A Refurbishment Framework with an Emphasis on Energy Consumption of Existing Healthcare Facilities

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Loughborough University

CERTIFICATE OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this thesis, that the original work is my own except as specified in acknowledgments or in footnotes, and that neither the thesis nor the original work contained therein has been submitted to this or any other institution for a degree.

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ABSTRACT

The healthcare sector is mainly characterised by changing technologies, increasing market demands, social pressures, and political pressures. A significant amount of money has been invested by the Department of Health through the National Health Services (NHS), Private Finance Initiative (PFI), and Local Improvement Finance Trust (LIFT) to provide healthcare services. This has resulted in development of several new healthcare facilities. Since formation of the NHS in the mid 19th century, significant developments in medical technologies, and increasing health and safety and privacy related concerns almost every decade new approaches towards designing were observed. Thus, modern technologies (interoperable tools) and concepts such as Building Information Modelling (BIM), building simulation, healthy/sustainable facilities, healing environments and so forth have been incorporated and proved to be major catalysts for a change in overall design practices for healthcare. Despite significant investment and advancement in technologies, many existing healthcare facilities, even today remain significantly unimproved or inadequate when energy and overall performance is considered. It is, therefore, important to evaluate existing facilities and, consequently, refurbishment processes and tools for the same. This was the focus of this research.

Recently, energy efficiency and carbon emissions are considered major issues by industry and government because of increasing importance of environment and issues related to global warming, climate change. In 2008, existing healthcare facilities were responsible for over £410 million worth of energy consumption and 3.7 million tonnes of CO_2 emissions. Considering the above mentioned issues, the government has imposed following two key targets especially for existing healthcare facilities; to achieve 55-65 GJ/100m^3 energy consumption and to reduce the level of primary energy consumption by 15 per cent (0.15 million tonnes carbon from 2000 level) by 2015. Also, the literatures suggest these facilities are energy inefficient because their performance is unsatisfactory and they fail to provide comfortable environment for patients despite significant energy consumption. Thus, these facilities should be considered for refurbishment. Recent developments in the construction sector such as BIM based tools or tools that are interoperable can help the project team involved during a refurbishment of a healthcare facility to take decisions and maintain acceptable environmental quality during and post refurbishment. However, there are many ideas and methodologies proposed for development of new healthcare facilities, but the challenges in using these methodologies, such as BIM, energy simulation for refurbishment of existing healthcare