferred along with some 400 NHS Trust and Foundation Trust hospitals, amounting to a total value (2013) of approximately £3bn. However, individual NHS Trusts still hold a considerable risk burden, as shown in Table 2.2, where the above risk categories were aggregated along with the assessed cost of remediation to provide a national picture of the Estates backlog burden (DoH, 2014).

Cox (2008), advises that caution is needed in the use of risk matrices, owing to their inherent limitations. He identified these limitations in Table 2.3. He argued that risk matrices must be used cautiously, and assumptions and judgements must be clearly explained. He also considered that, “For risks with negatively correlated frequencies and severities, they can be worse than useless, leading to worse-than-random decisions.”
Table 2.3 Limitations of Risk Matrices (Cox, 2008).

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Clarification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor Resolution</td>
<td>where less than 10% of randomly selected pairs of hazards can be correctly compared</td>
</tr>
<tr>
<td>Range Compression</td>
<td>identical ratings may be given to quantitatively very different risks; Errors (higher qualitative ratings) can be mistakenly applied to quantitatively smaller risks</td>
</tr>
<tr>
<td>Weak Resource Allocation</td>
<td>resources cannot be effectively allocated to risk mitigation based on the risk matrix categories</td>
</tr>
<tr>
<td>Ambiguous Inputs and Outputs</td>
<td>impossible to objectively categorise uncertain consequences because inputs and outputs require subjective interpretation, and different users may obtain opposite ratings of the same quantitative risks</td>
</tr>
</tbody>
</table>

2.7.2 The NHS Refurbishment Process

Essentially, buildings are composed of elements and components that have varying life-cycles and this means that, for example, flooring and interior decoration may require attention after as little as 2 years or alternatively the decorative condition may be considered acceptable for up to 15 years depending on use; sanitary fittings and windows might need to be replaced, depending on use or orientation, every 5-20 years (short-cycle), electrical wiring every 25-30 years; and service piping and ductwork every 40 years (medium to long cycle). In contrast, the structure, fabric and roofing may survive in excess of 60 years (long-cycle) and in some cases, beyond 150 years. Where regular testing and maintenance is lacking or impracticable, these replacement intervals will decrease. Hence buildings can be viewed as existing on various timescales, with each scale represented by different long cycle elements or short cycle components. Where a component with a short cycle replacement, for example a window, is neglected
or badly maintained, unnoticed water ingress can lead to cosmetic damage and in extreme cases over a number of years can cause considerable structural damage. Hence the building must work across all scales throughout its life.

Refurbishment tends to be an ongoing process across large acute hospitals. Diverse factors such as government or NHS Trust priorities, organisational efficiency, the introduction of new technology or revised models of care, dictate whether it is a few months or many years before a particular space is refurbished (Ariyo et al, 2012).

Where an entire building is being refurbished, there is also the option of enhancing the building envelope and improving its ventilation and thermal performance. Alternatively, framed buildings with glazing and infill cladding panels can be upgraded with more efficient glazing. Facades with pre-fabricated (unitised) curtain walling, or rainscreen cladding usually require total replacement.

Generally, NHS hospital buildings undergo periodic partial refurbishments, where only part of the building is refurbished (generally one or two wards or a department), although occasionally total refurbishment is considered, particularly where the existing building is sound and can be redesigned to provide a fully functional care setting to meet existing and future needs. Indeed refurbishment is more sustainable (Elefante, 2007), usually faster, and causes less disturbance to the site. However it appears that where a privately financed new build option is available (Private Finance Initiative or PFI), this may be preferred, as the design is not limited by the existing footprint or location.

The comings and goings of construction site traffic can seriously disrupt the smooth delivery of essential clinical supplies and, unless carefully managed, presents an increased risk to both patients and staff and to the smooth running of the hospital. Hence, the project planning process requires coordination between the contractors and the hospital client to ensure that this risk is minimised. As with any building programme in an occupied building, refurbishment activities must not compromise the functioning of existing critical systems. This can present life-threatening conditions for instance, when making infrastructure connections or where site equipment temporarily blocks hospital access.
Acute hospitals can be considered as complex systems (Begun et al., 2003; Buckle et al., 2006; Shiel et al., 2008; Lipsitz, 2012; Dekker et al., 2013), and changes to such systems can have unforeseen consequences. Large-scale ward transfers may involve considerable disruption to staffing schedules, as moves for very vulnerable patients may need to be carefully choreographed and patients must be accompanied by suitably qualified staff. In addition, ward routines may need to be modified and this may cascade on to neighbouring wards. As routines and protocols are designed to reduce the risks to patients, the subsequent changes may result in reduced levels of safety (Zhao et al., 2009). Consequently the process of risk identification and mitigation is essential at each stage of the planning process and proposed changes must be communicated to all affected staff.

Hospital systems have become highly integrated so that the range of patient-care requirements can be met with relative efficiency. However, the coordination of changes to these hospital systems can be complex, as each change may have impacts for any or all of the other connected systems. For instance heated catering trolleys are carefully timed so that food does not deteriorate during transit. Subsequent changes to delivery routes can affect the acceptability of the food, impacting patient recovery, as well as significantly complicating existing routines (Mavrommatis et al, 2011). Codinho et al (2008) point out that the existing literature is very limited in the area of integration of building design with building servicing. They identified that significant problems arise due to the lack of service delivery standards, constant changes in decision-makers, and multiple care patterns, as clinicians each choose their own plan for care delivery (Codinho et al 2008). Constraints, including the continually changing background of legislation, regulation and guidance related to disabled access, fire control, mechanical maintenance, noise, ventilation, electrical safety, energy profile and hospital design etc., all contribute to the complexity of designing and managing refurbishments.

Since refurbishments take place in an occupied hospital, the “go-ahead” for a project may depend on the identification of suitable alternative accommodation for existing patients. Hospital wards are specifically designed to suit patient’s clinical needs and patients placed in inappropriate wards face a greater risk (Goulding et al, 2011). In practice, not all wards have the same access to equipment, medical gases and vacuum.
Hence, wards are customised for particular needs e.g., paediatric wards have equipment ergonomically designed for children, whilst orthopaedic wards are designed and staffed to accommodate patients with limited movement capability etc. This specialisation can be a significant problem during refurbishments, as many UK hospitals have little, or no, decant space. When vacant accommodation can be identified, it frequently requires expensive modification to suit the temporarily transferred patients, and in some cases wards may have to be refurbished again to suit the needs of subsequent patients.

Buildings tend to be one-off designs that become further modified over time. They have fixed orientation and construction, and must cope with specific external temperatures and weather patterns for their location. Such patterns vary widely across the country and on occasion, within a single day. Buildings provide for a varied range of functions and managing building energy use is complicated by multiple users who have very different preferences for lighting and thermal comfort. People open doors and windows, use blinds, switch lights and appliances on and off, and use piped services intermittently, so interpreting building performance data can be a complex process.

2.7.3 Adaptation of Hospitals to Climate Change

A key problem for estate managers is maintaining an acceptable internal thermal environment regardless of external conditions. This is expected to become increasingly problematic as the climate changes. Buildings that regularly suffer from water ingress during storms or are susceptible to flooding may find that climate change exacerbates these problems. In particular, many hospitals have a selection of poorly performing wards, whose orientation or fabric construction make them particularly susceptible to overheating. This poses dangers for patients and makes working conditions very uncomfortable for staff.

However, hospital refurbishment can provide solutions to climate related issues. For example, external shading of windows along with mechanical ventilation can help in avoiding excessive solar gain in summer. There are issues associated with insulating existing hospital buildings, as heat gain from windows, care-related and other equipment, along with the activities of staff and patients, can be considerable. In the winter, retaining this heat might be desirable, but in the summer months such heat
gains can make the internal environment very uncomfortable. Increasing the level of thermal insulation may also reduce the potential for night cooling. Hence insulation, where considered, must be very carefully designed with matching ventilation strategies to provide year-round comfort.

Other options that can help to improve thermal performance include for example, the use of phase-change materials; hard/soft landscaping, “cool” planting and the addition of reflective surfaces; sealing the building to PassivHaus standards with natural or mechanical ventilation; or exposing soffits to improve night cooling (Short and Lomas, 2010). Specific combinations of some of the above measures (in some cases combined with reduced energy demand heating and cooling options) might allow buildings to function comfortably into the 2080’s, whilst remaining within the NHS energy target and CO\textsubscript{2} emissions and benchmark of 55–65 GJ/100 m\textsuperscript{3} based on existing climate predictions (Short and Lomas, 2010).

2.7.4 Successful Projects in the NHS

In practice, most NHS hospitals refurbish to meet a variety of objectives:

- to improve service delivery;
- to respond to changes in local demographics;
- to introduce technological innovation;
- to implement government priorities or take advantage of funding opportunities;
- to upgrade building services or address age-related building deterioration;
- to improve appearance or the functional use of space;
- and, more recently, to adapt hospital buildings to the changing climate.

The completion of a project on time and within budget hinges on a variety of factors and include the skills and abilities of the project team (Latham, 1994); an appreciation of uncertainty and risk; the clarity of the project objectives, (Taleb, 2007); appropriate project monitoring (Chua and Kog, 1999); the magnitude, constructability and complexity of the project (Chua and Kog, 1999); and the level
of project “over-optimism” resulting in unrealistic project cost and duration targets (Kahneman and Tversky, 2000).

A project cost is a real value (i.e. an amount that is actually paid for a service) and this can be determined with relative ease. However, the basis of whether such a cost provides value to an organisation is a more complex consideration. Robichaud and Anantatmula (2010) considered that the cost and profitability of a project refer to different aspects of the value spectrum, where costs are related to the negotiated values of specific packages of work to produce a project. On the other hand they viewed profitability as resulting from the value suggested by the business case for a project, compared with the actual cost/benefit resulting from the project.

“Cost, in the context of constructions projects, refers to the efficiency with which the project team crafts the deliverable. On the other hand, profitability of the facility speaks to how well the business case of the project was drafted and how well the cost/benefit of the deliverable was studied before commissioning the construction of the project deliverable.”

Robichaud and Anantatmula (2010)

Hence the ability of the project team in envisaging the likely benefits that should be delivered by a project have a direct bearing on both the cost and the profitability of the project. Failure to meet scheduled construction deadlines may have both financial and operational consequences for the construction process. For example, finance stream deadlines may not coordinate with project stages; and if a scheduled window is missed, specific construction tasks must wait for the next opportunity (Caldwell et al., 2009).

Hospital systems may be compromised if deadlines are missed and this can cause confusion and distress. For instance, the process of decanting a ward and transferring patients can involve significant risk, particularly when the patients are very vulnerable or severely ill. The transfer may require a rehearsal (with dummy patients) to ensure that the process is safe. Extra nursing staff (twice the usual compliment) must be scheduled well ahead of the event, both for the rehearsal and for the actual move. Usually nursing agencies supply the necessary additional staff and agency rates apply. Clearly the considerable time and costs associated with the process will escalate if deadlines are
missed and the transfer has to be rescheduled. Undeniably, for construction projects there are a great many factors that can contribute to delays; and while some are manageable, such as manpower shortages or minor design changes, others are less so, and might for example, relate to inclement weather at a critical time; or an unanticipated alteration in government funding, or perhaps to delays resulting from the discovery of a protected wildlife species or archaeological remains, etc.

Mansfield (2008), suggested that in practice, large refurbishment projects entail considerably greater levels of risk than new-build work, owing to the uncertainties posed by the existing building construction. Interestingly, Cooper and Chapman (1987) observed that project managers tend to rely, to a great extent, on past experience in assessing the risks of a refurbishment project, often ignoring recent relevant building information. In consequence, they may make inaccurate assessments of the level of project risk. However the most crucial aspect of project success appears to be related to how well the building satisfies the client’s aspirations. This is a rather grey area, as at present, few projects are measured against their original objectives, particularly as refurbishment projects may take place over quite extended periods and changes made during the course of construction may reflect a client’s radically altered requirements.

However, it is not yet widespread for buildings or refurbishments to be subjected to a formal post-occupancy evaluation (Cooper, 2001), so as to establish whether the performance meets either designer’s predictions or the client’s expectations. At present there are significant barriers to overcome (Riley et al., 2009; Williams et al., 2013), although the relatively recently introduced “Soft Landings” initiative may encourage an increased level of post-project evaluation. “Soft Landings” is a joint initiative led by the Building Services Research and Information Association (BSRIA), in partnership with the Usable Buildings Trust (UBT). The strategy was designed to provide a mechanism aimed at redressing many of the problems encountered by the users of new buildings. The “Soft Landings” approach reflected “the need for a smooth transition from the design and construction phase to the operational phase of the built asset” (Cabinet Office, 2013c) and encouraged designers and constructors to stay engaged with the building for at least three years beyond completion.
2.8 NHS Contractual Issues

The choice of procurement route is a critically important part of the process of efficiently translating the client’s objectives into a functioning built asset. Clients can choose to buy a “custom made” or “off the shelf” building or they might choose to refurbish an existing building. The issues are complex, but in times of financial cost-cutting refurbishment may be a convenient option with choices of financing methods. In Sections 2.8.2 and 2.8.3, the tendering of construction contracts to contractors is considered. First, some mention must be made of public-private partnerships, which are still currently favoured by the UK government for financing large projects.

2.8.1 Public-Private Partnerships

Finance options are essentially concerned with the process of allocating project risks (Witt and Roode, 2011) and the potential for spreading risk has helped motivate Public-Private Partnerships (PPPs). In theory, PPPs provide the opportunity for public authorities to transfer the risks that are most appropriate for the private sector to bear. The Private Finance Initiative (PFI) is a form of Public Private Partnership and, as the private sector is considered to be more efficient at managing their risks, this should result in lower overall costs. However, for various reasons, including the inexperience of NHS procurement at negotiating PFI risk, there have been a number of instances where PFI contracts have produced poor value (Shaoul et al., 2011; Pollock et al., 2002; House of Commons Treasury Committee, 2011).

2.8.2 Framework Agreements and Procure 21 (superseded by Procure 21+ and more recently by Procure 22).

The European Union (EU) presently requires public authorities to openly tender construction contracts that exceed a certain threshold value. However this may change as the UK withdraws from the EU Single Market. Open tendering ensures equal access to the process for contractors throughout the EU and supports competition. However there are systemic weaknesses inherent in this process. Large corporations have the advantages of scale and in times of recession will tender for smaller contracts, directly competing with smaller more localised firms. As national economies improve, large
corporations rarely bid for smaller contracts (or will require much larger profit margins) but local contractors who would normally take up these smaller contracts may have dwindled in numbers.

A framework agreement precludes the requirement for open tenders and is a procurement technique approved for use within the European Union (EU). The development of framework agreements eliminated the need for public advertisement of smaller projects and permits local contracting to prosper. Typically, it allows purchasers to select a contractor from a predefined group of regionally-based contractors, and in this way supports smaller local businesses and local skills retention.

Litigation is rare with these types of agreements and the developing relationships appear to be valued. Although framework agreements tend to be more expensive in the short term than lowest price bidding, they can result in long-term benefits and preclude the serious problems encountered of the late 1980’s of under-priced bidding, resulting in financial failure or poor quality (Witt and Roode, 2011). There are, of course, significant implications. Managers face a difficult dilemma in trying, on the one hand, to adopt sustainable procurement policies and promote the use of local labour, whilst at the same time trying to cut costs.

The NHS developed its own approach to construction procurement, known as ProCure21, which is based on a standardised framework agreement (a form of strategic partnering). ProCure21 was piloted and then brought into general NHS use in October 2003. It expired in September 2010 and its successor, ProCure21+, commenced in October 2010 and expired in September 2016. Procure22 commenced in October 2016. Procure 21 contracts (used for the Case Study 1 project) provided a Guaranteed Maximum Price (GMP) form of contract that gave some degree of cost certainty once the price had been agreed with the contractor and the detailed designs signed off. Any changes to the project by the client after this point incurred considerable cost penalties.

With ProCure21 the Principal Supply Chain Partner (PSCP) is equivalent to the Principal Contractor in traditional construction projects. (S)he contracts directly with the client to undertake the specified project, employing specialist sub-contractors to undertake allocated packages of work. The Procure21 process (and also Procure21+ and Procure22)
allows responsibility for the design and execution to be passed to the PSCP, using a risk register, and unspent funds (up to 5% of the total project budget), are shared equally between the two contracting parties. Contract savings beyond 5% of budget go directly to the client. The concern with this type of risk share is that there appeared to be no protection against contractors that overestimate the risks and consequently benefit from an increased risk pool share at the expense of the project budget.

ProCure 21 tenders were exempt from the requirement to advertise through the *Official Journal of the European Union* (OJEU), a saving in time of six to twelve months for a construction project (Caldwell et al, 2005).

The NHS ProCure 21 framework included a selected group of local, vetted contractors (at the time of the case study project this was six contractors). Research by Caldwell *et al*. (2005) identified key advantages to the Procure 21 framework agreements. In particular, they concluded that frameworks improve transparency while helping to remove barriers to attracting the best suppliers. For the NHS, Caldwell *et al*. (2005) contend that reusing the same supplier allows greater standardisation (particularly useful when considering modular construction) and helps to reduce costs (Caldwell *et al.*, 2005). They noted that under these agreements, publicly funded bodies like the NHS can build long-term relationships with small numbers of vetted contractors (Caldwell *et al.*, 2005).

“*The UK has always taken the view that the only sensible approach to such framework agreements is to treat them as if they are contracts in their own right. Hence, the practice has been to advertise the framework itself, in the OJEU, and follow the EU rules for selection and award of the framework.*”


As the framework details the terms on which the contracts will be awarded, it removes the requirement for advertising individual projects and provides transparency. The construction contracts themselves have also undergone some change. UK construction processes have long been governed by specialised and complex forms of contract along with industry agreements. These are well understood by the relevant industry professionals and trades and, until relatively recently, they underpinned all building
work (see the Joint Contracts Tribunal, JCT website http://www.jctltd.co.uk). At the same time, UK construction firms have a long history of damaging adversarial relationships and frequent recourse to litigation and the courts (Lord et al., 2010). Both the Latham (1994) and Eagan Reports (1998) argued strongly for a more collaborative approach to construction projects.

More recent contractual forms such as the NEC Engineering and Construction contract developed by the Institute of Civil Engineers (ICE), provide clearer language and encourage fairness and collaboration rather than resorting to litigation to solve problems (http://www.neccontract.com/). However these contracts have not proven especially popular and there appears to be some reluctance to move towards a less well understood system, thus increasing the overall level of risk. In addition, there has been significant criticism of the NEC construction contracts. Specifically, Ayres and Gertner (1992, p730) assert that, “Contracts that do not provide some kind of recourse for damages for each party are obligationally incomplete”. An implication of this comment, pointed out by Hughes and Maeda (2002), is that “the NEC’s drafting intentions would produce an “obligationally incomplete” contract”.

Gould (2015) in his report to the Society of Construction Law concludes, “Overall, NEC3 is a contract that is now being adopted by some sectors of the construction industry within the UK, and internationally. It adopts a drafting philosophy that many argue supports modern good practice, based on the recommendations given by Sir Michael Latham 20 years ago. It is not fully there yet, but the influence of Sir Michael’s report can still be seen today.”

2.8.3 Partnering

The Latham Report (1994) suggested that partnering and teamwork would improve industry relationships. Wood and Ellis (2005, p317) strongly supported this view and described partnering as, “… the most significant development to date as a means of improving project performance”. 
In theory, partnering involves firms working together with a shared non-adversarial culture to achieve a common purpose. This requires partners to develop relationships based on trust and where necessary to disregard organisational boundaries (Gadde and Dubois, 2010). However this is not an easy transition for many UK construction contractors. The benefits from partnering have been clearly seen at the local level (Gadde and Dubois, 2010; Laan et al., 2011) although there is conflicting evidence as to whether there is value in a more strategic wide-scale approach to partnering (Gadde and Dubois, 2010; Bygballe et al., 2010). Wood and Ellis’s research (2005, p324) identified positive advantages but they qualified this, suggesting that “... beneath the veneer of partnering some of the traits that have characterised the construction industry for years are still apparent”. With a somewhat similar view, Gadde and Dubois (2010) concluded that “deep-rooted cost driven agendas still persist in most transactions”.

The severe cuts in government spending during the 1980’s were blamed for the high-risk and under-priced tendering practices that took place in the construction industry. These caused contractors to either risk financial failure or “cut corners”, which resulted in poor quality, bankruptcies, and project delays (Ren and Lin, 1996). Contractor failure leaves the client in a very difficult position, as tight project schedules allow little time for recruiting new contractors and the necessary orientation process. This was bad for the industry and attracted criticisms in both the Latham Report (1994) and the Egan Report (1998).

In recent years the move to more collaborative procurement has shown benefits for both contractors and the NHS. However, Tennant and Fernie, (2010) worryingly suggest that,

“Framework Agreements are already the subject of intense scrutiny in a ‘more for less’ ‘show me the money’ politically charged environment.”

They go on to suggest that,

“the socially aware, humanistic approaches to construction procurement only receive a sympathetic foray into working practice during periods of economic optimism. Only to be quickly shed in favour of hard-nosed
business economics when confronted with growing contractual risk and shrinking company profits”. (Tennant and Fernie, 2010)

2.8.4 Scrutiny

Government policy, aimed at driving down costs, requires trusts to compete with each other and with the private sector for the provision of specialist services. The NHS Plan (published in 2000) radically reformed the NHS. Trusts that achieved “foundation” status (based on financial, quality and governance targets) were given significant control over their finances and the ability to respond to local opportunities for growth. However, the present financial climate has greatly limited the financial independence of Foundation Trusts and many Foundation Trusts and NHS Trusts have significantly reduced options for funding refurbishment.

Other challenges such as anticipating changing government priorities, locating available or suitable space (along with decant facilities if required) and managing the business case also play a role in the strategic planning process. Until fairly recently, refurbishments were often neglected in terms of strategic overview and frequently failed to fit with the accepted long-term plan; many were undertaken specifically to benefit from a time-limited funding opportunity directed towards a particular government priority (Greener, 2008). Many of these “ad hoc” refurbishments were subsequently found to be poorly located; difficult to service; or severely restricted future growth. For example, extensions may compromise future access routes, or infrastructure developments, limiting expansion. Moreover, the size and orientation of a refurbishment or extension may obstruct the further expansion of a “hospital street” making way-finding difficult and interfering with planned future development. Internal refurbishments can interfere with ventilation systems, restrict access, reduce flexibility or disrupt essential connectivities.

“Marginal-type decisions were often made in line with whatever the present government agenda happened to require, especially if there was the potential for greater funding to be attracted as a result of pursuing one activity rather than another” (Greener, 2008).
Since the introduction of the 1990 NHS and Community Care Act there has been a much greater focus on the financing of NHS projects (Shaoul, 2011) and, as a result, there is more detailed scrutiny of major refurbishment proposals. The development of the business case and final approval are subject to the protracted decision-making process of the NHS, but there may be some compensation through the benefits of increased strategic oversight, guiding future development. Contributions from various specialists including, clinical staff, estates and finance teams are generally required throughout the project, both to progress the brief and to contribute to the ongoing project development. This involvement of stakeholders from an early stage helps to encourage client satisfaction and reduce the quantity of construction changes (Ahmad et al., 2012).

The scrutiny process does not apply to minor refurbishments (below £200,000), where decisions are often made on a “piecemeal” basis and devoid of long-term strategic oversight. It is not uncommon for a centrally-positioned ward to be completely refurbished two or three times within a very short period (3-5 years) for entirely different purposes, whilst less central areas await a simple redecoration for ten or more years (Sheth et al, 2010). In most acute NHS hospitals, refurbishment tends to be an almost continuous process, across various locations and both patients and staff in affected areas must cope with disturbance or upheaval.

In 2014 the NHS introduced a new assurance based model, the Premises Assurance Model (PAM), for use by NHS organisations to assess how safely and efficiently they run their estate and facilities services. PAM has since been updated for 2016, to reflect changes in Health and Social Care legislation. The model was devised as a management tool that allows NHS healthcare providers to assure Boards, monitoring organisations and other stakeholders of the safety of NHS premises (DoH, 2016). However, it was also designed to provide NHS Trusts with a consistent approach to assessing their estate’s risk and compliance issues. It represents a move away from simple risk matrices towards a more detailed and evidenced approach. At present Trusts are being strongly encouraged to adopt PAM, however it is not yet a requirement, although this could change in the near future. At present, it is too early to determine what effect PAM will
have on Trust Estates management and portfolio decisions, although as a self-assessment tool, it is subject to a level of unintentional bias.

2.9 Refurbishment Process Improvement

The management of refurbishment projects shares a number of parallels with the development of highly engineered products in that they both involve complex solutions that must resolve the prevailing constraints of strict timescales, restricted budgets, challenging regulatory frameworks and variable supply chain relationships. As they each constitute major financial investments in their design and manufacture, careful planning prefaces both building projects and new product developments, and any revision of the plans may require significant levels of change. Whilst complex engineered products, such as aircraft are frequently refurbished, effort in engineering is predominantly directed towards creating new products based on existing version of the product. In building refurbishment however, change focuses on the existing building.

Engineering production has benefited to a greater or lesser extent from a range of innovations since the 1990’s. These include, for example, Business Process Reengineering, designed to improve process flow; Concurrent Engineering to integrate and optimise workflow processes; agile management also known as “extreme” project management for managing very complex projects; Lean production systems developed initially by Toyota to minimise waste and maximise productivity; Motorola’s Six Sigma methods to improve production and product quality; and Computer Integrated Manufacturing (CIM) to aid information exchange and reduce error.

These significant developments in engineering process are slow to infiltrate the wider construction sector. Kagioglou et al. (2000) suggested that the perceived lack of process driven improvement in the UK construction industry was a result of the “one-off” nature of construction projects and the proliferation and fragmentation of many construction sub-contractors. However in his 2003 paper, Winch reasoned that the “mass production” system may have limited relevance for the low volume construction sector. He argued that process models typical of the shipbuilding and aeronautic industries may be more applicable to construction projects, particularly the complex systems approach [Winch, 2003]. Recently Gambatese and Hallowell (2011)) concluded that a lack of
innovation is a major problem in the US construction sector. They identified strong barriers to innovation, typified by a reluctance to change and a lack of available resource to develop knowledge.

This reluctance to innovate might also be interpreted as caution. Green (2011) advises against simply transplanting successful strategies from very different contexts. He suggests that progress is contingent on an understanding of the historical constraints and the pervading sectoral influences that apply. He argues that continuity of demand may be a more important priority for a construction sector more sensitive to cyclical economic pressures than to cost efficiency, a key focus for engineering process research (Green, 2011). However, the specification of standardised or purpose-built modular buildings, assembled under factory conditions is becoming increasingly common and hospital examples include wards, cleanrooms and operating theatres, all constructed with significantly reduced fabrication times. These modules, with a design life of sixty years or more, are increasingly being considered as an alternative to traditional construction. Hence, when considering the appropriateness of innovations for refurbishment applications, it is possible that the engineering domain can provide a valuable mirror to practice, through which activities can be seen more clearly.

The construction industry, however, has appeared largely unconvinced by these or similar strategies for improving construction processes. The highly influential Latham (1994) and Egan (1998) Reports both highlighted the lack of process improvement and not surprisingly a similar concern is reiterated in the 2010-2012 coalition government’s 2011 Construction Industry Strategy Report,

“Recent studies highlight a number of key barriers to growth and the efficient operation of the construction market. There is broad consensus, spread both across the industry and its customers, that construction under-performs in terms of its capacity to deliver value and that there has been a lack of investment in construction efficiency and growth opportunities”.

“Government Construction Strategy” (Cabinet Office, May 2011)
The lack of progress has been attributed to the “one-off” nature of construction projects (Kagioglou, 2000) and the proliferation and fragmentation of many construction sub-contractors (Wild, 2002). However very complex engineered products like commercial sailing vessels, are also “one-off” products, manufactured largely on site, to individual customer specifications (Egbu et al., 1996) and these marine engineered structures do appear to benefit from advances in engineering process research (Clauss, 2002). Similarly, high value items like helicopters which can be tailored to an individual client’s operational needs and produced singly or in very short production runs (Eckert, 2004) have also been customised or refurbished using advanced engineering process methods. The Government’s latest strategy requiring central government departments to require Building Information Management for new projects by 2016 may ultimately afford the industry the opportunity to improve the construction process (Illozor and Kelly, 2012).

In effect, engineering production methods are increasingly being adopted in the healthcare sector to achieve bespoke or standard solutions to their space requirements, in the form of modular pre-fabricated buildings, constructed under factory conditions. Examples include modular clean rooms, operating theatres, and wards, all with significantly reduced fabrication times and as such, provide an alternative to traditional construction. However there is considerable debate as to whether innovations that deliver efficiencies in other domains would necessarily be applicable to “on-site” construction operations and that research in this area is lacking (Latham, 1994; Kagioglou, 2000; Sacks, 2010; Green, 1999). Green (2011), in discussing approaches for improving the management of construction projects, argues that it may not be feasible to simply transplant successful strategies from very different contexts into a construction environment. He argues that progress is contingent on an understanding of the historical constraints and the pervading influences which apply. Consequently, a judicious approach to introducing new strategies is needed.

A key area for improvement concerns the management of change during construction projects. This issue has been highlighted repeatedly as a major cause of delay and cost escalation (Egan and Latham reports; Buratti et al., 1992; Love and Li, 2000; Olawale and Sun, 2010). However, although there has been considerable research in project management, construction projects routinely continue to exceed their targets for both
cost and duration, and compromises to project goals are commonplace. In product engineering, research has focused on changes that occur during the product development process, change propagation and the need to be able to predict where changes will be required, with the aim of minimising disruption to schedules and reducing the cascade effects associated with changes either to highly connected components, or that occur early in the process.

2.10 Change

2.10.1 Change in Construction

Egbu (1994) highlighted that the major difficulties faced by construction were essentially associated with variations or change orders; maintaining cost control; the influence of occupier (tenants) and dust control. Since Egbu’s study, many researchers have commented on the problems caused by changes in construction (Kumaraswamy and Chan, 1998; Cox et al., 1999; Assaf and Al-Hehhi, 2006; Love and Li, 2000; Olowale and Sun et al., 2006). In 2006, a major three-year research study by Sun, Fleming, Senaratne, Motawa and Yeoh (sponsored by the EPSRC) developed an integrated approach to change which related project characteristics with initial causes and major effects. This clear linking of the multiple context-related factors to a change effect significantly enhanced the understanding of the change process in construction (Sun, 2006). They highlighted the ad hoc way changes are managed during construction projects and presented a toolkit comprising of a change dependency framework; a change prediction tool; a workflow tool; and a knowledge management guide, to assist decision-makers in coping with changes.

Analyses of very similar change problems had been taking place in product engineering research (Eckert 2004). The engineering approach, rather than trying to link the multiple causes and constraints to individual change events, instead sought to locate individual change events within pathways or sequences of connected changes that resulted from a common cause. This perspective allows a view of how a change can cascade through a
project, affecting one or multiple systems, and highlights the critical points that cause serious propagation.

2.10.2 Change Propagation in Engineering

Change in the engineering context may be used to systematically progress a product to suit a range of new objectives, for example; to introduce technological innovation; address new legislative requirements; respond to changes in demand; correct errors; or to reduce costs (Terwiesch and Loch, 1999). Research in engineering has been directed towards investigating how changes flow across a system (Eckert et al, 2004). Typically, engineering products have a high degree of interconnection between components and systems, so changing just a single component in a complex product may have critical repercussions. Consequently as a change is introduced, this may result in the need for further changes to connected components or to entire systems (Eckert et al, 2004). For example, a helicopter rotor is critical to the design and safe operation of the majority of a helicopter’s other airborne systems (Eckert et al 2004). Any change to such a strongly connected element will have widespread consequences for other connected systems and will generally cascade down to indirectly connected components further along each system pathway. The consequential surge of change which may develop from a single initiated change is termed “change propagation”. It may not be possible to envisage the full extent of such changes without a careful analysis of the connectivity of each element or system (Clarkson et al, 2004).

Connectivities between components of a system can be expressed in terms of inputs and outputs. In theory, if a component has many inputs and few outputs, then changes to any modules that provide inputs will affect the component. Alternatively, if there are few inputs to the component but many outputs, then any changes to the actual component will have consequences for the many output connected modules in the wider system (Keller et al, 2005). In a hospital situation, this could mean for example, that changes to a system database, accessed by a wide range of hospital systems, may cause a cascade of problems. Equally, most wards and out-patient departments need to access patient transport but the transport department has few out-going connections.
In a similar way, dependencies are connections from processes or products which are prerequisites to a following process or product. Many hospital systems display dependencies and this type of connection is vulnerable to changes to any previous stage of the process. For example a change to an autoclave specification may result in changes to the type or size of equipment that can be sterilised, or it may affect the rate of equipment sterilization, which may influence the availability of specialised instruments for theatre use.

Eckert et al. (2004) described change propagation as “the process by which a change to one part or element of an existing system configuration or design, results in one or more additional changes to the system, when those changes would not have otherwise been required”. The increased volume of change can be a significant problem both for construction and engineering projects. In a hospital refurbishment project, for example, the late discovery of a structural problem during a refurbishment, may entail additional changes to floor plans; changes in structural support; revision of mechanical and electrical system designs; changes to proposed circulation routes, fire-safety and surveillance systems; in addition to required sustainability targets. The problem may be compounded by the need to renegotiate contracts with sub-contractors; revise project documentation; and provide additional costing. Still further effects may include delays to schedules and the depletion of float-time, reducing project resilience.

2.10.3 Mechanisms of Change

Eckert et al, (2004), in their work on change in highly engineered products, identified specific modes of change propagation: change carriers transfer change to connected components but are not significantly affected by change; change absorbers accommodate changes, and whilst total absorbers are rare, partial absorbers or buffers contain the majority of changes, allowing a small proportion to be passed on. Resistors are critical aspects of a system and are only changed if there is no other option. They also observed that changes to strongly connected components resulted in numerous changes to the many connected systems which were then identified as change multipliers. These can lead to a problematic avalanche of changes, where the volume of
required changes increases and may be uncontrollable. Less challenging change episodes present as *ripples* where only a small number of follow-on changes is required. Eckert et al. went on to note that larger – but predictable – changes may result in *change blossoms*. These may require substantial effort to resolve, although the process may remain controlled, with the numerous changes being ultimately directed towards change absorbers. Table 2.4 gives examples of the effects of the above change mechanisms.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Effect</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change &quot;multipliers&quot;</td>
<td>Generate more changes than they absorb.</td>
<td>A change to the position or size of a lift shaft may require many further design and M&amp;E changes.</td>
</tr>
<tr>
<td>Change &quot;absorbers&quot;</td>
<td>Pass on less change than they receive.</td>
<td>Ensuring adequate float time; or including flexible or multi-purpose spaces in designs.</td>
</tr>
<tr>
<td>Change &quot;carriers&quot;</td>
<td>Carriers absorb a similar number of changes as those they trigger</td>
<td>Simple changes to geometric components e.g., changes to a connecting rod, where the length is unaffected but the cross-section changes.</td>
</tr>
<tr>
<td>Change &quot;resistors&quot;</td>
<td>Highly connected elements that restrict or reject change.</td>
<td>Changes to the building footprint, legislative requirements, or executive office size.</td>
</tr>
</tbody>
</table>

### 2.10.4 Options for Managing Change

Options for managing change can include integrating "change absorbers" at appropriate points, or by ensuring that design effort is directed away from "change resistors". Giffin et al. (2009) obtained data from a US government billion-dollar project and their work focused on the data that resulted from the development of globally distributed
hardware/software system. They studied 41,500 change requests that arose during the course of the project and identified recurring change patterns or "motifs". Specific "motifs" or patterns of change formed “building-blocks” of larger change networks. They classified change requests as either “parent”, “child” or “sibling” and mapped the relationships across specific networks of change. These motifs helped to identify components that resisted or rejected change, pin-pointed areas of wasted effort, and revealed relationships between successful changes. Looking at change in this way helps to provide an alternative perspective, and encourages a focus on both the predictable and the less obvious causes of change.

Giffin et al., (2009) provided a helpful visual representation of change networks while enabling a detailed systematic analysis. However the method requires a significant level of data for each change and in smaller refurbishment projects, this information may be unrecorded, inaccessible or unavailable due to issues of confidentiality. Nevertheless, there is a need to anticipate the effect of a change and its propagation. As noted by (Eckert et al, 2004), only when the impact of a change has been predicted can the time, cost, and resources be allocated to effect the change. Well-managed change is the next best situation to avoiding problems in the first place.

2.11 Conclusion

The areas of particular interest for this thesis include risk, resilience, project change and refurbishment, within an NHS environment. Initially the literature review looked at risk and how it can influence the perception of threatening events. Comprehensive risk registers are seen as a means to develop mitigation strategies to avert impending threats or dangers that may result in harm to patients, systems, buildings and organisations. However the review highlights that assessing risk can be complex and that risk assessments, as they are commonly produced, may misrepresent the actual level of risk.

This issue was further explored in terms of the Precautionary Principle, as this is particularly relevant to the NHS. The NHS aspires to offer the safest options that do least harm and to make “no regrets” decisions, where possible. The MMR vaccine issue highlights the problems that can ensue when the public’s perception of risk to their
families is at odds with that of the government, the research establishments and the NHS. It is possible that the perception of safety may be a significant component in providing a healing environment and as such must be an important consideration for resilient refurbishment.

The review considered a systems perspective and this approach may be appropriate for examining the component sub-systems of the NHS, their connections and interactions. Buildings are a significant NHS sub-system and it is the interactions and connectivities with other healthcare systems that appear to be critical considerations when planning refurbishment changes.

Issues of robustness, reliability and resilience were examined, in terms of achieving long-term continuity within the NHS. Traditional management has focused on improving robustness and reliability, by developing specific strengths and by reducing variability. However in a rapidly changing world, where demand is continually evolving, a resilient perspective promotes a dynamic response to change, whatever its form. As a result, resilience may enable an organisation to better react to threats, since resilient systems can persist or transform, depending on the influences that bear on the system.

Resilience, as a relatively recent concept in construction. Although output in this area has increased considerably over the period of this study, there remain considerable gaps relating to built environment resilience, for example, in the areas of resilience monitoring, resilience and sustainability, and the persistence of resilience programmes.

Published research in the area of refurbishment project change is scarce, in comparison to the established engineering project change literature. Where refurbishment research has been identified, it is often related to non-UK situations with only limited relevance, due to the dissimilarity of building types, contractual forms, the organisation of labour, and construction practices.

Refurbishment appears to have been the “poor relation” to new-build construction (Wood, 2003) and until recently, has been largely overlooked academically. The literature review highlighted considerable gaps in refurbishment literature generally, and this is particularly noticeable in UK research, in the areas of project cost or duration, stakeholder involvement, refurbishment boundaries and indicators of quality in project success.
Chapter 3 The National Health Service

A brief description of the English National Health Service may be helpful as an aid to understanding the drivers that bear on the organisation and the constraints that limit or restrict the options for change within the organisation. The information in this chapter is largely derived from NHS England or Department of Health (DoH) sources and where other authorities are used, they are cited in the text.

3.1 Overview of the UK National Health Service (NHS)

The UK NHS is the world’s largest publically funded healthcare system and lies fifth in the top ten of the world’s largest employers, surpassed only by the US Department of Defence, Walmart, McDonalds, and the Chinese People’s Liberation Army (NHS England, 2015). The NHS presently employs more than 1.6 million people (including 150,273 doctors, 377,191 qualified nursing staff, 155,960 allied professional staff and 37,078 managers), (NHS Confederation, 2016). Since the founding of the NHS, the UK has seen a population increase of approximately 25% (Office of National Statistics, 2016) and despite changes in models of care, treatment costs and medical technology, the NHS continues to offer a free and comprehensive health service to all UK residents whilst also providing emergency care for the UK’s 33 million visitors each year.

This high level of demand has obliged NHS hospitals to operate continuously at very high capacities, frequently exceeding 90% (Taylor, 2012; NHS England, 2013a). Indeed, there were 31 per cent more hospital admissions in 2014/15 (15.892m) than a decade earlier (12.102m) and in 2014/15, NHS staff completed 45 per cent more procedures or interventions compared to 2004/05, increasing from 6.848m to 9.920m (NHS Confederation, 2016). In particular, Accident & Emergency (A&E) services have been under severe pressure, with the total annual attendances for the year 2014/15 at 22.364 million, and this figure is over 25 per cent higher than the 17.837m visits of 2004/2005 (NHS Confederation, 2016). Despite this pressure on services, the Commonwealth Fund’s 2014 “International Comparison of Healthcare Systems” rated the UK NHS as the world’s most efficient and effective healthcare system (Kossarova et al., 2015).
3.2 Historical Context

From its founding in 1948, the NHS inherited over 2600 hospitals (Greener, 2008) including some from as early as the 18th century and included many elderly “Nightingale” wards or “Spine and Pavilion” Victorian institutions, which are based around long, narrow corridors of beds, visible from a single nurses station. This assortment of existing general and cottage hospitals, workhouse infirmaries, convalescent homes, infectious disease hospitals and sanatoriums had long been starved of funds and were considered inefficient and dilapidated.

![Picture 3.1 Bartholomew’s (Bart’s) Hospital London early 19th Century](image)

The new National Health Service, with its wide remit and developing clinical practice, required hospitals better able to cope with “modern” needs, however post-war Britain could afford to do little but patch-up the existing buildings. The Hospital Building Programme of 1962 was designed to replace outdated infrastructure and proposed that 90 new hospitals should be built (Greener, 2008). There was continuing debate as to the form that the “ideal” hospital should take to provide the most efficient, economic and effective working space.
Various configurations were considered, eventually giving rise to a number of low-rise, mid-rise and high-rise hospital building types, alongside the alternative, “Deep Plan Racetrack” forms (Francis et al., 1999). Further developments included the “Harness” system (Lewis et al., 1976), “Best-buy” hospitals (a standardised design which could be replicated across the country), and later the “Nucleus” and “Courtyard” designs, (low-rise grid plan structures that, in theory, could be easily extended).

More than a hundred examples of Nucleus hospitals and many variations of “Courtyard” buildings appear in NHS portfolios across the country (Francis et al, 1998). Since 1962, NHS hospital campuses have been developing progressively and most include a range of hospital building types.

Improved nutrition and immunisation programmes changed the nature of NHS hospitals, from convalescent care for diseases prevalent at the time of the NHS’s inception (tuberculosis, rheumatic fever, diphtheria, polio, and scarlet fever), to an acute clinical care model, with modern surgical and clinical and medical developments progressively improving the breadth of treatable conditions. Below is a link to a photograph of Inverness Hospital’s children’s ward (1948) showing the formal layout of the children’s accommodation, typical of the time.

http://www.nhshighland.scot.nhs.uk/News/Events/PublishingImages/RNI%20Childrens%20Ward%201948.jpg

A founding principle of the United Kingdom’s National Health Service in 1948 was to provide “care, free at the point of use” for the UK population and this, along with the introduction of National Insurance contributions, gave the promise of healthcare and security “from the cradle to the grave”.

3.3 Changes in Government Policy

Governance of a large organisation like the NHS is complex and decision-making tends to be slow and variable across its vast estate. Despite the progress since the NHS’s inception, funding issues, along with the conflicting political ideologies of successive governments, have resulted in recurrent attempts at its reorganisation or restructuring, with frequent episodes of cost-cutting (Tallis, 2004). Over the years, almost every
government has tried to improve the efficiency of the NHS organisation, resulting in recurrent outbreaks of restructuring, poetically described as “constant white water” by a member of NHS staff (anonymous, quoted in Tallis, 2004, p141, para. 2). Although many minor structural changes were made in the intervening years, major changes in 1974, 1982, 1990, 2000, and 2010 involved significant efforts to “rationalise” or “redesign” the provision of healthcare.

In 1990, the then Conservative government introduced the *National Health Service and Community Act (1990)*. This allowed hospitals and other healthcare providers to be given Trust status and become independent organisations with their own management. This led to District Health Authorities having a much reduced role, as trust hospitals began to opt out of Local Authority control. From the 1990’s onwards, smaller Trusts were amalgamated, smaller Health Authorities were merged and Family Health Services Authorities (serving GPs and care in the community) were amalgamated with District Health Authorities, and eventually Regional Health Authorities were replaced by Regional Offices. By 1996 the hierarchical structure set up in 1974 had entirely disappeared.

The National Health Service and Community Act (1990) also led to a system of “internal markets” within the NHS. The Act enabled Health Authorities and some General Practitioners to become purchasers of healthcare services, and consequently hospital Trust incomes became dependent on contracts from local purchasers. This competitive market system was rapidly and universally introduced, despite obvious drawbacks. For example, due to local geographical or population density factors, for many UK purchasers of healthcare, there would be only one feasible healthcare provider. Similarly, Trusts could not actually “cease trading”, so market rules had to be somewhat tentatively applied (Tallis, 2004, p143).

Following the 1990 Act, the principle of “contracting-out” was also established and investor funded firms or consortia were encouraged, through the Private Finance Initiative (PFI), to tender competitively for major NHS projects. PFI funding through the private sector, allowed the construction or management costs of a facility or service, to be borne by the private sector, whilst the NHS pays a regular tariff over a set number of years. The PFI contracting process has since attracted considerable debate, particularly
regarding those PFI contracts awarded early on, as trusts were inexperienced at costing the likely risks and a number of trusts have been left with severely damaging ongoing costs (Hellowell, 2013; Pollock, 2015; Owen, 2105).

The change to a Labour administration in 1997 brought even greater pressure to continue the “marketisation” of the NHS. Independent sector “Treatment Centres” began operating in 2003, run by privately owned organisations, but paid for by the NHS, to provide elective treatments specifically for NHS patients (Kelly and Tetlow, 2012). This was the first example of the private sector competing directly with the NHS to provide clinical care for NHS patients. In 2008 the “Any Willing Provider” policy (later amended to “Any Willing, Qualified Provider”) used patient choice to encourage competition between service providers in an attempt to improve standards of care. Initially this gave certain patients the choice, where it was locally available, between an NHS hospital and a qualified independent sector provider, if costs were comparable.

The 2010 government white paper, *Equity and Excellence: Liberating the NHS*, was formulated with the aim of establishing a clinically focussed healthcare commissioning system, purported to be more responsive to the needs of patients. According to the 2010 White Paper, legislative changes would be aimed at moving towards clinically led commissioning, increasing patient representation in the NHS, increasing the focus on public health, the streamlining of “arms-length” quality monitoring bodies, and a move towards increasing competition for healthcare services, from independent, charity and third-sector providers. This was shortly followed by legislation, *The Health and Social Care Act (2012)*, which radically changed the way the NHS in England is organised. As a result, Primary Care Trusts (PCTs) that had previously negotiated and commissioned services for their geographical area, were abolished and under the present system, local GP Clinical Commissioning Groups commission a range of secondary/acute healthcare services for their patients. This system is currently being rolled out to include primary care services.
3.4 NHS Trusts and NHS Organisational Structure

3.4.1 Trust Status

Presently there are several types of NHS Trusts: NHS hospital trusts or *acute* trusts, NHS mental health trusts, Community Health NHS Trusts, and NHS ambulance services trusts. Any NHS Trust can apply to become a Foundation Trust, that is, a semi-autonomous organisation within the NHS. Foundation trusts were designed to be different from standard NHS trusts as they were designed to allow a level of freedom in making decisions about how Trusts could achieve their local obligations, and as such they are accountable to their local populations. Foundation Trusts are authorised and scrutinized by the independent regulator, Monitor. The achievement of Foundation status requires the NHS Trust applicant to pass a variety of fiscal, governance and procedural tests. On achievement of Foundation Status, Trusts would be able to retain surpluses and decide how to use their assets. Recently the UK government maintained that all NHS Trusts were expected to achieve Foundation status. However Simon Stevens, the CEO of the NHS has suggested that it is very doubtful that struggling NHS Trusts would be likely to achieve Foundation status in the near future. In a keynote address to the King’s Fund’s annual *Integrated Care Summit* on 13th Oct 2015, he declared, “It’s time to call ‘time’ on the foundation trust pipeline” and “We are kidding ourselves if we think trusts are going to pass the criteria set out by Monitor.”

3.4.2 NHS Organisational Structure

Of the four regional bodies that make up the UK NHS: NHS England, NHS Scotland, NHS Wales and Health and Social Care in Northern Ireland, NHS England, (the focus of this thesis), is the largest and presently serves a population of 53.9 million people (NHS England, 2015). There are currently 154 Acute Trusts in NHS England (including 101 Foundation Trusts). Its organisational structure is shown in Figure 3.1.
The key leadership roles are shown in Table 3.1. In addition, there are a wide range of stakeholders that contribute to, or may be affected by, changes to any aspect of hospital service provide. The main stakeholders are listed in Table 3.2.

### Table 3.1 Key Leadership Roles in the NHS (NHS England, 2014)

<table>
<thead>
<tr>
<th>Office</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Secretary of State for Health</td>
<td>Is the UK government minister responsible for the nation’s health and has overall financial control and oversight of all NHS England’s delivery and performance.</td>
</tr>
<tr>
<td>The Chief Medical Officer</td>
<td>Advises the government on medical and scientific developments and provides professional lead for doctors, and directors of public health.</td>
</tr>
<tr>
<td>The National Medical Director</td>
<td>Is responsible for NHS England’s clinical policy and strategy and for promoting innovation.</td>
</tr>
<tr>
<td>Chief Scientific Officer</td>
<td>Are the heads of their respective professions and provide expert clinical advice across the health system.</td>
</tr>
<tr>
<td>Chief Dental Officer</td>
<td></td>
</tr>
<tr>
<td>Chief Pharmaceutical Officer</td>
<td></td>
</tr>
<tr>
<td>Chief Health Professions Officer</td>
<td></td>
</tr>
<tr>
<td>Sector</td>
<td>Stakeholders</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Health</td>
<td>NHS staff and their Professional Bodies/Industrial representatives</td>
</tr>
<tr>
<td></td>
<td>NHS Commissioning Groups</td>
</tr>
<tr>
<td></td>
<td>Local GP and Dental Practices</td>
</tr>
<tr>
<td></td>
<td>NHS Healthcare watchdogs</td>
</tr>
<tr>
<td></td>
<td>Local allied health professionals</td>
</tr>
<tr>
<td></td>
<td>NHS Ambulance Trusts</td>
</tr>
<tr>
<td>Business</td>
<td>On and off-site contractors, sub-contractors</td>
</tr>
<tr>
<td></td>
<td>Supply chain partners</td>
</tr>
<tr>
<td>Community</td>
<td>Patients and their families</td>
</tr>
<tr>
<td></td>
<td>Carers</td>
</tr>
<tr>
<td></td>
<td>Visitors</td>
</tr>
<tr>
<td></td>
<td>Community groups</td>
</tr>
<tr>
<td></td>
<td>Local media</td>
</tr>
<tr>
<td>Public Sector</td>
<td>Public Health</td>
</tr>
<tr>
<td></td>
<td>Local Council employees (Social workers, peripatetic teachers, Planning and</td>
</tr>
<tr>
<td></td>
<td>Building Control Departments, Transport Planning)</td>
</tr>
<tr>
<td></td>
<td>Police</td>
</tr>
<tr>
<td></td>
<td>Historic England</td>
</tr>
<tr>
<td>Third Sector</td>
<td>Voluntary Groups</td>
</tr>
<tr>
<td></td>
<td>Charities</td>
</tr>
<tr>
<td></td>
<td>Chaplaincy</td>
</tr>
</tbody>
</table>
The Department of Health is the ministerial department that provides strategic leadership for public health, the NHS and social care in England. It reports to the Secretary of State and has responsibility for leading, funding and supporting healthcare in England. It is itself supported by some 28 arms-length bodies and agencies.

A number of organisations are involved in monitoring the quality of NHS provision, including the Care Quality Commission, which registers and inspects both public and private healthcare providers. Monitor licences and scrutinises the financial and service performance of NHS healthcare providers, their payment systems and procurement. Where Trust financial or healthcare performance does not meet the required standards, Monitor can intervene and place Trusts under “special measures” and can if considered necessary, replace the senior management (see Section 5.3.2 of Case Study 2). The role of the National Institute for Health and Care Excellence (NICE) is to improve clinical outcomes for people using NHS, public health and social care services. NICE aims to ensure equality of treatment across England and consequently produces quality standards, and also provides advice and guidance to practitioners, healthcare managers and commissioners. Public Health England takes action to protect and improve the nation's health and wellbeing, and reduce health inequalities both socially and geographically. Other important healthcare organisations include the National Quality Board, whose purpose is to harmonise the quality goals across the NHS, and Healthwatch, which represents the consumers, gathers the views of communities and people using NHS services, and feeds their findings into local health commissioning plans.

3.5 Challenges for the NHS

3.5.1 The Aging Demographic

The demographic profile of Britain is changing and this will have significant implications for hospital care. In 1951, those reaching 85 years and over represented only 4 percent of the “over 65” population; however in 2012, the “over 85 years” group now represents 14% of the “over 65” population (Rutherford, 2015).
3.5.2 Co-morbidities

Care for elderly patients can be complex as they frequently present with more than one serious health condition (co-morbidity or multiple morbidities). Generally, patients are referred to particular specialities/departments or specific wards based on their reason for admittance. Most hospital systems treat patients according to a single diagnosis e.g., patients presenting with heart problems for example are placed in a cardiac unit, whereas a rheumatology ward supports patients with joint pain. It can be difficult to place patients with complex co-morbidities and consequently their care may be compromised. Consequently, this has led to the development of alternative models of care in some NHS Trusts, for example, by treatment via cross-discipline teams that do not characterise patients by a particular illness.

3.5.3 The Pace of Change

The NHS has been described as slow to change (Greener, 2008) and the process of introducing new initiatives can be complex, owing to the time required to develop new systems or models of care and the need to ensure patient safety. In addition, there may be uneven uptake for a number of reasons, such as staffing pressure, communication failures, financial restrictions or “change fatigue”. Change fatigue is typified by a lack of enthusiasm in staff for new initiatives, typically following frequent previous changes to systems that have had little or no positive outcome. Nevertheless, new therapies and technologies can bring opportunities to provide improved outcomes and reduced costs whilst saving valuable time. Accordingly, encouraging or motivating uptake is a key aspect of system transformation and enhancement.

Clearly, there are considerable challenges to be overcome if NHS hospitals are to maintain or improve on their existing levels of service. It may be necessary to find new ways of funding innovative technology and biomedical therapies along with the necessary training, and the changes to care pathways that will result (McMurray, 2010; Francis Report, 2013; Shah et al., 2013; Imison and Bohmer, 2013; Waring et al., 2013; Birrell, 1999; Confalonieri et al., 2007; Darzi Review, 2008).
3.5.4 Options for the NHS Estate: Where will patients be treated?

New initiatives impact on the hospital building that are needed. For example, specialist surgical centres that concentrate on specific procedures, such as hip replacements and knee operations, have shown improved outcomes and can help to reduce the pressure on acute hospitals. Similarly, localised testing, imaging and treatment through GP surgeries; the provision of post-operative or recuperative care at home or in the community; and improvements in telemedicine, may substantially alter the way care is provided and reduce the need for very large acute hospitals. Consequently, it is possible that NHS hospital buildings of the future may be smaller and more streamlined; or alternatively buildings may be more flexible with a loose fit, better able to accommodate a change of use, or a shift in demand. Whatever the shape of the future NHS, the existing buildings will be required for some time ahead. Hence, both existing and recently completed buildings will need to be refurbished and adapted, over time, to suit the changing climate and revised care models; and in addition, to exploit the benefits of new or disruptive technology.

**NHS complexity**

Large organisations like the NHS generally have specific problems due to the complexity that inevitably develops over time. Typically such organisations develop multiple interconnected systems that result in difficulties in communication; differences in performance; power blocks; silo mentalities; corralling of resources.

**Access and variation**

Although most patients have access to the health services they need, some will have to travel considerable distances. Some NHS patients will have free access to certain treatments (e.g., additional IVF treatments) for which NHS patients living in neighbouring areas may have to pay. The NHS attempted to even out the discrepancies of local care with the introduction of NICE. This was set up in 1999 as the National Institute for Clinical Excellence, and part of its purpose is to reduce variation in the availability and quality of NHS treatments and care. Although now functioning as the National Institute for Health and Clinical Excellence, its remit has grown, but equitable
access to healthcare is still one of its major concerns. However in practice, variations in access to care, and in care quality, still remain problematic throughout the English NHS.

**Producing a Business Case in the NHS**

When staff identify new care models or productivity improvements, suggestions are discussed with the head of unit. Projects must be developed as a business case and must pass a number of stage gates. Heads of units can authorise projects up to an agreed level, usually between £100,000 and £250,000 as far as the budget allows. Projects whose projected costs fall above this level must be authorized directly by the NHS Trust Board.

“(the clinician) would take the initial idea, get approval to develop the business case, he’d put together an outline business case and then a team would be taking the bid forward. So at that point then, all of the care models and including the requirement for built environment would be taken into account and we (the estates team) would be approached to take the brief, expand the brief, regurgitate the brief back to the client. So they would have a full understanding, and we would have a full understanding of what we are looking at and then we’d start working on the numbers and the sketch scheme design. We’d take professional advice from an external quantity surveyor, to put together a budget and take the business case forward on that basis”. Case Study estates manager.

**Drivers of change and constraints or limitations**

For the most part the NHS attempts to provide a high standard of care, however it is constrained by multiple limitations, which restrict the possible options for Trusts to manage their responsibilities for care. Trusts must also respond to changing external pressures and in a period of recession, it may be difficult to respond effectively.

Table 3.3 lists some common drivers of change.
Table 3.3 Drivers of change (Ariyo, O., 2012)

<table>
<thead>
<tr>
<th>Drivers of Change</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advances in clinical/ laboratory treatments and new models of care. Rapidly developing clinical technology.</td>
<td>Uncertain Funding. Rapidly increasing pace and costs of scientific /clinical/ technological/pharmaceutical innovation</td>
</tr>
<tr>
<td>Demographic trends: Aging population with multiple morbidities/population migration.</td>
<td>Difficulty of attracting and keeping suitable staff. Limited support for recovering patients in the community.</td>
</tr>
<tr>
<td>Competition between Trusts.</td>
<td>Frequent disruption due to political intervention/ economic uncertainty.</td>
</tr>
<tr>
<td>Public perception of the NHS.</td>
<td>Hard-pressed staff with significant administrative burden and frequent policy/ regulatory changes. Ill-chosen government targets.</td>
</tr>
<tr>
<td>Advances in communications technology.</td>
<td>Frequent equipment/ software updates required and necessary staff retraining.</td>
</tr>
<tr>
<td>Condition of Trust buildings/ maintenance backlog.</td>
<td>Scarce funding for non-clinical priorities. Existing onerous PFI contracts.</td>
</tr>
<tr>
<td>Changes in disease spread/pathogenicity.</td>
<td>Changes in antibiotic resistance.</td>
</tr>
<tr>
<td>Changes in population morbidity (e.g., increasing levels of obesity and diabetes).</td>
<td>Increasing level of funding directed away from acute care towards Public Health.</td>
</tr>
<tr>
<td>Increasing need to source new funding streams.</td>
<td>Trust budget deficits (e.g., requiring Sustainability and Transformation plans).</td>
</tr>
<tr>
<td>Increasing threat of disruption due to climate change/ terrorist activity etc.</td>
<td>High cost and significant timescale required to adapt NHS buildings to cope with climate change and other resilience issues.</td>
</tr>
</tbody>
</table>
3.6 Conclusion

This chapter on the NHS has necessarily been brief, but there are many sources of further information that are readily available. Websites of NHS England and the Department of Health provide much information; recent books include Lister (2008), Taylor (2012, 2013) and Player and Leys (2011).
Chapter 4 Methodology

4.1 Introduction

Research projects typically adopt a stepwise approach towards a specific outcome or goal, which may, for example, provide an addition to theory, or a tool to serve a practical application. The steps of the process can be non-linear or parallel, but should form a coherent and convincing overarching rationale, aimed at reaching a valid conclusion. Eckert et al. (2003) developed a research methodology based on the engineering design research process, which clearly identifies a series of steps that can be used to guide the research process throughout its multiple stages towards a valid conclusion. Although intended as a framework for engineering design process research, refurbishment design and construction process research appears to have many similarities, in that both are design oriented, multifaceted, and aspire to similar goals (elucidating process, developing theory and industry appropriate tools), and both may encompass extended time-frames. Indeed, Eckert et al.’s stepwise approach to achieving research goals appears to correspond to the DeDeRHECC team’s research process. Eckert et al., (2003) advise however, that the “Spiral of research” is based on a long term strategy for research teams, and that PhD research might normally be devoted to just two or three stages of the spiral. They warn, however, that students should have a strong understanding of the overarching research rationale that motivates each of the research stages.

Eckert’s spiral of design research (Eckert, et al., 2003): is a pragmatic design-based methodology aimed at clarifying the stages of the engineering research process. The methodology considers the long term, from initial empirical studies, to the development of a final outcome of the research, in this case validated industry based tools. The stages identified by Eckert et al. (2003) are as follows.

1. **Empirical studies.** These include case studies, or observational approaches, interviews, and a range of analytical methods, etc. Outcomes describe the studied process under specified conditions.

2. **Evaluation of empirical studies.** Here the validity of the research results is assessed, and whether or how far the results can be generalised.
3. Development of theory. Empirical research should lead to the development of our understanding of practice, through theories of design, mathematical process models, or analyses of “real” processes.

4. Evaluation of theory. Theoretical analyses should be compared with existing empirical data, and assessed both in terms of their philosophical and methodological assumptions and their grounding in more general theoretical frameworks, along with their relationship to analyses grounded in different conceptual frameworks.

5. Development of tools and procedures. Understanding people’s real needs for procedures and support is difficult. To be effective, tools must be developed that are grounded in a good understanding of the thinking processes and work practices of their users.

6. Evaluation of tools and procedures. The development of tools and procedures needs to be an iterative activity interlaced with evaluation of interim products, as users’ and developers’ understanding of the real requirements change when the users test the prototypes.

7. Introduction of tools and procedures. Tools that are considered useful as a result of the above procedures should be tested in industrial use.

8. Evaluation of dissemination. The results of the process of the tool development and its use must be assessed for validity and should fit with our general understanding of practice.
The research for this thesis is situated within the first two stages of the spiral and focuses on empirical studies, their analysis and their evaluation. It forms part of a large project whose aim was to examine sustainable, low cost, space cooling options for NHS hospitals. The essential focus of the research in this PhD is to identify the barriers that may obstruct or prevent the introduction of adaptation measures in NHS Hospitals to combat the threat of climate change. The other stages of the process, itemised above, have been carried out by the DeDeRHECC Team. A video of the thermal/ventilation focus of the DDRHECC project research, entitled “Robust Hospitals in a Changing Climate” was produced by Cook, P, Short, CA, Fair, A, Lomas, K & Noakes, C. and is available on YouTube at: https://www.youtube.com/watch?v=GvNjVQQmXLU.

Other outputs include the “Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare” by C. Alan Short, Peter Guthrie, Eleni Soulti, Sebastian Macmillan, (2015), and journal papers, (Lomas and Ji, 2009; Short and Al-Maiyah, 2009; Short et al., 2010; Lomas and Giridharan, 2012; Lomas, et al., 2012; Short et al., 2012; Eckert et al., 2012; Giridharan, et al., 2013; Iddon, et al., 2015; Short, et al., 2015). Conference papers include Masko et al., (2011); Garthwaite and Eckert (2012a); Ariyo et al., (2012); and Garthwaite and Eckert (2012b).
The underpinning research philosophy is based on Bhaskar’s *critical realism*, as explained in Collier (1994), and this is described in Section 4.2. The EPSRC funded DeDeRHECC project provides the context for the research and this is outlined in Section 4.3. An overview of the case studies is given in Section 4.4 and details of the ethics considerations for the research are noted in Section 4.5. The remainder of the chapter describes the mechanics of the case studies, and the way interviews were conducted and analysed. The methodology used for the preliminary study, conducted ahead of the case studies, is presented in Section 4.6, and the methodology and analysis for the case studies are described in Section 4.7. The approach taken in conducting and analysing the Expert interviews is described in Section 4.8 and finally, validation issues are considered in Section 4.9.

### 4.2 Research Philosophy

#### 4.2.1 Ontology and Epistemology

An ontology represents a particular world view or perspective on reality and concerns how we experience reality and how it can be sensed or detected. In essence, it questions existence such as, for example, whether there is a physical world “outside” – beyond the mind – that can be investigated or measured. Epistemology on the other hand, relates to how we understand and interpret what we see. A person’s understanding and knowledge about the world might be framed or constrained, for example, by their professional or personal viewpoint, be it a scientific, religious, humanist, atheist (or other) perspective.

> “Most theorists agree that knowledge is a justified, true belief but they differ in the requirements for the quality of the justification or in the context of the belief”  
>  
> *Dainty and Bosher, 2008.*

Consequently, it is fundamental to any research that there is clarity regarding the assumptions that are made about the world (i.e., the ontological viewpoint) and the way in which information based on these assumptions is interpreted (the epistemology). Such perspectives frame research and shape or constrain the interpretation of the
outcomes. In the mid-twentieth century Bhaskar (1978) developed a philosophical perspective to both the natural sciences, which he termed “transcendental realism,” and to the social sciences which he classed as “critical naturalism,” (Bhaskar, 1978; Collier, 1994). These perspectives, Bhaskar suggested, were both compatible and explanatory (Collier, 1994). Bhaskar went on to develop a combined theory of the natural and social worlds which he described as “critical realism” (Collier, 1994).

Natural science researchers attempt to describe, measure and predict consequences based on repeatable experiments in an effort to explain what they observe, and with the aim of contributing to an “objective” theoretical perspective. Social science researchers however, do not have the luxury of being able to repeat events, or alter key variables to observe the consequences. This is because their research considers the interactions, relationships or negotiations between people, whose accounts of such interactions will vary depending on their own particular perspective. Such accounts must be considered subjective interpretations of events. Unfortunately, events, experiences or negotiations cannot be repeated exactly, since many factors such as tiredness, mood, ambience, etc may fundamentally change how an event or negotiation transpires. Hence each interaction is unique and cannot be repeated exactly.

Critical realists accept that inductive (also termed retroductive or abductive) explanations can provide a useful framework for furthering an understanding of events (Easton, 2010). This means that an explanation can be suggested that accounts for a set of observed facts, and this process can act as a way of exploring the mechanisms that affect an event. The inductive explanation may either be correct, or it may be partially or totally flawed. Hence retroductive arguments are weak, due to their inability to gauge how closely they represent the “truth”. In practice, two or more retroductive arguments are compared to see which of the arguments better represents our understanding of how events might have unfolded. Alternatively, a retroductive argument can be made more powerful through support from additional evidence derived from other sources. Hence, arriving at the “truth” is seen as an iterative process where arguments are continually tested against a growing body of knowledge. For this reason, critical realist researchers embrace the widest possible range of methods to “uncover” the clearest picture of events, i.e., closest to the “truth” of events occurring in the “actual” domain. The process where the results from individual pieces of research about a topic, employ
different methodologies to help locate and support each other in presenting an improved picture is sometimes termed **triangulation**.

Hence, the critical realist perspective can be helpful for understanding and interpreting social structures in the NHS and interpreting how changes can cause outcomes that can be observed or studied (Easton, 2010). However Yeung (1997) argues that due to its limitations the critical realist perspective may be less applicable to generating theory (Yeung, 1997). These Critical Realist limitations may include the acceptance that all knowledge is fallible; that retroductive arguments may provide incomplete, or erroneous views of the world; and that some approaches to investigation may provide misleading interpretations of events, if taken out of context. Based on the work of Bhaskar (in Easton, 2010):

- In Critical Realism (CR) Terminology, objects or “Entities” are defined as the basic components of the CR theory and can be complex or simple. Architectural designs, people, structures, buildings, relationships, organisations, conceptions, systems or any phenomenon or object capable of being studied, can be considered as an entity.
- Critical realists posit that entities have “causal powers”. In other words, they can “give rise to”, “create” or “generate” an incident, a happening or an experience (Sayer 1992, p104, in Easton 2010).
- Entities may have a “liability” or a “susceptibility” to the action of other entities Easton (2010).
- “Mechanisms” can be considered as “the ways of acting of things” (Bhaskar, 1978, p14).

Easton (2010) explains that this perspective allows researchers to concentrate attention towards the defining entities, their relationships, their powers and liabilities. Consequently, the critical realist ontological view differs from the simple flat perspective of the “world out there” of the positivists or that of the “socially constructed world”, in that it is “transcendental” or “transcends” the flat.

Bhaskar’s CR view of the world (Easton, 2010) comprises a stratified view of the world and the strata are described as

- the “empirical”: the domain of the individual’s observations and experiences;
• the “actual”: events happen in the “actual” domain; and
• the “real”: mechanisms drive events in the “real” domain.

While events happen in the “actual” domain, Easton explains that they may go unobserved or may be construed differently by different observers. Consequently, the process of interpretation relates the “actual” and the “empirical” domains (Easton, 2010).

Easton further clarifies, that “it is not the case that the actual and the real cannot be observed, but simply that it may not always be capable of being observed” (Easton, 2010). Hence critical realists accept that our accounts of the world will be fallible and imperfect.

Critical realists consider that it is our “internal interpretation” of the “objects out there”, rather than the justification or the context, that is crucial and that our interpretation (or knowledge) is closely related to these “objects” (Yeung, 1997). They accept that society and its organisations exist; and that its “structures” and behaviours are related to observable events and have a causal explanation (Yeung, 1997).

Critical realist researchers have argued that our imperfect or inconsistent interpretations of the world require “the most searching and thorough exploration by the broadest range of methods” so that knowledge can be related as closely as possible to “reality” (Tsang and Kwan, 1999). Hence the variety of insights and thick descriptions\footnote{A thick description (as used in the fields of sociology or anthropology), typically describes aspects of human behaviour but in addition, includes contextual information. See, for example, Chapter 1 in Geertz (1973).} gained from using combinations of methods, contribute to building a rich picture\footnote{Rich pictures provide a visual representation of a problem or event based on a diagram built up from experiences and insights. Such diagrams encompass the form, context and processes of an event, or situation. See, for example, Checkland (1993).} of the events or relationships under study.

Key to the process of interpreting a “rich” picture, is a clear understanding of what can be said about the results derived from different types of studies, based on very different premises (Mingers, 1997, Chapter 1). Nevertheless, the process of triangulation has attracted considerable criticism. Crucially, the different perspectives adopted throughout the research, require that the research outcomes must be understood in the context of their ontology and epistemology. For instance, it may be inappropriate to
draw conclusions about a population, based on the results of a single case study. However, such a study can shed light on aspects of the events or relationships under investigation. For example, a researcher may wish to shed light on population outliers or exceptions, whose behaviour appears contrary to the normal model, and by this means permit the presence of a general relationship (Yin, 2009).

Crucially, the clear obligation to embrace a broad range of methods affords greater richness, power and clarity in the eventual research conclusions. Easton (2010) suggests that suitable approaches to critical realist research include case study research, and exploration of the motivators (including the decision-making processes), activities and outcomes of the mechanisms under study. Yeung, in explaining the broader CR method of iterative abstraction and retroduction, notes that “we should move from pure descriptions of the phenomenon to abstractions of possible causes” (Yeung, 1997).

4.2.2 Methodology Adopted for this Research

The research in this thesis is based on qualitative studies, where individuals’ accounts of an event or relationship provide the main source of data. This approach was adopted to unravel the complexities of the refurbishment process within the NHS. The methods included a review of the literature related to the topic areas, a preliminary exploratory study, four case studies of NHS refurbishment, and a selection of expert interviews. Qualitative methods were adopted to investigate “why and how” specific events unfolded, particularly those events that related to the case study projects. It was felt that a qualitative approach would elicit a real sense of what drives or motivates decision-makers when working within an environment of competing pressures.

Critical realists accept that qualitative methodologies are helpful when investigating viewpoints, understandings, and the interpretations of events and attitudes. Qualitative methods, in consequence, can be used to investigate causal mechanisms, by unravelling the relationships between entities and specific events. The structures that are studied could be the NHS, or people (such as managers), or systems (such as heating systems or IT systems) or effects, such as the consequences of global warming. For example, when investigating the views of managers on the potential for climate change to disrupt hospital systems, it was helpful to elude their views and motivations regarding global
warming and the pressures that might limit or encourage the implementation of remedial measures. However, events or outcomes are the focus of this investigation, along with the behaviour or activity that causes, triggers or affects them e.g., refurbishments, interventions, or heatwaves (Easton, 2010). Qualitative methods are useful in eliciting views and in clarifying how such views can be conceptualised, such as for example, what the perception of a participant’s “satisfaction” with the hospital environment reveals about the interviewee, and their awareness of the workplace. Thus qualitative methods can be used to explore unfolding professional views of, say, resilience, probe the perspectives on the refurbishment/adaptive process in the NHS, or disentangle the multiple roles of the NHS in refurbishment and the process of decision-making.

"Qualitative research is a form of social inquiry that focuses on the way people interpret and make sense of their experiences and the world in which they live. A number of different approaches exist within the wider framework of this type of research, but most of these have the same aim: to understand the social reality of individuals, groups and cultures. Researchers use qualitative approaches to explore the behaviour, perspectives and experiences of the people they study."

Holloway (1997, p.2)

Quantitative research methods were also adopted when comparing specific “objective” or measureable phenomenon. For example, they were used in evaluating refurbishment cost data and in assessing or comparing determinate data in documentary evidence (e.g., data from building plans and hospital room data sheets) used in the preliminary modelling process.

Construction research is largely dominated by the positivist research paradigm and in the past this has led to criticism of its historically “blinkered” and “reactionary” approach to alternative methodologies (Dainty, 2008). Research in the NHS has tended to rely largely on such objectivist/quantitative research, partly because much of the research focus is on large scale “double-blind” trials with patients, to obtain reliable and repeatable “gold standard” results regarding patients’ responses to interventions. However, although such methods may capture convincing quantitative evidence (supporting a particular clinical therapy, for example), they may not capture the
underlying difficulties experienced by patients, and consequently there may be unexpected reluctance by patients to undergo particular treatments. Hence, owing to their explanatory power and the ability to identify “intangible factors”, qualitative methodologies are becoming more common and both the NHS and the construction management research communities have embraced multi-methodological research approaches (Dainty, 2008; Pope and Mays, 1995).

The process of managing constraints has been studied from an engineering design perspective (Eckert et al., 2001; Eckert et al., 2004; Wynn et al., 2007; Eckert and Clarkson, 2010; Clarkson and Eckert, 2010) and changes to designs can be the cause of serious delays and failure to meet targets. It was considered that an approach to change, developed by engineering design researchers, may also be helpful in refurbishment situations. Their perspective views changes to projects in terms of the ability of different mechanisms (absorbers or multipliers of change etc. are explained in Section 2.10.3) to affect the course of changes.

Many quantitative studies have identified that change is a problem for refurbishment (Ogunlana et al., 1996; Cox et al., 1999; Kaming et al., 1997; Touran, 2003; Hanna et al., 2004). Sun and Meng, (2009) reviewed sixty-four papers that used quantitative methods to investigate the impacts of changes to projects. However, there have been comparatively few studies that employed qualitative methods to obtain a richer picture of the change process. Sun and Meng, (2009) identified only 13 papers that explicitly used interview methods, out of 101 papers examined. It is likely that a deeper understanding of the barriers and constraints that operate during the NHS refurbishment process might help in framing solutions to some of the areas that the NHS finds problematic. Qualitative methods appear particularly appropriate for shedding light on the assumptions and motivations of those involved.

4.3 The DeDeRHECC Project

4.3.1 Context

*The Changing Climate*
Global climate change has begun to have clear impacts for local weather systems around the world and the consequences can be seen in the decline in Arctic winter ice, record-breaking storms, stronger hurricanes/typhoons, longer and more intense droughts/heatwaves, widespread floods and serious land-slips (Troccoli, 2014; WHO, 2008; Mika, 2013). The principal cause of climate change is considered to be anthropomorphic i.e., resulting from the release of the carbon (as carbon dioxide) by man (ICCP, 2014) during the combustion of carbon-based fossil fuels for electricity production, heating, industrial processes, agricultural production and transport.

Towards mitigating the effects of climate change, in 2008 the UK government passed the Climate Change Act (2008), committing the UK to meet 80% reductions in CO2 emissions by 2050 (against a 1990 baseline). This target has placed onerous commitments on large UK organisations to reduce their energy consumption. The UK has met its annual targets year on year, however figures for the period 2014-2015 show a rise in CO2 emissions from both buildings and transport and projections suggest that the UK is not on track to meet its 2023-27 carbon budget (Climate Change Committee, 2016). Unfortunately, the global economic downturn, the plethora of available renewable technologies and the scarcity of independent advice or guidance has made investment in renewable energy a complex and speculative process for NHS estate managers who need to achieve real reductions in their carbon footprints and reduce their overall energy costs.

### 4.3.2 The Design and Delivery of Robust Hospital Environments in a Changing Climate project (DDRHECC)

The Design and Delivery of Robust Hospital Environments in a Changing Climate project (DDRHECC), was set up to investigate sustainable options for summer cooling for existing NHS Hospitals. Many NHS hospitals are already struggling to provide suitable environments during hot summers. Heat waves for the UK are predicted to increase not just in frequency but also in duration and intensity (Confalonieri et al., 2007). The NHS is committed to increasingly onerous energy targets which aim to reduce CO2 emissions to 26% below 1990 levels by 2020, and to 60% below 1990 levels by 2050. This would rule out the extensive use of air-conditioning due to its heavy energy requirement.
Consequently, suitable sustainable alternatives for cooling are badly needed to cope with the predicted, increasingly hot summer temperatures. Such measures may require changes to the structure, fabric, floor plans or care models within existing hospital buildings.

*The DeDeRHECC Objectives*

In 2003 the severe heatwave that affected France and much of southern Europe resulted in more than 70,000 fatalities (Robinea et al., 2008), and caused wide-scale problems for electricity production, depletion of water resources, and disruption to infrastructure. In Britain some 2000 heatwave related deaths were recorded in 2003 (Haines et al., 2006) and a further 600 fatalities were attributed to a subsequent UK heatwave in 2006 (D'Ippoliti et al, 2010). The proximity of these severe weather events, together with the recurrent heavy flooding of 2002 (Glasgow), 2004 (Bocastle), 2005 (Kent) and 2007 (Northern Ireland, Yorkshire and the Midlands) focused attention towards the materialising impacts of the changing climate.

In 2008, the UK research councils and government departments launched the “Living with Environmental Change” partnership to provide advice and support to decision-makers in government, business and society, along with tools to mitigate, adapt or benefit from environmental change. As part of its contribution to this high-profile partnership, the EPSRC funded a selected group of research projects to look at the impacts of climate change and possible adaptation options for the built environment and supporting infrastructure. The Design and Delivery of Robust Hospitals in a Changing Climate Project (DeDeRHECC) was one of these initial EPSRC funded projects, during the period 2009-2012. It was set up to investigate sustainable options for summer cooling for existing NHS Hospitals.

*Funding*

The project was funded by the EPSRC and supported by the Department of Health.
The Project Team

This project was led by Professor Alan Short, Professor of Architecture at Cambridge University and resulted from a collaboration between Cambridge University, the Open University and the Universities of Loughborough and Leeds. The non-academic project partners included the Department of Health in Leeds and four participating NHS Trusts.

The Project Investigators

Professor C. Alan Short, (University of Cambridge, Department of Architecture),
Professor C. John Clarkson (Director, University of Cambridge, Engineering Design Centre)
Professor Kevin Lomas (Loughborough University)
Professor Cath Noakes (University of Leeds Pathogen Control Centre)
Professor Claudia Eckert (Department of Design and Innovation at the Open University);
Dr Alistair Fair (Project coordinator, University of Cambridge, Dept. of Architecture)
Dr Giridharan Renganathan (Loughborough University)
Dr Owolabi Ariyo (University of Cambridge, Engineering Design Centre)
Research Students: Pam Garthwaite, Mary Lou Masko and Louis Fifield
Consultants: Arup and Davis Langdon.

4.3.2 Project Partners

NHS Collaboration

Four NHS Hospital Trusts agreed to provide access to hospitals sites, data and estates records, and the Department of Health in Leeds agreed to assist.

The Trusts were geographically well-spread and provided access to hospital buildings and opportunities to research ongoing and completed refurbishment projects. They also
identified dedicated staff as points of contact. The Hospital Trust partners authorized access to resources, such as facilitating interviews with key project participants, and they also provided documentary evidence, such as hospital plans and refurbishment documentation. The Department of Health in Leeds agreed to collaborate and provided expertise in specific areas.

The support provided by the individual hospital trusts varied considerably. One NHS Trust provided access to projects and to hospital wards and to the contractors involved in the projects, and in addition it assisted with arranging individual or multiple group interviews. A further NHS Trust allowed visits to ongoing site work, provided access to staff and post-project meetings, and released considerable project documentation for research purposes. However access to projects and data in the two remaining NHS Trust organisations was sporadic and somewhat variable.

**Academic Collaboration**

Four academic institutions agreed to collaborate as partners for this research project: the Universities of Cambridge, Loughborough, Leeds and the Open University. The academic partners contributed essential expertise and facilities for research, along with financial and academic support for project PhD students. The following were the main academics in the project.

- **Architecture Group (Cambridge University):** Professor C. Alan Short (Principal Investigator) and Dr Alistair Fair: Historical perspective; NHS architectural building types; Resilience; safe design strategies for hospital space cooling.
- **Cambridge Engineering Design Centre and Open University Group:** Professor P. John Clarkson, Dr Labi Ariyo and Mary-Lou Masko (Cambridge University); Professor Claudia Eckert and Pam Garthwaite (Open University): Hospital system connectivities; change prediction; building and system resilience; NHS decision-making.
- **Loughborough Group:** Professor Kevin Lomas and Dr Girir Renganathan, Louis Fifield: Building monitoring and simulation; cooling strategies; predictive climate models.
- **Leeds:** Professor Cath Noakes: Airflow and pathogen control.
4.3.3 Organisation, Communication and Objectives

The full DeDeRHECC team met at regular intervals to discuss progress, monthly at the start of the project but at three- to six-monthly intervals during the later project stages. However the managing group met with either the Loughborough group or the EDC/OU group more frequently. Meetings tended to be either exploratory, (open to a wide range of ideas or suggestions) or, alternatively, more focussed towards a specific issue. The team meetings were always very positive and team members were cheerful, enthusiastic and welcoming. The discussions embraced the range of upcoming research issues and contributions from all of the participants were welcomed. Meetings provided a forum for discussing aspects of data acquisition such as, for example, consideration of the form and format of interviews, identifying the participants and discussing shared objectives. The individual research needs of the team members were also considered and brief lists of issues/questions for interviewees were collated before each set of interviews. The team also considered options for dissemination: DeDeRHECC publishing goals, conferences and issues relating to the DeDeRHECC film.

The Research Gap

The following are the DeDeRHECC Project objectives relevant to this thesis.

- Provide recommendations for detailed refurbishment strategies.
- Examine complexities and barriers to adaptive refurbishment that delivers increased robustness and lower energy consumption.
- Disseminate project outcomes widely through the health, construction and research communities.

Alongside the project priorities, the ARCC (The Adaptation and Resilience in the Context of Change network, who are the coordinating body for EPSRC climate change research) identified specific gaps in built environment climate research. These include:

- Adaptation versus other factors with higher priorities.
- Adaptation issues over longer timeframes.
- Refurbishment and retrofit: more is needed on building change.
The review of the literature identified that changes to refurbishment projects are a major cause of cost and delay, and consequently, it was considered that investigating change and the mechanisms of change during refurbishment projects might provide insight into how refurbishment might impact building resilience (Adaptation and Resilience to Climate Change Network, 2011).

In addition, the ways in which resilience was interlaced with the refurbishment/adaptation process in the NHS appeared “woolly” and indistinct. Resilience, as it relates to buildings, was a relatively new area of research at the outset of this thesis and peer-reviewed publications were comparatively scarce. This was particularly the case in comparison with the disciplines of ecology or psychology, which had a well-established resilience literature. From the literature, it was not possible to ascertain how resilience might apply to building refurbishment.

4.4 Overview of the Case Studies

The research questions for the case studies were focussed towards unravelling and clarifying the NHS refurbishment process and gaining an understanding of its resilience. Considerations included determining who benefited from refurbishment changes and where there were conflicts, and whose priorities prevailed. In addition, the case study approach provided insight into the complex web of connected NHS systems that were affected by the refurbishment process, particularly with respect to the risks associated with changes in routines.

“Case study evaluations are valuable where broad, complex questions have to be addressed in complex circumstances.” (Keen and Packwood, 1995)

Yin (2009), suggests that the case study approach is particularly appropriate for establishing “how” and “why” decisions are made (Yin, 2009, p27). For this research the DeDeRHECC team used case studies from four NHS hospital trusts to elicit the perspectives and experiences of stakeholders in relation to the working environment, to their aims for hospital estate planning for the future, and to the refurbishment/adaptation process. These case studies form the backbone of this thesis.
The case study projects were provided by the four NHS Trusts who had agreed to become partners in the research. The Trusts were willing to provide access to refurbishment projects and the opportunity to meet with stakeholders. This access included the staff, contractors and consultants involved in the planning, construction and use of the refurbished project accommodation. They also agreed to release essential accompanying documentation, including building plans, data sheets and some limited information related to costs.

The case studies are described in detail in Chapter 5. They are referred to either as:

1. Neo-Natal Unit (NNU)
2. Orthopaedic Modular Extension (OME)
3. Acute Admissions Unit extension (AAU)
4. Teenage Cancer Ward (TCW)

Alternatively, (for brevity) they are described as Case Study 1, 2, 3 or 4.

The data obtained in the case study research derived from semi-structured interviews, from the published literature, including normative standards and legislation, and also from NHS released documentation. In addition, informal conversations with estates team members and stakeholders were helpful in providing context and adding richness to the documented accounts. Not all of this supplementary information was formally recorded but, where possible, brief notes were made following encounters.

During the interviews or in casual conversations, the participants often alluded to other ongoing or completed projects undertaken during their work with the trust. Where relevant, these threads were followed up to provide further detail or enhanced context to the case study projects under investigation.

The four case studies were phased so the work load could be evenly spread across the planned 3.5 years project period. The timing of the case studies is shown in Figure 4.1.

At the outset of each study, a site tour was provided by each of the partner trusts, to familiarise the Team with the sites and selected projects within the broad hospital campus. Numerous site visits followed for three of the four studies, to attend meetings; to interview participants; to gather data; and to make ward observations.
Two of the Trusts were particularly helpful in arranging site access. Consequently it was possible to develop detailed depictions of the first two projects specifically, the neo-natal unit and the orthopaedic ward. The remaining two trusts were less able to devote resources to the research, although it was possible to interview particular staff and contractors for the AAU extension project. For the final project, the cancer ward, only the trust’s project managers were available for interview, although numerous visits were made to the hospital site.

4.4.1 Case Study 1: The Neo-Natal Project (NNU)

The Neo-natal project, described in detail in Chapter 5 (Section 5.2), provided a significant opportunity to study an on-going refurbishment project, within a working hospital. This was a partial-refurbishment project that underpinned the total redesign of
the Neo-natal service provided by the Trust and involved construction work on two floors of an existing hospital building.

**The NNU Post-Project review**

In addition to site visits during the refurbishment, access was granted for the author and two other members of the DeDeRHECC team to attend a final post-project review meeting (as observers). This meeting was intended to provide the opportunity for key actors from all parties to come together, to examine the critical stress points or highlights encountered during the course of the project, in some detail. The overall aim of the process was to embed any learning derived from the project, within the formally recorded project review process.

This review process presented a succinct summary or overview of the project’s progression and included open discussion of problematic episodes as well as occasional allusions or hints related to other serious project issues, whilst in addition, recognising the project’s successes. Most Neo-Natal project stakeholders were represented, including client representatives, contractors, consultants and NHS staff users. Key actors were invited to give their observations and reflections on the planning, briefing, procurement, design, management and construction stages of the project, together with their views regarding the outcome. Notes were taken throughout by the three researchers and compared for agreement and consistency. This process helped to highlight fundamental themes, which permeated the case study projects and aided the analyses process.

In addition to site visits to all four of the case study hospitals, a two day ward observation of Case Study 2 period provided helpful detail of the user perspective. Notes were also taken for all visits either by team members or by the project co-ordinator and circulated to the DeDeRHECC team.
4.5 Ethics Approval

Research in the NHS is closely scrutinised, safeguarded and strictly controlled. The NHS has developed exacting governance systems in an attempt to ensure that research studies involving NHS patients and staff on NHS premises, are carried out ethically, and result in well planned, replicable and high quality research. The fundamental requirement for ethical research is that no harm should come to any research participant or to the researcher.

“The definition of 'harm' is quite broad and this could even include upset or stress as a result of talking about their learning in an interview or questionnaire, or from taking part in an observation.” (Open University Human Research Ethics Committee, 2014)

Ethical issues are fundamentally important where vulnerable groups such as those suffering illness, or mental health issues, or whose personal circumstances have become the focus of research. Fortunately, the DeDeRHECC project team were advised by the NHS that they were not required to apply for full ethics approval through the NHS’s National Research Ethics Service (NRES)\(^3\) system owing to the nature of the study. Essentially, this decision resulted from the “buildings related” focus of the research, particularly as patients would not be involved.

However, the DeDeRHECC team were advised that ethics approval from the individual trusts taking part in the study would be required. Subsequently, approval for the research was granted from each of the Trusts taking part in the study, at all four sites.

The Open University also required that this thesis research was registered under the OU Human Research Ethics System. This application was made and although the OU Human Research Ethics Committee “online checklist” indicated that no further action would be required, a discussion with a member of the ethics team was helpful in identifying the relevant issues, as described below.

In all studies that involved participants, consent forms were sent to each individual well ahead of time, along with a brief rationale for the study and a copy of the semi-

\(^3\) Since 2011, NRES has been subsumed into the Health Research Authority.
structured questionnaire. The consent form provided details of the DeDeRHECC team members, and in addition a brief resume of the research problem area that the project was aiming to address, along with details of how the project was funded. The form also advised that there was a likelihood that interviews would be recorded and, in addition, explained how any recorded or documented information would be used and how it would be stored. At the start of each interview, participants were asked to sign and date the consent form. All consent forms were forwarded to the DeDeRHECC team on completion of the interviews to be stored in the DeDeRHECC Project archive.

4.6 The Preliminary Study

It was felt that an appreciation of how front-line staff viewed the working environment would be very helpful in designing the case studies, especially if it shed light on the problems of hospital refurbishment and the importance of resilience to the nurse’s role and to patients. Consequently a preliminary study was conducted to inform the case studies.

The participants in the preliminary study were senior nurses or nurse trainers. All but one had permanent lecturing posts at the Open University. The final participant was a suggested contact from one of the above nurses. The nurses and nurse trainer agreed to attend a semi-structured interview relating to the hospital environment and the need for resilience in the nurse’s role. All but one of the lecturers had previously been a nurse for over ten years though they had very different professional and geographic histories. (The remaining lecturer taught English/humanities to nurses and travelled to many different hospitals to teach them.) The former nurses had experience of private and public hospital nursing, both in the UK and worldwide and, in addition, some also had experience of being a hospital patient. The nursing experience of the sample also differed and ranged from mental health nursing, general nursing, paediatric nursing, through to intensive care nursing and midwifery. In addition, a variety of cultural perspectives were represented within the sample. Before joining the Open University, all of the nurses had reached very senior nursing positions as either a ward sister, clinical nurse manager or departmental matron.
As this preliminary study was undertaken at a very early stage of the research, very little was known about the issues that would be important to the nursing staff and it was considered that semi-structured interviews would provide the most useful method for gaining insight into the problems faced by nurses in their daily routine. Haigh (2008) considered that face-to-face interviews are very useful for “getting the story behind the participant’s experiences” (Haigh, 2008, p113). Haigh also suggests that “The interviewer has great freedom to change the direction of the interview and formulate new questions ... the interviewer’s relationship with the respondent is a more opened-ended exchange, focussed on a topic”.

The preliminary study involved the following tasks:

1. Review literature on process and pitfalls related to interview.
2. Use the research questions to develop a suitable semi-structured questionnaire and prepare a consent form, along with a brief summary of the Study.
4. Invite OU nurse trainers to take part in the study (by email).
5. Send details of project, along with questionnaire and consent form to respondents. Arrange dates/ venues (an iterative process) and provide map/directions.
6. Obtain recording equipment and training in its use.
8. Brief reminder (by email) a week before the interview for each participant.
9. On the day: arrange the room and provision of coffee/ tea/ biscuits etc.
10. After each interview, an email thanking each participant.
11. Arrange storage of documents/ consent forms, etc.
12. Transcription and analysis.

The review of the literature (step 1) made it clear that bias is a primary concern in conducting interviews (see, for example, Yin, 2009). Bias of some form cannot be avoided, as any interaction between people will always be subject to the assumptions, past experiences, attitudes and moods of all of the participants that operate on the day.
In addition, the interview process can be influenced by the ambiance of the surroundings. For example, a noisy cafeteria can cause some people discomfort, especially if they have a hearing disability or if they are concerned about privacy. Participants, on occasion, may be tempted to tell the interviewer what they think she/he would like to hear, while others may be concerned that they will be criticized in some way for their views or shortcomings in knowledge or performance. In addition, almost all people like to present their past actions in a positive light (Yin, 2009).

However, while bias in interview situations cannot be eliminated, it can be reduced. The following are recommended guidelines that were followed in conducting the preliminary study and case studies.

- Prepare questionnaires ahead of time
- Present each interviewee with the same questionnaire, in the same format ahead of the interview, so that they are not worried about what they will be asked
- Maintain a pleasant but calm persona that is non-judgemental and reassuring
- Avoid the possibility of misinterpretation by, for example, crafting questions that are not too long; or by ensuring that double negatives are avoided.
- Avoid leading the interviewee towards a particular viewpoint or response.

A further recommendation was to electronically record interviews and where possible retain any notes made, to ensure that any sources of bias can be identified. (Notes will always contain some level of bias, for example, in selecting what to record, in the accuracy of the notes, or in the understanding or interpretations of the note-taker.) One interview in the preliminary study was by telephone and could not be recorded and one interview was recorded but the recording was unintelligible. All other interviews (in both the preliminary study and case studies) were recorded satisfactorily.

4.6.1 Open-ended Semi-structured Questionnaires

An open-ended semi-structured questionnaire was devised as a guide for discussion. Open-ended questions were developed from the research questions and also from issues identified in the ongoing literature review. In advance of the interviews, the
questionnaire was forwarded, along with a copy of the consent form and the project synopsis, to those respondents who had agreed to take part in the study.

The aim of the questionnaire was primarily to aid in the elicitation of preliminary information concerning hospital environments. Essentially, the questionnaire was intended to provide background to the research and a sense of the interviewee’s experience of the hospital environment. Further, it was thought that an understanding of their view of their role and of the issues that were important to them was fundamental to this thesis. The questionnaire was designed as a guide to steer the conversation towards the areas of the hospital environment and considerations of resilience, but it was not intended to be restrictive. Consequently, where areas of interest opened up, participants were encouraged to continue with their accounts.

The questionnaire was divided into three main sections covering the hospital buildings, the hospital environment and finally the problems associated with changes to the hospital spaces and routines. Questions were designed to elicit specific aspects of the nurse’s experience and each question encompassed a number of prompts (or bullet points), to provide guides where interviewees might need additional encouragement.

Achieving a balance between avoiding bias on the one hand, while also being encouraging and friendly was quite challenging. “Over-friendly” or ingratiating interviewers may be distasteful to some participants, similarly uncommunicative or taciturn interviewers may limit the interviewee’s responses. Consequently, there seemed to be a dilemma between maintaining the necessary level of encouragement that conveyed to participants that their contribution would be valued, whilst simultaneously remaining detached and neutral. It was essential to build relationships with the nurses to ensure that they would be happy to continue helping with the research, should that be necessary. However, it was difficult to achieve this relationship-building process whilst maintaining a detached and neutral demeanour. Consequently, it was felt that it was important, particularly for the preliminary study, to be welcoming and positive about whatever the participants wished to contribute in answering the questionnaire. However, a neutral manner was adopted as far as possible, during the ensuing discussions.
The interviews for the preliminary study were carried out on site at the OU and were either face to face, or in one instance where availability was very limited, by telephone. Table 4.1 lists their durations.

All interviewees were asked to sign the “consent form” immediately prior to the interview process and all consent forms were forwarded to the DeDeRHECC team archive. A brief written synopsis was provided to introduce the project and explain the purpose of the research. It included details of what would be required of the participants. The consent form outlined how their confidentiality would be safeguarded and how their data would be used and stored.

Table 4.1 Duration of nurse interviews

<table>
<thead>
<tr>
<th>Participant</th>
<th>Date</th>
<th>Duration</th>
<th>Transcription</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse 1</td>
<td>9/11/09</td>
<td>37:25</td>
<td>Partial Short section inaudible</td>
<td>Particularly concerned about privacy issues and noise – has wide experience. Was in an operating theatre that had to be closed because of heat.</td>
</tr>
<tr>
<td>Nurse 2</td>
<td>10/11/09</td>
<td>Full</td>
<td></td>
<td>Very limited available time – only available on telephone at that time.</td>
</tr>
<tr>
<td>Nurse 3</td>
<td>10/11/09</td>
<td>41:52</td>
<td>Full</td>
<td>Mentions the importance of stress in patient care and of noise during refurbishment. Interesting definition of resilience. (Interview conducted with Professor Eckert.)</td>
</tr>
<tr>
<td>Nurse 4</td>
<td>11/11/09</td>
<td>20:37</td>
<td>Partial. Part of tape inaudible</td>
<td>Was only able to meet me between meetings. Interesting definition of resilience.</td>
</tr>
<tr>
<td>Participant 5</td>
<td>11/11/09</td>
<td>43:48</td>
<td>Partial</td>
<td>Interviewee is not a nurse but has been teaching nurses for many years and has considerable insight into hospital design due to many student tutoring visits and student feedback.</td>
</tr>
</tbody>
</table>
Most of the interviews were recorded. For two interviews that were not recorded, notes were taken at the time and formally written up as soon as possible after the interview.
At first, it was difficult to avoid leading the interviewee occasionally, especially if they required clarification or an additional prompt, hence two initial “practice” interviews have not been included here. Avoiding this form of bias was a skill that took considerable effort, however this improved with practice.

4.6.2 Analysis and Implications from the Preliminary Study

Two approaches to analysing the study data were taken. The first approach involved listening attentively to the recordings very frequently, i.e., each recording was replayed between 10 and 12 times, and notes were taken at each replaying of the recording.
When no new insights or perceptions were noted from a particular recording on further replaying, then the next interview recording was subjected to the same treatment. By this process, a strong degree of familiarity with the data was developed, and each subsequent replaying allowed different aspects of the interview to reveal unanticipated significances.

The second approach to analysis was through “thematic Analysis” and involved the scrutiny of the transcripts that were made of the recordings, and which were then coded using descriptive “codes” that were applied to “threads” of data. Transcripts were coded and key themes or “threads” were highlighted. Individual “post-it” notes were made for
each interpreted data thread, or group of similar threads, illustrated in Figure 4.2. The data threads on the notes were then abstracted into categories that could encompass groups of data threads e.g., short quotes from interviewees; data from building plans; background information etc. Table 4.2 shows examples of threads and the evolving higher order categories, and for some key themes, the source transcripts have been included.

Figure 4.2 Early stage of analysis

Emerging topics, such as, for example, nurses’ concerns about transporting vulnerable patients to operating theatres/imaging suites etc., were identified from the recordings or the transcripts, and categorised as groups, such as “perception of risk” or “patient transfer”. The groups were abstracted both as “connectivities” and as “risks” and then subsumed into the broader category “system vulnerabilities”. Using the display boards, it was possible to both develop the abstraction process whilst retaining a level of richness (lost when using an A3 Excel spreadsheet due to space limitations). This process of categorising data, and then reclassifying it within broader groupings is aimed at revealing predominant themes within the data. It was sometimes difficult to be literal in categorising some of the data threads, as occasionally they could be interpreted in a
number of ways. Unfortunately it was not possible to compare the abstraction process with co-workers for this data set, as would be expected for validation.

### Table 4.2 Analysis of preliminary study showing “categories” and “data threads”

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender issues—mixed wards a problem</td>
<td>Nurses “Making do” to keep system running</td>
<td>Infection control – complex issue – affects patients, procurement, hygiene, cleaning, training and systems etc.</td>
<td>Gender issues – female (and children) have different needs&lt;br&gt;Nurse transcripts 1, 2, 3, 6, 8 &amp; 9</td>
<td>Connectivity, is key to functionalit y</td>
<td>Patient/nurse controls preferred</td>
<td>Management makes a huge difference to system efficiency</td>
<td>Maintenance, is a big issue for buildings and equipment</td>
<td>Economic and practical aspects of long travel distances</td>
<td>Strict protocols, with no, or limited freedom to adapt routines – can be difficult to adapt when refurbishing</td>
</tr>
<tr>
<td>Privacy and dignity need to respect</td>
<td>Travel distances - patients at risk esp after surgery&lt;br&gt;Transcripts 1, 2, 3, 6, 8 &amp; 9</td>
<td>Privacy and dignity – patients need respect</td>
<td>ICT culture&lt;br&gt;Foreign to some&lt;br&gt;Nurse transcript 6</td>
<td>Daylighting&lt;br&gt;Essential for recovery</td>
<td>NHS culture does not allow much criticism</td>
<td>Reliable Equipment needed from purchase to disposal</td>
<td>Access – parking a problem for staff&lt;br&gt;Patient&lt;br&gt;Access&lt;br&gt;High levels of responsibility but little authority</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot and uncomfortable environme nt</td>
<td>Identity is central to resilience</td>
<td>Single rooms visibility is crucial</td>
<td>Vulnerability – makes hospital stay worse</td>
<td>Discharge speed limits productivit y</td>
<td>Buildings-equipment variable</td>
<td>Complex systems</td>
<td>Staffing – need more</td>
<td>Visibility – single rooms – need training</td>
<td>Communication crucial constrained by shift system</td>
</tr>
<tr>
<td>Lack of staff</td>
<td>Flexibility – to adapt to patient needs</td>
<td>Equipme nt failure</td>
<td>Local control</td>
<td>Catering–internal travel distance – and patient feeding issues and quality&lt;br&gt;Transcripts 1, 2, 3, 6, 8, 9</td>
<td>Décor issues&lt;br&gt;Crucial to patient’s perceptio n and confiden ce</td>
<td>Variability across the country</td>
<td>Bank nurses cannot replace own staff</td>
<td>Family support – needs of families</td>
<td>Continuing professional development essential – but often skimpy</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>-------------------------------</td>
<td>-----------------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Security of belongings</td>
<td>Return after setback</td>
<td>Patients need secure space</td>
<td>Too long for some</td>
<td>Condition of buildings</td>
<td>Lack of personal space – must cater for all</td>
<td>Nurse-much time lost moving patients over long distances</td>
<td>Anthroponometric design – people different size and shape</td>
<td>Difficult to contribute ideas or innovations</td>
<td></td>
</tr>
<tr>
<td>Noise -interupts sleep and hence delays healing</td>
<td>Capacity to manage complex demands</td>
<td>Bank nurses not familiar with systems</td>
<td>Home nursing ideal but not yet available</td>
<td>Chaplins/multicultural space Needs</td>
<td>Home-like ambiance</td>
<td>Lack of respect – cog in a wheel</td>
<td>New hospitals more shops / own choice</td>
<td>Storage –always need more</td>
<td>Strict hierarchy can sometimes constrain patient care</td>
</tr>
<tr>
<td>Patients and staff must be thermally comfortabe</td>
<td>Adaptabilit to a variety of roles and situations</td>
<td>Other patients in ward can raise alarm</td>
<td>Complex system difficult to cater for multiple morbidities</td>
<td>Sterile supplies – high humidity reduces packaging life.</td>
<td>Noise is a big issue</td>
<td>Team – care approach - much improved</td>
<td>Location of resources is critical</td>
<td>Windows must be openable but comply with safety</td>
<td></td>
</tr>
<tr>
<td>Views outside help to distract</td>
<td>Inner resources and life experience</td>
<td>Long waiting times for scans etc increase risk</td>
<td>Single rooms preferred by some but not all</td>
<td>Views and distractions very important / entertain ment</td>
<td>Flexible space required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of defensible personal space</td>
<td>Need to be resourceful to supply patients needs</td>
<td></td>
<td></td>
<td></td>
<td>Home-like ambiance Noise reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Through the abstraction process it was possible to see patterns emerge. For example, the many issues associated with “safety and risk” were also closely linked with “design focus” and with “systems issues”, through the similarity or recurrence of the data threads in each category (Table 4.2). At this stage, this indicated that either the users (in this case, the nurses) had a level of systems thinking, (for example, how design can impact the safety of patients), or alternatively that they were concerned with managing care issues due to design problems (e.g., blocked corridors due to a severe
lack of storage space). The abstraction process allowed key concepts to become clearer. From this, the possible relationships between entities (Table 4.3) were indicated. Alternative relationships were considered until the most probable/ convincing relationships emerged and explained the data.

Table 4.3 Entities with Effects and Associations (from categories and threads)

<table>
<thead>
<tr>
<th>Entities</th>
<th>Associations</th>
<th>Possible Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS</td>
<td>Management, hierarchy</td>
<td>Risk, cutbacks, efficiency drives</td>
</tr>
<tr>
<td>Risk</td>
<td>Accountability</td>
<td>Protocols, Infection control</td>
</tr>
<tr>
<td>Patients</td>
<td>Treatments, journeys, beds, rooms, wards, visitors, gender, pain, comfort</td>
<td>Safety, well-being, dignity, security, respect (Ulrich, 1991)</td>
</tr>
<tr>
<td>NHS Staff</td>
<td>Resources, equipment, security, ICT</td>
<td>Roles, teams, identity, comfort, resilience, temp staff,</td>
</tr>
<tr>
<td>Hospital</td>
<td>Constraints, access and parking, connectivities, multiple systems,</td>
<td>Change, stress, travel distances, standards,</td>
</tr>
<tr>
<td>External environment</td>
<td>Supplies, weather events,</td>
<td>Stress, shortages, risk</td>
</tr>
<tr>
<td>Internal environment</td>
<td>Heat, draughty, noise, humidity</td>
<td>Harm, comfort, (Lomas &amp; Giridharan, 2012)</td>
</tr>
<tr>
<td>Refurbishment</td>
<td>Décor, equipment, furnishings, noise, dust.</td>
<td>Disturbance, risk, delay, travel obstacles</td>
</tr>
<tr>
<td>Design</td>
<td>Space and flexibility, décor, views and distractions, home-like ambiance, storage space, window opening,</td>
<td>Dissatisfaction, delay, staff frustration, patient confidence</td>
</tr>
</tbody>
</table>

The critical realist perspective accepts that entities have “causal powers”, so it is possible to link entities, through their actions or influence to outcomes. Subsequently, entities (key actors, groups, systems, organisations) were identified from the data (Table 4.3) and as the analysis proceeded, and categories were redefined to better reflect the data threads, a clearer picture of the entities under study and their proposed effects, emerged.

The issue of transferring patients between wards or theatres is used as an example of how the analysis process progressed. Nurses commented on the process of moving patients between wards or to theatres and the coded transcripts illustrate the coding process (Figures 4.3 and 4.4). Moving patients was associated with a patient risk code as patients are particularly vulnerable when returning from theatre and it was also classified as a design issue because the distances are considerable and there are no facilities for emergency interventions along the length of most long hospital corridors. The thread was also categorised under availability of resources as accompanying patients to and from surgery in a large hospital can involve a 40-60 minute round trip. On a surgical ward, where many patients are scheduled for surgery, this process can require the attention of one or more nurses for most of their shift. Hence, this thread was also classified under system pressures as trained nurses are required for this, should a problem arise. A nurse must know for example, not only how to cope with a cardiac arrest, (or other life-threatening problem), when the patient is at a considerable distance from necessary equipment or appropriate help, but also be very knowledgeable about the layout of the hospital if help is needed quickly (also classified as design: way-finding and as agency/professional role).
The categories were abstracted until all of the data was subsumed into higher order categories that could represent the data. Entities were identified from the categories (Table 4.3). The associations linked to the entities were also abstracted from the categories and data threads. The possible “Effects” are suggested outcomes of causal...
pressures from the entities under study, identified by the nurses’ comments, or extracted from the literature. The entities and effects identified from the categories were used to build a tentative framework or matrix. The initial “rich picture” showed the direction of influences derived from the data in the recordings/transcripts, and also from the literature review. This is shown in Figure 4.5 which illustrates the influencing relationships between stressors and vulnerabilities that began to emerge over the course of the literature review and the preliminary study.

The Figure 4.5 matrix diagram has been developed from the data, to assist senior NHS nursing staff to consider how proposed refurbishments may stress aspects of their own ward or department and to consider appropriate mitigation measures.

Figure 4.5 Matrix Diagram: the developing Stressor/ Vulnerability Framework

4.6.3 Study Outcomes

The key themes resulting from the abstraction process included “refurbishment design”, “resilience” and “system risks and pressures”. For example from the re-categorising process (or iterative abstraction), and from further interviews with nurses, a key finding from the refurbishment design theme appeared to be that nurses are deeply concerned
about issues related to workplace design, and that their tacit knowledge is largely overlooked.

The study identified that the questionnaire focussed too heavily on issues associated with the thermal environment, and did not sufficiently address the nurses’ concerns about the hospital as a workplace or about their views on hospital design, nor did it fully explore the connectivities between their nursing priorities and where these might conflict with those of other hospital systems. The study emphasised that nurses have little understanding or knowledge of refurbishment processes, although they were keenly interested in design. They were concerned about efficiency and frustrated by what they considered to be examples of “poor” design. It became clear that the nurses would welcome greater participation in the design process at an early stage.

The participants’ focus towards resilience was primarily towards their role and they were reflective and insightful regarding how it contributed to their practice. It was clear from the study that the interviewees felt that refurbishment was very important, and they suggested that it added to patient confidence regarding their treatment, and in addition, made the patients feel valued. However, the nurses had little conception of the refurbishment process other than as it related to their own working efficiency or their, or their patient’s, perceptions regarding the décor. Most of the nurses had an appreciation of the problems associated with working in hot climates, e.g., how high humidity affects sterile packaging. However, the nurses did not appear to appreciate how climate change may affect future nursing practice in UK NHS hospitals. Figure 4.6 suggests how entities and their effects developed from the analysis process (c.f. Table 4.3) may interact in developing nurse resilience.
4.7 Conducting and Analysing the Case Studies

4.7.1 Analysis Method for the Case Study 1 “Post-Project Review”

Early in the research process, the NHS conducted a “Post-Project Review” meeting of the Neo-Natal unit refurbishment (Section 4.4.1) that comprises Case Study 1. This provided the opportunity for the DeDeRHECC group to obtain an overview of an NHS refurbishment process. All parties involved in the refurbishment were represented at the meeting including the client, designers, main contractor, sub-contractors, consultants, the medical team and the user group. Key players in the refurbishment were invited to give their observations and reflections on the planning, briefing, procurement, design, management and construction stages of the project, together with their views regarding the outcome. Three DeDeRHECC researchers were present as observers and each took notes throughout.

Following the meeting, notes were compared for agreement and consistency. An analysis similar to that used for the Preliminary Study was carried out.
4.7.2 Analysing Case Studies 1 to 4.

Subsequent to the Case Study 1 “Post-Project Review” (Section 5.2.1), key players were invited to take part in semi-structured interviews (Tables 5.1 and 5.2) and recordings were transcribed for analysis. Due to the number of interviews and the volume of transcriptions, this type of analysis was not considered practical; however transcriptions of the interviews were interrogated initially, against the themes which emerged from the “Post-Project Review” analysis, which reported on all stages of the project and represented the primary stakeholder perspectives (patients’ and parents’ representatives, clinical staff, the client, and the refurbishment contractors).

Interviews for each of the case studies were arranged through agreed hospital contacts (typically an estates senior manager) with details relayed to the team by the DeDeRHECC team co-ordinator. Topics/questions for the interviews were invited from team-members and fed into a semi-structured questionnaire well in advance. As with the preliminary study, these questionnaires were forwarded to the interviewees along with a copy of the consent form and project synopsis. The project synopsis introduced the project and identified the purpose of the research and what would be required of the participants. The consent form outlined how their confidentiality would be safeguarded and how the data would be used and stored.

The interviews were conducted largely by the DeDeRHECC co-ordinator and the principal investigators, but team members were encouraged to probe a particular reply or topic further, as their interests were kindled. This process was a very useful learning experience as the interviewers were experts in their fields with significant experience. It is not possible to totally eliminate interview bias, as the process is an interaction between individuals and people respond to each other in very unpredictable ways. However, as far as possible, the team had reduced the potential for bias by following the same procedure at each interview. Interviewees were given a brief introduction to the project and then asked to sign the consent form. The co-ordinator invited the interviewees to discuss their role in the specific case study events; how they saw the outcomes; and whether there had been any issues that had been important to them. The semi-structured questionnaire was then used to direct the interviewee towards
individual team member’s areas of interest. The co-ordinator was very careful to encourage the participants to provide their own account of events, in their own way.

All of the interviews for the case studies took place either at the specific hospital under study or at the premises of the consultants or contractors. Rarely, an interview was conducted by telephone; however, the format was identical to that used in the face-to-face interviews. Subsequent to the interviews, an email was sent, thanking each of the participants and to the hospital contact who coordinated the process.

Where an interview was not recorded (i.e., telephone interviews), notes were taken by the team members present and notes were compared for content and consistency.

The recorded interviews were transcribed by the project administrator, or by an outsourced transcription service. The transcripts were checked against the recorded interview by a team member present at the interview. The transcripts and recordings were made available to the team through the project web-site. A detailed account of each of the four case studies is provided in the following chapter (Chapter 5).

4.7.3 Analysis Methods

The data analysis for case studies followed a similar pattern to that identified for the preliminary study with nurses. However, the analysis differed in that the neo-natal unit transcriptions were interrogated against themes which emerged from the “Post-Project Review” of the neo-natal refurbishment described in Section 4.7.1. Hence the initial coding phases could be omitted. The “Post-Project Review” themes were found to be appropriate for all four case studies. The higher-order codes or categories were then reclassified in a number of ways to better represent the data and identify patterns and emergent themes. Key categories or themes were used to interrogate the remainder of the transcripts. The transcripts were further interrogated using the word processor “search” option, to locate examples of emergent phrases or words that were similar or related to the emerging topics.

The transcripts highlighted that individuals sometimes gave differing accounts of the same events. Where varying accounts arose, this served to illustrate how perspectives differ, and may alter an individual’s perception or experience of unfolding events. No
one account could be regarded as a “true” description of events but rather, all accounts were considered to be valid interpretations, from each individual’s perspective.

“Critical realists accept that there are differences between the empirical, the actual and the real, and that data are collected from people as well as from, and about, material things. As a result they accept that any explanations are necessarily fundamentally interpretivist in character” (Easton, 2010).

As the research progressed the categories resulting from the post-project review were modified and other themes were added as they emerged from the transcripts. The most commonly occurring themes are given in

Table 4.4.

Table 4.4 Showing examples of Key Categories developed from data “thread” categories

<table>
<thead>
<tr>
<th>Key Category</th>
<th>Data topics or “thread” categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes</td>
<td>Solution finding; Snagging; Re-work; commissioning; hand-over; scope and boundaries; urgency; long-term view</td>
</tr>
<tr>
<td>Users/ Value/ Satisfaction</td>
<td>added value; overall value; satisficing; value engineering; client and user objectives</td>
</tr>
<tr>
<td>Financial Risk</td>
<td>Project Risk register; risk sharing; supply chains; uncertainty; contract limitations; delay; scope</td>
</tr>
<tr>
<td>Finance</td>
<td>Delays versus costs; GMP; culture; finance streams; standing financial instructions; sharing issues; Board meeting time-tables; reduced funding/cuts</td>
</tr>
<tr>
<td>Governance/NHS/DoH and Government policy</td>
<td>Oversight ; Procurement; contracts; and frameworks; targets; representation; silos; stakeholders</td>
</tr>
<tr>
<td>Relationships and trust</td>
<td>Team approach; cooperation; leadership; community; conflicts; communication; client/ contractor and client/ user relationships etc. ; line management issues; contractor dominance; co-operation; patient-focus; professionalism</td>
</tr>
</tbody>
</table>
### Key Category | Data topics or “thread” categories
--- | ---
**Process Issues** | Project management; scheduling snags; Integration; existing structure; surveys; trades; late failures; asbestos; lead times for replacement parts; maintenance and stores; aging/failing services; maintaining continuity of service; resilience in services design

**External Factors/Drivers/Constraints/barriers** | Legislation; Trust finance streams; executive meeting dates; supply chains; climate issues; local infrastructure;

**Design/Sustainability** | Solution focus, creativity and reframing; *BREEAM/**AEDET* issues; design innovation; infection control; connectivity; DoH design guidance (HTMs, HBNs)


### 4.7.4 Case Study Modelling

Originally, it was envisaged that some form of modelling process would help to identify critical connectivities or failure points between the projects in progress, the refurbished accommodation and/or the hospital buildings. The supporting data for the case studies was very varied in type and quality and included hospital plans and room data (sometimes contradictory or out of date), some limited project accounts data, hospital long-term plans, site details and contractor information. The data supplied with Case Study 4, for example, was in the form of room data sheets and floor plans. Examples of these are given in Figure 4.4 and Figure 4.5. The documents contain much information but frequently fail to include essential details.
Figure 4.7 Case Study 4 Room data sheet (abridged) for level 2
It was felt that Design Structure Matrices would be appropriate for identifying both the observable and the less obvious links between key components, activities or events. A Design Structure Matrix or “DSM” (Steward, 1981) is a simple tool that aids analysis of complex systems. Consequently DSMs were used to locate critical connectivities or dependencies. DSMs were constructed for two of the case study hospitals, Case Study 1 and Case Study 4, (Eckert, 2012, unpublished). The DSM’s were constructed from a square grid of columns and rows of equal dimensions. Each of the column and row headings along both axes, were identical, and labelled in the same order i.e., along the top and left side of the grid. An example is shown in Figure 4.6.
Only Case Study 1 (the Neo-natal Unit) provided an informative set of models. For this study, a helpful staff member volunteered time to provide the additional information necessary for the mapping process. This enabled a DSM to be produced for the Maternity Unit that linked to the Case Study 1 Neo-natal Unit (Eckert, unpublished). From this DSM (shown in Figure 9), patient and staff journeys were mapped against the data and plans provided. Critical spaces and connectivities became apparent and it was possible to identify areas with high patient flows, where changes might be either desirable or challenging. It also helped to identify significant bottle-necks, issues associated with critical flows and excessive staff travel times etc., that supported comments made by staff regarding their working conditions and problems at the case study hospital.

Figure 4.9 DSM highlighting critical flows and patient dependencies for Case Study 1
A number of attempts were made at connectivity mapping for Case Study 4. The connectivity mapping process involved coordinating the room data sheets provided by the trusts (containing information about space usage for each room) with the plans provided for the floor of the hospital under study. It was then necessary to check the floors above and below the study space for additional three dimensional connectivities. Once all of the connectivity links were identified and mapped, it should then have been possible to consider how the connectivity links would be affected by a change to any of the rooms or access points across the various levels. This process was made particularly challenging by the limited information in the room data sheets. The mapping process worked relatively well for small spaces that could be accessed and surveyed by the team. However, it was not possible to scale the process up without significant additional input from the hospital trust partners. For Case Study 4, the high level data that was provided did not give enough detail for useful conclusions, and the low level data showed few interactions.

4.7.5 Supporting Documentation

While a broad selection of building drawings and plans were made available for the existing buildings of the case study hospitals, there was somewhat less supporting documentation for the refurbishment projects. Where documents or plans were supplied, they generally related to the early project stages, whilst final stage documentation was relatively scarce. Hence the documents were largely used in attempts at connectivity mapping, or to corroborate the accounts given by the interviewees on significant points.

Limited cost information was made available and this served to support the financial details provided in the accounts from the interview participants. However it was not possible to obtain a full picture of the process of risk sharing as this information was not accessible.
4.8 Additional Expert Interviews

Additional expert interviews were also undertaken to add further explanatory detail or to provide additional perspectives. These experts were selected through recommendations (generally by reputation rather than personal contact) from the study participants and their professional contacts. Some of the interviews were carried out by the DDRHECC team and others were associated only with this thesis. However, the process for all interviews was identical to the format used for the case study interviews and the participants were sent details of the project, the topic areas and a consent form in advance of the interview. These interviews included the following experts, selected from a variety of fields.

Table 4.5 Details of expert interviews

<table>
<thead>
<tr>
<th>Expert</th>
<th>Recording</th>
<th>Transcription</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hospital planning specialist</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Social worker</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3. Hospital estates manager</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Specialist NHS Contractor</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5. Building energy expert</td>
<td>Notes only</td>
<td>N/A</td>
</tr>
<tr>
<td>6. NHS Hospital health and safety officer</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7. University estates manager</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>8. Architect (hospital designer)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>9. Hospital Consultant (Clinical)</td>
<td>Notes only</td>
<td>N/A</td>
</tr>
<tr>
<td>10. Hospital statistics administrator</td>
<td>Notes only</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Interviews that directly contributed to the research were transcribed, however the remaining interviews informed the context of the studies by providing additional background or explanatory detail. The transcribed expert interviews were conducted and analysed in the same way.
4.9 Validation

4.9.1 General

Validation in social science research is a much contested issue and there are many differing viewpoints, with concerns around whether validation is actually achievable (Wolcott, 1990), and also about the many forms that validation may take (Maxwell, 1992; Lincoln and Guba, 1985; Seale, 1999). The criteria for validation may depend on a variety of requirements and may include, for example, the perspective taken by the researchers, the purpose of the research, the design of the research study, or the level of conceptual abstraction. Clearly it is not possible to demonstrate credibility for qualitative research in the same way as in positivistic research, where randomised trials (the “gold standard” for positivistic research) can provide reliability and replicability. This is because field research almost inevitably involves interactions between individuals and can never be fully replicable.

While reliability is necessary for validation, it is not sufficient. A laboratory’s digital thermometer may give the same temperature reading reliably, every time it is used. However due for example to an internal malfunction, the thermometer may not be displaying the correct temperature of the samples being measured.

Social science validation is often described as involving four conditions: internal validity (whether there is a causal relationship between a research study’s intervention and outcome); conclusion validity (considers whether a relationship of any form exists between the object of study and the outcome of the research); construct validity (how the study demonstrates conceptually, that there is an actual causal relationship); and external validity (the possibility of generalising the results of the research study to other fields), (Calder et al., 1982; Drost, 2011; O’Leary-Kelly and Vokurka, 1998).

Alternatively, Maxwell (1992), identified five forms of validity for qualitative studies including “descriptive validity (the factual accuracy of the researcher’s account), interpretive validity (describing and communicating the participant’s meanings), theoretical validity (the degree to which the researcher abstracts or conceptualises the data and establishes the proposed causal relationship), generalizability (the extent the
research outcomes can be generalised) and evaluative validity (relates to the researcher’s evaluative frame of reference).”


Seale (1999) identified what he considered as a “bewildering” array of validation criteria and suggests that this proliferation of concepts reflects the difficulties that qualitative methodologists, aiming for an “overarching” quality system, have had in making their ideas “stick”.

It has been said that there is no flawless way to assess validity or the “truth” of a situation i.e., no “God’s-eye” view (Putnam, 1990), and consequently no study can be considered to be “the truth” or completely objective (Maxwell, 1992).

This is also the position of critical realists (following Bhaskar, 1978) who accept that there is no way to achieve a “true” description of objects or events and hence that a variety of methods should be used in an attempt to achieve a picture that comes as close as possible to “reality”.

In a similar spirit, Lincoln and Guba (1985) considered that “thick descriptions”, are necessary to provide narrative about the study and context, so that judgements about validity can be made by others. However they cautioned that there is no available guidance on how thick such descriptions should be.

4.9.2 Credibility Validation

Lincoln and Guba (1985) suggested a number of validity checks to help in the demonstration of rigor in qualitative research. For example they considered that credibility requires, amongst other criteria, peer debriefing, and triangulation. They also suggested that “negative case analysis” remains an important aspect of validation, that
is, the search for negative influences and consequent altering of the model or conception until no further weaknesses can be discovered.

However Lincoln and Gruber (1985) considered that member checks were the most crucial technique to establish validity. Member checking involves discussing the study description and conclusions with the research participants for their agreement and validation of accuracy and interpretation. This may be a difficult process where the research bears upon sensitive issues or when the conclusions are particularly abstract and hence, may require considerable explanation.

4.9.3 Validation for Research in this Thesis

The main forms of validation for this research came from the process of “member checking” with the estates managers of two of the study hospitals and two of the industry experts, as well as the peer review process following presentations before academic conference audiences and the subsequent publication of three conference papers and one journal article. (It had been hoped that the outcomes from this research would be presented alongside those of the DeDeRHECC group at planned validation events with stakeholders and with the wider NHS and academic community, but personal circumstances made this impossible).

The member checks with the study participants helped to confirm the accuracy of the accounts and of the research and the validity of interpretation of the various frameworks developed. The estates managers from Case study 1 (neo-natal unit) and Case study 2 (modular orthopaedic ward) were contacted and agreed to a further interview. One interview was carried out in person (1 hr and 9 minutes) and the other by telephone (56 minutes). The face to face interview was recorded, and notes were made during and following the telephone interview. The participants were emailed with framework diagrams either in advance, or during the course of the interview. The frameworks were explained and following this the estates managers both accepted that the basic interpretations and conclusions of the research were valid. Both interviewees agreed that the two frameworks (the Change Framework and the Resilience Framework) described the processes involved and that the predicted outcomes were reasonable. A
minor addition to the change framework was suggested, and this was incorporated into
the model, and approved by return email.

In addition, two expert interviewees (one hospital based estates manager and one
industry-based estates manager) were shown the Change Framework and both experts
accepted that it represented the change process effectively and that the framework
provided a helpful perspective for predicting or mapping possible change trajectories
when planning complex change scenarios.

The Change Framework was also circulated to the co-researchers on the DeDeRHECC
team, who were present at most of the interviews or familiar with the transcripts for
comment and discussion. It was agreed that the framework provided a useful model of
the change process as described during the case studies.

Triangulation from case study documentation and other research within the DeDeRHECC
group also added to the validation, particularly the results from the DeDeRHECC project
Delphi study on Resilience (Masko et al, 2011).

Eckert et al. (2003) argue that each succeeding phase of a research study can contribute
to the validation of each of the preceding phases. Hence the conclusions from one case
study may be borne out by the following case study. This was the case with the first
three case studies, where the results of each study informed the questions for the
following study. In particular, case study 4 (the cancer ward) provided the opportunity
to question a number of estates managers regarding the range of issues encountered in
the three previous studies and to test the conclusions drawn.
Chapter 5 Empirical Studies

5.1 Structure of the Chapter

This chapter describes the four hospital case studies that were undertaken with the DeDeRHECC project team and which underpin each of the subsequent thesis chapters. The studies were from geographically well-spaced English regions, serving differing population sizes, and reflecting the different categories of Trust status. Each study was based on a specific NHS Trust refurbishment project that was either in progress, or that had been recently completed at the outset of the research. Three of the case studies included a series of semi-structured interviews with the key participants and stakeholders of the projects, including the consultants, contractors and client representatives. The remaining case study (Case Study 4) comprised individual and group interviews and informal discussions with both clinical and estate staff.

Interviews were largely semi-structured and were focused towards the work environment, the hospital buildings and selected recent refurbishment projects, along with more general comments on refurbishment and maintenance considerations within the Hospital Trust. The interviews were designed to provide data on the management of hospital buildings and the perspectives of those working in the hospital and for those involved in maintaining and adapting them to function comfortably, particularly in a changing climate. The studies used site and ward observations and included the assessment/evaluation of associated documentation (where available), notably reports of meetings, building plans and site maps. The studies were underpinned by the literature review, which contributed to an enhanced appreciation of the research topics/themes. The aim was to use the insights gained through a variety of methods, to develop a ‘rich picture’ of the events and relationships under study, appreciating that the various contributors may have conflicting but equally valid perspectives. The differing methodical approaches also allowed “triangulation” of the data, and in this way, provided an enhanced picture of the areas under study.

The four case studies are described in turn in Sections 5.2 to 5.5.
5.2 Case study 1: Neo-natal Unit (NNU) Refurbishment

5.2.1 Introduction and Participants

This NNU project was located within a large Midlands teaching hospital, and was commissioned following the embarrassing failure of a £700m project that aimed to deliver a major PFI hospital, with state-of-the-art facilities. As a result of this failure, the NHS Trust suffered financially and was struggling to provide high-quality services within a number of extremely dilapidated hospital buildings, located over a number of sites. Hospital-wide cuts to budgets were instigated and although the case study budget was exempted, the project team made significant voluntary cuts during the course of the project and these critically affected the project’s scope.

![Picture 5.1 First Neo-natal Project site-visit.](image)

Although site visits had been carried out during the course of the project, the primary information gathering stage of the study began on completion of the fully refurbished neo-natal unit. At this stage, information regarding the progress of the project could be
collated and released by the Trust and the contractors. Two team members were invited (as observers), to attend a post project review meeting where all parties involved in the project were represented. This was a rare opportunity to access an NHS refurbishment project review process and made this case study particularly useful, in that all members of the refurbishment project team were present to discuss issues and contribute to the review, and the principal NNU project team members shared their observations and reflections. The meeting provided an opportune starting point for the case study interviews, as the meeting had indicated potential areas for further consideration. Subsequent to the meeting, interviews were conducted with members of the project team. Details of the interviews and interviewees are given in Table 5.1. The key communications links between these members and the groups they represent are shown in Table 5.2 and Fig. 5.1 and the project reporting links are shown in Figure. 5.2.

Table 5.1 CS1 Client Appointed Project Team Interviews

<table>
<thead>
<tr>
<th>Participant</th>
<th>Organisation</th>
<th>Role</th>
<th>Interviewer</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Project Director</td>
<td>In-house</td>
<td>Overall lead. Liaison with Trust Board. Commercial planning</td>
<td>DeDeRHECC project coordinator Arch/ OU teams present</td>
</tr>
<tr>
<td>b</td>
<td>Project Manager</td>
<td>Consultant</td>
<td>External consultants advising on procurement</td>
<td>As above</td>
</tr>
<tr>
<td>c</td>
<td>Project Development Manager</td>
<td>In-house</td>
<td>Development and coordination of Trust projects (Facilities)</td>
<td>As above</td>
</tr>
<tr>
<td>d</td>
<td>Cost Advisor</td>
<td>Consultant</td>
<td>Advise on cost issues related to project (interviewed jointly with PSS)</td>
<td>As above</td>
</tr>
<tr>
<td>e</td>
<td>Project Site Supervisor (PSS)</td>
<td>Consultant</td>
<td>Site supervision (Trust’s representative.)</td>
<td>As above</td>
</tr>
<tr>
<td>f</td>
<td>Clinical Lead</td>
<td>In-house</td>
<td>User Group Design Development Lead</td>
<td>As above</td>
</tr>
<tr>
<td>g</td>
<td>Nurse Manager (Matron)</td>
<td>In-house</td>
<td>User Group Design Development</td>
<td>As above</td>
</tr>
</tbody>
</table>
### Table 5.2 CS1 Contractor Appointed Project Team Interviews

<table>
<thead>
<tr>
<th>Participant</th>
<th>Organisation</th>
<th>Role</th>
<th>Interviewer</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>h Construction Manager</td>
<td>In-house</td>
<td>Strategic support (all projects).</td>
<td>Pam Garthwaite</td>
<td>32</td>
</tr>
<tr>
<td>i Architect</td>
<td>Consultant</td>
<td>Briefing, final design, technical and detail drawings.</td>
<td>Pam Garthwaite</td>
<td>38</td>
</tr>
<tr>
<td>j Project Manager</td>
<td>In-house</td>
<td>Project planning and progression; Communication/ Liaison</td>
<td>Pam Garthwaite</td>
<td>15</td>
</tr>
<tr>
<td>k Design Manager</td>
<td>In-house</td>
<td>Management of design information</td>
<td>Pam Garthwaite</td>
<td>55</td>
</tr>
<tr>
<td>l Senior Quantity Surveyor</td>
<td>In-house</td>
<td>Cost control and advice</td>
<td>Pam Garthwaite</td>
<td>42</td>
</tr>
<tr>
<td>m Quantity Surveyor</td>
<td>In-house</td>
<td>Cost control and advice</td>
<td>Pam Garthwaite</td>
<td>53</td>
</tr>
</tbody>
</table>

![Image of communication links]

**Figure 5.1** Neo-natal Project: key communication links
5.2.2 Project Drivers

The NNU case study was a £10.2m refurbishment project in one of the largest NHS Trusts in the UK. The hospital campus was located within a busy city centre, serving a population of approximately 300,000 people and with a maternity service delivering 10,000 babies each year, attracting expectant mothers from well beyond the catchment area. The hospital was scheduled, in 2005, to begin the planning process for replacement with a new £711m technologically advanced facility to be secured through the Private Finance Initiative (PFI). However in 2007, the incipient project was cancelled, due to spiralling costs. The total cost of the new facility was originally projected to be £711m, but this figure rose to £921m during an initial two and a half year planning process. The up-front costs incurred during this planning period amounted to some £27m, at which point the project was aborted, and left the Trust both embarrassed and very risk averse. Under the PFI scheme, the majority of the hospital’s aging buildings would have been replaced and two existing satellite facilities were to be fully
refurbished. The consequent “planning blight” during the planning and design phases of
the scheme, left the Trust with a portfolio of uneconomic and deteriorating hospital
buildings, which had been starved of maintenance for a number of years due to the
impending transfer of functions within the proposed “hi-tech” hospital.

The study building was a case in point, as it had long been scheduled for demolition.
Following the new PFI hospital cancellation, the Trust needed to make urgent
improvements to those services deemed to be operating at high risk. External
consultants were tasked with determining the risk priorities and the resulting evaluation
identified the Neo-natal Unit (NNU) as the highest risk. Maternity services were central
to the Trust’s strategic long-term plans and an upgrade for the facility was considered
essential. Hence, the unit which had been operating under considerable strain, over
three geographically dispersed sites, was prioritised for action. Restructuring the service
would significantly reduce travel time for key clinicians and a “state of the art” facility
could be provided at a central location. The board agreed to the proposal and a
refurbishment budget of £10m was approved. However, due to the high risk associated
with the existing service, the project was constrained to a very tight 12 month timescale.

5.2.3 The Neo-Natal Project Changes

The project involved the refurbishment of two non-adjacent floors within a 1960’s multi-
storey hospital building. Although the entire building was severely in need of upgrading,
the budget for the new unit was strictly limited and it was considered essential that the
scope of the project did not extend beyond the neo-natal unit. The services to the
ageing building were in extremely poor condition and were shared, in most instances,
with the other hospital departments occupying the building. Clearly, it was essential that
during the refurbishment process, the remainder of the continuously occupied hospital
should continue to function normally, with minimal disruption. A particular worry was
the very sensitive In Vitro Fertilisation (IVF) laboratories housed on a lower floor, hence
vibration was a very serious concern. Construction noise and vibration were similarly
problematic for the vulnerable or recovering patients in neighbouring wards and these
risks were carefully managed or mitigated.
The process of risk management was formalized in the development of a detailed risk register that amalgamated the likelihood and impact of all the perceived project risks. These risks were then weighted against process constraints and an economic value estimated. The total values for all the identified risks, together with a further contingency allowance (an additional resilience factor), were included within the budget and in this project amounted to the very significant sum of £6.1m. As the total project value was £10m, this sizeable risk sum gives some indication of the uncertainty associated with the project from the perspective of the principal actors.

5.2.4 The Procurement Process

The trust commissioned architects to draw up initial plans with the intention of using a traditional procurement route. However as the business case was being compiled it became clear that the 12 month target would be impossible, so it was decided to switch to the more collaborative and recently devised NHS procurement route, ProCure21. The Trust was unfamiliar with this procurement route and was most apprehensive, but there
did not appear to be an alternative route that could promise completion on time. As noted in Section 2.8.2, with ProCure21, the Principal Supply Chain Partner (PSCP) is equivalent to the principal contractor in traditional construction projects and contracts directly with the client to undertake the specified project, employing specialist subcontractors to undertake allocated packages of work.

The company that won the contract to become PSCP for this project, offered a superior design which elegantly resolved the initial constraints, changing the position and shape of the main corridor so as to free up valuable space. However, this corridor now crossed the principal axis several times, resulting in a greater overall corridor length with several corners. In hospital design, the decision to lengthen a corridor route is not taken lightly, as there are system implications, notably that emergency routes are longer and corners are slower to negotiate, particularly for patients on trolleys; and visibility is curtailed. However for the neo-natal unit these constraints were considered less problematic, as the cots were both small and manoeuvrable, and the resulting travel distances were not thought to be excessive.

The main driver for the design were the clinical needs of the neonatal unit, which were largely regulated by Department of Health (DoH) guidelines HBN 21 (2008), although now superseded by the Health Building Note 09-03 – Neonatal units 2013 (DoH, 2013). The number of neonatal bays was determined both by the limited available space and by the budget. The designers opted for slightly less circulation space than recommended by the NHS guidelines as the design was open-plan, so circulation space could be flexibly shared with the neonatal bays. Hence, they managed to accommodate the required number of bays. The capital cost for the incubators and their associated service pendants (designed to provide monitoring and clinical support) were major cost factors, and this was weighed against future staffing costs for each cot, demand forecasts and throughput estimates. A level of resilience was built-in during the design process by adding expansion capacity which, although not capable of supporting acutely critical babies, could be used for babies who were recovering. Hence a further bay was equipped with limited function pendants, but was not yet required for use.

Clinical users were very competent at expressing their needs and the unit was ultimately designed around the needs of the babies in their care. The emphasis in redesigning
hospital spaces focused on meeting technical requirements whilst achieving the best possible clinical environment.

5.2.5 Contractual Considerations

The procurement system (Procure21) allowed the costs of necessary design changes, iterations or system upgrades to be included in the costing until a Guaranteed Maximum Price (GMP) had been agreed between both parties. Consequently major aspects of the design tend to be frozen at the GMP stage. As a case in point, some of the partitions that were scheduled for removal were discovered to be “shear walls” that structurally brace the building, so changes to the design were required to maintain the building’s integrity. As the GMP had not yet been agreed, these changes could be included within the overall agreed price.

In contrast, towards the end of the project it became necessary to change the flooring material throughout the Unit (after it had been fitted) as the infection control audit identified it as unsuitable. The revised specification for the flooring would have pushed the project well over budget. Fortunately, the PSCP negotiated a concession from the suppliers which they passed on to the project. It is, perhaps, questionable that PSCPs use their position of power to redistribute costs across the supply chain, as in the case here. However, this is beyond the scope of this thesis, although it may be an important issue for the resilience of the wider construction life-cycle process.

Typically with construction contracts, there are serious penalties associated with delay. The contracting parties try to minimise the effects of the various assessed project risks through the risk register or contingency fund. Under the Procure21 system, any unspent risk funds that remain at the end of the project are shared between the client and the PSCP. The aim of Procure21 is to foster transparency and openness between project partners. Hence the PSCP must inform the client if there is a problem on the horizon that may cause delay or involves cost implications so that they can claim extra time depending on the contractual risk share. The PSCP did not however, always take advantage of their opportunities to request extra time and they tended to “internalise” minor problems. Eventually the PSCP became concerned that delays had accumulated, in total amounting to six weeks. This meant that the PSCP’s slack or schedule reserves
were severely depleted and, crucially, this represented a significant constraint during the closing stages of the project. The PSCP had to “squeeze” the final stages of the project to maintain the tight schedule.

A PSCP must tread very carefully, as in general they try to ensure that they are in a good position to obtain further business from the client. To this end, they try to portray themselves as “solution focused” rather than “problem fixated” and often opt to internalise problems rather than present the client with a succession of minor irritations. Hence, the PSCP will often delay informing the client of a problem, at least until some form of solution or alternative option has been identified. However, too long a delay may severely limit a client’s choice of options and preclude any opportunity to contribute to a preferred solution.

It was hoped that Procure21 would help avoid problems of this type, by providing increased levels of transparency and communication, encouraging a greater degree of openness. Although it was evident that communication between the contracting parties was very good in this project, there was clearly a limit to the level of frankness that could be achieved. It should be noted that there were also reservations on the client side as they wished to ensure that the PSCP did not overcharge them, due to a possible misconception of the NHS Trust’s ability to pay.

### 5.2.6 Additional Constraints

The project was not only constrained by time and budget, but also by a variety of factors within and beyond the immediate project context. Connectivities to other hospital systems and wards were particularly problematical, so new access routes had to be developed and signposted. Concerns about security are always high on the list where children are involved. Even parents do not have free access to the unit and must be ushered in by staff. Providing access for a large number of un-vetted construction workers to a restricted area was a significant issue. In effect, it was necessary to build an entirely new access route with its own lift, to accommodate the construction traffic and materials, both for security purposes and so that other wards were not unduly disturbed.
The new Unit design included its own dedicated high capacity ventilation system, isolated from the main building ventilation system, as it could not provide the ten air changes per hour specified. Hence the additional plant increased the building’s environmental system complexity, without providing further benefit to the remainder of the building. Indeed, many of the hospital’s service systems were ageing or inefficient but decisions of whether to repair, renew or postpone work, were dependant on the risk of system failure. This risk was evaluated in terms of the risk to patients, the system retrofit costs, and the difficulty of access after refurbishment. For example, it was decided to replace the failing hot water system for the entire building, but to limit window replacement to the refurbished floor only. The need to minimise disturbance to adjacent wards was a major ongoing constraint and limited the type and extent of survey work that could be carried out. In consequence, there were many unwelcome surprises during the construction period that forced additional changes.

5.2.7 External Factors

Beyond the exigencies of the ongoing financial crisis which had a significant impact on the project scope, a number of other external factors had considerable impact on the project progression. Modifying existing buildings often involves dealing with aging structural details, a jumble of M&E systems, leaky facades and restricted footprints.
Hence the new or revised standards are extremely difficult to achieve in buildings designed during an era of low-cost energy. The variety of procurement routes, phasing options and construction contracts frequently complicate the process by adding additional uncertainty. Also, besides fire safety design and building regulations, there is a vast amount of clinical design guidance that must be sensibly addressed within the remit of a healthcare refurbishment project. There are also local planning considerations, infection control issues, waste management legislation and hospital system dependencies that must be appreciated. The designers attempted wherever possible to meet these multiple constraints.

The project required a “very good” rating under the British Research Establishment’s Environmental Assessment Method (BREEAM), as funding for future projects might be dependent on achieving this. However, this constraint led to a “point-scoring” approach to sustainable design and impacted the project team’s ability to provide the most appropriate sustainable solutions. The design guidance relating to BREEAM at the time of this study was aimed at encouraging best practice and energy thrift in health-care construction projects, but was not entirely appropriate for the partial refurbishment of older hospitals as it was concerned primarily with the assessment of whole buildings. As a result of opting for the Procure21 route, the design also required assessment under the Achieving Excellence in Design scheme and the cost of implementing this represented a further 6% of the total budget.

In addition to the above, emergent problems can surface at any time during the project and are rarely predictable. Here, the contractors had only just arrived on site when the first obstacle materialised. Apparently, it is not possible to begin work where nesting wild birds are present on the site, as was the case here (1981 Wildlife and Countryside Act, as amended 1991). This led to the threat of an immediate two week delay, and as such, led to the first of many changes to the project schedule. However, the delay was largely mitigated through the reshuffling of subsequent work packages by the project manager. Work that would not disturb the birds was brought forward and the delay was reduced to less than a week.
5.2.8 Process Issues

The refurbishment of the occupied hospital had to be carried out within very tight constraints to minimize risk and disturbance. Essential services could not simply be disconnected, as other areas of the building were still in use, and as a result the refurbishment work was scheduled around existing hospital priorities. Work by the contractors involving noise or significant intrusion was carefully scheduled and time-limited and this was a key feature of the project risk assessment. In this project the PSCP worked very hard at negotiating long noise-free periods with nursing staff, who would then warn their patients. Ear defenders were provided for all patients and staff, and even specialist new-baby ear defenders were sourced for the neo-natal cots, although these were eventually shelved as the babies were located at some distance from the noise.

Work tended to be carried out in a piecemeal fashion to allow the other floors to function; for instance it was rarely possible to turn off the water supply as it also supplied the delivery suites above. This placed further constraints on the detailed running of the project. The extent of the pre-project survey was severely restricted by the presence of asbestos and the need to avoid intrusion to the adjacent occupied wards. Building information (drawings, plans) were scarce or inaccurate and consequently, many unexpected problems emerged when work was about to start or was underway. Essentially, the team had to provide appropriate solutions very rapidly. Additional connections to many of the existing services were problematic or impossible. This was particularly the case for the steam-heating system, considered to be “too high risk” for further connections. It was also extremely difficult to make new connections to the aging cast-iron water-main as there was a serious level of corrosion. In addition, on numerous occasions live electrical cables and water pipes were discovered buried in concrete walls.

“...we had a lot of uncharted services that we didn’t know about until actually we started doing intrusive surveys ourselves. There were reported to be over 60, something like 68 uncharted services...and existing pipe-work condition was found to be pretty rubbish different materials were being used, different sizes and connections. It was all a bit of a mixture;
cast iron pipe in the risers – it’s a problem to tap into, to make tapings into cast iron is very, very difficult.” Case Study 1, Contractor Team Manager.

Necessary modifications to system designs were sometimes needed at a late stage but were not always possible because too many follow-on decisions had already been taken. Such situations posed real dilemmas. For example, at one point a critical component could not be used because it did not meet a newly revised standard, and a suitable replacement required many months for delivery. Resolving such difficulties required solutions that were, at the least, resourceful and frequently innovative, clearly suggesting that creative solutions contributed to the overall resilience of the process (project creativity is considered in considerably greater detail in Eckert et al, 2012).
5.3 Case Study 2: Modular Orthopaedic/Medical Wards

5.3.1 The Modular Ward Extension Project

This project concerned an acute hospital, serving a growing population in the north-east of England with a severe lack of overflow beds. The study explores the successful construction of a £10m modular ward extension to the central hospital block in crowded hospital grounds on a steeply sloping site.

In July of 2007, the hospital’s estates department were tasked with finding a solution to the Trust’s acute accommodation problem that could meet a target completion date of the 24th December of the same year. This meant that the procurement, construction and commissioning of the new ward block had to be complete and ready for occupation in just short of six months. Two modular building contractors were asked to submit tenders for a capital build and a lease purchase option over 25 years.

Link to a view of the proposed modular extension:


In the previous year the Trust’s estates team had set up Framework Agreements with a variety of preferred construction partners, to speed their procurement process. A project team was formed as soon as the project was suggested and key risks were identified. The project posed an almost impossible challenge to the selected Framework partners, and the estates team capitalised on this by encouraging a real sense of camaraderie amongst the team. The partners would have to work together to accomplish what appeared to be an unachievable task and surprisingly, the contractors "bought in" to the project with real enthusiasm. Planning permission was considered as the most significant early risk factor but in the event, full permission was granted within five weeks. Weekly team meetings were programmed. The NHS decision making process can be relatively slow, so important project stages were arranged to coincide with Trust Board meetings. This meant that decisions would be fast-tracked as the project was already a high priority for the Board.
5.3.2 Project Drivers

Seasonal surges in patient numbers, typically resulting from winter influenza or Norovirus outbreaks, oblige hospitals to maintain planned periodic bed surpluses. An additional constraint on bed supply involves the cyclical ward deep-cleaning process, essential to achieving the government’s infection control targets. This process requires that existing patients are decanted to alternative accommodation while their wards are subjected to steam or chlorine cleaning, followed by hydrogen peroxide (or equivalent) fumigation. This has been very problematic for the Trust in the past, and failure to achieve year-end infection control targets would expose the Trust to penalties in excess of £1m.

Until recently, the hospital trust has been under severe financial stress with significant budget shortfalls over several successive years. This eventually resulted in the independent regulator for NHS Foundation Trusts (Monitor) opting, for the first time, to use its legislative powers to remove the existing Trust chairman and appoint a replacement. Following this intervention, morale at the hospital improved significantly and projects previously awaiting decisions were finally processed.

In particular, the Case Study 2 project was approved and prioritised for rapid completion, owing to the significant financial consequences of non-compliance with recent government legislation. Sustained pressure from the media and stakeholders over a number of years, regarding the anxiety suffered by patients in mixed wards, eventually resulted in a commitment from the government to end mixed sex accommodation by 2010. This pledge, to ensure “privacy and dignity” in hospitals was accompanied with targets (associated with limited short-term funding) for hospitals to provide single-sex wards and personal hygiene facilities. These needed to be in place by the target date or penalties would ensue. The high priority attached to the project was directly linked to these urgent government targets and the need to avoid penalties. The Trust could not meet the targets without the decant space that the project would provide, and substantial fines would be imposed if either the infection control or gender-specific accommodation targets were not met by 31 December. These targets and associated fines, along with a pressing need for flexibility, were the principal project drivers.
5.3.3 Motivating the Team

A key feature of the project was the agreement of all the key players to prioritise the project and make themselves personally available at any time (usually by mobile phone) either for their knowledge and expertise, or to provide immediate decisions, as required. Each member of the team also agreed to produce their work on (or before) the due dates. A regular and popular social gathering, the Friday “curry night”, facilitated communication and remained a strong motivator throughout the course of the project (this good humoured event followed the weekly team meetings). One contractor failed to meet expectations at an early stage of the work and was immediately replaced. This may have acted as an added incentive for the remaining participants to keep to deadlines and so remain “on board”. In fact, the social aspect of the project appeared to be an important feature and was highlighted by most of the participants as a major reason for prioritising this project’s work over other competing demands. Interviewees stressed that members of the team had a strong camaraderie and enjoyed opportunities to meet. Not surprisingly, some participants also indicated that they felt that the option of further work with the Trust would be dependent on achieving satisfactory performance.

Table 5.3 describes the interviews that were conducted with the project participants.

Table 5.3 Interviews Modular Ward Extension

| Client Team: Deputy Director of Estates (Project Lead); Assistant Director of Estates (Project Team - Design); Assistant Director of Estates, Policy and Development (Trust Liaison); Director of Estates (Strategic planning). | 90 minutes (group session). |
| Consultant Architect Team: Architect (Design Consultant); Design Specialist (Senior M&E Design); Design Specialist (M&E Design); Structural Specialist (Structural Design) | 61 minutes (group session) |
| Cost Consultant: Principal Quantity Surveyor (Cost and programme control) | 44 minutes |
5.3.4 A Modular Solution

The architects, along with key Project Team members, prepared sketch layouts based on their knowledge of ward operations and hospital design guides. The design was based on 2 x 24 bed wards on two upper stories. The clinicians involved were made aware of the very limited time-scales for the project and that this would severely curtail the consultation process. The designs were presented to the clinical teams for immediate response in a “once-only” opportunity for their input. Finalised designs were then prepared.

It was clear, from the start of the project, that a modular solution would be the only option for achieving the required completion dates. Key members of the project team visited a selection of modular contractors with NHS expertise, to assess their capability for achieving the preliminary design within the timescale. Two contractors (PKL and Yorkon) were asked to submit tenders for a capital build and a lease purchase option over 25 years. Only one contractor met the required criteria and was subsequently appointed. The architects and the modular contractor worked together to adapt the designs for modularisation.

The ground floor of the extension was to be added at a later date, but the two upper floors in the main block were to be integrated. The original concept had included an additional third floor. Later changes to the project removed the third floor level along with the ground floor foundation slab, owing to cost constraints. However, the changes to the ground floor were unpopular with senior management as they had hoped to limit the amount of future heavy construction needed when the ground floor of the building was eventually to be added. They only acquiesced to the change when it was explained that suitable foundations could not be designed without knowing the final purpose or loadings.

The contractor chosen for the ground works was concluding an existing contract on the site and was able to start immediately. The site was very steeply sloping and the
enabling works involved the removal of 12,000 cubic metres of earth and the construction of a 4.5m retaining wall. However, early in the process it was discovered that the main electricity supply cable ran across the site. The only possible route for the diverted cable was through a near-by nurse’s access tunnel and, in consequence, the tunnel height had to be altered to provide the required clearance. The contractor was able to divert labour from elsewhere on the site, so that the work did not fall behind schedule. Although there was a significant cost associated with the extra work, it was covered under a separate infrastructure maintenance contract and did not detract from the project budget. The critical path for the project was determined by the module delivery date. All other project dates were obtained by working back from this date and the 20 week construction period was programmed for completion on 22nd December.

5.3.5 Crisis Point

A major problem emerged when it was discovered that the groundworks contractor, who was behind schedule, was unable to devise a support system for the crane that was needed to place the modules in position. This presented a crisis for the project, as time was at a premium and there was negligible float within the schedule. In the event, the Project Team pooled their expertise and over the course of a weekend, devised an appropriate solution and the project returned to the original trajectory. The 700 tonne crane was delivered on time using six lorries and assembled in situ. In the event, the placement of the modules was slightly delayed because for two days the wind speed exceeded the maximum 12 mph crane operating conditions.

The modules were not fully fitted internally and required a succession of trades to complete the internal fit-out. This was due in part to the limited time available, but there was also a need to ensure that the standard of finish met the trust’s requirements. Users were particularly anxious that the new wards should be continuous with the rest of the hospital and that there should be no noticeable difference. Hence the floors were to have no detectable deflection and all surfaces should feel solid and traditionally finished. There was also concern that the walls should be able to support additional fittings as required. The hospital had previously had two modular extensions but had been concerned at the limitations imposed by this form of construction. Difficulties
encountered in fixing shelves or wall-mounted equipment to somewhat flimsy wall linings, in the Trust’s other modular buildings, encouraged them to insist on a specification that used traditional finishes. In fact, the specification included plywood linings to all modules.

5.3.6 Contractual Considerations

The client’s architects had already prepared outline designs, and the client contracted them to continue working with the modular contractor to complete the design. A second contractor was appointed to undertake the enabling and construction phases of the work. The tender documents were sent out and returned within a few weeks, rather than the usual months. The client’s architects worked with the modular designers, as the modular contractor had specific constraints and technical requirements that had to be accommodated within the design. Work often preceded the arrival of the formal documentation, due to the level of trust engendered by the client project team. A crucial aspect of the project was the choice of separate contractors for the enabling works and the modular construction. The Trust felt that separate specialist contractors would be better able to use their particular expertise to deliver on time. However, there was no contractual relationship between the contractors and this imposed a degree of risk for the project, as there was a real possibility that poor communication between the contractors might threaten the success of the project.

5.4 Case Study 3: Modular Acute Admissions Unit (AAU)
This study examines a modular extension to a block of Watford Hospital to house an Acute Admissions Unit (AAU). Watford Hospital is on the edge of London and is one of three hospitals that together make up an NHS Trust. The Trust serves a population of nearly half a million people, and in addition attracts patients from north London, and the surrounding counties for particular specialities. At the time of the study, the trust was undergoing a £34m rationalisation of its acute services across its three sites. However, this meant that unpopular closures of units and wards at other sites were planned. £25m had been allocated for restructuring the acute services at the study hospital site and a £13m modular AAU extension was a key component of the strategy. Although the study hospital is scheduled for eventual replacement, a temporary extension was considered the most cost effective method of providing the restructured service in the short-term (considered to be in the region of ten years). The building is situated on a moderately sloping and congested site, closely surrounded by hospital buildings of varying ages and constructional form.

5.4.1 Project Drivers

Work to the proposed £350m Watford Hospital and Watford PFI Health Campus was planned to begin in 2013/2014 with the Campus completion date of 2035. However the start date was delayed until 2016, with no date yet for the new hospital replacement project. Meantime, the trust is consolidating acute services such as Accident and
Emergency services (A&E) to a single site to improve the standard of its round-the-clock service provision and to reduce costs. As might be expected, this was highly unpopular with catchment populations that were about to lose their local emergency service, and it eventually led to a public enquiry. As a result of the enquiry, the Trust was directed to continue with its restructuring but lost considerable time in the process. A number of temporary projects had to be prioritised to allow the Trust’s rationalisation process to proceed, and the AAU extension was a key aspect of the new strategy.

The need for the new unit resulted from a re-design of the acute admissions process and a revised model of care. Existing acute admissions patients entered the system through the A&E (Accident and Emergency) Department and were assessed by a number of junior staff over an extended period (sometimes two to three days), before eventually being evaluated by a consultant for confirmation of diagnosis and selection of appropriate treatment. This process could be significantly prolonged if patients were admitted at weekends. An alternative proposal was to admit acute patients immediately to an AAU, where patients could be assessed by a senior member of staff or consultant within the first few hours of admission. It was considered that this alternative plan
would provide a much improved care model and, at the same time, reduce the potential for bed-blocking by patients who could safely return home. The proposal was approved by the Trust Board and the necessary £13m extension was agreed.

5.4.2 Planning the Modular Acute Admissions Unit (AAU) Project

Link to view of a second-story modules being installed:

http://www.newscertain.com/2008/05/02/uks-largest-acute-admissions-unit-arrives-on-site-in-watford/

Picture 5.6

It was clear from the start that the building would be temporary (approx. 8-10 years), as the AAU would be incorporated within the new PFI hospital on completion. Hence it made sense to develop a modular solution that could be both reconfigured and relocated when its existing function would be transferred to the new facility. It was argued that a modular extension would be much quicker to construct and would reduce overall costs. However, this was not the case, and for a number of reasons the project exceeded initial cost and time projections.

Preliminary designs were for a four-storey extension but this was later reduced to three storeys to keep costs within budget. A significant obstacle surfaced as the new care model was fully developed. Under this system it would be essential that the imaging suite and labs should be situated on the intermediate level between the two clinical floors. This was a substantial change to the original plans, where the delicate imaging equipment and labs had been located on the ground floor, with dedicated concrete foundations to support their vibration-free operation. The architects and modular contractors were then tasked with developing a structural framing and support system that could provide a sufficiently deflection-free floor (at first floor level), for the section of the building that would house the vibration-sensitive equipment.
5.4.3 The Project Solution

Eventually a concrete frame solution was devised, along with concrete-floored modules that met the required specification. This revised solution meant that a time extension and further funding had to be obtained from the Trust. The concrete framed modular support system developed for this project was innovative, in that the system was specifically designed to limit deflection and transferred vibration within the upper floor.

Link to view of crane used for module installation:


This low-vibration framing system would be potentially of use to others and has since been included in the contractor’s marketing catalogue. In this case the research and development costs for the system were funded by the NHS, thus benefitting the contractor, and in turn, the NHS gained by achieving an innovative and bespoke solution. A simulated model of the module placing process can be seen at https://www.youtube.com/watch?v=cDeoN9COb4Y although the concrete framed section can only be glimpsed at the rear of the module placements.

5.4.4 Project Constraints

There were a number of constraints affecting the project, including the restricted site and the temporary nature of the requirement for an extension. Initially, it was not obvious that a modular solution would be cost effective. However, when it became clear that the building would be demountable with the option for re-use elsewhere on the site, the solution appeared more promising. The constructional complexity of the project was also an unexpected challenge as late changes meant that, from a relatively simple modular extension, the project progressed to an innovative modular development. It was the growing appreciation of the restrictions imposed by the revised model of care that led to the need for changes to the design. These changes involved significant innovation but at a greatly increased cost.

Table 5.4 Acute Admissions Unit (AAU) Interviews
<table>
<thead>
<tr>
<th>Participant</th>
<th>Organisation</th>
<th>Role</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trust Chief Executive Officer</td>
<td>Client</td>
<td>CEO, planning, managing, reporting etc.</td>
<td>67*</td>
</tr>
<tr>
<td>Associate Director, Infrastructure</td>
<td>Client</td>
<td>Estates management</td>
<td>67*</td>
</tr>
<tr>
<td>Associate Director, Strategic</td>
<td>Client</td>
<td>Estates management</td>
<td>67*</td>
</tr>
<tr>
<td>Developments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital Planning Consultant</td>
<td>Consultant</td>
<td>Estate design and planning</td>
<td>34</td>
</tr>
<tr>
<td>Participant</td>
<td>Organisation</td>
<td>Role</td>
<td>Duration (minutes)</td>
</tr>
<tr>
<td>Architect</td>
<td>Consultant Architect</td>
<td>Planning and design consultant</td>
<td>36</td>
</tr>
<tr>
<td>Contractor appointed Key Project Team members</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultant Architect</td>
<td>Principal Contractor</td>
<td>Overall scheme design, management</td>
<td>60</td>
</tr>
<tr>
<td>Mechanical Services Design/ Engineer</td>
<td>Contractor</td>
<td>Building Services design and installation</td>
<td>48</td>
</tr>
</tbody>
</table>

*group discussion;  telephone interview; face to face interview

### 5.5 Case Study 4: Cancer Ward Refurbishment

This study concerned the refurbishment of an NHS hospital oncology ward within a medium height tower building, originally constructed in the late 1960's. [See Short et al. (2012) for further construction information]. The hospital Trust, situated in the east of England, is one of the best performing Trusts in the country and has been praised for its strategic approach and its high standard of patient care.
5.5.1 Project Drivers

A children’s charity presented £2.9m to the Trust exclusively for the refurbishment of the teenage cancer ward. The Trust saw this as an opportunity to consolidate its oncology services and agreed to contribute £800,000 to the project.

An internal view of the finished Watford AAU can be seen in the following link:

http://www.yorkon.co.uk/projects/watford-general

5.5.2 Project Constraints

There was a severe lack of decant space to accommodate patients in the teenage cancer ward during its refurbishment. This made planning of the project particularly difficult, especially as the Trust saw the project as an opportunity for rationalising other adjacent clinical specialities to improve their connectivity with essential services. To this end, a complex sequence of ward decants and refurbishments was set in motion.

These decants could not take place until additional refurbishment works were completed that accommodated each cohort of transferred patients. This is because the decanted patients could not be transferred to their receiving wards without necessary and considerable alteration to those wards to meet their clinical needs. In effect, for the oncology refurbishment to progress from design to construction, a considerable amount of "enabling" work had to be completed. Clearly, this was not enabling work in the traditional sense, as it consisted of a sequence of decants and refurbishments [see Kagioulou et al. (2000) for an interesting discussion on what constitutes “enabling” work].

Link to a plan view of the Teenage Cancer Trust Ward

http://www.orms.co.uk/work/teenage-cancer-trust/
5.5.3 The Cancer Ward Refurbishment Project

The following were the major steps in the project. They heavily feature the series of decants of patients.

1. Relocate patients occupying level 5 to elsewhere in the hospital (which involved additional work beyond the scope of the study).
2. Refurbish level 5 to accept high dependency patients from Level 9.
3. Transferring the high dependency transplant patients on Level 9 to level 5.
4. Reconfigure the Vertical Terminal Air Conditioning (VATC) system on level 4 so as to enable the installation of additional showers needed for orthopaedic patients (who were initially on level 8).
5. Temporarily transfer the orthopaedic patients on level 8 to Level 4, to allow essential survey and services work to be done on level 9. Existing patients on Level 4 could be accommodated elsewhere in the hospital.

Link to view proposals for the Teenage Cancer Trust Unit

http://www.roystoninblue.co.uk/aboutTCT.php

Table 5.5 Interviews with Cancer Ward refurbishment project participants (Case Study 4)

<table>
<thead>
<tr>
<th>Team</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Trust Project Team (Four NHS project manager participants)</td>
<td>66 minutes (Group session)</td>
</tr>
</tbody>
</table>

The section of the building identified for the new teenage cancer ward had not been refurbished before and there was a total absence of any information regarding the condition of the structure or services. In consequence the process was plagued with programme changes. In addition, the difficulties involved in carrying out surveys in an occupied hospital made the process of determining the underlying structure and location of services extremely challenging. The process resulted in some significant
surprises and work was rescheduled accordingly, but this stretched the restructuring process well beyond the original timescale.

The patient transfers also had to be orchestrated with care, and additional funding streams established. This also extended the time-scale and increased the total cost of the project. As with most hospital refurbishments, asbestos removal was a significant issue, particularly as there was little in the way of documentation, to indicate where it was likely to be found. Unexpected pipes and cables and crowded service voids added to the complexity of the task. Other surprises included the presence of significant holes in the concrete floors, covered over with thin sections of plywood. A major complication involved ensuring sufficient plant room space for necessary plant and this was a particularly difficult problem that took considerable time to resolve.

In the event, the whole process took approximately twelve years and the total cost was in the region of £11-12m.
Chapter 6 Change in Refurbishment Projects

“The major difference between a thing that might go wrong and a thing that cannot possibly go wrong, is that when a thing that cannot possibly go wrong goes wrong, it usually turns out to be impossible to get at and repair.”  Douglas Adams, author of A Hitchhiker’s guide to the Galaxy

6.1 Introduction

This chapter focuses on the refurbishment process in NHS hospital buildings. It explores the problems that beset the individual refurbishment project, and considers the constraints that operate and may lead to the loss of key objectives or desired outcomes. By concentrating on the micro level or magnified view, this chapter examines the first of the three thesis levels identified in Section 1.1.

The world is unpredictable, so changes are almost inevitable during a large project that involves a complex series of tasks. In the case studies, project changes occurred for a variety of reasons and were often associated with variable weather conditions, communication issues, or the uncertainties or surprises that almost always arise during the complex refurbishment process. Some changes had little or no apparent consequences whilst others required major adjustments to ensure that projects stayed on schedule. Changes could be client generated or result from external pressures, such as amendments in legislation or government funding. Although the initial briefing may be comprehensive, it is not possible to anticipate the client’s evolving needs or the client’s developing understanding of how the new or revised model of care will fit within the newly designed and refurbished accommodation. Hence, client induced changes often arise from the client’s emerging understanding of the project as the design developed.

“…..its life, I guess, that projects do change, because life is dynamic”. (Case Study 1 estates manager).
It is the way in which changes are incorporated into a refurbishment project and the constraints that affect them that are of particular interest here. Some changes result in the need for a number of further changes and hence changes can propagate across a project. Generally, the later a change is made, the more disruptive or costly is the final result (Ibbs, 2005). As noted by Eckert et al., (2004) propagating changes, at any stage of a refurbishment process will generally involve additional expense or cause delay, but later changes will be more complex to resolve due to the agreed or “frozen” stage of the design.

Contractual issues can play an important role on the cost of changes, and these will vary somewhat with the chosen procurement route. For example, with the NHS procurement route Procure21+, the cost associated with early changes can be absorbed within the agreed final budget or Guaranteed Maximum Price. However later changes to the project will be problematic, as this will generate further unplanned changes to schedules, equipment, suppliers, or to project financing and contracts. Assaf and Al-Hejji (2006) found that in general, “fixed price” contracts had an increased risk of cost or delay and they attributed this to an increased number of change orders. This “fixed price” type of contract is designed to provide the customer with some control over the contract sum: a fixed price for the work is agreed, changes to the agreed design are discouraged, and any changes attract significant cost penalties. Nevertheless, change orders are quite commonly needed so that the designed space better meets the evolving needs of the client, even though such changes tend to be costly and may be a source of delay. Indeed, when the Case Study 1 project manager was asked about the impact of changes during the project, in relation to overall project success, he commented wryly,

“*The only thing guaranteed about a “Guaranteed Maximum Price” is that there will be a price – but it’s not guaranteed and it certainly isn’t the maximum*”.                                   Project manager, Case Study 1.

This chapter also describes a framework model developed to unravel change processes in refurbishment projects. In this framework a refurbishment project is envisaged as a simple scaffold composed of a number of “layers” relating to distinct sequences of connected processes, as shown in Figure 6.1.
Changes can take place on different layers, propagate between them or be mitigated across them. The framework will be described in detail and its usefulness illustrated by examining the case studies.

The design and production of complex engineered products shares a number of parallels with construction refurbishment: they both have detailed plans with specific objectives and both must manage the prevailing constraints of strict timescales, restricted budgets, challenging regulatory frameworks and variable supply chain relationships. A third aim of this chapter is to exploit the case studies to investigate whether changes to refurbishment projects create similar patterns of change propagation to those observed in engineering change. If so, engineering projects and hospital refurbishment may both benefit from the same tools and, in addition, each will add insights to the other.
Section 6.2 describes the propagation of change and constraints on the change process that operate during NHS refurbishment projects, where examples illustrate how the options for managing change can be limited. The new framework model is described in Section 6.3 and related to change mechanisms that occurred in the case studies. These include new mechanisms, such as “change deflection”, “change modification” and “enabling” change, which are identified and described. Section 6.4 compares building refurbishment with engineering projects and consider their patterns of change propagation. Section 6.5 considers the management of the change process and identifies some options for reducing the risk of serious propagation. Concluding comments are given in Section 6.6.

6.2 Change propagation and constraints

6.2.1 Change propagation

Large refurbishment projects have complex planning, design and construction phases and changes to any aspect of the process are likely to propagate. Figure 6.2 shows critical hubs in a midwife-led maternity unit. A large number of possible propagation routes (light blue circle) can result when changes are made to critically connected hubs in the system (dark blue circle).
Figure 6.2 Change Propagation Tree for a Mid-wife Led Unit (Eckert, unpublished)

Significant changes to any aspect of a project, once the designs and specifications have been agreed and signed off, will most likely be problematic. Unanticipated changes can be particularly troublesome and decisions may be required “then and there” with little opportunity for consultation. Such changes may for example, require modifications to project schedules, changes to components or mechanical/structural changes, requiring additional finance and/or procurement changes, and involve considerable levels of coordination. Typically, a change to the dimensions or the function of a space might
involve changes to any or all of the following: heating and ventilation calculations; electrical connections; lighting and service cabling; additional structural support; hot water, waste, vacuum and medical gas connections; fire safety systems; access and security arrangements; quantity and pricing information; infection control and interior design specifications. There may also be impacts on the user’s operational planning and a change may also affect connected spaces and involve still further redesign.

As the project progresses other factors may force additional changes, such as an unexpected structural surprise, emerging client needs, serious weather events, or the failure of a contractor. In a tightly constrained programme, these changes can be very challenging. One key aspect of managing a hospital refurbishment project is directed at limiting the propagation of any proposed changes beyond the geographic boundary, to try to reduce cost escalation and delay, and restrict disruption to the care process within the building. A common feature of hospital refurbishment is the trade-off that involves localizing a system change or improvement to constrain the overall project cost.

However, localizing a system change also restricts any potential benefit to only the project area, and correspondingly condemns the remainder of the building to be served by inferior or less resilient systems. As this type of segregation or partition continues with subsequent projects, the building services management becomes increasingly complex, with older less efficient systems continuing to operate alongside the newly introduced systems that service only the refurbished area. These aspects of refurbishment are discussed further in Chapters 9 and 10.

The stage at which a substantial change is made is crucial, as late changes may have implications for both the ongoing design and construction processes; previously frozen designs may require additional changes with considerable downstream consequences. Additional finance/insurance may be required and the necessary approvals may incur further delay. Typically other impacts may include the need for rework to existing designs or completed construction work, or to related system designs. Still further delays may be generated due to the long lead times in sourcing or fabricating alternative components or resulting from the need for regulatory consents.
The process of negotiation can be particularly time-consuming e.g., when navigating listed building consents or when renegotiating crane access in major cities. A further complication may involve ensuring that all parties are aware of changes, and this requires high standards of communication and document management. Once the price has been agreed between the contractor and the client, further changes will have increasingly significant cost implications. Hence, managing change is a critical factor in achieving project goals and a key aim of this thesis is to understand how changes impact on the downstream refurbishment process.

6.2.2 The effect of constraints on the change process

Building projects are subject to a wide range of constraints which may limit the options for mitigating change.

- **Regulatory constraints**: A complex regulatory framework applies to construction projects in health-care, with onerous Department of Health recommendations, local planning conditions and Building Standards, along with a wide range of technical standards and regulations, which constrain design work and, as they are generally aimed at new-build work, they are not always appropriate for refurbishment projects. Advisory standards that could not be met in all respects, were reflected back to the Trust directors and agreed as an ongoing risk.

- **Financial and contractual constraints**: Contractual issues or disputes are significant features of construction projects and historically have been a continual source of problems. Nationally agreed contracts such as the Joint Tribunals Contract are used and underpin each party’s perceptions of the construction process. However, the change of procurement route to P21 and the introduction of the New Engineering Contract resulted in delay in the Case Study1 project at a fairly crucial stage. Financially, such delay is problematic, as interest rates and inflation are calculated for identified project stages and associated with specific accounting periods.

- **Procure21 and the Guaranteed Maximum Price (GMP)**: When using the NHS procurement system P21, a GMP is agreed between the client and the principal supply chain partner. Problems resulting in a cost that is identified before this
agreement can have their costs included in the contract sum. Surprise discovery of problems after this point involves significant extra work and will impact on the construction schedule, unless there is a mechanism for absorbing additional cost or delay.

- **Building and process issues**: Minor refurbishments to occupied buildings usually take place in a piecemeal fashion, working on small sections with continual interruptions and complex restrictions. Essential services cannot simply be disconnected, as other areas of the building may still be in use and as a result, refurbishment work is scheduled around existing hospital priorities. Work by the contractors involving noise or significant intrusion, tends to be carefully scheduled and time-limited and this is a key feature of the project risk assessment.

- **Physical constraints**: Changes to particularly constrained systems such as soil waste systems, may be low-cost, but may require expensive floor plan changes or may seriously affect user satisfaction. Some systems may be so highly constrained that changes cannot be made, not necessarily because they are highly connected, but because they must be carried out at specific stages. For example, a component cannot be used if it does not meet a newly revised standard, or has a lead time of many months. Such changes cannot propagate as there is no downstream option and consequently the change (called a reflected change) is reflected back to the point of origin [Eckert et al, 2004].

### 6.3 A framework model of the change process in refurbishment

A framework model is proposed for clarifying the effects of changes and their propagation. The model is described in Section 6.3.1 and then its usefulness is illustrated by considering the propagation of changes in the four case studies. Case Study 1 is examined in detail in Section 6.3.2 and the other three studies are briefly examined in Section 6.3.3.
6.3.1 The Change Propagation Framework Model

The framework model is a set of layers and shows the directions of potential changes as changes propagate. An example is shown in Figure 6.3. In this framework, the “supply chain” layer corresponds to the procurement of materials, equipment and personnel; the “finance/governance” layer corresponds to the underlying legal relationships, structural hierarchy and financial management of the project; the “process” layer includes the scheduled construction events, processes, or operations; the “building” layer embraces the structural, fabric, access, services and envelope characteristics; and the “use” layer includes all aspects of user or client requirements, including functionality and design aspirations.

For other projects the layers might differ. They might, for example, include a facility/maintenance layer; or where governance issues might be pertinent, as in the re-design of services within a large new extension, it might be helpful to separate the finance and governance layers. Required changes can be modelled along each layer.
from project start to handover, showing where in a sequence of events, a change might propagate. However, many changes may “jump” layers and affect other areas of the project.

Changes can propagate horizontally along any of the layers during the project. For example, a change to a scheduled event on the process layer may be absorbed within the process layer by using “slack” or buffer periods. However change may propagate between layers, as there are often cost or design implications associated with any complex change. As the project progresses, some changes may cascade across to all layers, resulting in significant extra work to achieve realignment with project goals or targets. Conversely, changes can be mitigated on a specific layer which then absorbs or limits change to other layers, as part of this mitigation. To make sense of the interlaced relationships and procedural priorities it was useful to differentiate between changes that impacted the project globally, across all layers; changes that propagated just beyond their immediate boundary; and changes that did not cascade beyond their operative layer.

6.3.2 Case Study 1 (Neo-natal Unit refurbishment)

Within the wide scope of the NNU refurbishment project, there were many changes and only very minor changes were restricted to a single layer. Rather than exhaustively discussing all these changes, selected classes of change are highlighted and relating to the modelling framework in Figure 6.3.

Procurement and contract changes

Change in one layer propagating to an adjacent layer

The change of procurement route to Procure21 occurred at a late stage in the planning process, when it was clear that the project could not meet its deadline using the protracted traditional procurement route. The Procure21 Framework provided a short and vetted selection of possible contractors, which afforded a level of security in the crucial choice of principal supply chain partner, who sub-contracts and manages the project. This change propagated widely at first as a change “blossom” (see Section 2.10.3) but was limited by the relatively early stage of the project development. The
change propagated financially and administratively along the “governance” layer due to the increased costs of the Procure21 Framework (6% of budget) and across to the “process” layer as there was an unanticipated need for an environmental assessment (a further 6% of budget).

**Emergent changes**

As noted in Section 5.2.8, the original survey of the hospital building was limited in scope due to the constraints of a working hospital and the need to minimize intrusion to other parts of the hospital, and maintain patient privacy in adjacent wards. As with many older buildings, modifications over the years were poorly documented, so there were many structural surprises; with active water pipes and electric cables embedded in walls. Voids were often fully utilized or contained unexpected live services. A number of problems emerged during the construction phase and most involved changes to building services and affected various layers of the project. A major concern was the extent to which such problems might propagate beyond the project boundary to the rest of the building.

*Contractor related issues: Change propagation along a single layer:*

Often propagation within a layer will be unreported, as the normal mechanisms for absorbing change such as using float-time or re-sequencing are designed to contain minor changes. However more significant changes have the potential to affect key project goals. During the last few weeks of the NNU refurbishment, the electrical subcontractor became insolvent. The learning curve for a replacement contractor would have been immense. Consequently the Mechanical and Electrical (M&E) main contractor redeployed their own workforce to complete the contract, thereby also acting as “absorbers” and internalising what could have been a significant delay. However the arrival of twenty to thirty craftsmen, needing orientation, information and work plans, significantly contributed to the compression of the project in the final six weeks of the contract period. This severely squeezed the commissioning process, but as the client was knowledgeable and involved in the project from the start, this was not considered to be a major problem. However there were additional external propagating effects, as the M&E contractor’s other contracts were considerably delayed.
Building related issues: Change propagation across multiple layers

Subsequent to achieving an agreed Guaranteed Maximum Price (GMP), the water supply system was found to be in such a poor condition that it required replacement throughout the entire building and needed Trust Board approval to meet the extra costs. In addition, the presence of asbestos was greatly underestimated, resulting in significant delay and requiring specialist contractors. Consequently these changes propagated from the process layer across to the governance layer. Change also propagated to the user layer as design changes were required to accommodate new service runs.

Change absorption and the GMP

By contrast, the vulnerable condition of the heating system had been identified during the original survey, and full costs were included in the GMP so that an additional change order was not necessary, and further propagation was avoided.

Redirected changes

Interior design problem: reflected change, change absorption and change attenuation.

The most sustained challenge to the project was associated with the issue of the interior design and layout. Interior design, although a relatively low cost item, is particularly important to clients as the very tangible end result of their aspirations. The contractor had commissioned an architectural practice, who after several consultations and workshops provided the clients with very unsatisfactory designs and were then dismissed. However there was no provision for an alternative option in the contract documentation and the change was reflected back to the client (Eckert et al., 2004). A possible remedy might have involved some form of change absorption e.g., a further scheduled consultation with the interior designers or a contractual requirement for an alternate scheme. Eventually, the necessary pressure for change became so weakened or attenuated that it resulted in the client’s usual interior design solution of “hospital green” or “hospital blue” walls and with standard flooring. Hence this was an example of change attenuation.
Change of scope: Change “deflection”

As the project design progressed and the costs became clearer, it was apparent that either a change to the brief, or alternative funding, would be required if targets were to be met. The primary focus of the project was the main neo-natal wards on the lower level. The refurbishment of the areas devoted to supporting functions on the upper level was of less critical importance and was eventually separated out for alternative funding. However this diverted work package still remained under the overall project umbrella. In effect, when the project hit a cost barrier, the project team took the decision to re-scope the focus to only the essential work. The re-scoping of the changes to the upper level was “deflected” along a substantially different pathway. This “change deflection” was pervasive and propagated to all layers of the project (See Figure 6.3). Although this significant change resulted in “ripples” of change (Eckert et al., 2004) across each project layer and required work to revise the project documentation, schedules and contracts, it did not get out of hand. Critically, downscaling allowed more time for the completion of the essential work to the lower floor of the building. An estimated £300-500K of additional funding was needed to complete the work to the upper level and fortunately, this was later realised from unspent project risk resources and augmented by charitable donations.

6.3.3 Case Studies 2-4

Case Study 2: Changes to the modular orthopedic wards

The urgent need for additional ward space was the main driver for this project and the deadline was “fixed and final” and related to governmental infection control targets (c.f. Section 5.3.2). When a problem with the groundworks contractor threatened delay, the project team focused their efforts to find a solution. This kept the project on track and changes were limited to the building and process layers of the project and did not propagate significantly.

Case Study 3: Modular changes to the Acute Admissions Unit (AAU)

This project involved the construction of a three-story modular Acute Admissions Unit (see Section 5.4). The crucial changes resulted from the emerging understanding by the
client of the new admissions process. This meant that a vibration-free framing system was needed. This fundamental need was a change multiplier and affected all layers of the project. The change propagated to the financial layer as an innovative form of structural support would be required. There were also contractual issues (governance/finance layer) with the modular contractor, as he would be required to develop (R&D) a solution to accommodate the proposed changes. The change also propagated to the process layer as the developing programme had to be revised to accommodate the new framing structure.

**Case Study 4 Cancer: Ward refurbishment**

This project involved the refurbishment of three floors in a 1960’s hospital tower block (c.f. Section 5.5). Its main changes involve around two distinct change mechanisms, which are referred to as enabling changes and change modifiers.

An enabling change is not integral to the design but must be made to allow a project to progress. Many of the changes that characterized this project were “enabling changes“, as the ward could not be refurbished until existing patients were suitably provided for. This type of change is also subject to complications of reflection and propagation to multi-levels.

A change modifier is a mechanism that modifies (reduces or enhances) a required change, rather than significantly altering the scope of the project. During this refurbishment, the needs of minor changes were tempered to a small extent by altering the cost and/or the extent or the type of work. For example, when a change of cold-water tap was necessary, to meet revised legislation, a form of cold-water tap was identified that significantly reduced the cost and installation work, while providing a much reduced opportunity for Legionella growth.

### 6.4 Features of refurbishment and engineering projects

For many years there has been a perception that significant developments in the engineering process, such as developments in lean production, concurrent engineering,
collaborative systems and agile management, are slow to infiltrate the wider construction sector. Engineering projects face some similar problems to those encountered in building refurbishment. In particular, both are tightly planned and any divergence from a plan may entail significant levels of change. They also face similar problems of time and cost. There are, of course, also marked differences. In engineering design the focus of change research has been on the management of the engineering design process, while in building refurbishment a wider perspective is required to include the contractual frameworks that underpin projects. There is also greater flexibility in the use or function of a building than with most engineered products which tend to be carefully optimized for a particular use. For buildings users, there is a certain degree of flexibility over how a function is carried out within a particular space so, for example, it is possible to vary how a laundry process is sequenced, affording options for where the laundry room is located.

Drawing on themes identified in the literature and from analysis of the case study project interviews (including discussions with case study participants), various key characteristics of refurbishment projects emerged and are presented in Table 6.1 under “Construction Refurbishments”. These characteristics appear to profoundly affect how changes are carried out and whether and where changes propagate. Table 6.1 also contrasts these characteristics with features of engineering product development (Eckert, personal communication).

Table 6.1 Distinctive Features of Construction and Engineering Projects (Garthwaite & Eckert, 2012)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Construction Refurbishments</th>
<th>Project</th>
<th>Comparison with Engineered Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key indicators of success</strong></td>
<td>Duration/ cost/ quality remain key indicators of success and penalties have led to careful risk management. Compromises on build quality, value for money or advances in process, may compensate for time lost.</td>
<td>Case Study 3 Sections 9.2.4 and 5.4.3</td>
<td>Product sales are the key indicator of success. Re-order rates and uptake of extended warranties indicate success in operation. Recalls are costly and affect brand image.</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Construction Refurbishments</td>
<td>Project</td>
<td>Comparison with Engineered Products</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Design changes</td>
<td>Frequent changes: Users’ understanding of their needs matures with the emerging building.</td>
<td>NNU Section 6.1</td>
<td>Early changes related to “user-led” requirements. Later changes respond to problems. Constraints can be varied, e.g. by freezing components or systems.</td>
</tr>
<tr>
<td>Post-project changes</td>
<td>Post-project amendments, although expensive, can provide an alternative option to delaying the hand-over date.</td>
<td>Case-Study 1, Sections 8.2.3, 8.3</td>
<td>Occasional post production upgrades for specific customers; option package amendments or distinct redesign projects.</td>
</tr>
<tr>
<td>Possibility to negotiate directly with clients.</td>
<td>Negotiated “workaround” solutions that clients can “live with” may be preferable to expensive alternatives.</td>
<td>NNU Section 9.3.5</td>
<td>User input during requirement gathering.</td>
</tr>
<tr>
<td>Refurbishment issues</td>
<td>Refurbished buildings are rarely optimised. The tendency is to balance the level of improved performance against the likelihood of escalating the cost.</td>
<td>Case Study 1 NNU Section 5.2.4</td>
<td>High volume automotive refurbishment is integrated into the “auto-servicing” sector. With “low volume/high value” products, refurbishment provides an opportunity for introducing innovation.</td>
</tr>
<tr>
<td>Certification</td>
<td>Building standards are not retrospective (at present) and do not extend to unaffected areas of the building. Depending on the system, testing may be required e.g., air-tightness, etc.</td>
<td>NNU Section 9.3.5</td>
<td>Certification relates to the whole product and onerous testing is required to ensure that the entire product performs safely.</td>
</tr>
</tbody>
</table>
The table shows that there are many differences in detail between construction refurbishment and the development of engineered products, but there are also a number similarities, particularly in their underlying concepts. Hence an understanding of developments in product engineering, especially those related to change and the introduction of technical innovation, may be very useful in helping to conceptualise the change process in building refurbishment and vice versa. In particular, the way in which contractual relationships affect the change process is very evident in construction and motivated the Change Propagation Framework model described in Section 6.3.1. Insights obtained through employing the Change Propagation model may be relevant to engineering product development.

Further discussion of the similarities and differences between building refurbishment projects and engineering design projects is given in Garthwaite and Eckert (2012b), which focuses on the topic.

### 6.5 The management of change

Refurbishments, like all construction projects, are highly iterative and have various stages, and although some are concurrent, there are clear gaps where the design information needed for the project to proceed has yet to be determined or agreed. This is particularly problematic as the planning process requires multiple complex inputs and timely information from the various project teams, usually well before necessary data is available. Hence, decisions about the project often have to be made before the
necessary detailed data is available. Later developments of the design then require further changes to design work by other project design teams. The design manager from Case Study 1 reported that he had received over 5,000 emails requesting information about proposed design changes during the development of the neo-natal unit design.

In Case Study 1, conflict at key points of the project, relating to the interior design concerns for example, resulted in a failure to progress or “project drift”. This subsequently compressed the clients’ aspirations into the final few weeks of the contract. The project remained within budget, chiefly due to the reduction in scope and to the very detailed project risk register, which identified the major anticipated risks and set aside sums to cope with such eventualities. The most serious anticipated risk was associated with construction noise causing disturbance to patients, and which strictly limited the time available for drilling tasks. Pre-emptive action included agreeing quiet periods, or short service disruptions, and sourcing “low-noise/low vibration” drills. In addition, the principal supply chain partner, as a major supplier of health-care services, was able to secure discounts from its supply chain partners further along the chain, which reduced the costs associated with specific required changes.

The breakdown of the interior design process was not dealt with in a timely fashion and continued as an unresolved issue for many months. Due to the long lead times required for furnishing and fabrics, it was likely that the longer the delay in ordering, the poorer would be the final design solution. Eventually it was clear that the required changes were not being managed but opportunities to remedy the situation were gradually disappearing. The client finally took the interior design function back “in house”. Hence, the change could also be considered as “attenuated” or protracted, as there is less and less opportunity for the change to occur. The delay meant that the necessary change could not achieve its desired outcome, and the end result was a “hospital standard” interior, and was very far from the original specification. While the final outcome was tolerable, the end users were less than enthusiastic. Hence the required change became “attenuated” or weakened over time, resulting in a disappointing outcome. This was due, for the most part, to the client’s inability to provide a “professional standard” interior design service. [In the case of engineered product development, only on very rare occasions could a reflected change have an alternative option for resolution.]
Typically in product engineering, a reflected change cannot be made; however if the change is considered to be essential, the process would be actively managed through negotiation by the project “architect”, tasked with overall responsibility for integrating the product development process, and who coordinates with all of the teams involved.

Another feature of Case Study 1 was that financial decisions regarding any significant cost deviations were reliant on approval from the Trust Board of Directors. This meant that contractual changes with serious financial implications were dependent on the monthly schedule of Board Meetings (this delay could also have propagating effects). Other project changes were considered or analysed by groups set up at the outset of the project. The User Group considered any changes that might impact on the clinical functioning of the unit, whereas cost control was the remit of the project quantity surveyors. The project manager attended as many of the group meetings as possible and reported potential problems or necessary changes to the Project Director.

### 6.6 Summary

This chapter looked at the special features of refurbishment projects and explained how changes can propagate across a project. It also explored the range of constraints that can affect the way in which changes can be managed. The Change Propagation Framework Model developed in Section 6.3 is designed to assist NHS estates or industry professionals to trace the course of changes across refurbishment projects and to highlight areas where the risk of change propagation is significant. The process can be very helpful in identifying change trajectories, spotlighting change multipliers, and evaluating appropriate locations for change absorbers. Section 6.3 also provides a vocabulary for discussion of refurbishment change mechanisms such as, “change attenuation”, “change deflection”, change “modifiers”, change “absorption”, and “enabling change”.

Change reflection appeared to be less problematical in construction than for engineered products. In the case study projects there were significant opportunities for difficult changes to be absorbed, and this was due in part, to the flexibility and creativity of the
project team and of the construction contractors, who sometimes acted as absorbers of change by re-scheduling work packages and re-negotiating costs with suppliers.

Essentially, the long-term implications for the functionality and resilience of overall buildings or the hospital campus may be dependent on the decisions made to resolve changes during the refurbishment process. By identifying specific mechanisms and their subsequent effects, problematic changes can be planned for or avoided. Further, through studying the trajectories of change in refurbishment projects it should be possible to predict some of the distinctive difficulties of this complex working environment and plan the inclusion of suitable strategies for absorbing any potentially propagating changes.

Careful analysis of project changes by the estates team and the participating contractors, along with the consideration of strategies to limit change propagation, should help to ensure that the resilience of the building or campus is enhanced rather than compromised by future refurbishment projects. The Change Propagation Framework can help in this process, particularly if adopted during the end-of project review, where project problems and successes are considered and where learning or new knowledge can be formally embedded in project documentation.
Chapter 7 Refurbishment: Constraints and Barriers to Resilience

“If you feel that these people don’t know what they’re doing, and it looks like the paint’s peeling off the walls, it doesn’t inspire you with confidence. However good the clinicians are, it just doesn’t inspire the confidence. So the environment is a huge part of the care that we give.” Senior Nurse, Case Study 1.

7.1 Introduction

This chapter looks at NHS hospitals and focuses at the meso level, exploring the refurbishment process and its effects on individual hospital buildings. Refurbishment involves the integration of a wide range of activities, and is aimed ultimately at providing the client with an enhanced environment and sufficient flexibility to meet his existing and anticipated needs. Chapter 5 identified that changes to refurbishments projects frequently occur and Chapter 6 examined the consequences of changes for the hospital building at the micro level. Essentially, this chapter considers the meso level and highlights how refurbishment changes affect not only the connected hospital systems during refurbishment projects, but may also impact the care environment, the building’s systems and integrity and, additionally, cause difficulties for future refurbishments.

When a refurbishment project is proposed it will generally involve considerable cost and require some form of evaluation before approval. Typically for the NHS estate, this takes the form of a feasibility study, leading to the preparation of a business case, so as to determine whether the basic concept is sound, financially viable and whether the proposal can be accommodated within the Trust. Once the process is underway and there has been a consideration of the alternative options for premises, the chosen accommodation will be subject to a structural survey (where possible) and, ideally, an evaluation of the project’s fit with the Trust’s long-term plan. The likely value of the proposal determines the level of scrutiny it receives. As the project develops, the briefing process elicits the user needs and provides an analysis of the constraints and affordances that determine the final form of the project. The business case identifies the
project parameters, procurement route, governance and financial planning. Trusts may have slight variations on the timing or procedures, but in general, the process seemed to be similar for each of the Trusts that collaborated in this research. Once the details are finalized and the design process is underway, many critical decisions will have already been made and, as the design evolves, necessary changes may become much more difficult to accommodate.

Section 7.2 suggests a definition for refurbishment, developed for use with NHS applications and possibly for wider application. Section 7.3 looks at the choices and constraints involved in choosing whether or when to refurbish. Section 7.4 considers the timing of refurbishments and the timescales they address. The principal refurbishment drivers that are contributing to the increasing need for NHS hospital refurbishment, are considered in Section 7.5, and Section 7.6 explores the major constraints affecting the process and conflicting issues that arose in the neo-natal unit case study. Section 7.7 considers issues from climate change on hospital refurbishment. Concluding comments are given in Section 7.8.

### 7.2 Definition and Terminology

#### 7.2.1 Definition of Refurbishment

The definition of “refurbishment” has been under debate amongst academics and construction professionals for some time, mainly owing to the broad range of activities that are frequently described as “refurbishment.” This lack of precision presents difficulties, particularly for example, with regard to the financing of projects, as refurbishment is treated quite differently from new-build schemes for taxation and procurement purposes.

The question of appropriate defining criteria was particularly active around the turn of the century (1995-2005), although research in this area is less active at present. To date, there has been relatively little progress in defining “refurbishment,” and it is likely that industry and professional associations would welcome a descriptive definition suited to a range of applications and set within an appropriate context or framework. Quah in 1998 described the term as a “generic” or “umbrella” concept (Quah, 1998) owing to the
very wide range of processes that are frequently labelled as “refurbishment” (see Section 2.6 of the literature review).

Many similar words appear to be used interchangeably with “refurbishment”. Various examples of alternative terms used in this way were recorded during the course of the literature search and case studies. They include: reinstatement, adaptation, modernisation, redecoration, renovation, restoration, alteration, improvement, modification, conversion, rehabilitation, restyle, update, upgrade, extend, reconfigure, remodel, refit, repair, repurpose and renewal (Egbu, 1996; Hardcastle, 1997; Highfield, 2000; Mansfield, 2002). Typically the terms reinstate, restore and repair, renewal, rehabilitate, are applied to insurance claims or to Listed Building work that focus on returning premises to their original state; and the terms repair, refit and reinstate, are prevalent in maintenance and repair work that does not involve a specific upgrade. The remaining terms, adaptation, modernisation, redecoration, reconfiguration, renovation, alteration, improvement, modification, conversion, restyle, update, upgrade, remodel, repurpose and renewal are used to describe a range of refurbishment projects. Some of these terms are specific, such as extend or adapt, but there does not appear to be a clear rationale for choosing a particular refurbishment term. Most of the terms mentioned above were used from time to time by the interviewed hospital estates professionals in relation to specific projects. For example, the term repurposing was used in discussion relating to the use of ex-nursing accommodation for new offices, in Case Study 3, and remodelling, redecorating, upgrading and extending were used frequently in all of the case study Trusts. Many different terms were used in general conversation during hospital visits but their use was not recorded.

For this research it was necessary to clearly identify what is understood within an NHS context by the term “refurbishment” and to establish a context for the preferred terms used by the professionals within the NHS projects studied. Hence, the interview transcripts were examined to determine what terms were used for refurbishment, how frequently each was used, in what context, and by whom. The results are summarised in Table 7.1. The table shows the range of preferred terms, their frequency of use, and the professional(s) using them. It omits terms that were used only rarely (less than three times in total).
Table 7.1  Frequency of Selected Key Terms Used by professionals during the Case Study Interviews

<table>
<thead>
<tr>
<th>Terms used more than 5 times</th>
<th>Refurbish</th>
<th>Upgrade</th>
<th>Adapt</th>
<th>Extend</th>
<th>Reconfigure</th>
<th>Sustainability</th>
<th>Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yorkshire Architects Group</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yorkshire Building Service Engineers</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Northamptonshire Estates Manager</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td></td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Leicestershire Estates Manager</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Yorkshire Estates Manager</td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambridgeshire Project Managers</td>
<td>39</td>
<td>3</td>
<td>31</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hertfordshire Architect. Group</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hertfordshire Estates Managers</td>
<td>15</td>
<td>2</td>
<td>2</td>
<td></td>
<td>14</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hertfordshire Architect</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>London Design Engineer</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leicestershire Building Contractor</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hertfordshire Engineer</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Hertfordshire Estates Manager</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Leicestershire Quantity Surveyor</td>
<td>6</td>
<td>15</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
All the case study estate managers used the term “refurbishment” to describe the very wide range of work carried out within each of the case studies, despite the fact that the case study construction projects were distinctly different and ranged from the off-site manufacture and installation of a prefabricated modular extension, to the design and construction of entirely new ward/s within an existing shell. For the purposes of this thesis, “refurbishment” was initially defined in a very broad sense, so that the term covered all the work that the stakeholders and estates professionals of NHS Trusts refer to as refurbishment. However, quite soon this description was found to be unhelpful, and a more accurate attempt at a definition is presented below.

From the interview transcripts, the rationale for most of the projects concerned the provision of improved services for patients; improving the efficiency of space utilisation; extending the building life; limiting fossil fuel consumption; or improving infection control. However there is some debate regarding the need for a rationale to be included within a definition. Eckert et al. (2004), working in the product engineering domain, concluded that regardless of the causes of a change, the processes or tasks described within the definition remain inherently the same and consequently, that a rationale is unnecessary. This is a very pragmatic view that takes for granted a clear familiarity and rationale for the work undertaken. However, an accurate and succinct working definition that ideally contains only the information necessary to clearly identify
the entity being defined can be very helpful in certain situations, such as when developing policy or when building a business case. Moreover, a rationale may provoke the user to think through issues that may be very pertinent, but might not be initially apparent. For example, when considering or instigating a project, the rationale might emphasise future flexibility, or focus attention towards curbing climate change.

Using both the interview transcripts of NHS estates professionals, consultants and contractors, and also the literature review, a definition suited to NHS refurbishment purposes was developed and is given in Figure 7.1. The definition might be considered by some industry professionals as somewhat too broad for use within the construction community as a whole, as it includes building extensions that require new construction work. In addition, the definition does not clearly define how issues such as the retention of only the original façade, or the maintenance and retrofitting of services within an existing building, should be considered. Nonetheless, it describes the range of work described as “refurbishment” during the research interviews by the NHS estates personnel and professionals associated with NHS projects.
Revised Refurbishment Definition

The reconfiguration, upgrade, modification, extension or adaptation of an existing building, or parts of a building for the purpose of:

- achieving current or advanced standards of efficiency, utility, hygiene and comfort, whilst minimising emissions and waste;
- improving building or site infrastructure, access, or parking facilities;
- mitigating future climate change; adapting to changing conditions;
- changing a building or part of a building to suit an alternative purpose or priority; or retaining the façade only and rebuilding, largely within the confines of the original building;
- extending a building using modular off-site or traditionally built construction;
- upgrading internal or external building finishes or appearance;
- providing transitional or short term accommodation;
- creating temporary or permanent links to other adjacent or local structures;

Refurbishment may involve changes to the structure, configuration, fabric, finishes, appearance, services, infrastructure, fittings, fixed or mobile equipment, or technology, and may include modification of the building footprint or envelope.

Rationale

The underlying rationale is to ensure economic, sustainable and resilient service provision, through encouraging flexibility, and maintaining functionality for the effective life-cycle of the built asset, with regard to the changing climate. This includes the requirement to manage inflows and outflows sustainably, thus minimising waste and systematically reducing polluting contributions to climate change.

Figure 7.1 Revised Refurbishment Definition

7.2.2 Types of Hospital Refurbishment

Hospital refurbishments can be partial, involving specific areas, wards, facilities, or departments, or it can involve the closure of the building whilst it is completely refurbished throughout. There appears to be some disparity between Trusts regarding what might be classed as refurbishment and what can be considered as regular maintenance. In some Trusts, maintenance can include the simple redecoration of
existing surface finishes, and may extend to renewing components such as windows or doors, whereas other Trusts consider this internal “refreshing” process to be refurbishment. However any more substantial improvements are classed as refurbishment. In the case study Trusts, refurbishment tended to fall into one of the following five categories.

**Cosmetic refurbishment (all case study Trusts):**

Typically termed a “face-lift” by estates professionals, this involves complete redecoration of an area, including new surface finishes and new floor coverings. The process may include the installation of new fittings, such as lighting, sinks and taps, and grab handles and other accessibility equipment. Nurse stations or reception areas may be refreshed. New furniture, fittings and screens may be included. Bathrooms will have new cubicles and appliances fitted.

**Upgrading (Case Study 4 Trust):**

This usually includes cosmetic refurbishment but, in addition, new services or equipment is added, which can sometimes require a revised floor plan. For example, wards may be upgraded to suit high dependency patients by installing the necessary piped services, ventilation and monitoring equipment. Hence some level of space redesign or “stripping back” of existing finishes may be necessary to remove unnecessary equipment etc., and allow the installation of required services. Some level of asbestos mitigation may be necessary. Security systems/fittings may be updated.

**Partial Refurbishment (Case Study 1 Trust):**

For this process, a hospital may remain occupied, although patients in the areas to be refurbished are decanted to other wards. The process is restricted to a specific part of a hospital building (typically one or two wards; occasionally, a whole floor level; or in some cases, a department) and may involve the complete stripping back of all internal finishes and services to expose the original structure. Partial refurbishment can involve enlarging the building footprint by extending beyond the building envelope. A refurbished space is usually redesigned and, where required, new services, heating, IT and electrical systems, ventilation and medical gases, and a vacuum system may be
added. Asbestos mitigation may be necessary. Components such as windows may be replaced. Typically, new décor, finishes and fixtures along with selected upgraded systems and equipment are provided.

Total Refurbishment (All case study Trusts):

The building is emptied and completely stripped back to the supporting structure and all internal and external finishes are removed. Some excavation may be required to install new foundations to support additional loads. A new building envelope may be required and designed to provide improved thermal performance. Generally, new and efficient lighting, M&E and environmental systems are included, designed to harmonise with the building envelope; and the functionality of the space is enhanced with improved appearance and “cutting edge” clinical care equipment. Improved building management systems are usually included. Although there were no examples of this process during the period of this research in any of the case study hospitals, in two of the Trusts the process was being considered for specific buildings in the near future.

Extension to a building or linking between buildings (Case Studies 2, 3 and 4 Trusts):

The hospital may be extended to provide additional space or a fixed facility, such as a plant room or an imaging suite, or to provide “high-tech” laboratories or a ward block, for example. This is essentially a new build process, although there may be some disruption and remedial work required, where the new extension is connected to the existing building. Extensions may be of modular or traditional construction and care must be taken to ensure that the building integrity is maintained where the new structure connects to the existing building. Surprises at connection points in the original structure can be the source of considerable cost or delay, if remedial work is necessary.

7.3 Why Refurbishment rather than New-Build?

The NHS could not afford the cost of replacing all its ailing buildings over the relatively short period that remains before climate change is likely to make many hospital
buildings noticeably uncomfortable for patients. Clearly, this would be an extremely unsustainable objective, considering the long design life of built assets (usually a minimum of 60 years) and the huge investment in their construction, both in terms of finance and embodied energy. Refurbishment is a sustainable alternative to new-build construction and enables buildings to maintain their effectiveness throughout, and frequently beyond, their design-life. Essentially it affords the opportunity to update hospitals with advanced technologies and innovative models of care when the opportunity arises. Also, even for partial refurbishments the introduction of energy saving plant and equipment with advanced energy control systems can provide improved thermal comfort whilst significantly reducing the carbon profile and energy costs (Roberts, 2008; Kolokotsa et al., 2009).

However there may be good reasons for choosing not to refurbish. This could include, for example, the high cost and risk associated with correcting any structural deterioration or fabric decay in buildings with advanced deterioration, so it may prove cheaper and more efficient to consider replacement. Alternatively, a building may be unsuited to its present use, with no obvious alternative purpose.

The long-term planning priorities for a hospital campus may fundamentally influence the decision of whether or not to refurbish specific buildings, regardless of the life-cycle imperatives or considerations of the building’s condition. Also, the restructuring of services across a number of Trust sites may result in good buildings being considered surplus to requirements. In such cases, where there is no possibility of repurposing hospital buildings for use by the NHS or other purchaser, there may be a case for demolition if the site could be better utilised for the benefit of the hospital. However, the position may be further complicated by any PFI contracts that may be in place, which may radically reduce the available options for estate rationalisation, refurbishment, restructuring, or for the sale of specific buildings.

Ideally, refurbishment can provide accommodation with an improved layout, improved appearance, a more effective use of space, new technological innovations, along with efficient low-energy building services. However, in some situations refurbishment might not be able to provide the desired functionality or connectivity, due to limitations of the building footprint, the excessive travel distances, or the restricted plant space, for
example. Refurbishment also provides the opportunity to correct problems such as asbestos removal. All NHS premises are required to produce an asbestos risk register and most Trusts are aiming to remove asbestos through a planned programme of removal following the completion of their asbestos surveys.

Condinhoto et al. (2008) found that designers become involved in the refurbishment process at a relatively late stage, often when the major decisions about the configuration of the project have been made, and this may be too late to make best use of their skills in achieving the optimum fit between the existing space and the client’s aspirations. This was the case for one of the refurbishment projects in this research (Case Study 1) and it can be one contributing factor when buildings or parts of buildings fail to achieve their potential. In one interview an estate manager (expert 3 in Table 4.5) described how a badly positioned building on his hospital campus (less than 15 years old) hampers access to the site and severely limits future development. However he felt that it would be uneconomic and unsustainable to replace this relatively new building, and consequently, future options for the site continue to be constrained by this earlier and very restricting decision.

7.4 Timing and Timescales

Refurbishment can be planned within a building’s life-cycle or it can be *ad hoc* and carried out in response to specific drivers, such as the availability of time-limited government funding, or the need to enlarge a department or add additional space. Refurbishments in the case study Trusts tended to be approached on a “piecemeal” basis (where and when required), rather than being included as part of a building’s planned life-cycle upgrade.

The partial or total refurbishment of a space usually involves stripping back to the original shell and replacing the piped services as far as practicable, along with the installation of any additional or new plant and equipment. The work may involve necessary repairs, extensions or changes to the original structure, and possibly the replacement of components such as windows and doors as required, along with the installation of the most recent “high-tech” clinical equipment. Additionally, an interior
design process is usually included that provides advice/schematics for desired wall and floor finishes etc., and includes consideration of key properties for surface materials such as hygiene and infection control, sustainability, durability, fire-proofing etc., within the revised clinical layout.

In practice, in all the hospitals visited, refurbishment appeared to be an ongoing and almost continuous process in some part of the hospital campus. Departments, wards and theatres were redecorated, upgraded or partially refurbished when possible, usually as a result of departmental requests to support innovative models of care, or as a part of the planned maintenance programme, or to increase productivity by, for example, adding additional theatres or decant space. In some cases refurbishment resulted from specific funded projects, for example the neo-natal unit restructuring and refurbishment was undertaken to reduce the Trust’s strategic vulnerability. In Case Study 4 a refurbishment was undertaken as part of a larger scale restructuring process and was funded by a charitable donation specifically directed towards upgrading an adolescent oncology ward.

Ideally, for a building to be efficiently utilised over the long term, a series of planned refurbishments should be considered at the outset, programmed to suit specific goals throughout the full building life-cycle. However, this involves accounting for numerous uncertainties, such as the likely time interval between each refurbishment until functional obsolescence, and this will be specific to the building for new user (or change of use); the probability and timing of funding famines; medical technology developments; or changes in the demand for services etc. Hence it is necessary to consider not just the immediate goals of a department or unit, but also the long term development of the entire building, its future as part of a developing hospital campus and NHS property portfolio, and with consideration for the aspirations of the trust and the community it serves.

Central to this process should be an analysis of future trends or risks. Uncertainties that must be included within such a risk analysis include developments in communications technology and telemedicine; changing access needs and connectivities; future models of care; future patient funding options; procurement issues; patient preferences; demographics; developing patterns of disease; and significantly, the extent of climate
change. These may all affect the ongoing effectiveness, flexibility and adaptability of a built asset during its design life and beyond. Figure 7.2 outlines the choices available for various types of buildings and relates these to the likely outcomes of such choices. The range of possible buildings (blue highlight) is associated with the available options available for tackling their management (purple highlight): preservation, maintenance, refurbishment, adaptation, transformation, demolition or transformation (Sealy, 1984; Mansfield, 200; Mansfield 2008; Mansfield 2009). Outcomes (orange) are suggested and result from conversations with estates managers and other experts interviewed during the course of this research and from the reviewed literature (Britain and Rogers, 1999; Thomson et al., 2006).

Figure 7.2 Refurbishment options and outcomes

A fundamental problem with refurbishment hinges on the fact that even where the project objectives are strongly emphasised, the immediate imperatives of designing and constructing a refurbishment project within tight timescales and budgets often means that long-term priorities are shelved in favour of emerging issues that become immediate problems. One project manager talked of the “thankless and frustrating” task of trying to prioritise sustainability.
“I always feel in this department, that the majority of projects that we do are all very reactive, and that makes it difficult in a number of ways to plan and get the finances that you need to deliver a sustainable project that you can be proud of. Most of the time we’re flying by the seat of our pants trying to get things done because we’re restricted by time and by budget.”

Project Manager, Case Study 4.

As a change modifier, value engineering can be an effective mechanism for keeping costs to a minimum whilst achieving equal or even enhanced performance. However, in practice it can occasionally involve a process of trimming the project of “non-essential” elements. Clearly, the perspective of the value engineer may heavily influence what can be considered to be “non-essential”, and for large projects this process is frequently undertaken by a team of project quantity surveyors, drawn from both the client’s and the contractor’s organisations. Unfortunately it is likely that the goals that support such strategic objectives as sustainability and resilience may appear to be the easiest to discard when budgets are under threat. This may be due to their limited immediate value, but perhaps more importantly, to the late stage of the project in which sustainable equipment, technology and finishes are often included.

It appears from the case studies that where there are overspends early on in a project, it is the activities downstream that are squeezed to avoid time or cost penalties. This is not surprising, as it is the early stages of a construction project that focus on the “hidden” but often very expensive processes that modify or adapt structural elements or environmental service systems. Two hospital estate managers from very different locations complained that advanced control systems for their buildings were casualties of the value engineering process, with the resulting impact on their plans for achieving their future energy reduction targets. In practice, where budgets are constrained, environmental systems that involve considerable cost but provide long term benefits, such as Combined Heat and Power (CHP) plant with absorption chillers to provide summer cooling, may be substituted by a traditional heating plant with much poorer lifetime value and greatly reduced sustainability credentials. Typically this will save on capital cost but the long term revenue cost may exceed the “short-term” savings to the project budget, and in addition, the environmental benefit of carbon reduction is lost.
7.5 Refurbishment Drivers

Perhaps the most common reason for refurbishing a building is the condition of the building and its suitability for purpose. Within the case study hospitals there were examples of a number of immediate refurbishment drivers, such as when the building fabric and finishes deteriorated due to age and wear in the Cardiac Unit of Case Study 1; or to accommodate the requirements of new technology (Case Study 1 neo-natal unit); to suit a new business opportunity (Consultant at Northamptonshire hospital); to extend or improve the organisational use of space (All Case Studies); to improve the energy profile (Case Study 4); to allow the introduction of new systems, new models of care, or processes (Case study 3); to reduce clinical risk (Case Study 1); to modify the internal environment (All case studies); and when a client or service users demand change (Case Study 1). In this section refurbishment drivers are discussed, using features of the case studies to illustrate points.

Picture 7.1 Case Study 1: South elevation

Many hospital buildings built in the latter half of the 20th century are struggling to provide suitable environmental conditions, or to support existing space standards for safe working, and many have reached the limits of expansion, owing to building or site constraints.
Case study 1 was carried out in a hospital that had previously been scheduled for replacement with a high-profile, state-of-the-art, new-build hospital. The planning process had been underway for a number of years before this major project was abandoned. This meant that only legally required maintenance, for example essential plant requirements such as regular lift maintenance etc.; severe water ingress issues; and essential hygiene maintenance, had been carried out on the already failing buildings for more than five years. Many of the hospitals service systems were aging and operating well beyond their design life and achieving regulatory compliance for aging equipment was considered an increasing risk.

Perhaps surprisingly, the most problematic buildings are not necessarily the oldest buildings and, for example, the “Pavilion” hospitals of the 19th Century (Nightingale Wards) appear to show considerable environmental resilience (Short et al, 2012). However, it can be challenging to provide the space flexibility required by modern care models in these buildings, owing to their relatively narrow footprints. This was particularly true of the Case Study 2 hospital where their traditional Nightingale ward configuration coped poorly with modern nursing practice. Bed-spaces were crowded by monitoring and drug-delivery equipment. Nurses had to squeeze into the tight gaps between curtain, chair, patient’s storage, IV drips and monitors to provide essential care. This situation was exacerbated by pressure on the hospital to respond to the intense demand for services, resulting both from the increasing numbers of elderly patients with complex care needs, and the rising demand within the general population. Previous attempts to reconfigure these wards had resulted in the loss of bed spaces. Hence, the essential aim of future refurbishment is to minimise the loss of beds while improving accessibility, infection control and hygiene compliance, as far as possible, with the HBN/HTM guidance.

In the Case Study 4 hospital, one ward housed in a 1970’s low-rise block had very limited storage and no place for the temporary stowing of bulky equipment such as wheelchairs, trolleys, incubators and monitors. Consequently, these items cluttered the hallways and any vacant space, which partially obstructed the access corridors and restricted the use of quiet rooms and communal areas. Patients, staff, food trolleys, and medical supplies had to navigate around obstacles and this posed an additional risk for
patients, which could be critical in the event of fire or other emergency. Such a situation is at best inefficient and either the model of care, or the existing use of space had to be reviewed. Either of these requirements would normally indicate a case for refurbishment.

Changes in public attitudes sometimes drive refurbishment. Pressure on General Practitioner (GP) Surgeries has resulted in many members of the public by-passing GP surgeries and going straight to hospital. Media attention in 2011, focused on the difficulties of patients in mixed gender wards (BBC, 19th May). The UK government responded with its policy on “Privacy and Dignity” which included interventions and targets with fines for non-compliance, along with limited additional funding. These measures were designed to encourage the provision of single sex wards and associated single-sex shower/WC provision. With Case Study 2, the Privacy and Dignity policy and targets dictated the strict time-scale for remedial refurbishment work. Similarly, DoH infection control targets precipitated the urgent need for decant space in two of the study hospitals, to allow wards to be emptied for deep-cleaning. Changes in demographics or disease patterns can also drive the need for refurbishment; hospitals must respond to changes in demand for particular specialities such as the recent rise in demand for bariatric beds and diabetes care, and the reduced need for infectious disease care, e.g., for Tuberculosis, Scarlet Fever or Polio etc.

The need for “connectivity” can also be a driver of refurbishment. For emergency patients and those needing urgent surgery, the risk of harmful outcome increases dramatically as their distance to necessary diagnostics/treatment increases. This means that for patients at risk, travel distances to and from surgery or imaging suites must be kept as short as possible. Also, such “at risk” patients must be accompanied by trained medical staff at all times, so where distances are great, wards can lose two or more trained nurses for half-hour periods regularly throughout the day.

Surgical wards clearly have a need for close proximity to theatres, recovery and imaging, but there are many specialities that can make a good case for improved connectivity. According to the Case Study 3 CEO, balancing such needs is always a complex process. He noted, “You need to have access to diagnostics and we don’t really want patients going outside ... particularly if it’s patients in beds.” Consequently, the areas with the
perceived highest clinical risk, tend to get priority locations near imaging or theatre suites. A specific example of poor connectivity was given by a senior manager from Case Study 3:

“at the moment, the maternity block and the main block are linked by underground corridor that has a single point of failure in one of our lifts and when that fails we have to pay for an ambulance to sit outside the maternity block to wait just in case there is a patient needs to be moved, which isn’t an especially great picture.”  Senior manager interviewed for Case Study 3.

Similarly, in Case study 4, one driver for the protracted cycle of refurbishment “enabling” work was to cluster the cancer facilities together and improve internal connectivity within the oncology services group (c.f. the beginning of Section 5.5.2).

Other drivers that were mentioned during discussions, or in the literature, included the need to attract high quality staff and this requires exceptional facilities, where competition for staff is high. On occasion, refurbishment may be driven by the need to attract new income streams, such as developing particular specialities (Case Study 1) or private patient capacity. Alternatively there may be a need to include clinical education or training accommodation.

In some cases, support services such as laboratories, or special facilities such as rehabilitation units and therapy pools need to be upgraded. Restaurants must also meet hygiene standards and require regular upgrades. Other “hotel” services such as laundry or security (surveillance systems etc.), admin and ICT systems also age and equipment or systems become obsolete.

Increasingly energy systems are being upgraded in many hospitals across the UK, as funding becomes available (University of Cambridge, 2015), and fossil fuel systems are being gradually replaced by more sustainable options, often leading to reduced energy costs and this creates a strong incentive to retrofit new systems and refurbish (Case Study 4). The changing climate will require hospitals to adapt their accommodation as internal temperature thresholds are challenged and patient risk increases. It appears most likely that this will be a pressing driver for refurbishment over the coming years.
7.6 Constraints and Conflicting Priorities

To understand why the refurbishment process may result in poorer than expected outcomes, it is necessary to examine the particular constraints that limit how refurbishment is carried out in NHS hospitals and the options for managing changes. In addition, it is also necessary to understand the barriers, either rigid (for example, legal, regulatory, technological or cultural), or flexible (e.g., financial or political, or process), that act to restrict progress or limit the available options for managing change. Conflicting priorities can act as a significant constraint, and may be the result of unwitting but differing perspectives of the stakeholders (as in Case Study 1, where the contractors attached low priority to interior design, compared to the users, who identified this as a core priority).

7.6.1 Refurbishment Constraints

Hospitals operate continuously, without respite, throughout the year and this has significant implications for NHS refurbishment:

1. Refurbishments are frequently carried out in occupied buildings. This means that all environmental, clinical and care systems must remain operational, at all times. Systems such as hot and cold water, heating, lighting, ventilation, medical gasses and vacuum systems, catering, laundry and support systems, imaging suites, laboratories, pharmacy and security, etc., must be provided continuously (Case Studies 1 and 4, see point 2 below).

2. An unplanned or unexpected service break can result in a life-threatening risk to seriously ill patients. Hence, if new connections are needed to existing services, such as water or electrical services etc., any breaks in supply must be carefully negotiated with all users, so that any possible problems can be mitigated. (This was particularly relevant in Case Studies 1 and 4, where connections to critical services, such cold water systems, had to be coordinated with all other building users and hence, system shut-down times had to be strictly adhered to).

3. Commonly, patients or staff that are occupying an area proposed for refurbishment will have to be decanted to alternative accommodation that
has been modified to suit their particular needs. Sometimes it is necessary to move more than one ward, because both horizontal and vertical access may be required and walls, floors or ceilings must be opened up to access service runs or structural details. (This was necessary for Case Study 4’s succession of moves that were required to regroup the oncology department.) Where equipment is in constant use, often without backup capability, such as ventilation equipment, scheduling breaks for refurbishment connections can be challenging.

4. Unanticipated interruptions of services pose a serious threat. During the refurbishment process it is not unusual to find surprises, such as live wires or pipes embedded in walls, under floors or in service ducts as happened in two of the case study hospital projects (Case studies 1 and 4). However, every attempt was made to keep such interruptions to a minimum and minimise their effects.

5. Planning or regulatory issues can delay projects while problems are negotiated or compliance is achieved. This was a concern for Case Study 2, where time was critical, however permissions were granted quickly and the schedule was not adversely affected.

6. Technological problems can also threaten a project with cost increases or delay. In Case Studies 1 and 3, problems arose that impacted the schedule. For Case Study 3, moving the imaging suite from the ground floor to the 1st floor, added the technical requirement for a vibration-free structure which considerably delayed the project and increased costs. With Case Study 1, plant room space was insufficient and plant had to be sited at some distance from the building, requiring considerable design and technical adjustments.

7. Cultural factors can affect projects, for example the need to meet gender specific targets added a significant incentive to planning the refurbishments required for the Case Study 2 hospital (Section 7.5).

Other constraints arise from the nature of construction work, which typically has a number of unwanted impacts that must be very carefully mitigated, so as to avoid injury to patients or staff. Potential unwanted impacts include noise, vibration, dust, excess
traffic, and access complications. Vibrations can upset delicate hospital equipment, particularly in In Vitro Fertilisation (IVF) and pathology labs, and it can close operating theatres. Noise can also be a serious problem for surgeons and for the seriously ill, for whom undisturbed rest is critical for recovery. In Case Study 1 special low-noise and low-vibration drills were compared and tested, to minimise disturbance. In addition, construction dust is a known hazard to health (Health and Safety Executive, 2013) and poses a particular threat to patients with breathing difficulties. It is also the case that dust dispersal has infection control implications which may involve the need to coordinate with the hospital’s Hygiene and Infection Services team.

Access for construction workers and construction traffic across the hospital site can be particularly problematic. Construction workers must have suitable access, but for security reasons, it is necessary to segregate them from patient occupied wards and corridors. For this reason separate access must be arranged. In the hospital in Case Study 1, a (temporary) dedicated external lift had to be provided to allow access to the site for construction workers and for building materials. Essentially, construction traffic must be well planned and monitored, so that it does not interfere with the ambulance transport or visitor access, or with the critical supply chain deliveries that are essential to hospital functioning.

Of course, the biggest constraint on refurbishment and maintenance is funding, which is the primary reason that many hospitals have a considerable backlog of maintenance [nationally assessed at in excess of £4 billion in 2012/13 (NHS Hospital Estates Statistics, 2013a)]. One interviewed estate manager reported repeated instances of water ingress through the building fabric in a high profile hospital cardiac ward, list

“the building was opened in 1964, anecdotally we’ve been told that it leaked ever since it opened…..It’s quite badly detailed….We get water…..through the window frames and making puddles on the floor. The building looks bad because it hasn’t been well maintained um it hasn’t been looked after. It’s suffered typical kind of NHS lack of investment……”

Estates Director at a London hospital.

He was particularly concerned that the care provided could be impacted by the poor performance of the building and that the reputation of the hospital could suffer.
“We’re probably recognised as being one of the best hospitals in the country but.... you can’t aspire to be one of the best in the world and have water on the floor around some very sick patients...... it’s just not acceptable to be keeping them in a building that, that performs so badly”

Estates Director at a London hospital.

7.6.2 Conflicting Priorities: the Neo-Natal interior Design Issue in Case Study 1

As the briefing process develops, it hones in more on exactly how these requirements are to be met and what precisely the participants (the client and the users) really need to do; and how the building must function to support their aspirations. However what the briefing process does not appear to do so effectively, is to identify the subtle differences that may exist between the participant’s roles and their consequent priorities. For example, the clients’ chief priorities will relate to a facility’s delivery date, project cost, running costs and efficient design, whereas the users may prioritise the interior design or appearance and functionality or “ease of use”. During the early design stages of the project, there may be greater opportunities to resolve any such differences, rather than later in the project, where options are very limited or zero.

Picture 7.2 Advanced Technology: Dräger Neo-natal Pendants
This was particularly the case in the Neo-natal unit, where different priorities of the client and users required considerable negotiation. In their research in paediatric units, Monti et al. (2012) showed that an appropriate environment can significantly reduce parental stress. The case study neo-natal project users (that is, the clinical and non-clinical staff; the babies’ parents or guardians, and visitors) aspired to a well-equipped and specially designed environment that they felt would best promote the health of the seriously ill babies and reduce stress for the parents (low noise materials, low level lighting, soft colours etc.), and would also provide suitably designed space for the bereaved. The nurses represented the needs of the babies as they felt they could best articulate their care needs. In addition, the nurses passed along the views of parents to the designers; the parents’ priorities were similar to those of the nurses, although they also requested parental accommodation along with a well-designed space for siblings to play.

The client (the NHS Trust) was supportive of these aspirations, but because of their role as managers of the entire estate, they also had other tacit concerns. The client’s slightly different perspective was focused towards the critical success of the neo-natal unit, but the client was conscious of the overarching governance responsibilities for preventing death or injury to neo-natal babies through technical, environmental or professional failures. So their focus might be considered to be more directed towards the clinical/technical care of the sick babies than towards the holistic healing process for all the family. Their broader priorities also included the continued functioning of the building, managing the needs of the other building users, and minimising interruptions to the operation of the hospital as a whole.

Added to this difference in perspectives between the client and the users, were the priorities of the other major player in the refurbishment process, the principal supply chain partner. His attention was concentrated on the smooth progress of the construction process, the safety of the building, compliance with normative guidance, regulatory systems and safety requirements, achieving targets and maintaining profit margins, along with developing a good relationship with the client. The differing priorities meant that where obstacles surfaced, there were different perspectives to be considered in achieving a successful outcome that was acceptable to all.
Links to examples of aspirational design

(1) ZGF Architects: Randall’s Children’s Hospital, Legacy Emanuel


(2) Designinc: Royal women’s Hospital Neonatal Unit


(3) redacted image: showing attractive neonatal unit interior with beach motif–

**Aspirations versus delivery**

(3) The staff and parents had aspired to a functional but also attractive Neo-natal design, perhaps similar to the units in Designinc: Royal women’s Hospital Neonatal Unit


(3) redacted image: showing attractive neonatal unit interior with beach motif–. However the interior that was delivered was strictly functional and was considerably short of “aspirational”. Clearly, for two of the three major players, the interior design was a relatively minor priority whereas, for the users, it was of major importance. The users (staff, parents and babies) were not knowledgeable regarding the constraints of structural systems or plant requirements and were not experienced in expressing their needs: they were focused totally towards the end-use and professional care requirements. They could not really understand why the considerable budget of £10m could not accommodate the relatively small requirement for interior design.
In this case, the decision making process for the interior design had been scheduled relatively early on in the project and the contractor had employed a consultant architect to determine the client’s and users’ needs and present an appropriate scheme. When presented with the final proposals, both the client and the users were very unhappy with them. This led to the contractor complaining of time issues and frustration with the users’ inability to make agreed decisions on décor and furnishings etc.

Unfortunately, the contract documentation failed to identify how the problem of the client’s dissatisfaction with the designer’s proposals should be resolved. Worse, the interior designer left employment shortly after the initial presentation. This left the contractor with a problem that they failed to tackle throughout the remainder of the project.

“we knew it was coming up but it was always sort of, a soft and woolly issue and we didn’t bottom out the interior design anywhere near quick enough and unfortunately we were caught by the interior design architect being laid off just after Christmas 2010, which didn’t help so we lost that speciality after a few weeks. That never regained, the architect had to take it back. So that was a problem that hit us and I should have managed that situation better but ...” Contractor’s Design Manager.
According to the project quantity surveyor, the interior design issue was “hard”. The users could not agree on the range of alternatives offered by the designer and were regularly late with decisions. Proffered colours schemes and room designs either received no decision or were repeatedly rejected. This made communication difficult and hence there was only limited contact between the designers and the user group. As a result the designer, who was at the time suffering from a chronic illness, was not able to offer further options or provide the design quality anticipated. The nurses complained that they had asked for soft nursery colours in the bays and cheerful colours in the family rooms. They were provided with colour schemes in variations of dark maroon and beige. The issue remained unresolved for months.

Eventually, as no progress was being made, in the final few weeks of the project the client took over responsibility for the interior design, and adopted a dictatorial style with the users. They were offered two choices from the hospital’s standard interior design options (essentially blue or green), neither very aspirational, with little in the way of feature lighting or décor and with no real connection with the purpose of the unit. Although the users were happy with the functionality of the new unit, they were plainly disappointed. The outcome was particularly frustrating for the users as they had previously been resigned to working under difficult conditions and were promised priority when the “state-of-the art” hospital was proposed. Even when this major project was scrapped, the users were promised a “cutting-edge” refurbishment that would be designed to their needs and with their requirements prioritised.

Generally, nurses have only a relatively limited opportunity to contribute to most projects and often it is only the senior nurse that is involved in design discussions. In practice, once the briefing process has been completed, any nursing contribution to the actual design is likely to be at a fairly late stage. If the briefing process is rushed or ineffective, contributions from staff at an early stage of the project might save considerable expense at a later date. As one might expect, nurses were also particularly focused on functionality and efficiency, and many of the interview comments returned to the problems of poor workplace design that affected work efficiency, in one form or another. On other projects nursing teams had been involved in user groups but, in the
Case Study 1 project, user group meetings tended to act largely as a means of cascading information downwards from the project manager rather than as a conduit for contributions to the design. Users groups were able to ask for small changes to room design, but these were generally only considered if there was a very clear functionality issue.

7.7 Climate Change Considerations

7.7.1 Revised Normative Guidance: Design Guidance, Regulatory Requirements

Climate change predictions suggest that the UK will have longer and more sustained heatwaves, more severe storms, more common electrical storms, increased wind speeds, and more frequent incidences of serious flooding. Many UK building design parameters, that were stable for a large part of the last century, have undergone considerable revision over the last two decades (see for example, Pretlove and Oreszczyn, 2006; BREEAM, 2010; Zhou, 2014). It seems likely that design parameters will have to change further, and this will have significant implications in, for example, the choice of construction materials and system loadings. Commonly specified materials may not withstand the increased temperatures predicted, and structural systems may not cope with increased wind-speed, rainfall or snow loads. It has been suggested that metal roofing and flashings (e.g., lead) may suffer excessive creep or oxidation as temperatures rise, reducing their effective life, and even reinforced concrete may deteriorate faster due a projected higher rate of carbonation, directly related to the increased levels of CO2 in the atmosphere (Steffens et al., 2002; Kumar and Imam, 2013). These and similar issues may affect the design life of existing and recently refurbished buildings.
7.7.2 Energy and Comfort Considerations

Energy management is a particularly important issue for NHS Trust estates managers and it is given a high priority in estate management budgets,\(^4\) due to the high cost of fossil fuels, the cost of carbon allowances under CRC Energy Efficiency Scheme, and the need to limit the potential for further climate change. However, the varied nature of individual hospital trust portfolios makes the task of choosing the most appropriate energy management strategies both complex and uncertain. Estates managers have also expressed some concern over the difficulty of selecting the most effective refurbishment options or retro-fit technology to mitigate the effects of climate change. Lack of advice regarding appropriate and effective solutions or exemplars was identified as a problem by managers in two of the four case studies.

A further issue is that, while most Trusts have examples of modern, state-of-the-art buildings, some are managed through PFI contracts and consequently are beyond NHS control. In general, these PFI hospitals have fairly strict internal temperature specifications, but as the climate warms, the NHS has no power to compel the PFI management to adopt sustainable air-cooling solutions.

Some of the measures designed to keep spaces cool in hot weather also protect against heat loss during cold periods, so that measures to improve the general thermal performance of buildings can help, to some extent, to future-proof the building stock. However, increasing the level of insulation may, in some cases, exacerbate existing overheating problems, particularly where there are significant levels of unshaded south-west facing glazing.

Also, by increasing the levels of thermal insulation, there may be less benefit from night cooling. However, as many hospitals are unable to utilize night cooling at all, due to their remarkably inflexible climate control systems, this may not be a significant consideration. The Case Study 3 estates manager pointed out that their heating system

\(^4\) Energy Efficiency Scheme is to be replaced after Oct 2019 with an increase in the Climate Change Levy.
controls cut in as soon as the temperature drops below 18°Celsius, regardless of high daytime temperatures, thus preventing any natural night cooling.

7.7.3 Hospital Adaptation to Climate Change

Given the size of the NHS retained estate, adapting hospitals to a changing climate will take time and will be expensive, but the consequences of climate change pose a serious risk to vulnerable patients. To mitigate this risk in an affordable way, the adaptation process to prepare hospital environments for warmer summers should start in earnest and be steadily implemented on an ongoing basis.

The need to adapt hospitals to mitigate climate change emerged in several ways during the work reported here and through the DeDeRHECC project. The preliminary study and case studies identified that nursing staff were already finding that particular wards had unacceptably hot working conditions and they also had complaints from patients regarding the excessive temperatures experienced during warm weather. The DeDeRHECC project monitored ward temperatures, linked these data to national temperature data and climate predictions, and developed statistical projections to simulate thermal conditions in representative English hospitals from 2030 – 2080. Their data clearly suggest that rising temperatures will cause significant thermal stress (Lomas and Giridharan, 2012). Without intervention, many wards and waiting areas will become progressively unusable in spring and summer periods.

For the case study hospitals, the requirements of the Climate Change Act (2008) and the Carbon Reduction Commitment (CRC) appear to be concentrating estates strategy towards installing and retro-fitting low carbon M&E systems. Two of the case study hospital trusts have invested heavily in new energy centres. They both have opted for similar energy solutions and expect to cut emissions by as much as 50% using a combination of biomass and CHP. Almost all of the estate managers interviewed were enthusiastically replacing their existing lighting (mostly fluorescent luminaires) throughout their estates with Passive Infrared (PIR) sensors and energy efficient Light Emitting Diode (LED) systems, or other similar systems as the opportunity arose.
However there is some debate as to whether this will result in the level of savings predicted. The replacement of incandescent lighting results in very considerable savings but recently fitted and well maintained fluorescent lighting may not offer as great a reduction in energy use.

![Image of corridor lighting](image)

**Picture 7.4** The introduction of energy efficient lighting systems at the BRI

However, there has been slow progress in developing solutions to the summer overheating concerns common to many hospitals, considering that this is an escalating problem. Two hospitals (Case studies 1 and 4) had installed what is considered to be an efficient CHP system designed to reduce the carbon footprint, but neither had sufficient funds to include absorption chillers. The latter readily available technology would have provided a more sustainable cooling option for critical spaces than the typical option of adding energy-hungry direct expansion units for the most severely affected wards (Kavvadias et al., 2010; Shahrestani et al., 2013).

This research has highlighted the way in which climate change mitigation measures can be eroded or disregarded even when included as desirable goals during the planning process. In Case Study 1, for example, sustainability was a key factor in the choice of flooring for the Neo-natal unit, as both the designers and the users were keen to opt for sustainable materials where there was a choice. Moreover, the value engineering team agreed that there were no additional cost implications and sustainable flooring was specified and ordered. However, at a late stage, the Infection Control and Hygiene
(IC&H) team objected to the flooring and insisted on the specification of a non-sustainable floor finish that was more suited to their cleaning processes. As the client’s priorities were apparently focused towards safety, and minimising disruption to routines, a non-sustainable flooring option was eventually adopted. In effect, rather than pushing for the IC&H team to alter their cleaning regime to suit the preferred sustainable flooring, the client opted for the pragmatic solution. This choice appeared to be contrary to the Trust’s sustainability policy. In practice, it seems that policies do not always result in desired outcomes.

From the interviews, hospital managers are very aware of the problems of global warming and climate change, and they aspire to be in a position to opt for sustainable solutions. Unfortunately, they are severely hindered in this objective by the need to meet targets and manage rising costs, rather than being focussed towards the future and the wider needs of the hospital.

7.8 Summary

Clearly, changes required during the course of refurbishment projects are a significant source of disruption for hospital buildings, for staff routines and ultimately for patient care. In particular, the need for access to hidden services and improved funding are critical constraints for both refurbishment and for ongoing maintenance. Consequently, refurbishments may not provide the level of value to the building that might be expected, as a result of the strict financial restrictions that limit the scope of each project, and of the necessary changes to projects that may result in weakening the final outcomes and reducing overall hospital resilience. An engineering resilience perspective, (Section 2.5.5) prioritised by management could help to ensure that systems function more effectively and that sustainable and climate related goals are retained. This prioritised approach should help to foster long-term prudence within NHS Estates staff, and attach real value to future benefits and promote appropriate adaptation as required.
Chapter 8 Mapping Project Changes

8.1 Introduction

The major cause of the failure to achieve refurbishment project goals stems from the need to make changes to the design, materials, or processes. Change has been identified as the most common cause of failure to achieve key targets, typically cost or speed of construction. It is clear that design or programme changes during refurbishment projects, present real concerns for project managers due to their potential to disrupt or delay projects. This delay may increase cost uncertainty and cause additional disruption to hospital facilities. These types of refurbishment changes are of particular interest here, as there may be significant benefit in teasing out the underlying mechanisms that operate, when unexpected or relatively insignificant changes develop into complex problems.

From the case studies, the lack of accurate information at critical stages frequently influenced the level and complexity of change, particularly crucial details relating to an existing building’s structure, condition, modification, or the location of services. The necessary changes, not surprisingly, tended to follow very different trajectories. Sun et al., (2006) noted concern about the *ad hoc* way changes are made. Their approach to managing change was to link common causes with effects. Alternatively, Eckert and colleagues’ engineering perspective (Eckert et al., 2004) linked individual changes in sequences or cascades of connected changes. Analysis of how these changes were managed helped to identify both the predictable and the less obvious consequences of change and the mechanisms that operated.

The Change Propagation Framework model (Figure 8.1) is a reiteration of that advanced in Chapter 6 and is used here, not specifically to analyse change progressions, but rather to determine whether patterns of change can be identified in the case study refurbishments. The neo-natal project (Case Study 1), the modular extension (Case Study 3) and the cancer ward refurbishment (Case Study 4) are looked at in detail here.
Specific changes are mapped against the Change Propagation Framework (CPF) and analysed in more detail to explore the patterns of change that develop from an initial change event. These are examined and compared with the change trajectories that have been reported within the product engineering domain (Eckert et al, 2004).

To outline the remainder of this chapter, Section 8.2 proposes the use of pathways to map changes and Section 8.3 considers whether it is possible to identify recurring patterns of change or change motifs. Section 8.4 introduces change loops, which may be used to represent some “difficult to manage” changes and the problems of rework and across-layer changes. Section 8.5 provides a summary of the key points.

### 8.2 Change Pathways

Separating out the project layers helps to identify the various agents that act during the various stages of a project. The client, designer and end-users identify the key requirements of the project through the briefing process. This process takes place early
in the project and generally sits within the “use” and “building” layers. Additional expertise can be obtained from the “finance” layer regarding cost, procurement strategy and contract form. The design and construction processes are focused within the “building” and “process” layers, and supported by the “supply” and “finance” layers. However, good communication and cooperation between all layers is essential to achieve the aims of any refurbishment project. As noted in Chapter 6, changes in any single layer can propagate along each layer, or escape the layer and cross to other layers of the project. (Projects can contain multiple layers depending on the complexity of the project, the players and processes involved and may include for example, stakeholder layers, regulatory bodies, phasing etc.)

Each layer develops strategies and expertise for working within their own area of activity. For example, contractors cooperate to shuffle work packages to suit operational requirements when the weather is unfavourable, or the need arises (for example, see Section 5.2.7). In effect, each of the layers has very separate sets of expertise, and when problems arise in one layer that has repercussions for another layer, this may lead to a breakdown of understanding. For example, the estates manager for case study 1 required essential changes to areas beyond the contract boundary. Administrators in the finance layer were unsupportive, as they did not understand the nature of the problem,
(see Section 9.2.2). Similarly, designers may understand the basics of estimating costs, but the complexities of pricing complex refurbishment/construction work or evaluating financing options is generally beyond their expertise and where necessary, quantity surveyors are employed to provide preliminary cost advice or full design cost planning (Chappell and Dunn, 2015). Contractors may misinterpret user priorities/preferences or the client’s governance requirements (Damian, 2007). Finance managers are acutely aware of funding streams, interest payments and penalties, and associated problems when deadlines are missed, although professionals in other layers may be unaware of such pressures.

When problems occur within a particular layer, there are various strategies that are commonly adopted to mitigate or solve the problems. Project managers are adept at manipulating schedules or managing reserves of resources. However, when problems propagate across layers, there may be few options for resolution, as these cross-layer problems may be beyond the usual experience, or working knowledge, of those operating within a particular layer, and cooperation with experts from other layers may be required in order to develop collaborative or innovative solutions. Problems that cross layer boundaries, in consequence, can be less tractable or malleable than those that occur within project layers, as there will often be little in the way of “slack” or reserve resources available for these generally unexpected “across-layer” problems, in comparison to the more commonly encountered “within layer” problems.

Each of the case studies showed examples of "within layer" problems (e.g., the schedule changes required by the presence of nesting wild birds, Section 5.10.7) and "across" layer propagation e.g., (the changes to the cold water system, in Sections 5.3.1 and 7.3). However the changes that crossed layer boundaries were, in general, more difficult to address. It was generally the case that additional funding or other resources limited the spread of the problem. This means that problems eventually become tractable, but budgets across other areas of the project become pressurised. On rare occasions this is not the case and, for example, the sourcing of essential components that have very long lead times can result in real problems for project managers, and that can result in considerable change propagation. In comparison, engineering change is very highly constrained and few options exist for containing change propagation.
8.2.1 Pathways within a Layer

A pathway denotes the usual route from one activity to a subsequent activity (or series of activities). A blocked pathway might occur when, for example, planning permission is refused for a particular stage of a project, or necessary financing is unavailable. Activities that cannot be started or completed are termed *blocked activities*. For example, a blocked activity might occur when a survey shows the presence of asbestos and, in consequence, an activity must stop or be postponed until the asbestos has been removed. Generally, if an activity is blocked, the subsequent pathway will also be blocked. Figure 8.3 illustrates situations with blocked activities and blocked pathways.

![Blocked activity and blocked pathway diagram](image)

Figure 8.3 A blocked activity and a blocked pathway

In the case studies, common problems within a project layer were often mitigated by well understood strategies or “work-arounds”. Typically these included either rescheduling a sequence of tasks, or the provision of additional resources. Koopman and Hoffman (2003) consider that adaptations or “work-arounds” can identify a poor fit
between technology, procedures and the actual conditions of work. In the
design/construction process, the mapping of pathways can help to identify such “work-
arounds”. For example, in the neo-natal project (Case Study 1), the need to avoid
disturbance to patients in adjoining wards meant that work was delayed while the
contractor determined which type of drills produced the lowest or acceptable levels of
noise. This also meant that drilling work was limited to specific times and other work
was scheduled to compensate for lost time. Additionally, although the Estates team
were aware that asbestos was present, the extent of the problem was greatly
underestimated. In Figure 8.4 activity B represents the stripping out of the ward. This
activity was delayed while the additional asbestos was removed (activity C) and the
normal sequence resumed at activity D.

![Figure 8.4 Delay for asbestos removal](image)

A very similar pattern was observed in the cancer ward case study (Case Study 4),
where again pre-construction survey information was limited. The change pattern due
to the presence of asbestos was very similar to the change patterns identified in the
Neo-natal study, so they can be represented in the same way as in Figure 8.4, with the
same interpretation of the activity nodes. More generally, where change patterns are
repeated it is possible to identify "motifs" of change (see Section 8.3).

### 8.2.2 Pathways across Layers

Changes to the Modular Extension project (Case Study 4) involved supporting a 700
tonne crane (Figure 8.5) that had to be sited only 2m away from the top of a newly
erected 4.5m high retaining wall. During the installation, the crane was moved upwards
along a steeply sloping access road that was supported by the retaining wall (see Figure 8.6).

Figure 8.5 700 tonne crane used in the modular extension project

Figure 8.6 Shows crane support for the modular unit installation.
Providing adequate support for the crane caused problems and these are shown diagrammatically in Figure 8.7. The red circle in the photograph shows the 4.5m retaining wall (behind the steel frame) and the problematic foundation. This foundation was necessary to provide additional support for the crane and its loads, and was positioned under the white concrete surface at the top of the wall. At a very late stage the groundworks sub-contractor acknowledged that their designers were inexperienced, causing a blocked pathway (B→D) and failure to design an adequate supporting foundation (D) for the additional crane loads.

![Diagram](image)

**Figure 8.7 Crane support design failure: changes across layer boundaries**

The additional support needed to complete the design activity D came from experienced professionals currently employed in construction activities on the process layer (F→G). This change diverted key team members from planned tasks on the process layer and delayed downstream activities. Consequently, the process of constructing the crane support (H) was delayed and the placing of the modules (J) was also delayed.
8.2.3 Global Change: Change propagating across all layers of the project

The effects of the American financial crisis, which initially surfaced in 2007/08, were also felt in Europe and the UK, and eventually impacted on the NHS. Budgets were squeezed and managers were asked to find savings. Although the Case Study 1 (neo-natal unit) business case had been approved in 2009, the ongoing national financial crisis meant that the scope of the project had to be reassessed. Managers deemed that the clinical services provided by the neo-natal unit could not be compromised. However it was considered that the accommodation designed for the neo-natal babies’ parents and the associated communal areas could be cut back. Consequently Level 2 work was prioritised and only the essential clinical support spaces (laboratories and laundry) on level 5 were retained within the project scope, so that the project could keep within schedule, within the reduced budget. Hence the refurbishment of both floors of the unit would not be possible due to lack of finance and the remaining section of the work would have to be completed post-project. The consequences are mapped in Figure 8.8.

![Figure 8.8 Global change: Project re-scoping in Case Study 1.](image)
Pathway activity (a) represents the refurbishment of both floors, which could not advance. The project was re-scoped to concentrate on the refurbishment of the lower floor and the change to (b), originating in the Finance layer, propagated to all other project layers. The funding crisis affected the project globally, requiring the reorganization of the design process; and the project programming and work flow; and the contractual arrangements. Hence, it affected activities in the supply chain layer (c), the process layer (d), the building layer (d), and ultimately impacted the user’s operational processes and aspirations (f).

8.2.4 Mapping Groups of Changes

Griffin et al., (2009) analysed 41,500 changes that were made during an eight year system engineering project in the USA. They used graph theory to analyse the data set and the changes identified, and their connectivities were mapped using a Design Structure Matrix (DSM). Changes were identified as “parent”, “child” or “sibling” changes and networks of changes were analysed for change patterns. This type of analysis allowed probabilities to be derived for the complex change propagations that they encountered. Individual networks resulting from a single change or group of changes sometimes involved 2,500 further documented changes, although most of the networks that they identified involved less than ten changes. Figure 8.9 shows a simple change network from Giffin et al. (2009) that identifies 11 connected change requests.
In the projects encountered during research for this thesis, change propagation tended to be limited to comparatively short chains, typically involving between 2 and 10 follow-on changes. The focus for this thesis has been to look at change mechanisms and to identify a simplified means of representing the change sequences within and across the project areas (or layers), to enable estates professionals to map change patterns easily, across their completed projects, to improve future project planning.

8.3 Identifying Change Patterns/Change Motifs

“Mechanisms are ‘nothing other than the ways of acting of things’. A causal explanation is one that identifies entities and the mechanisms that connect them and combine to cause events to occur.”


As the project changes in the case studies were mapped against the Change Propagation Framework model developed in Chapter 6, (Figure 8.1), various patterns of change (at different scales) became evident. The cascading changes from an initial (originating) change were represented as a linear or branched sequence of changes, and aligned with...
the corresponding layer or layers of the framework grid. A number of recurring “motifs” were observed and, as both Eckert et al., (2004) and Giffin et al., (2009) found, different initial changes showed similar patterns of development.

Figure 8.10 shows two commonly occurring motifs. They arise when a pathway contains a blocked activity. Both motifs illustrate a “work-around” adopted to solve the problem termed a “by-pass curve”. To enable a return to the desired pathway, the by-pass curve can require an additional activity (or a number of activities), as in the top motif in Figure 8.10 when it is termed an *activity mediated by-pass curve*. Alternatively it can merely require an alternative route for the existing activity, as in the lower motif in Figure 8.10, when it is termed a *pathway mediated by-pass curve*. As examples, if an activity cannot progress because resources are limited, the options might include either channelling funds from another activity (pathway remedy) or developing an alternative solution (activity remedy).

(i) “By-pass curve” - activity mediated

(ii) “By-pass curve” - pathway mediated

Figure 8.10 Activity mediated and pathway mediated by-pass curves

The following are examples of by-pass curves from the case studies
(i) In Case Study 1 an M&E problem arose because there was insufficient space for the new engineering plant. The M&E heating design came to a halt until an off-site location could be found for the new boilers. Once a new site had been located and agreed, the design process recommenced and designs were revised to include long-distance connections. The propagation from this change did not expand beyond the building layer as all necessary work could be undertaken using existing layer resources: nor did the ensuing changes develop into a change “blossom”. The M&E changes, with their mitigation activities, corresponded to an activity mediated by-pass curve.

(ii) The pathway mediated by-pass change motif describes the changes required by new infection control guidance issued at a very late stage of the Case Study 4 neo-natal extension project. A series of *Pseudomonas aeruginosa* outbreaks in Northern Ireland’s neo-natal units were ultimately traced to the water supply. This bacterial infection, with similar but not identical growth requirements to *Legionella* spp. could be prevented by the use of specialised taps. The existing tap specification was unsuitable and it was thought that new taps would have to be purpose-designed. To avoid delaying hand-over, the taps would have to be installed post-completion. However, the project manager located suitable alternative taps without the requirement for specialist design. The new taps, although relatively simple to install, were problematic due to the late stage of the project and the very large number required. However, the problem did not propagate to other layers of the project as the costs were similar and the contractor absorbed the additional labour cost.
Project changes can be represented in a linear sequence or they may be shown as branching laterally as in Figure 8.11, where the *fork motif* shows a “branching” change in a single plane or project layer.

The motif in Figure 8.11 maps the changes in Case Study 1 that were required when the water supply system to the Neo-natal unit was found to be in extremely poor condition (B) and required both replacement and additional asbestos removal. The cast-iron water main showed severe deterioration and new connections could not be made (D), and the remainder of the existing pipework required replacement. Hence an additional asbestos survey was required (J) and asbestos had to be removed (K). The water supply system (F) and (L) could not be replaced until the asbestos work was complete. This work meant that other scheduled M&E work (G) and (H) were also delayed.

The resultant changes were costly and time consuming and affected all the central areas of the building and propagated to most of the other layers of the project. The severity of the propagation was due, in part, to the late stage of the project at which the problem was identified. This was after the agreed Guaranteed Maximum Price had been established and well into the construction phase. Had the problem emerged prior to the
agreement of the GMP, a large proportion of the cost could have been included within the contract. A further obstacle involved obtaining access to all the necessary floors and voids of the building to replace the old pipework without exposing patients and staff to excessive dust and noise. This was an example of “scope creep”, as change was not contained by the project boundary and propagated to other areas of the building. The problems were only resolved by a combination of securing additional finance, rearranging schedules, and slightly reducing the clinical floor space. The changes meant that the nurse’s lounge and an adjacent WC were very tightly squeezed and barely met requirements (an unpopular outcome).

Figure 8.12 is a simplified representation of the activities resulting from the problem with the mains water supply, as the solution to that problem corresponded to more than one branching chain. However, each chain existed within a single project layer (or plane) and changes propagated orthogonally across layers. Figure 8.12 shows the orthogonal propagation of changes across two project layers.

![Figure 8.12 Orthogonally branched change "surges" typical of across-layer changes (here shown affecting two project layers).](image)
The above change motif, termed a change “surge”, shows how a single necessary requirement can become a multiplier of change. Mapping this change process and the identification of a pattern (or motif) makes it easier to determine the location of similar change multipliers within a project. Surges of change appear to be particularly problematic at late stages of a project, where emergent complications such as sub-contractor failure or unavailability of specialised components result in complex rescheduling or late redesign work in an attempt to provide timely solutions.

Other examples of this type of “surge” of change propagation included the problems associated with the Case Study 2 modular extension, when the design was changed to abandon the third floor of the extension, along with the ground-floor foundation and slab. The changes propagated from the building layer of the project to the finance and user layers and required considerable redesign work, although the changes had a beneficial effect on the overall project cost.

The change surge in Figure 8.12 differs from the “ripple” or “blossom” of change seen in engineering changes, where the “ripple” of change eventually settles down and is resolved. This is not always the case in refurbishment, where surges that spread across a number of project layers may leave unresolved elements that can create further propagation or may just be left as “hanging threads”. This might be due to as yet unknown parameters, or to the long lead time required for revised components, or may result from the perceived difficulty of a particular change. With the interior design problem in Case Study 1, the contractor suggested that the failure to progress was at least partly due to a reluctance of the users to engage as a group, because they could not agree or make decisions collectively and meetings were unproductive. Whatever the case, a surge of change may be almost overwhelming at the initial stage and some necessary changes can get overlooked. These overlooked items may be relatively minor and resolved during the snagging process that takes place in the handover period. However some “hanging threads” can be critical, and result in failure to meet targets or a litigation.
8.4 Change Loops

One type of motif that recurred in slightly different configurations essentially resulted from “loops” of change. These occur where scheduled activities are interrupted and a sequence of non-scheduled activities has to be completed in order to return to the original sequence of events. This may be due to an emergent problem where work cannot continue until a solution is found and the unscheduled remedial activities are completed. It is also typical of situations where rework is required, perhaps due to poor workmanship, for example. In practice, almost any enabling work that does not actually form part of a project can also be described by a loop motif, particularly where programmed work is suspended until the enabling work is complete. It also depicts work that must be done off-site, outside of the project schedule.

Identifying these motifs may be particularly helpful in identifying where “waste” activities occur (where “lean” methodologies are practiced) or in achieving a more detailed picture of non-programmed (over budget) costs.

8.4.1 Change Loop within One Layer

The changes shown in Figure 8.13 describe the situation in Case Study 1 where rework involving the re-laying of flooring material and had to be completed before the suspended programme activities could continue. In this case, the changes were required as the flooring specification did not meet infection control requirements. The oversight resulted from the difficulty of scheduling meetings with the infection control team leaders and the design team as the shifts of both groups rarely overlapped. In this case study, members of one team missed a key meeting (a common occurrence). The contractor, whose responsibility included the specification of the correct materials, absorbed the costs and the changes were managed within the process layer and did not escape to other layers. Consequently the change loop is mapped in the same plane as the original activities.
8.4.2 Across Layer changes in the Case Studies

Various change sequences that move across layers can be described by loop motifs. The mapped examples in Figure 8.14 show four different types of loop. These will be described in turn and instances given of where they arose in the case studies.

Figure 8.13 Remedial loop: This illustrates work within a project layer or plain
Independent Loop

An independent loop Figure 8.14 (i), represents a sequence of changes in which changes to one or more layers of a project result from events that originated beyond the project boundary. This differs from other loops in that interrupted project activity cannot proceed until the cause of the delay is removed. The interrupted activity is then able to continue. This type of change could, for example, result from ongoing work connected with major hospital infrastructure replacement and affect various layers of the project by changing infrastructure locations, blocking access roads or diverting labour resources (where the same contractor is involved in both projects). An example of an “independent loop” motif occurred when Case Study 1 was re-scoped due to external financial pressures and interrupted activities that had been delayed to await permissions to progress.
Rework Loop

A rework loop Figure 8.14 (ii), occurs if the interrupted rework activity is essential for the sequence of activities to progress. However, the activity that is interrupted is replaced by the reworked activity and the schedule resumes as before. The rework activity may be a repeat of the original activity but with improved attention to design or installation, or perhaps a somewhat different activity or component is required before the programmed sequence of activities can continue. Hence, the rework process usually requires additional resources from another project layer. Consequently the rework loop is orthogonal to the scheduled activities within the project layer. This type of change occurred in Case Study 3 where the frame for the modules had to be redesigned to suit client requirements. Other connected work was suspended until the new frame and affected modules could be redesigned.

An example of the rework loop is the frame re-work required for Case Study 3. The project could not progress until a new framing solution for the modules could be developed to support the imaging equipment, as described in Section 5.4.2. The emerging needs of the client led to the requirement for changes to one aspect of the build, specifically, a vibration-free concrete frame and flooring system for the imaging modules. The diagnostic imaging unit had been originally destined to be installed on the ground floor supported on specially designed foundations. However, the briefing process failed to fully capture how the revised care model would work in newly designed space. The client’s emerging understanding of how the new unit would function affected the design process. The clinicians began to realise that risks to patients would increase if they were too distant from the imaging unit. Consequently, it would have to be centrally located between the two clinical floors. There was no design flexibility to relocate the imaging unit modules within the existing frame as it could not provide a vibration-free platform. Accordingly, a new vibration-free framing system had to be devised and constructed to support the first floor imaging unit. This had to be fully designed along with details of how the modules would connect to the remainder of the structure before the rest of the project could go ahead. The resultant system comprised a section of concrete frame which interlocked with specially designed concrete floored modules.
Enabling Loop

An enabling loop Figure 8.14 (iii), maps the changes that are required in a sequence of activities when the activities must be completed to allow other processes to progress. This change loop is typical at the start of construction where “enabling works” tend to be most common; they are activities that are needed for a project but do not form part of the works, such as the installing of site huts or the clearing of a construction site. Once the enabling work has been completed, subsequent activities within the programmed sequence of activities can continue. An example of an enabling loop occurred in Case Study 3 where the height of the nurse’s access tunnel had to be changed to allow the diversion of the main electricity cable (see Section 5.3.4 for a more detailed description).

Cascade Loop

A cascade loop Figure 8.14 (iv), maps a number of unscheduled related or non-project processes that are required to allow the scheduled project work to continue. This might involve additional changes within other project layers, or even changes to non-project areas, such as connected hospital departments or systems, and may require a cascade of changes.

An example of the cascade loop motif included Case Study 4 and the enabling series of moves required to progress the work for the Teenage Cancer Trust Project (see Section 5.5.2). The objective of the project was to provide a refurbished teenage cancer ward and the refurbishment of the work was being financed by a charity. However the Trust needed to group its cancer services together and needed to delay the refurbishment until a ward could be secured within the oncology cluster on Level 9. The process of making space available adjacent to the oncology cluster could be considered to be enabling work; in effect, very similar to the site clearing process for a new-build project. The high dependency transplant patients presently on Level 9, had to be transferred to Level 5. However, this could not occur until Level 5 had been refurbished. The patients occupying level 5 had to be relocated elsewhere in the hospital (which involved additional work beyond the scope of the research study). Following this transfer, Level 5 was refurbished. The orthopaedic patients on Level 8 were then temporarily transferred
to Level 4, (to allow essential survey and services work to level 9 to be done). However, to accommodate the transfer of these orthopaedic patients to Level 4, the vertical terminal air conditioning system on Level 4 had to be completely refigured, as a result of the installation of the additional showers needed for Level 8 patients. The patient transfers had to be orchestrated with care, and additional funding streams established, hence the extended time-scale for the project.

8.5 Summary

It is clear that changes made in refurbishment projects share some similarities with the production of engineered products, but there are considerable differences in the way changes propagate. In refurbishment projects most changes that propagate tend to result in relatively short cascades, usually within their own layer. Across layer changes can be more difficult and the trajectory of the change path can be more complex, diverging into different branches and producing a “surge” of change, similar to a “blossom” of change seen in engineering projects (Eckert et al., 2004). However unlike its engineering parallel, refurbishment surges of change may not be fully resolved, resulting in hanging tasks or threads that require post-project remediation. The most common change motifs or change trajectories were examined to see if they could shed light on the mechanisms of refurbishment change. Change loops appear to be more common than originally expected and further research would be helpful to understand how they affect the normal progression of projects and their consequent impact.

Other change trajectories that were identified included by-pass curves, and surge arrays. These appear to be the most common change trajectories, and their frequency of occurrence is probably under-estimated. Many examples were reported by professionals who explained that small problems are usually dealt with without recourse to change orders, but are negotiated “on site.” Only the more significant changes appear to go through the formal procedures.
Chapter 9 Missing Systems Thinking: Implications for Resilience

“A common mistake that people make when trying to design something completely foolproof is to underestimate the ingenuity of complete fools.” Douglas Adams from “Mostly Harmless” (1993), Pan Books, London.

9.1 Introduction: A Systems approach

Systems are made of parts and for the system to work, the parts of the system must interact. This is essential, as it is only the interactions that produce the system outputs. Each part of the system is designed to produce or enhance these interactions. Clearly, without fully understanding the nature and range of these interactions, changing or enhancing parts of a system is unlikely to improve the system. Indeed in complex systems, such changes can result in unexpected or serious consequences, which can then propagate across the system (as seen in Chapters 6, 7 & 8).

Over time, most systems require review, upgrade or refurbishment in order to replace obsolete procedures or technology and enhance their reliability and resilience. Building refurbishments provide this opportunity. However, NHS partial refurbishments are rarely planned with consideration for the building in which the refurbished ward or department must function, and system defects frequently go unattended. A systems perspective towards refurbishment could provide a more sustainable approach to building management.
System Resilience

Resilience is a fuzzy concept that is difficult to pin down, particularly in a building system context. Estate managers like something they can measure, regulate or monitor, or a plan that they can itemise for action. However system resilience is not easily measureable, and nor is it possible to determine whether, or when, it is achieved. As yet, there is no definitive view on what resilience should specifically entail for many hospital systems. Parts or layers of a system might be resilient, but if a single key system has insufficient backup or resources, for example, then there is a risk to the system as a whole. Ordinarily, resilience might be expected to emerge, as resilience-enhancing measures become systemically integrated throughout an organisation. Nonetheless, an organisation cannot guarantee that all of its weak links have been eliminated and that its resilience is fully and permanently embedded in its procedures, its monitoring, or its learning and training systems, i.e., that resilience is actually “there” within the system, somewhat like the fabled “emperor’s new clothes”.

Hollnagel et al., (2011) suggest that resilience, like safety, is not a system property i.e., it is not something a system “has”, but it is what a system “does”. He contends that developing resilience within an organisation is more than just providing resources to deal with recurrent issues, like anticipated local flooding or other likely threats: it is about maintaining functionality for the long term and this requires significant investment, both of resources and training (Hollnagel et al., 2011). High Reliability Organisations on the other hand, function reliably for long periods by managing variability, constant horizon scanning for threats, and by maintaining a sensitive watch on operations (Section 2.4.2. Aspects of both of these perspectives may be helpful to estates managers in improving system resilience for their estates.

Hospitals must be resilient in the face of multiple, known and unknown threats, such as the changing patterns of disease, the aging population and microbial resistance. The threat of climate change will, in some areas, require considerable adaptation. As refurbishments are usually ongoing in hospitals (at one or more locations, at any time),
this almost continuous process could provide a crucial opportunity to improve resilience by including climate adaptations across NHS hospitals.

At present, refurbishment project drivers include: the level of clinical risk for a particular activity; improving operational efficiency (restructuring/centralising and creating essential/ key connectivities/adjacencies); the availability of funding; avoidance of penalties (e.g., missed targets); regulatory compliance; severely deteriorating fabric or services; energy sustainability.

**The NHS as a system**

The NHS can be considered as a multi-level or multi-layer system (Figure 9.1) and ill-considered changes to parts of the system can propagate widely, and may be difficult to resolve (as described in Chapters 6, 7 & 8). This study demonstrates that in many cases, propagating changes can result from a lack of systems thinking, particularly where changes to systems escape their organisational layer and cross system boundaries.

![Figure 9.1 The NHS: A multi-layer system](image)

**Structure of the chapter**

Essentially, this chapter considers how system thinking can be missing at various levels of an organisation and makes clear why this can result in problems for individual system
layers and for the system as a whole. These system issues then become barriers to resilience over the long term.

Section 9.2 identifies missing systems at all levels in the NHS organisation and uses a multi-layer approach to considering key issues. System thinking is assessed on the user (Section 9.2.1), project (Section 9.2.2), building (Section 9.2.3), NHS Trust (Section 9.2.4) and NHS Estate layers (Section 9.2.5). Section 9.3 identifies some possible mechanisms of resilience in refurbishment applications and discusses how “work-arounds” can help to ease system pressures. Section 9.4 looks at risk and the implications of refurbishment for NHS resilience. Section 9.4.1 considers the NHS’s key internal resilience risks using the layer framework, Section 9.4.2 briefly considers how hospitals manage their external risks, and Section 9.4.3 examines NHS Trust’s strategic approach to connectivity. Section 9.5 explains how planned refurbishment can improve building resilience and suggests how “resilience opportunities” funding could support building refurbishment through encouraging cost sharing between projects and maintenance. Section 9.6 concludes by reprising how scope “creep” along with building refurbishment planning, can be considered as a “resilience opportunity.”

9.2 Missing System Thinking

9.2.1 Missing system thinking: user layer

The layer diagram above (Figure 9.1) helps to identify related issues that affect particular NHS estates layers. Each of the layers has system issues that relate to refurbishment. Issues that escape layers and cross system boundaries may have resilience implications for the wider system.

Clients rarely have the expertise to visualise how spaces will work three dimensionally and how connectivity between different areas may be compromised by particular aspects of the design. This is particularly the case when the new model of care has not been fully developed at the briefing stage and the users’ understanding of the model grows as the design evolves. Clients and users usually need additional time at or before the briefing stage of a project to develop a better understanding of how the refurbished space should work. This can be difficult, as clinical staff may be working “flat-out” or
“firefighting” emergency issues on a regular basis, with little time to devote to future planning.

Where time is short, the design process may be iterative and user understanding evolves alongside the design process. In such cases, changes to the project are almost inevitable since users are likely to identify oversights or discover better ways of working, requiring changes. Similarly, in some cases stakeholders are not included early enough in the briefing process, or are not included at all. This again may well lead to changes to a project.

9.2.2 Missing system thinking: the project layer

As noted above, there is often insufficient time for a thorough briefing process to elicit all of the client’s and users’ requirements. As a result, there can be a continuous stream of requests from clients or users for minor changes to a project. As these changes accumulate, significantly increased costs or delay to project schedules can result. These continuous changes may cause an expansion of the project boundary, often termed project (or scope) creep. In fixed price (GMP) contracts, project managers tend to respond to requests for changes by asserting that budget or time constrains will not allow additional work, often without considering whether the suggested changes might provide improved functionality benefits for the client over the long term. Indeed, they have a disincentive to explore such considerations, as they are highly focused towards the final project cost, as are some Trust Boards.

However, where scope changes can directly improve the functionality or flexibility of the space or the functioning of the building, there should be a responsibility to seriously consider the benefits. Improvements in space design that aid functionality can result in reducing the need for additional staff, which can have very long term financial advantages, and may offset the increase in project cost. In addition, refurbishment represents a rare opportunity to gain access to building systems or structural details. The increased cost to a project may be far outweighed by the high cost of failure and urgent repairs that can result from aging systems.
Scope Issues

Project requirements must usually be defined early on in the process so as to establish the budget. These help determine the scope of the project and, once the budget is fixed, all participants are incentivised to stay under budget, which discourages scope creep. However, scope creep is common because new requirements can arise from both emergent and initiated changes. The following are prime examples.

- Discovery of numerous small problems with existing building (Section 5.2.8)
- External influences (changing legislation/regulations etc.)
- New or revised ways of working (“models of care”) may not be fully developed at the refurbishment planning stage (Case Studies 1 and 3).
- Value engineering process may encourage/drive additional savings to accommodate the new requirements or save money for the client (discussed in Section 9.4.1)
- Value engineering may remove features that are seen as value added or important to the user but are not considered important by the client, hence uncovering/highlighting discrepancies between the objectives of the user and those of the client. (Section 7.4)

One example of scope creep in Case Study 1 concerned the lighting circuit in a room not included within the project scope. The project manager described how he needed to change the circuit because it could not support additional loads from the refurbished space:

“this room we’re working with, the power circuits for the lighting and heating were being fed from next door. And we’re not doing any work in them rooms, but the reality is that we have to change the lighting circuit... the project directors just want to see the bottom line, and rightly so, but they don’t
particularly want to hear…. they call it project creep, we just call it common sense.”

Project Manager, Case Study 1.

The following influence diagram (Figure 9.2) illustrates the problem and shows the interactions between the two rooms. When project directors focused on the room to be refurbished, they failed to see the essential connectivities and missed an opportunity to improve the resilience of the building and of the refurbishment.

![Influence diagram: adjacent rooms with connected electrical subsystems](image)

Figure 9.2 Influence diagram: adjacent rooms with connected electrical subsystems

Consequences of scope creep can be substantial. In Case Study 3, the briefing process aimed at eliciting requirements for the project was deficient, in that it failed to match the new care model with the new unit design. This failure would impact the future unit’s functionality and affected all the organisational layers. The clinicians had not fully understood the significance of providing the diagnostic equipment on the ground floor. The briefing process should assist users to think through the detailed care model and how it should work. At a very late stage, they realised that the connectivity problem was unsurmountable with the existing design and that an innovative approach was necessary. Fortunately, the Trust took the view that the functionality of the Unit was a priority and agreed to fund the additional costs of reworking the design.
Project Planning Issues

The planning process can be very costly and a project may be rejected/terminated, so front-loading the briefing process to better extract/disentangle the requirements involves high risk. However, a rushed briefing process and/or hasty decisions can have unfortunate consequences. These include the following issues that arise from missing systems thinking.

- Connectivities can be missed.
- With minor projects and refurbishments, piecemeal refurbishment can lead to a building strategy that fails to coordinate refurbishments within or between buildings and consequently fails to benefit from efficiencies and benefits of scale. For example, in Figure 9.3, building 1 may have a partial refurbishment in 2010 for £10 m and Building 3 in 2015 for £20 m, while if they had both been refurbished in 2011 it would have cost £14 m.

![Diagram of building connections](image)

**Figure 9.3 Piecemeal refurbishment: missed synergies**

- Synergies can be missed that could benefit both the project and the building (fabric, structure, operation or services etc.), particularly if the design or construction processes were planned in such a way as to encourage dual objectives. Figure 9.4 illustrates synergies (interactions) between a building and
a series of partial refurbishments. Over time the building systems/components can be upgraded through planned refurbishment and enhanced resilience.

Figure 9.4 Missed synergies between partial refurbishment projects

9.2.3 Missing system thinking: the Hospital Building layer

Most partial refurbishments appear to be uncoordinated or “piecemeal” refurbishments. That is, they tend to be isolated, one-off building changes, rather than part of a coordinated refurbishment planning process for the building. This is the most obvious feature of missing system thinking at the hospital building layer.

This lack of system thinking has resulted in examples of “run-down” hospital buildings on each of the case study sites. It seemed that for many buildings, it was only as their systems approached or reached failure point, that significant building system problems were considered for repair/replacement. To a large extent this may be the result of the absence of planned maintenance programmes.

A hospital’s sub-systems operate over a range of scales. Hospital buildings may function for in excess of 200 years. However, the various components of the system have much shorter life-spans. Water systems, depending on specification, should function for 30-40 years; while wired systems will need to be renewed within 20 - 30 years; and components such as windows have a design life of 15 to 20 years. For ICT systems, it
may be only 3 to 7 years before replacement is necessary. In addition, unexpected developments may require additional changes to systems, such as those brought about by disruptive technology or new legislation. Examples of such unexpected developments include the recent advances in wireless technology; and legislation that required significant improvements to water systems, essential for *pseudomonas* remediation in neo-natal units.

Managing these aspects of scale has traditionally been the responsibility of maintenance. However, it is very difficult to introduce planned maintenance into a facility that must remain constantly operational, as the downtime needed for regular repairs can result in significant care issues. Many hospitals have “reactive” (or “corrective”) maintenance programmes that respond when systems are at, or very near, failure point. However, there is a level of uncertainty attached to this approach, and failures can result in the need for urgent and often expensive “emergency” maintenance for key systems (Pantzartzis et al., 2016). For this reason, refurbishment projects represent a vital opportunity to replace or improve building systems, components and details. Coordinated refurbishments can be planned to replace entire systems over time. Synergies between maintenance and refurbishment operations could provide opportunities for sharing resources, such as scaffolding, equipment etc., and afford considerable cost savings.

However, project budgets and schedules are firmly managed and, for the case study Trusts, work over and above that which was strictly necessary was generally discouraged. Hence improving the resilience of the building is rarely a consideration and minimising project costs is frequently prioritised.

For example, in Case Study 1 it was not possible to connect to the existing water supply systems due to advanced corrosion so repair work to the existing system was included in the project. However, window replacement was restricted to the refurbished floor only, even though all the windows required replacement and scaffolding was in place.

“…..it’s a fully occupied building, there’s asbestos there, we don’t know what the services are like, forty years old, if we touch this pipe here it could burst over there.”  

*Project Manager, Case Study 1.*
The following are potential problems with piecemeal refurbishment:

- reduces flexibility: open flexible spaces are gradually enclosed (Section 9.5.1);
- increases building environmental system complexity (Sections 6.3.2, 9.5.2);
- may result in poor system integration, or the inequitable distribution of resources (Section 5.2.6);
- can impede connectivity, disrupt natural ventilation etc. (Section 9.5.1);
- can result in missed opportunity to reduce costs (Section 9.5.2);
- complicates wayfinding (Section 2.8.4);
- repeated uncoordinated refurbishments and maintenance operations can damage existing systems (e.g., fire protection Section 1.1);
- areas that have been newly refurbished provide stark contrast with neglected areas, leading to staff frustration and dissatisfaction (See discussion in Section 10.2.4);
- hospitals are, to a considerable extent, judged by their appearance and cleanliness (Whitehead et al, 2007). Scuffed paintwork and stained, pitted surfaces are more difficult to clean, resulting in hygiene issues, and may impact patient confidence in the quality of care (Section 7.6.1).

9.2.4 Missing system thinking: Trust Board layer

Project Approval and Risk in the NHS

Trust Boards generally encompass significant financial expertise within their membership, but construction knowledge and experience is often lacking. Trust Boards may not be aware of the risks from the range of predictable or surprising pressures that
can affect schedules, such as the issue identified in Chapter 5 (Section 5.2.7), where just the presence of nesting wild birds delayed the project. Also, hospital buildings may suffer from unsuspected structural or engineering system problems and such risks are additional to the business risk for the project concept, and this aspect may not be fully explained to them. Perhaps due to their specific expertise, the missing systems thinking in Trust boards shows mainly in their focus on cost and timescale when approving projects or judging their success, and in their short-termism and lack of strategic planning.

Funding and Criteria for Project Success

An essential precursor for project success depends on the ability (or willingness) of clients to provide adequate time and funding to achieve the project’s objectives. Hence, correctly scoping the work to be done within a project for an appropriate time-scale is crucial for negotiating an achievable maximum price (GMP). Clients usually have to tailor the extent of their requirements (i.e., the scope) so that the budget and/or the time available is insufficient.

“Most of the time we’re flying by the seat of our pants trying to get things done because we’re restricted by time and by budget.” Project Manager, Case Study 4.

The image in Error! Reference source not found. succinctly makes clear why the “faster, cheaper, better” approach is destined to result in failure.

![We have three kinds of service available](image)

Picture 9.1 Optimism bias
One estates manager mentioned that he needed to be “positive” when approached, and that it was important to identify project risks but not to overstate them. Consequently, a very delicate balancing process is needed, to ensure that project risk is accurately represented but that Trust board members are not unduly deterred. Spotlighting the risks may have helped to avert some of the more serious project failures. However, this could also result in the shelving of “promising” or beneficial projects with significant known risk, but which can be adequately managed. As combined project risks are now presented in risk registers, this may suggest that perceivable risks have been evaluated and that mitigation measures are available. However in some projects with considerable uncertainty, risk estimation may be difficult to determine with a level of accuracy, as is generally the case with the refurbishment of older hospitals buildings (see Section 2.7.4).

Lovatto and Kahneman and (2003), identified an unintentional bias (termed “planning fallacy”) or tendency by advocates to overestimate the benefits and underestimate the costs of their projects (MacDonald, 2002; Lovello and Kahaneman, 2003; Flyvbjerg et al., 2005, Flyvbjerg et al., 2009). Certainly the aspirations of a Trust board can lead to overly optimistic plans.

“They wanted a facility that’s fit for 21st century healthcare - they want to be a ‘leading edge’ centre, so it was trying to push the boundaries as far as you could within the constraints of the four fixed exteriors, and an internal drainage system that’s falling to bits...” Programme Manager, Case Study 1.

Similarly, project managers in the Case Study 1 project were in agreement that, on many occasions, either their project budget or time-scales were unrealistic for the work required, particularly considering the risk associated with refurbishing older buildings. In practice, optimistic project budgets or schedules essentially condemn projects to fail from the outset, or at some stage considerable re-scoping will be required. The re-scoping of the Case Study 1 project significantly reduced the budget, but also drastically reduced the flexibility of the finished unit. Projects with severely restricted budgets may fail to benefit from the client’s emerging understanding of how the refurbished space will work and consequently any insights into how the space could be more efficiently
used may be lost, if the project scope is strictly defended and the option to include crucial efficiency changes is precluded.

In one case study Trust, the estate manager complained that not only was there no budget surplus, but that there was insufficient funding to meet legal responsibilities. The NHS estate as a whole has a very significant maintenance backlog (amounting to approximately 10% of the value of the estate) and this presents a continuing and growing risk. Furthermore, the changes that will be required to adapt hospitals to the changing climate will significantly add to this burden.

**Short-termism and lack of strategic planning**

Refurbishment can prolong the life of buildings and provide improved utility and comfort. However when poorly planned, refurbishment can result in buildings that become increasingly problematic to maintain and unpleasant to occupy. Managers are reluctant to plan too far in advance, due to external funding or budget uncertainties.

> “if you were planning a new hospital you'd have a strategic approach ... but people have just put stuff where there's been a space. They've never really considered things like patient movement and infection control and all that sort of stuff, what the infection plume would be of carting somebody from one extreme of the hospital to the other”.

Estates Director, a Northamptonshire hospital.

Hospital buildings represent a very large and long-term investment. To obtain the best value from such assets, there needs to be long term planning to ensure continued functionality and continuity of maintenance. However an effective long term approach to building planning appeared to be limited or missing in three out of the four Trusts.

> “I think if you were going to do any detailed planning I don't think you would want to plan any further than two years ahead because things change so much.”

Project Manager, Case Study 4.

Historically, Trusts appear to have considered their clinical specialities almost as “Lego” blocks that could be slotted in and out of spaces in hospital buildings as required, or as
funding became available. In practice, refurbishments to relocate these specialities have strict budgets and rarely include allowances for building upgrades, unless there is a known and substantial threat of service failure. Trust Boards may choose not to fund problems that come to light after a project budget has been agreed and consequently buildings can continue to operate with worsening system risks for considerable periods.

9.2.5 Missing system thinking: DoH/NHS Estate layer

One of the estates managers interviewed recounted instances during the previous decade where funding for refurbishment had been available for very short periods to support specific government priorities. Examples include dermatology funding in 2007/8, the recent “Privacy and Dignity” funding related to gender specific accommodation, and the additional funding associated with infection control targets. Some of these “time-limited refurbishments” have resulted in significant ongoing shortcomings. For example, an estates manager at the hospital in Case Study 2 recounted an episode where a ward was refurbished with two dedicated isolation rooms to improve infection control and meet targets. The following year, as space was at a premium, both isolation rooms had to be further refurbished as gender specific bathroom accommodation, so as to comply with the Government’s Privacy and Dignity priority funding target.

“the majority of projects that we do are all very reactive and that makes it difficult in a number of ways to plan and get the finances that you need to deliver a sustainable project that you can be proud of.”

Project Manager, Case Study 4

9.2.6 The need for Resilience

At the NHS England level, NHS hospital estates appear to have the following problems:

- Funding shortfalls (Section 7.6.1)
- Since the closure of NHS Estates in 2005, a strong coordinated NHS Estates Strategy appears to have been lacking. As a result of Sir Robert Naylor’s Review
(Naylor, 2017) of the NHS estate, the government plans to establish a new national body to provide “strategic estate planning” for the health estate.

- Lack of harmonised response to the warming climate.
- Condition of the Retained estate poses a significant risk to the NHS: building system failures affect productivity and can be life-threatening (Section 5.2.6).
- Uneven level of repair in hospitals may affect morale (Section 9.2.3)
- Existing buildings and some recently completed buildings are unprepared for climate change and become extremely hot in warmer weather (Lomas and Giridharan, 2012).
- Lack of Estates expertise on NHS Trust Boards.

“Very few trust chief executives have an estates and facilities background, but it’s really important that leaders understand the importance of the estate.” Dr Sue O’Connell, chief executive of Community Health Partnerships (CHP) in “Building Better Healthcare”

Such conditions limit the options available for hospital management to configure their services in the most efficient format and hence critically limit the progress that can be made towards sustainable change. Clearly NHS hospitals have only limited resilience and safeguarding services under existing demand is resulting in considerable pressure on staff and equipment. As the climate changes and systems become increasingly compromised. Hence, the need to increase hospital resilience has recently become a consideration for estates departments.

9.2.7 A systems Approach to Resilience

A long-term perspective towards refurbishment is clearly needed, that views the refurbishment process as a strategy for developing resilience and continuity. Such a refurbishment perspective should encourage managers to adopt prudent choices that value future benefits. A systems approach to refurbishment helps in that it encourages a coherent overview of all of the interconnected healthcare care systems, so that features that contribute to long-term continuity can be identified.

A hospital system can be considered as a combination of its social sub-systems (clinical, managerial and support staff), together with its technical sub-systems (equipment,
environment, communication, and infrastructure). Collectively, these sub-systems, combine to provide an integrated holistic, “socio-technical system”, where both the social and technical components interact to provide care services. Managers or clinicians make decisions that regulate, operate, or adapt care and technical systems (clinical, environmental, technological, smart systems etc.) and the technical systems afford the means or capability to undertake patient care.

Hollnagel (2011), suggests that to be resilient, such systems must be able to anticipate likely threats, (Chapter 2.5.5) accurately identify what is happening and respond, even if a threat does not actually materialise (Hollnagel, 2011).

Such threats that do arise, may have been anticipated, and detailed action-plans may be available. Alternatively threats may be surprising, that is, considered improbable, or beyond previous experience, and have no predetermined solution. Further, “creeping onset” threats may appear which, though developing slowly at first, become critical if remedial action is delayed.

This range of threats suggests that a hospital’s resilience will be contingent on the presence of resourceful staff in key positions, able to make educated decisions, based on current knowledge of the available personnel, equipment and finances, and an understanding of hospital systems and requirements. Effective management may need to reorganise, transform or adapt the hospital, by modifying its care models and/or its technical systems, following an event or change, so that the facility can maintain service provision, to suit altered conditions or changing needs.

In effect, hospital socio-technical systems may be considered, not just as complicated systems, but as “complex adaptive systems that are dynamic, non-linear and highly interconnected with emergent properties and feedbacks that control responses” (Marchal et al., 2014).

If hospitals are to develop resilience in the increasingly likely event of serious climate change, senior management need to be responsive and prioritise and support the adaptation process.
A resilience perspective can also be helpful in ensuring an appropriate response to sporadic or intermittent threats, such as utility service interruptions, major incidents, or that are likely to impact hospitals over many years. This is enabled through developing a range of resilience resources, and developing training and awareness in staff. Consequently, over the long-term hospitals become better able to anticipate likely threats and plan avoidance measures, or provide resources to enable a prompt and full recovery.

Resilience for the NHS, must be particularly concerned with adapting or transforming the care system in response to changing circumstances, so that it continues to meet the needs of the community. Increased levels of migration towards, or away from a catchment area can severely impact a hospital’s ability to function. Typically, where demand surges, services become overwhelmed; equally, when demand declines, a hospital’s income suffers and service provision become threatened. Similarly, changes in disease patterns, treatment regimes or technology can impact the way in which hospitals or other community services provide health-care for patients.

Hence a definition of NHS system long-term resilience has been developed which draws on ecological resilience literature (Holling, 1973; Walker et al.2004), (considered in Section 2.5.1) and also engineering resilience safety literature (Hollnagel, 2011), (considered in Section 2.5.5) and has been developed for use within the NHS and is included below.

9.2.8 Inclusive Definition of Resilience for the NHS

The following definition has been developed from the initial definition presented in Section 1.3.3, towards a long-term perspective, that views intermittent serious incidents or major threats as catalysts for necessary change. This perspective encourages a continuing closer match between the services that are required by patients and the most effective means of delivering the necessary care.

**Inclusive NHS Resilience Definition**

In the event of anticipated or surprising critical risks, or of slowly emerging threats, NHS systems must ensure the safety of individuals and provide continuity of care. Experienced
personnel, along with spare or flexible reserves, redundant systems and/or shared resources, should be available to enable an appropriate response regardless of the form of the threat, or combination of threats. Solutions may draw on the creativity and dedication of the workforce. Hospitals must develop the capability to adapt or reorganise systems, and temporarily or permanently transform, in response to changed or changing conditions.

The above definition identifies the potential need for hospital systems to transform so that they may be capable of responding to changed conditions following a major event. Indeed, a resilience perspective encourages a proactive response to such changes, mitigating serious service interruption and consequently safeguarding patient care.

9.3 Mechanisms of Resilience

Flexibility, creativity and work-arounds are the main promoters of resilience. In this section flexibility and creativity are first described, then mechanisms that encourage or discourage resilience, and lastly work-arounds.

The term “stressor” is used in various domains to describe factors which impact resilience negatively, however the remaining mechanisms have not previously been identified.

9.3.1 Flexibility and Creativity

Flexibility is a fundamental promoter of resilience. Technical system flexibility provides alternative options of use during disruptive events. For example, one estates manager explained that the infrastructure power lines are designed to operate with some flexibility: the local power provider’s network of power lines are sized to continue operating in the event of a line failure, through the increased capacity of each line to carry the additional load of a failed line. This is described as an (n-1) system. He explained that there is also an agreement with the provider to prioritise the hospital’s power supply in the event of disruption, adding still further resilience.
Design system flexibility was essential in the Case Study 1 solutions, where nurses and end users were closely involved in planning the layout and functioning of the new unit. In the past, according to one of the nurse interviewees, clinicians and architects frequently made such decisions without consulting nurses, or including their views in the design process. This is borne out by the consultation process in Case Study 2, where modular wards had a strict time limit for installation. Here the nursing staff had only minimal opportunity to comment on the designs, and decisions were mainly taken by the estates team or designers with very little input from clinical staff.

Another significant promoter of resilience is creativity and the ability to find elusive solutions. This may involve a process of constraint negotiation or of reframing the problem, so as to achieve an acceptable solution. For example, a creative solution was required for transporting essential staff to and from NHS hospitals during severe weather. An enterprising hospital manager developed rotas of local “4x4” car owners who volunteered their services, an arrangement that has now become standard practice across the country during emergencies.

In this research, the Case Study 1 programme manager considered that the neo-natal refurbishment project required creativity to keep it on track:

“The project team recognised the need for creative solutions to meet the ....conflicting requirements of the users, the client and the regulatory process.....”

Case Study 1 Programme Manager.

The size and scale of the NHS organisation encourages flexibility in contractors. When problems arose during Case Study 2, sub-contractors prioritised the NHS project over their other ongoing projects. Hospitals are an important source of regular work and sub-contractors deployed workers away from their other projects to speed the Case Study 2 activities, when required. Their rapid response was partly due to the need to secure future work, although they were also highly motivated for that particular project by the team camaraderie.

Unfortunately, plans for resilience can get compromised. The Case Study 1 manager described how the neo-natal project was planned to have all of the cots to be suitable for the most at risk babies (i.e., “acute”) and these cots could also be used for slightly
less risk babies (“high dependency”). However, funding issues meant that half of the cots would only be suitable for “special-care” babies and hence, would not be suitable for either “acute” or “high dependency” babies, greatly reducing the unit’s flexibility. Moreover, upgrading the unit so that all cots were “acute” would be very unlikely as it would entail excessive disruption and cost:

Well we’d have to shut it and upgrade it again. In terms of putting the pendants in we’d have to take all the ceilings out, rerun the gas pipe, and of course the consequence would then be we’d need ventilation and air conditioning, which we now haven’t put in. The ducts are small, we’d have to put new ducts in. We’d probably have to put a new plant in, because we can’t take off the existing plant.” Project Manager, Case Study 1.

9.3.2 “Absorbers” of Shock or Disturbance

Absorbers mitigate shocks with little or no necessity for change, and hence impart resilience. For example, most construction projects include an element of “slack” (extra time), or redundant systems which allow flexibility in the event of an emergent problem. For Case Study 4, the Teenage Cancer Ward refurbishment, the project timescale expanded exponentially as the difficulty of the task was fully appreciated (i.e., the need to group all the oncology services together). However management did not rein in their aspirations, but provided the additional resources, hence absorbing the identified difficulties. They went ahead with the project and planned the necessary permanent and temporary moves to allow its completion with additional time (11 years in total).

For Case Study 2, the reverse was the case and time was of the essence. The modular wards had to be in place and operational by the DoH cut-off date to meet the Infection Control target. Otherwise the hospital would be subject to a hefty fine. Here the limiting resource (time) was eased by the availability of other resources, such as a sufficient budget (available to employ more staff and more effective equipment), immediate access to decision-makers, project team cohesion, and rapid deployment of alternative solutions when required. Hence the resilience of the project was not compromised by the lack of a particular resource, but mindfully mitigated by the project team.
These illustrate that there can be options that trade-off gaps or weaknesses in a project’s resilience by substituting alternative resources, such as spare/redundant equipment or by including flexible resources, such as open-plan or loose-fit spaces that can have multiple uses, or spare financial reserves that can be accessed to solve a variety of problems in an emergency.

9.3.3 “Transferors” of Resilience

Transferors pass resilience within systems or between systems. They help to develop resilience by, for example, sharing or transferring resources or expertise. Resources such as mobile equipment, communication systems and emergency units may all be considered as resilience transfer agents as they enable capability or expertise to be transferred to the point of need. This can be external. For example, when a major incident is called, a wide range of resources from the surrounding area can be directed towards the emergency team. Internally, transferors can include such processes as developing shared resources between wards, or protecting staff availability by the use of volunteers for non-clinical roles.

“Good will” can transfer benefits from the donor to the recipient. In essence, good will can support and promote successful projects, as it eases situations where the progress of a project may be in doubt. It limits the need for recourse to the legal system and frequently both donor and recipient benefit. This aspect was particularly important in Case Study 2, where “buy-in” or the good-will of the project team was essential to the project being delivered on time. This was also the case in Case Study 1, where the principal supply chain partner (PSCP) “absorbed” a significant loss through not claiming for additional time during the project. Hence he was both an “absorber” and a “transferor” of resilience – he transferred this benefit (the cost he absorbed through unclaimed time) to the project. Without this benefit the project would have most certainly run over time and risked being considered as a failed project by the NHS. Hence, the PSCP also benefited from this generosity by ensuring the continuity of the project, where funding was very tight, and by maintaining their image as a solution focused organisation with a positive approach, thus making themselves more attractive for future NHS projects, and consequently contributing to their own organisation’s resilience.
9.3.4 “Stressors” and Resilience Inhibitors

Stressors and resilience inhibitors are non-beneficial. Stressors reduce the capability of a system to withstand the pressures that may be acting on it. They may be external in their origin, such as adverse changes in government legislation. They may also result from the uncertainty of potential external events related to tipping points, such as, for example, a change in climate, the Gulf Stream, or the earth’s magnetic field; or geophysical such as sea-level rise; or alternatively national financial or political failure; e.g. war, food or refugee crisis.

Stressors may also be internal pressures that result from a variety of causes, such as reduced funding or difficult targets, or reorganisations. Depletors reduce the resources available to a system as, for example, when neighbouring or competing systems choose to “grab” rather than share unused space, or resources. Hence internal competition can be a stressor and a risk to an organisation’s resilience. Other stressors are low morale and change fatigue, which may reduce staff willingness to engage with innovation and may also impact staff retention. The overload of paperwork or “red tape” was frequently cited by the interviewed nurses as a source of frustration, causing them to “lose” valuable time attending to patients.

“I think there definitely is, (room for innovation) yes, but I think that is compromised within the NHS by all the different regulations. There are so many different stakeholders, each with a particular agenda to push whether it’s infection control or the easy access to services to whatever else it might be.”

Case Study 1 Programme Manager.

Resilience inhibitors constrain or deplete resilience. For example, legislation or regulations can limit the options available to resolve issues. For instance, transfers between different estates budgets might be restricted or access to a budget denied, even when emergency issues arise.
9.3.5 System Resilience: “Work-Arounds”

Work-arounds are the standard means of being resistant to small-scale problems. (A work around to a large-scale problem is termed an intervention or a creative solution.) Koopman and Hoffman (2003) argue that “sharp-end adaptations” help to avert disruption and that monitoring work-arounds can provide a method for assessing a system’s capability i.e. how brittle the system may be. According to Koopman and Hoffman (2003), adaptations or “work-arounds” indicate areas where there is a poor fit between the technology or protocols and the actual way procedures are carried out. In contrast, Hollnagel et al., (2011) consider that such “work-arounds” are examples of adaptations to the pressures on the system in complex organisations and indicate resilience in action.

Hospitals frequently rely on “work-arounds” to enable complex and essential processes to progress or to stay within budget. One project manager decided not to do an air test, even though they expected the building would pass, as in 12 to 24 months the vapour barriers were very likely to become compromised.

“I made that decision and we weren’t going to do an air test, because the cost of doing that is about £60,000 - to do an air test.” Estates Manager, Case Study 1.

In the case studies, other “work-arounds” were necessary to provide additional necessary project funding, which is an “across-layer” issue between the estates team (process layer) and the finance systems (finance layer). Project risk is calculated as a percentage of the total project cost and for refurbishment projects this is usually much higher than for new-build projects. One estates manager described the difficulty of explaining to the finance department the real level of risk associated with a refurbishment to a very old building,

“How can you go in with a 25% risk on a £10 million contract? - Well, you know, it’s a fully occupied building, there’s asbestos there, we don’t know what the services are like, forty years old, if we touch this pipe here, it could burst over there…..They don’t want to hear that…..They want to hear, oh, about 5%. And sometimes 5% is never enough. And then we have to rob maintenance
programmes to pay for things that we then have to deem outside the scope of the contract.” Estates Manager, Case Study 1.

Many of the hospital system connections operated through the hospital hierarchy. This was quite noticeable during the research interviews and is illustrated in the “layers” diagram in Section 1 of this chapter (Figure 9.1) where hospital systems, as in many organisations, were clearly stratified and could be separated out in “layers” with relative ease. Scheduling meetings with representatives from the different systems such as Infection Control or Housekeeping, for their input to specific refurbishment projects was difficult, as they appeared to have very limited additional capacity. Informal connections did exist between staff of related systems that need to have regular interaction, such as nurses and physiotherapists; ambulance staff or pharmacists; or through social groups. However, these links were less predictable. Where systems were strongly connected, necessary changes appeared to be communicated effectively, but where links were more tenuous i.e., in systems less directly connected, communication appeared less dependable.

This has important implications for patient safety as, for example, small changes to refurbishment schemes may fail to be communicated when necessary. A recent example of this (not from the case studies) concerned a refurbishment where testing of an altered medical gas system was in progress (McCrea, 2013). Nurses in a near-by ward, also using the same medical gas supply, were not alerted to the work or warned against connecting patients to the system. Two patients were exposed to the “test” gas rather than their prescribed medical gas (McCrae, 2013).

System autonomy exists where individual systems place barriers between their activities and those of the remainder of the hospital. This affects the cohesion of the hospital organisation. Such barriers may be essential for working i.e. physical barriers for security and require pin-codes for access; or they may be operational, where there is no-one available to answer telephone calls. Other barriers may be significant, and units may reduce their connections with the hospital by locating to a distant site, or by developing other sources of funding. Sometimes these barriers may be essential “self-preservation” work-arounds that allow a system to continue to provide its essential function where there is very heavy demand, by limiting access from outside the system. One
facilities/project manager explained how difficult it can be to get cooperation between different hospital systems,

“.....people just won’t give you access ..... because it has a massive impact on other areas. If it’s within the same division, directorate, clinical specialty, then you’ve got some sympathy with people and they’ll, you know, tolerate a little bit of, you know, work down here because of work upstairs. If it’s outside the division then we get no cooperation whatsoever.” Estates Manager, Case Study 1.

Co-operation between systems should be an essential feature of the NHS, but the degree of co-operation varied markedly between the Trusts observed during the study. Case Study 2, a Trust recovering from very severe financial problems, had benefitted from new management and there was a strong “can-do” attitude permeating the hospital culture. This was in sharp contrast to the Trust with the Case Study 1 hospital, where the Trust was under considerable financial pressure and staff appeared unsure about their future.

Also during Case Study 1, the design “work-around” of accepting the risk of not following the HBN guidance regarding circulation space and providing an “open-plan” ward allowed the design to progress and include more of the key requests of the users. The “work-around” also helped to ease some additional constraints the design team were concerned about, such as how to provide the necessary access and fire control, in addition to all of the requested facilities.

“The biggest one we didn’t comply with is space. The cot spaces comply, but the circulation space we don’t. So even the size of our bays with cots in, they’re not meeting the HBN. But actually operationally we’ve delivered immense improvement in service and...they’re happy”. Estates Manager, Case Study 1.
9.4 Implications for Resilience

9.4.1 Resilience at Macro, Meso and Micro Levels

In this subsection, resilience of the NHS at the macro, meso and micro levels are considered in turn.

Resilience at the macro level (the NHS Trust layer)

Typically, the risk of failure for a hospital system is assessed in relation to the possible impacts and the probability of the known risks occurring, along with the options available for mitigation. At present, Foundation Trust Boards determine the levels of acceptable risk based on DoH guidelines and expert advice. For example, the Trust board of the hospital in Case Study 1 employed consultants to assess their key risks and then they developed mitigation strategies based on the consultant’s report.

The purpose of this process was to highlight where a Trust’s major anticipated threats lay, and addressing these risks was an overriding concern. In this respect CEO’s and their senior managers are engaged with resilience, as they are responsible for the uninterrupted provision of the trust’s healthcare services. In some cases this will require significant changes, such as the restructuring of an existing service, possibly in concert with a refurbishment or a new build project. However there are multiple constraints affecting their available options for refurbishment. One manager from Case Study 3, when asked about refurbishment constraints, remarked

“…… sometimes they’re incredibly constrained … essentially we haven’t got room to swing a cat. And you’ve got to keep continuing to deliver the full service as you do it....”

Senior Estates Manager, Case Study 3.

Resilience at the meso level (the “Building” layer)

Taking a holistic life-cycle view helps to develop a resilient approach to refurbishment, with obvious benefits:
• It allows timely access to technical systems: costs, manpower and equipment can be shared between projects and maintenance programmes so that project priorities and building issues are both addressed (Section 9.2.3)

• It promotes planned or staged replacement of whole building systems and components: heating, H&C water, electrics, ICT and piped gases; windows, roof work etc., to provide improved resilience (Section 9.2.3)

• It promotes a continuous planned building improvement programme, which may be more acceptable to Trust Boards than expensive episodic maintenance funding requests. Increased project costs that might result from sharing costs, may be difficult to justify on a one-off basis, but may be more acceptable when associated with a continuous improvement programme (Section 9.2.4).

• Continuous planned interventions should help to reduce the maintenance backlog, so that flexibility and asset values are improved (7.6.1).

• The aim is to improve overall resilience and sustainability.

Resilience at micro level (the Project layer)

The essential characteristics of project resilience appear to relate to maintaining the integrity of the project schedule and, to this end, an element of financial, resource-based or time-related “slack” is almost always included. This means that there is a small and strictly limited period of additional time or resource to allow for unexpected events. However, if serious problems arise there is usually a need for additional funding or extensions to the project, unless the time can be made up by speeding up activities scheduled later in the project programme. In practice, unexpected events occur frequently and project managers attempt to keep to schedule by various strategies. These include utilising project “slack”, rescheduling the order of activities, or increasing the manpower of an activity (cost implications). Project managers usually include some
form of value engineering activity to stay within budget. Case Studies 1 and 2 both show very useful illustrations of how project resilience can be either fostered or degraded.

A refurbishment is the building equivalent of an engineering change. It may be required to change the purpose of a space or to improve functionality. A well-planned and comprehensive refurbishment process can be considered as “resilience in action”, renewing a building’s aging or defective systems and improving functionality. However, there are a number of ways that stressors may negatively affect the resilience of a project.

The following stressors are common to many projects:

- Almost all refurbishment projects are unique and there may be only limited existing experience to guide the process, so that each project may “throw up” novel problems (Section 5.2.7).
- Project funding may be insufficient for objectives (Section 8.2.3).
- Existing building information may be sketchy or absent (Section 8.2.3).
- Changes often propagate, and can critically affect resilience.
- Clients/users are inexperienced in articulating what they want (Section 7.6.2).

The presence of absorbers can increase resilience, even if they are located on different levels. For example, funding mechanisms on one project layer can mitigate procurement or supply difficulties on a different layer by relaxing financial constraints. Thus, a refurbishment project can absorb and propagate changes on different levels. Also, the refurbishment process allows dialogue with stakeholders, and satisficing compromises may be possible (a process that is a promoter of resilience).

9.4.2 Resilience to External Risks

Horizon-scanning is a key aspect of maintaining resilience in the face of external risks. Managers must be aware of changes in legislation, political climate, public attitudes,
environmental issues etc. so that, where possible, risks can be considered before they impact. Many NHS hospitals have only limited ability to operate under emergency conditions, due to critical system constraints such as inadequate back-up facilities or perhaps an inaccessible location. For example the Case Study 2 hospital maintained only a 24 hour water storage capacity; whilst the Case Study 1 hospital had a very limited back-up power generation capacity.

Disruption to critical supply lines due to prolonged weather events (e.g., heatwave, snow or flood) or infrastructure failure (e.g., communications, rail, road or bridge failure) can be very serious, as patients can be stranded and essential staff may not be able to reach the hospital. Specialist pharmaceutical drugs or blood products with a short shelf life may need to be delivered urgently, and consequently transport disruptions or supply system failures can be life-threatening for critical patients. Hospitals have detailed plans that come in to play as external events impact. However, problems arise as unlikely combinations of risk occur, for example when a major incident occurs (e.g., a train derails) during a snow-storm and access is severely restricted, or when communication links fail during heatwave conditions. On such occasions, plans may be insufficient and resilience is dependent on key actors, with knowledge of operational capability, making appropriate decisions, and supported by resourceful staff.

Hospitals manage their risks by changing and adapting so that the risk is reduced or eliminated. Indeed hospitals systems are increasingly being considered, like the ecosystems that they somewhat resemble, not just as complicated systems, but “complex adaptive systems that are dynamic, non-linear and highly interconnected with emergent properties and feedbacks that control responses” (Marchal et al., 2014).

Senior managers within the NHS are gradually beginning to embrace the paradigm view of the world as an interconnected set of complex systems where the outputs of one system become the inputs of another. However, it is not clear how well this perspective has been cascaded across the estates function.

“We should be designing for flexibility and adaption............. I’m an advocate of systems thinking........I think there’s a gap in systems thinking”

Senior Estates Manager, Case Study 2
9.4.3 Strategic views of connectivity

Real problems can arise from failing to achieve key connectivities. This was the issue with the Case Study 3 extension, where connectivities between the Acute Admissions Unit and the A&E department were mismatched. Patient flow needed to be directed to specific floors depending on length of stay. The failure to identify this crucial connectivity issue substantially increased the project costs. Here, necessary changes required by the user layer had repercussions for the hospital building, for the NHS Trust, and for patients, as the considerable sum required for the rework could not then be spent elsewhere.

“Now there was an award for vascular treatment….. and all of the hospitals apply….. We went up against Hospital N. We weren’t awarded the vascular contract… we were actually going to make the ground floor of (Building P) a vascular ward. Now (we are) actually making (it) a cardiac ward because we’ve been awarded the cardiac contract.” Estate Manager, Case Study 3

Connectivities appear to be a crucial issues in hospital refurbishment planning and much effort is dedicated to achieving improved access to key hubs for critical clinical specialties, such as diagnostic suites or theatres. Nevertheless, clinical priorities appear to change over relatively short periods, as funding stream opportunities arise or disappear; as specialties gain or lose key staff; or contracts are awarded elsewhere.

This can be a problem for estates managers, as refurbishments are largely clinically led and this may constrain the development of a coordinated and systems-based refurbishment strategy that depends on the planned refurbishment of each section of a building, depending on the age and condition of the various systems. This issue illustrates the difficulty of harmonising short term clinical objectives with long-term refurbishment goals. However, a planned refurbishment strategy can accommodate clinical priorities, providing that long term goals are not sacrificed and that each refurbishment contributes to the functionality of the building’s systems as far as is practicable.
9.5 Improving Resilience: Planned Refurbishment

Refurbishment can prolong the life of buildings and provide improved utility and comfort. However when poorly planned, refurbishment can result in buildings that become increasingly problematic to maintain and unpleasant to occupy. In contrast, a planned system of refurbishment has many benefits. Section 9.5.1 reviews some of the problems that have arisen from poor long-term planning in the case study hospitals. Section 9.5.2 discusses the merits of a planned refurbishment system and advocates the setting up of “Resilience Opportunities Funds”.

9.5.1 Long-term System Resilience Issues

Time pressures frequently appear to constrain the decision process and crucial decisions can be made without a systematic evaluation of the ramifications that can result. Indeed decision-makers may not be aware of the consequences of their decisions for specific users. Poorly planned refurbishment have also resulted from Government attempts to improve specific specialities with dedicated funding that was available, only for a very limited period. Such funding resulted in piecemeal refurbishments, carried out in haste, without the benefit of long-term planning and evaluation.

One outcome was that refurbishment projects sometimes utilised the closest available space, without consideration of the original design purpose, or the complexities of servicing such sites, and with little regard for future planning requirements. The Case Study 1 hospital had an example of disjointed development with buildings positioned inappropriately, and similarly, at the Case Study 4 hospital site, buildings either blocked further expansion, or adversely affected patient flow across the site. According to the estates manager, this has resulted in care systems with poor connectivities, detours that result in long travel distances and the need for complicated way-finding systems.
Many grid-patterned “nucleus” hospitals have lost their “lungs” (or green ventilation spaces between blocks), and now require complex mechanical ventilation systems. Indeed the need for additional plant to support the extra accommodation loads further “eats” into remaining spaces, reducing storage and amenity areas. In a project that was underway during the study period in the Case Study 4 Hospital, a courtyard was being “developed” to house a Lung Function Unit (See Picture 9.2). For this refurbishment, pre-fabricated modules were lifted by a long-boom crane, over the top of the existing buildings.

**Picture 9.2  New lung function unit sited in courtyard (Case Study 4)**

A senior nurse commented that the day-to-day functioning at the hospital in Case Study 4 is frequently constrained by the need to continue as normal during the numerous construction and maintenance processes that take place on a regular basis throughout the year, requiring further detours and temporary closures.

### 9.5.2 Improving Resilience: Planned Refurbishment

There are several drawbacks that result from a “piecemeal” approach to refurbishment planning, as described in Section 9.2.3. An alternative approach, i.e., a long-term
planned system for refurbishment may have considerable advantages. A number are listed in Section 9.4.1 (under Resilience at the meso level). Further benefits could include:

- efficient up-to-date systems can be introduced when access becomes available (as in Case Studies 1 and 4);
- climate moderating adaptations can be systematically included as part of the ongoing partial refurbishment process. However, it is important to note that Short et al., (2015) researched various strategies for adapting existing hospital buildings but warned that none of the options investigated would be eligible for funding under existing DH’s EEF Scheme (NHS Energy Efficiency Fund) due to the impracticable returns on investment required by the Treasury i.e., 2.4 within 5 years;
- buildings are more likely to benefit from an ongoing planned improvement process, compared with the ad hoc system presently adopt (Section 7.4);
- managed maintenance costs and more resilient buildings could result.

A planned refurbishment process allows buildings and systems to be refurbished continuously, spreading the cost over long periods. Newer construction generally has less need for system replacement, but there may be functionality issues or the need for a change of use. Older buildings require significant replacements at specific periods of the life cycle, particularly when embedded systems (in walls and under floors etc.) and plant are reaching the end of their economic or functional life.

Most importantly, partial refurbishment provides the rare opportunity to access embedded systems. Lack of access is a key constraint in managing and maintaining buildings. Making full use of access opportunities makes economic and procedural sense, as both costs and disturbance are reduced. In addition, the need for downstream emergency maintenance is much reduced.

While partial refurbishments may provide added functionality or upgraded facilities, there may be disadvantages. According to a specialist environmentalist services consultant to NHS hospitals
“......systems in older buildings are often mysteries even to the people who manage them. There will be a history of refurbishments and minor works such that nobody really knows the system intimately, or could locate every pipe, outlet, and potential risk area. More worryingly, equipment may be found to be unfit for purpose or obsolete, making repairs and maintenance difficult.”

Andrew Steel, Air Hygiene and water treatment Specialists (Steel, 2016).

A long-term planned refurbishment programme may reduce the need for additional isolated systems, thus reducing the tendency for a building’s environmental/mechanical systems to become overly complex.

A proposed “Resilience Opportunities Fund”

For a planned refurbishment system to be effective requires it to be properly funded. To the writer, this suggests that a hospital should set up a “Resilience Opportunities Fund” that funds refurbishment, with the partial refurbishment process as the essential backbone of planned building management. The benefits from having systematic refurbishment rather than piecemeal refurbishment are so great, that the fund would be cost effective and self-sufficient over the long-term.

Planned partial refurbishments by managers that have a strong understanding of the building’s needs would be the basis of a resilience perspective. Systems access, made available during any planned refurbishment process, would automatically be assessed for synergies with existing building needs. In this way, building systems could progressively be replaced before they become critical.

Refurbishment project proposers however, might well be reluctant to support objectives that could possibly hinder or in any way interfere with the development of their project. Consequently encouraging a pro-active approach by funding resilience opportunities separately, through a dedicated “resilience” budget may overcome these concerns. Estates managers along with project proposers, would be motivated to search for synergies or opportunities to share costs. At present, it appears that the process of sharing costs occurs mainly when projects are at high risk of exceeding their budget and the maintenance budget is “raided” to support some aspect of the work. However, resilience funding would avoid this approach. This research suggests that a planned and
resilient approach to refurbishment would reduce the haphazard and disorganised management of existing buildings and lead to more resilient and sustainable buildings.

It has long been understood that waiting till systems fail to repair them is the most expensive approach to maintenance. For the NHS, “emergency maintenance” involves considerable risk both to patients and to systems operation. Resilience planning that included synergies with refurbishment projects would be able to significantly reduce maintenance costs and may also reduce the likelihood of expensive “surprises” for refurbishment projects.

The following summarises suggestions for improving resilience:

- greater focus on requirements elicitation during the briefing process (Sections 7.6.2 and 9.2.1 and 9.2.2);

- greater understanding of the consequences of over-optimistic cost estimates and project completion times – delays, cost overruns and severe stress (Section 9.2.4);

- introduction of “Resilience opportunity” (RO) funding, and where possible, multi-purpose accommodation should be considered to increase flexibility and improve overall resilience (Section 9.3.2);

- earlier opportunity for discussion between estates and people devising models of care (Section 3.5.4);

- risk register only considers known risks: Enhanced contingency funding to cover emergent (unknown or combined) risks (Sections 2.3.1, 5.5.5, 6.3.3, 7.7.2, and 7.6.1);

- improved understanding/discussion of project constraints is required at Board level (Section 7.6).

9.6 Conclusion

Refurbishments have strict boundaries and scope expansion, or scope creep, is usually considered to be a cost/delay generator. However, there are situations where scope
Change can also be considered as a “resilience opportunity” to improve systems and increase whole building value. For example, if an emergent building/services problem arises and an insight by client identifies an improved way of working and improving productivity; or if there is a significant oversight in the briefing process, but there is an opportunity to remedy fabric or system deterioration or improve the carbon footprint.

Taking advantage of such opportunities in addition to a planned refurbishment process, should significantly reduce future costs. Consequently interventions should be funded through “resilience opportunities funding” rather than through the project budget, so that resilience improvements can be planned and monitored and so that project outcome metrics are not penalised. Resilience funding will reduce maintenance and downtime costs and it should save money in the long-term, through early interventions, shared equipment and access, improved system performance, greater reliability and reduced maintenance/downtime. Buildings will provide a safer more resilient environment with reduced carbon footprint.
Chapter 10 Discussion and Conclusions

“Climate change will amplify existing risks and create new risks for natural and human systems.” UNFCCC Intergovernmental Panel on Climate Change, (2014).

10.1 Introduction

This thesis explores refurbishment in NHS hospitals and considers how the *ad hoc* or “piecemeal” approach to refurbishment can affect hospital resilience. Changes to designs, processes, components or schedules can be a major risk for hospital refurbishment projects, so change was considered to be an important area for investigation. The approach taken was to view the refurbishment change process through different lenses: The refurbishment project at the micro level, the building in which the refurbishment takes place at the meso level, and finally at the macro level, the NHS Trust as a holon\(^5\) within the NHS estate as a whole. This approach was helpful in providing a snapshot of the various levels of NHS’s refurbishment operations. In particular, it helped to shed light on the more obscure and sometimes ambiguous interactions that take place in complex organisations such as the NHS and their construction partners, as they work together towards a particular goal.

\(^5\) The term holon is used in a similar way to that described in Koestler’s “The Ghost in the Machine”, 1967.
Consequently, the unravelling of these linked relationships and practices became more tractable, affording an insightful exploration of the mechanisms of change in NHS refurbishment projects. This approach highlighted the different objectives and constraints of the various actors in the different layers of the NHS organisation. The research suggests that ultimately, short-termism in decision-making, the mismatch of priorities between the different actors, and inadequate funding, all contribute to the failure of the partial refurbishment process to improve the resilience of NHS buildings over the long term.

10.2 Does this thesis address the aim of the research?

The question of whether this thesis meets the original aim identified in Section 1.6, may be evaluated by examining how effectively the research questions that were developed to interpret the aim, have been shaped and answered. In particular, it is necessary to understand whether the research has helped to provide a clearer picture of the hospital refurbishment process. The thesis has attempted to disentangle the web of interconnected hospital processes, stakeholders, and systems involved in refurbishment that can singly or in combination, influence the process. This research is ultimately aimed at supporting the DeDeRHECC “adaptation of hospitals to climate change” research, by identifying the barriers, constraints and influencing factors that could limit, reduce or possibly enhance the effectiveness of refurbishment as a climate adaptation process. The research questions that were identified in Table 1.1 are reproduced below in Table 10.1. (An additional column provides cross-references that identify where the question has been considered.) Each question is addressed in turn below.
<table>
<thead>
<tr>
<th>Research Question</th>
<th>Particular Concerns</th>
<th>Considered in:</th>
</tr>
</thead>
</table>
| How are refurbishment projects carried out in the NHS? | • What are the main drivers, barriers and constraints to hospital refurbishment?  
• How do changes impact the refurbishment process  
• How does the change process unfold and what mechanisms underlie the refurbishment change process.  
• How do changes to refurbishment projects impact on stakeholders? Are some refurbishment objectives less likely than others to survive the design/construction process?  
• Is there convergence or mismatch in the priorities of the contractor, user and client? | Sections 7.5 and 7.6.  
Chapters 6 and 7.  
Section 6.3.  
Sections 7.4 and 7.7.3.  
Section 7.6.2. |
| How does scope expansion impact refurbishment projects? | • How does strict adherence to refurbishment project boundaries; or alternatively accepting some degree of scope expansion or “scope creep”, influence project/building/hospital/NHS resilience?  
• Are there benefits that could be achieved permitting specific scope changes? How could such benefits be re-interpreted in terms of project success? | Section 9.2.2.  
Sections 2.7.4, 6.1 and 9.2.4. |
| How is hospital building resilience affected by refurbishment? | • Why do project changes impact connected hospital systems?  
• How does the building refurbishment process affect resilience in NHS Trust hospitals, and/or the NHS organisation?  
• Can partial hospital refurbishments compromise the resilience of NHS hospital buildings over the long term? | Chapter 6.  
Section 9.4.  
Chapters 7 and 9. |
10.2.1 How are refurbishment projects carried out in the NHS?

**Refurbishment Drivers**

Ideally, hospitals would be designed to suit patient care with the most effective “cutting-edge” care models. However the pace of innovation in clinical research and associated developments in technology, although accelerating rapidly, is not matched by increases in the speed of hospital construction, which remains frustratingly slow. Consequently this ideal situation may actually be unattainable. Particularly where time is of the essence, refurbishment of existing buildings may be a sensible alternative. In fact, there are a number of drivers of NHS refurbishment (Section 7.5) and these can be grouped as either external drivers, or internal drivers. The drivers of refurbishment are summarised below in Table 10.2.

Table 10.2 Drivers of Refurbishment summarised from Chapter 7.5

<table>
<thead>
<tr>
<th>External drivers</th>
<th>Internal Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To integrate innovations in clinical care techniques and technology</td>
<td>• Reducing hospital risk, e.g. restructuring to reduce travel between sites, or upgrading high risk buildings or infrastructure</td>
</tr>
<tr>
<td>• To accommodate new models of care</td>
<td>• Reducing clinical risk, improving connectivities; and hygiene</td>
</tr>
<tr>
<td>• To improve productivity, to reduce pressure on the system</td>
<td>• Improving building condition</td>
</tr>
<tr>
<td>• To care for the aging population nationally; and in addition local demographic changes: elderly people generally have greater care needs</td>
<td>• Replacing aging systems or M&amp;E equipment</td>
</tr>
<tr>
<td>• To adapt to the changing patterns of disease: Diseases such as scarlet fever, smallpox and tuberculosis no longer require sanatoriums; oncology and obesity services etc. increasingly require specialised accommodation.</td>
<td>• Attracting staff</td>
</tr>
<tr>
<td>• To address people’s cultural needs and changing preferences for care, as GPs surgeries become pressured, many by-pass GPs and go straight to A&amp;E departments.</td>
<td>• Achieving regulatory compliance</td>
</tr>
<tr>
<td></td>
<td>• Extending or improving layout e.g., creating decant space or improving suitability for purpose</td>
</tr>
<tr>
<td></td>
<td>• Responding to new government initiatives, funding opportunities</td>
</tr>
<tr>
<td></td>
<td>• Expanding key services and developing new income streams such as private patient services</td>
</tr>
<tr>
<td></td>
<td>• Developing clinical education and training accommodation</td>
</tr>
<tr>
<td></td>
<td>• Improving laboratories; and “hotel” (laundry and catering), or other services etc.</td>
</tr>
<tr>
<td></td>
<td>• Responding to government pressure to meet targets/ deadlines or to attract funding</td>
</tr>
</tbody>
</table>
In this research climate change did not feature strongly as a driver for adaptation, other than as an approach to managing carbon emissions (climate mitigation). “Climate adaptation” was not mentioned as a priority, even though three of the four case studies have examples of very vulnerable spaces that regularly overheat and are likely to give rise to increasing levels of heat stress in patients and staff, as the climate warms.

**Barriers and constraints to hospital refurbishment**

The essential contributing dynamics to poor building performance appear to be the *ad hoc* nature of hospital refurbishment, along with the ambitious targets set for each refurbishment project, the tight control of project boundaries, the limited funding available, but most significantly, the failure to plan holistically for the building over the long term, and to benefit from opportunities presented during refurbishments to improve the building’s overall resilience (Chapter 9).

Other issues such as the lack of existing building information and the difficulty of gaining access for surveys; along with the user’s uncertainty in how a revised care model will work in the newly refurbished space, may all result in unplanned changes to refurbishment projects. Such changes squeeze the project budget, and lead to the loss of key objectives, sacrificing building improvements, such as advanced Building Management Systems (see Section 7.2.2), for example, or neglecting to tackle serious weaknesses in building systems as they are encountered (Case Study 1), due to strict budget targets. Such decisions are somewhat questionable: rare access to systems was available, the expertise and specialised equipment was on-hand, and the consequences of delay included much increased costs at a later date, along with the gradually increasing risk of sudden system failure.

The pressing problems facing the NHS Estate stem mainly from its legacy of aging inefficient buildings and the very limited funding available to replace or refurbish those with highest risk. Many of these elderly hospitals were designed to accommodate simpler care models at a time when energy costs were much lower and the climate considerably cooler. Many older hospital buildings have footprints that are clearly unsuited to emerging cutting-edge care models; having little flexibility, limited storage space and narrow (Nightingale) wards. Some of these buildings are in very poor
condition with a significant backlog maintenance burden. Many have over-sized, inefficient service systems that, for various reasons, overheat in winter but provide little or no cooling in summer. Chapter 5 (Sections 5.2 to 5.5) describes four case study hospitals that have buildings suffering from these or similar issues.

Another key constraint that affects all refurbishment within the NHS, stems from difficulties associated with surveying hospital buildings in advance of any necessary work. In Chapter 5, two case studies hospitals (Sections 5.2 and 5.5), had to maintain patient safety during refurbishments in buildings that were interlaced with asbestos, and in one hospital (Case Study 1) contractors had to work very quietly, causing minimal disturbance or vibration. In practice, surveys for such buildings tend to be sketchy or very limited in scope. Consequently, during a refurbishment project, surprises can be very costly, and can result in failure to meet project targets or in the loss of desired objectives. This was the situation with both Case Studies 1 and 4 (Sections 5.2 and 5.5), where unexpected areas of asbestos were encountered. Other problems included live cables found buried in walls and a severely deteriorated cold water system, which resulted in delays.

As illustrated in the case studies, achieving desired connectivities can be a crucial driver in the planning of refurbishments. The requirement for improved connectivity had very expensive repercussions for the Case Study 3 extension (discussed in Sections 6.3.2 and 8.4.2), which resulted in the need for a major change to the supporting frame of the new extension to improve the connectivity of the new imaging suite with the newly added clinical units.

It is also the case that the priority attached to particular services can change over a relatively short period, and newly refurbished areas may require still further refurbishment, if an alternative objective is prioritised, or new targets introduced. This was the situation with the Case Study 2 hospital, where two isolation rooms were created to meet new targets for “Infection Control”. Due to the lack of an alternative option, both rooms had to be completely refurbished the following year for use as separate gender bathrooms to meet “Gender Equality” targets. Examples such as this involve significant cost and disruption (see Sections 5.3.2 and 9.2.5).
The impact of changes on the refurbishment process

Moat refurbishment projects are unique and there may be only limited experience or research to guide the process, so each project has the propensity to “throw up” novel problems. Case Study 1 illustrated how the legal necessity to protect wild birds, required a delay to the works during the nesting period, and this involved considerable reshuffling of work packages to ensure that the interruption was kept to a minimum. The resulting changes propagated, although propagation was contained and what could have been a three weeks delay was limited to five days. This type of change could be tracked using the Change Propagation Framework model developed in Section 6.3, which identified specific layers in a project’s organisation. With some problems, as with the cold water system in Case Study 1, changes cascaded beyond the process layer, where construction work takes place, to other layers including the finance, building and use layers. Refurbishment is usually “in progress” in most hospitals at any one time, so this illustrates that propagation of change problems can be a significant source of risk to hospital functionality and patient care.

A refurbishment can be considered as the built environment equivalent of an engineering change. Engineering change may be extremely constrained and difficult to progress, owing to the very strict parameters that govern, for example, the size, shape or function of a product. In comparison, a refurbishment project is pliable and can absorb significant change through various strategies, such as the inclusion of additional risk funding or slack time within the project (Section 9.3); through contractor negotiated discounts; or by changing the order of work packages, etc. Using the Change Propagation Framework developed in Chapter 6, (Figure 6.3) it was possible to see that propagated changes often remain within the same layer, and sub-contractors within the same layer were usually well aware of each other’s constraints and had their own well-tried methods of managing them. However, the changes that propagated to different layers were problematic, as contractors and stakeholders from separate layers were often unaware of each other’s constraints. For example, a missed reporting deadline may not be of great concern to a construction sub-contractor, but may represent a major hurdle to hospital staff in the finance layer (as described in Section 6.5). One estate manager suggested that organisational silos can make communication difficult
between departments and this can contribute to the difficulty of resolving cross-layer changes.

Consequently, the Change Propagation Framework model was helpful for identifying the various layers of refurbishment projects, and in following the trajectories of changes that propagated during the case study projects (Sections 6.3.2 and 6.3.3).

**The impact of changes on stakeholders**

The failure of the interior design work in Case Study 1 is extremely interesting as an example of reflected change because the environment surrounding the problem was particularly intransigent. Once the initial design was rejected there were virtually no alternative options for revisiting the issue. The construction schedule was severely constrained and there was no outlet for the change, and it was simply reflected back to the client. A possible remedy might have involved some form of change absorption e.g., a further scheduled consultation with the interior designers or a contractual requirement for an alternate scheme. Eventually, the necessary pressure for change became so weakened or attenuated that it resulted in the client’s usual interior design solution of “hospital green” or “hospital blue” walls and with standard flooring. Hence this was an example of change attenuation.

The pattern of decants and refurbishments required for the Case Study 4 Teenage Cancer Ward project (Section 5.5.3) to progress had interesting features. The changes propagating from the charitable donation of £2.9m, resulted in the Trust spending £11 - £12m on an ongoing undertaking that spanned 12 years. However, the project funding allowed the Trust to achieve other connected goals during the process and forwarded the Trusts rationalisation plans and some limited refurbishment needs of the building. This was clearly a case of long-term strategic planning, although unfortunately the strategy was limited to achieving the required restructuring goals and overlooked the option of significantly improving the building’s resilience. In consequence, the remaining building life was considered to be in the region of ten years, whereas, had a resilience perspective to refurbishment been in operation over this period, the building life may have been considerably enhanced. As hospital buildings are very frequently occupied for periods well in excess of their intended life, this may have been a better option.
Mismatch of priorities: contractor, user and client

Clients generally intend refurbishments, as far as possible, to be suited to the needs of staff and patients. However, where changes are required, the clients’ overarching priorities tend to focus on limiting the overall project cost and maintaining delivery targets, whilst other objectives may be sacrificed to meet these goals. Clients also want to be made aware of any arising issues, so that they can decide whether to retain, modify or lose an objective, or find an alternative solution.

Contractors are also motivated mainly by budget concerns, but their long-term goal is usually to ensure that the client will want to retain the contractor for future projects. Hence, successful contractors, like the PSCP in Case Study 1, wished to appear solution-focused and often absorbed difficulties (such as extra time activities), rather than appearing to be unable to deal with arising issues (Section 9.3). Consequently, there are clear opportunities for failures in communication and this may result for example, in unnecessary changes; required because the contractor delayed informing the client of a problem, hoping that a solution would “turn-up”. This was the situation in Case Study 2, where the sub-contractor was unable to design a suitable foundation.

Users, on the other hand, although consulted at the briefing stage, may have few opportunities to affect the course of the project. The users in Case Study 1 had little understanding of the structural issues that severely impacted the project budget early in the schedule, and which considerably squeezed the downstream activities that included the interior décor. For the contractor, and to a lesser extent for the client, the outcome was very satisfactory. However, for the users, one of their key requirements was for enhanced interior design and this remained largely unfulfilled.

A particularly serious issue involves the difference of perspective that may exist between the contractor and the client. Although funding may be tight, NHS clients are very aware of the issues related to climate change and the need for climate mitigation measures. However, contractors may have very different views and may not consider climate mitigation or adaptation a priority, particularly when considering project targets and profit margins. Where decisions need to be made “on the spot”, the client’s perspective may be overlooked and any sustainable options (that may be low on the
contractor’s priority list) may be relegated in favour of more familiar alternatives. Indeed, contractors on the Case Study 1 project appeared to have little patience with the AEDET process and regarded it as a “tick-box” exercise, and in consequence, the necessary points were awarded but the real benefits of the process were only partially gained (Section 7.7.3). Moreover, the value engineering process may remove features that are seen as value added or important to the user although not considered important by the client and hence the process may uncover or highlight discrepancies between objectives of the user, client and those of the contractor (Section 7.4).

**Change mechanisms: a vocabulary to aid discussion**

The research identified that similar change mechanisms to those seen in engineered product development projects can be seen during the refurbishment process (Section 6.4). Absorbers, constants, multipliers, carriers, and reflectors of change were also identified in refurbishment projects (Eckert et al., 2004). Change reflection however, appeared to be less problematical in construction than for engineered products. In the case study projects there were significant opportunities for difficult changes to be absorbed (Case Study 1, Section 5.2.5). This was due, in part, to the procurement process employed, and in part, to the flexibility and creativity of the project team and of the construction contractors, who sometimes acted as absorbers of change by re-scheduling work packages and re-negotiating costs with suppliers. However, the availability of direct communication with the client, which is rarely possible in product engineering, was also a significant factor, as alternative options to resolve problems could be suggested and discussed, so that a compromise, or tailored solution could be agreed (Sections, 6.5).

Additional mechanisms were encountered and described in Chapter 6, such as change deflectors, that in essence, refracted further change by various means, notably by altering the scope of the project in Case Study 1. In addition change modifiers were also identified. This change mechanism, not only reduced or alternatively enhanced the necessary degree of change, but significantly altered the type of change required. For example, in Case Study 1, (Section 6.3.3), a form of cold-water tap was identified that
significantly reduced cost and installation time while meeting revised legislation for Legionella control.

Change propagation may be the result, for example, of essential value engineering decisions (change modifiers), or a consequence of the scaling-down of design aspirations, or scope change (a change deflector). This may result from a structural change that has been required, or as a response to emerging technology, such as revised foundations needed to support new imaging equipment. In Case Study 1 it was possible to avoid ongoing propagation by separating out a segment of the project work for alternative funding or out-sourcing (Section 6.3.2). Hence “change deflection” was a mechanism for avoiding serious change propagation whilst maintaining the integrity of the project. Nevertheless, due to the limitations associated with shared resources and the eventual need to integrate with the final project, there remained the possibility of interference between the two work streams, or drift from the main objectives.

The problem of reflected change can be extremely difficult to manage. This occurs where the change environment is so severely constrained that there are no options for a change to occur, so changes must be reflected back to the originator of the change. It can imply that tolerance margins are too restrictive. What is clear from Case Study 1, (Section 6.3.2) is that where absorbers of change were included at critical project stages, changes did not propagate significantly. However not all the case study projects were so resilient and absorbers were not always included, or were insufficient for the level of risk (Section 5.2.5).

10.2.2 How do scope changes impact refurbishment projects?

Scope Change in NHS Projects

The hospital refurbishment process is complex and involves collaboration between many stakeholders, which provides considerable opportunity for misunderstandings.
Although communication is crucial throughout the project, it is particularly important at the briefing stage. The project scope is defined before and during the briefing process and priced accordingly. Scope expansion or “scope creep” is considered to be a serious barrier to achieving project targets and there were many examples identified across the research case studies. The following are some common causes of scope creep that have been considered.

**Drivers of Scope Expansion or Scope Creep:**

**New “Models of Care”**
New or revised ways of working may not be fully developed at the refurbishment design stage, and consequently, it may be only when users try to map process within the finalised floor plan that operational hurdles can be identified. This was the case with the design of the new Neo-natal Unit where staff failed to identify the need for additional WC accommodation, and late changes to the design were required (Section 8.3).

**Emergent or initiated changes**
New requirements may arise from emerging concerns, for example, from changing legislation/regulations, or through emergent problems, such as the discovery of the poor condition of the Case Study 1 cold-water system (discussed in Section 6.3.2).

**An oversight in the briefing process or failure in requirements elicitation**
The failure to identify the need of a very specific location for the imaging suite in the Case Study 3 project could be regarded as significant oversight in the briefing process Section 8.4.2). Had sufficient time been devoted to the briefing, perhaps this issue could have been foreseen. Scope creep from poorly defined requirements is often considered a problem that should be excluded from remediation, as it can cause significant cost escalation. However, (as discussed in Chapter 9), poor planning is often the result of time pressure to progress the business case. If poor planning cannot be mediated by scope change, the user’s workflow in the completed refurbishment may be considerably less efficient.
10.2.3 How is hospital building resilience affected by refurbishment?

Each of the above refurbishment “scope” issues can impact either the building’s systems or functionality and may also impact the user’s performance or productivity. Where this is the case, the resilience of the building can be compromised if its functionality has been curtailed through poor decisions relating to project costs.

**Project Changes and Resilience**

Often refurbishment involves a modest redecoration or “a face-lift” and makes little or no impact on the fabric or services of the building. However many refurbishments appear to be carried out with a specific goal, such as the transfer of patients to another area of a hospital, perhaps as part of a restructuring strategy. These transferred patients may require that specific services are provided, for example, ventilation systems, vacuum or medical gases and these must be included in their new temporary or permanent upgraded accommodation. Hospitals are continually carrying out such transfers or refurbishments, for example, to improve connectivities, to expand particular specialties or to further other specific goals. However, as seen in the introductory chapter to this thesis (Section 1.1.1), such refurbishments, if not carefully monitored can gradually impair fire containment or other systems, resulting in a significant reduction in a building’s resilience.

Refurbishments in the study hospitals were often undertaken to serve short-term goals and these “piecemeal” refurbishments tended to be uncoordinated and have little or no overall strategy that would guide or support the long-term improvement of the building. Newly installed systems (HVAC, mechanical ventilation, etc.) serving different sections of the building may be isolated and incompatible with other building systems, and designed to serve only a particular area. Although the resulting system diversity may in some instances add to resilience, the overall result is a hospital with systems that are overly complex, with limited system integration. Refurbishment and maintenance can become extremely challenging in older hospitals, due to the huge variety of component parts and the increasingly complex “tangle” of pipes and ducts, often with little in the way of system schematics to aid repairs or upgrades (Section 6.3.2 and 9.5.2).
Central areas of a building with good connectivity to critical services may be refurbished two or three times within a five year period, whilst other more peripheral areas may have only a cosmetic “face-lift” once in eight to twelve years. Some systems, such as electrical wiring, need to be tested regularly and replaced at set intervals (approximately 25-30 years), so upgrades should occur at least within this time-frame. Some partial refurbishments, if poorly planned, can “lock-in” specific functions, which reduces flexibility and can complicate access or way-finding (Section 7.3). Imaging suites, for example, usually require specific foundations and once placed, are rarely moved. Consequently any future hospital configuration planning can be affected by such constraints. Indeed the placement of long-term buildings or extensions, if poorly considered, can affect the development of a hospital site for many years, severely affecting its planning, access or infrastructure (Sections 2.8.4 and 7.3) and thus impacting its resilience.

**Hospital refurbishment and holistic building resilience**

It is important to appreciate that resilience is a concept, not a physical state, hence it is not a parameter that can be physically measured. In practice, resilience can be confused with the process of developing robustness to particular events or threats, where measures are designed to prevent or mitigate a known or likely event. However, this does not necessarily result in resilience. The resilience of hospital buildings depends heavily on the ability of building managers to plan ahead for building changes and make appropriate choices when change is required, so as to ensure that the hospital as a whole benefits from the changes (for example, Section 5.3.1). Refurbishment on its own does not appear to improve hospital resilience.

Concepts such as *robustness* and *reliability* differ from resilience in that they are concerned with maintaining the status quo in the event of known, probable or manageable threats. Consequently organisations may be robust to a range of envisaged threats and yet still be severely affected by unlikely events (or combinations of events) that have not previously occurred or even been considered.
Changes to connected systems, refurbishment projects and project resilience

Well-designed “whole building” refurbishments to hospital buildings generally ensure that the building’s systems and functionality are upgraded and this process is designed to improve the overall building resilience. Partial refurbishments, when carried out as part of an ongoing programme, are also intended to contribute to the overall improvement of the building and its resilience.

However, only one of the case study hospitals appeared to espouse this holistic approach. Most refurbishments, like the Case Study 1 refurbishment, focused directly on the work needed to enable the refurbished space to function, with little consideration for the remainder of the building. Where replacements or repair work was needed to systems that also served the remainder of the building, only the most essential work to the system was carried out. Even the very long term refurbishment process in Case Study 4 was designed as part of a strategy to consolidate a department, and largely overlooked the possibility of improving other deteriorating aspects of the building at the same time.

Problems are likely to arise when a building’s life is extended for much longer than originally intended. This is not an unusual situation. In this research, two out of four of the case study buildings had been in use for considerably longer than planned (Sections 5.2 and 5.3), and this was the case for many of the other buildings in the case study Trusts’ portfolios. In such cases, systems that gradually become fragile over time, will have a significantly increased risk of service failure.

Resilience of the NHS Estates organisation

Clinical priorities take clear precedence in hospital decision making, and maintenance and necessary life-cycle refurbishment projects tend to be very low on the priority list. Indeed the built environment that houses, connects and supports all aspects of clinical care is rarely represented on Trust boards. This has contributed to hospital estates being starved of maintenance funding in many Trusts and hospital buildings appear to have suffered in consequence. In practice, estates managers allocate funding to meet
compliance issues, and new projects can only be considered if funding remains Sections 7.5 and 9.2.4).

10.2.4 Can partial hospital refurbishments compromise the resilience of NHS hospital buildings over the long term?

Hospital buildings, along with their management, essentially act together as a socio-technical system and the critical systems within a hospital building must contribute to the resilience of the whole. If an unexpected failure or serious external event should arise, alternative options should be available and management must have accurate knowledge of system operations and resources to respond appropriately.

The findings of this thesis suggest that in two of the case study Trusts, critical systems in specific hospital buildings were “brittle” or had only limited back-up (Section 9.4.2). In the event of a failure, it is likely that these hospitals would be placed under considerable pressure. Further, each of the case study Trusts had buildings with one or more serious challenges, such as aging environmental systems, (Case Studies 1 and 4), unresolved high risk maintenance (all case studies), inadequate/inefficient infrastructure (Case Study 1 and 2), inflexible spaces (all case studies), or structural issues (Case Study 4). Some of these issues had been addressed as they were identified but others, due to the lower level of risk, the high cost, or the propensity to cause disruption, may have been deferred pending an appropriate opportunity or sufficient funding. NHS Trusts are required to identify their risks within their asset registers, but there is little in the way of oversight to ensure that these risks are comprehensively assessed or that registers are accurately updated, even though this is a legislative requirement (Regulation 3, of the Management of Health and Safety at Work Regulations 1999)

Refurbishment Decision Making

The case study estates managers were in agreement that many of their predecessor’s refurbishment decisions have proved to be sub-optimal. Sub-optimal decisions can result from pressures related to the urgency or level of risk associated with a project,
the availability of time-limited funding, or the power politics within the Trust, etc. In particular, estates managers considered that they have often lacked the evidence with which to make more appropriate choices, or the necessary resources. Such concerns are critical since, for example, the inappropriate siting of an extension can interfere with long-term hospital campus plans (Section 2.8.4).

In some cases poor choices can be ameliorated or even eliminated by competent remedial action supported by a well-developed long-term planning process (Section 7.3). However, managers find it difficult to prioritise long-term plans when urgent high-level pressure directs their attention elsewhere. It is also the case that even well planned refurbishments may become ineffective within a very short period if they fail to include sufficient flexibility (Case Study 2, Section 9.2.5). Such flexibility or “loose fit” is essential to manage unexpected events that call for changes, which is a relatively common occurrence in an NHS hospital. The resulting loss of efficiency and flexibility depletes resilience, in the long term making it difficult for an NHS Trust to respond to changing needs or new funding opportunities.

“Piecemeal” refurbishment

Piecemeal refurbishments can result in inequalities in care for patients – some patients receive “cutting-edge” care with innovative systems and equipment in refurbished accommodation, whereas others in lower priority wards must be content with less advanced treatment (the Case Study 1 Neo-Natal Unit and the Case Study 4 Cancer Ward). Periodic or “piecemeal” refurbishments may also be a major contributor to the loss of a building’s resilience, through the gradual erosion of existing systems (such as the fire-control systems failure highlighted in Chapter 1, (Section 1.1.1) or by the increasing complexity service systems as described in Chapter 9.

However, if refurbishments could be focussed towards always maintaining or improving the whole building’s systems, as the opportunity arises, building resilience may be significantly improved over the long term. Hence piecemeal refurbishment as it is now undertaken,
• can result in increased system complexity, with proliferating pipework etc (9.5.2)
• or results in poor system integration (5.2.6)
• can impede connectivity and disrupt natural ventilation etc.
• ignores or misses opportunities to reduce costs
• complicate wayfinding
• compromises building resilience.

10.3 Key Contributions

This research has reviewed the literature to identify the factors that contributed to, or promoted, resilience and analysed those systems or organisations that demonstrated resilience, and those that did not (Holling 1973; Dekker, 2011; Hollnagel et al., 2011). Through the case study analysis, this research has disentangled the interconnected motives, events or consequences that affected the progress of the NHS refurbishment projects studied, and considered the implications for NHS hospital resilience. In particular the thesis has provided the following key contributions:

• Development of a framework to map the trajectories of project changes across NHS and linked contracting organisations (see Chapter 6, the Change Propagation Framework Model)
• The identification of the mechanisms of change in refurbishment projects (see Section 6.3 and Chapter 8)
• The development of a vocabulary to aid in understanding change issues in refurbishment projects. (see Section 6.3)
• Articulating the role of refurbishment in supporting the resilience of hospital buildings (see Chapter 9)
• Suggestions towards developing the resilience of Hospital buildings (see Section 9.3)
10.4 Limitations of the Work

Limited “buy in” from two of the case study Trusts meant that the access to refurbishment project staff and data was somewhat less than hoped for from these partners. A further case study would help in confirming the explanations of mechanisms found in the original four case studies, or in identifying alternative explanations for the processes and mechanisms observed.

10.5 Conclusions

Many hospital refurbishments have been well planned and carefully executed, but in almost all cases there will have been an emergent issue that caused some level of disruption to the schedule, even if it were relatively minor. However, some projects, according to one interviewed manager, have been either hasty, inappropriate or particularly costly. “Rushed” projects have been undertaken in pursuit of specific short term goals e.g., as part of funding bid, that may, or may not have materialised; or as an intermediate step in a series of planned moves (Section 9.2.5). Occasionally, a refurbishment has been proposed as a reactive solution to a temporary problem, with only limited consideration for the future needs of the building (Section 9.5.1). The NHS has had many projects that have been late in delivery, thus having the potential to constrain local, or hospital-wide functionality and creating problems for contractors in scheduling their future work. What is particularly troubling is that project managers are often in the position where they must choose between either exceeding their budget, or losing desired objectives. Financial pressures often require managers to opt for the latter course (Section 2.8.5).

The consequent scaling down of aspirations can lead to considerable disappointment for both staff, patients and other stakeholders (Case Study 1 Neo-Natal Unit interior design). In this thesis, the review of the literature identified that project change is also considered to be a major factor in the cost escalation and delay of construction/refurbishment projects (notably Sun et al., 2006). Consequently, understanding the causes and mechanisms of change is an essential step towards preserving the integrity of a project, by pre-empting the need for change, or through
limiting its effects. Hence, an understanding of the change process in refurbishment contributes to the overall resilience of the project. In addition, where a project adopts a holistic building perspective, this should also contribute to the resilience of the building being refurbished.

10.6 Further Work: Create Tools and Make Recommendations for the NHS

The focus of this thesis has been an analysis of the problem of the refurbishment and resilience in the NHS, rather than developing detailed measures to address it. Based on the findings of this research, the following areas are worth considering for future work.

Further Analysis on Resilience Barriers

In the analysis of resilience a number of potential avenues for further investigation suggested themselves but would have required further interviews, such as exploring the apparently cross-purpose priorities that cascade downwards from the DoH and from NHS England. For example, how significant financial savings can be achieved, whilst a range of other priorities must continue to be met such as legislative compliance, maintenance backlog mitigation, sustainability targets met etc.

Change Impact Prediction

To minimize the impact of change, it would help if the mechanisms involved in making changes could be identified and studied to appreciate how patterns of change develop across a refurbishment project. The “blossoms” and “ripples” of change suggested by Eckert et al (2004) have been used to identify where changes in engineering projects have escalated “out of hand” or have been successfully contained. This perspective on change has not yet been considered to any great extent in the construction literature but has been found helpful in product engineering applications. Hence, this analysis process may be appropriate to construction/estates professionals in embedding learning from their projects and contributing to the post-project review process (Section 4.4.1).
Refurbishment and Hospital Resilience

Due to the high cost, and the embodied energy invested in hospital buildings, it makes economic sense that they remain clinically functional for as long as possible. Accordingly, refurbishment projects must deliver increased spatial flexibility, appropriate design for the changing climate, and should support whole building resilience. Project process efficiencies, including absorbers to reduce change propagation, can help maintain key objectives whilst reducing costs. However it is not yet clear at which stages of a project absorbers should be included, and what absorbers would be most effective (Sections 2.10.3, 6.6, 9.3.2 and 10.2.1).

Planning for Resilience: Modular vs Traditional Construction

Decision-makers must consider whether it might be better to plan for a much shorter design life for hospital extensions by using modular factory-built structures. The resulting hospitals might predictably be more efficient, with improved infection control, providing a better fit with changing hospital needs. Limited life buildings can accommodate the latest technology and such buildings can be constructed rapidly to meet emerging needs, allowing a more focused provision of services. There are however considerable downsides to such a policy. Modular buildings frequently have lower levels of flexibility due to their form of construction, and these buildings can be hard to live with, as they can be difficult or impossible to modify. Even simple operations like putting up a shelf or adding an extra doorway can be problematic, owing to their structural limitations. In addition, although they are quicker to build, they are no less expensive than existing hospital construction, and they will need complete replacement at much shorter intervals (generally 10-60 years) compared with traditionally built structures (60-200+ years).

Adapting NHS Hospitals to the Changing Climate

Estate managers are asked to ensure that their buildings are future-proof and resilient as far as practicable, but typically they are barely managing today’s imperative demands
and have few resources available for non-urgent needs. Against a background of goals, targets and uncertainty, they are tasked with improving both the sustainability and resilience of their decaying buildings, generally without the necessary resources. England’s hospitals are already too hot, and the changing climate will exacerbate this problem, so that estates managers will have to provide low energy solutions to avoid compromising their carbon reduction achievements. As changes to hospital estates take considerable time, it will be too late to adapt buildings when the problem becomes critical. However, even where sustainability goals are strongly prioritised during the project development process, the resulting sustainable objectives may still be fragile and easily displaced by items of greater constructional or operational significance. Changes in client priorities, or changes resulting from other imperatives during the project, may result in a requirement to abandon aspirations for the more expensive sustainable systems for the project, and a consequent reduction in overall sustainability and resilience in the refurbished building.

It is possible that such downgrading of objectives may, to some extent, be countered by change pathway management and by careful spotlighting of sustainable objectives during the course of the project. AEDET evaluation may ensure that specific sustainable measures are included during the briefing process but this does not necessarily mean that the contractors or other stakeholders are fully committed to sustainable priorities. Hence when immediate or “on the spot” decisions must be made, it is essential that contractors and clients share a common understanding, or coveted adaptation goals may be lost.

Trust management must appreciate the long-term investment that their buildings represent, and similarly plan patient care over the long-term: recognising the complex web of influences that underlie both the demand for care, the care process, and the care setting. Management must be cognizant of the constraints that limit the options for adaptation and factor this into the long-term planning process. This would help in highlighting significant relationships between departments and key services within the care environment. Changes to hospitals have the potential to disrupt these essential relationships. Indeed, connectivity issues may become even more important over the
long term, as advanced care models become increasingly dependent on technological support. Even small disruptions to very connected systems may affect patient safety.

The NHS and Contractor Interface

Refurbishment in hospitals can be a complex and demanding adaptation process for hospital staff. The interface where brittle or tightly coupled healthcare systems interact with construction processes is an area of high risk. Even small changes to health care routines can result in serious consequences, as strict protocols and practices come under pressure to meet changing requirements. Fortunately, construction contractors tend to be loosely coupled and work in small relatively independent units that can make decisions and adapt. Hence the flexibility available within construction systems may act to release some of this pressure and reduce risk. Contractors frequently appear to develop innovative solutions to difficult problems, or they moderate their systems to “ease” the refurbishment process along. However where communication is limited, it can be difficult for contractors to determine exactly where the critical problem areas might lie. Contractors appear to employ considerable creativity in solving or ameliorating likely problems, but at present, they largely absorb the associated costs or delays (Sections 8.3, 8.4, 9.3.3). Research directed at exploring this interface might provide an opportunity for improved communication between contractors, hospital clients and stakeholders, and reduce the possibility of surprise and delay to projects. The ability to mitigate construction project risks may reduce the need for changes and limit the resulting propagation.

It is possible that certain stages of a project are more prone to change and hence, are more prone to risk of serious propagation. If this is the case, further research may be appropriate, targeted towards recognising the points at which change absorbers or modifiers would best be deployed. In addition, exploration of those mechanisms that act to support project objectives and absorb or minimize the effects of change would be very useful. The prediction of risk and the nature of constraints could also be usefully considered. This would help to inform the development of change prediction tools for construction projects that can exploit the pliable nature of construction change. Emergent issues may also benefit from analysis to highlight predisposing factors or
limiting conditions. Further work will consider the effects of constraints on the change process and how, by varying or reframing the constraints, the probability of serious propagation may be reduced.

A regularly updated register of the challenges that can arise might help to inform the briefing process and can pre-empt some of the most likely obstacles. Research could focus towards how best this could be accomplished and how it could be integrated within the project change tool. This could include actions that support the key goals, such as incorporating change absorbers etc. In addition the identification of absorbers or modifiers, associated with exemplars of good practice, could safeguard desired project outcomes. Further, a tool to support stakeholders in identifying their needs may also be valuable during the earliest stages of the refurbishment process and can help to focus attention towards the key goals and make sure they are prioritised at each stage of the project.

**Opportunity for Improvement or Resilience Opportunity**

Refurbishment projects provide real opportunity to improve systems and increase whole building value through synergies with the existing building, for example where equipment, scaffolding, or access to systems that are buried in walls, floors or ceilings, can be shared (as discussed in Section 9.2.3). This could significantly reduce maintenance or system replacement costs in the long term.

Where real benefits from a project change can be envisaged, such as significant improvements to work flow or efficiency; improvements to safety; or opportunities to improve the resilience of the building, then scope enhancement might be viewed as a resilience opportunity (RO). Such opportunities may arise as a result of an emergent building/services problem such as the failing cold-water system in Case Study 1, that led to a significantly improved water system, (Sections 6.3.2 and 10.2.2.). Consequently “Scope expansion or creep” can be considered as:

- A “resilience opportunity” to improve physical, environmental, technical and operational systems, and to increase whole building value through synergies
with refurbishment projects; access, expertise, options for, or use of equipment, scaffolding etc., (see Section 9.3.)

- An opportunity to improve post-project efficiency and resilience (Section 9.5.2)
- An opportunity to significantly reduce future refurbishment/maintenance costs (Section 9.4).
References


NHS choices (2013). *About the National Health Service*. 
http://www.nhs.uk/NHSengland/thenhs/about/Pages/overview.aspx (accessed 18/03/2016).

http://www.nhsconfed.org/resources/key-statistics-on-the-nhs (accessed 03/05/2016).


http://www.preventionweb.net/files/13954_reviewoflondonhospitalfires1.pdf


https://www.ucisa.ac.uk/~media/groups/pg/events/2009/framework_agreements%20guide%20OFC%20pdf (downloaded 15/05/2013).


http://www.ons.gov.uk/ons/index.html (accessed 08/03/2016)


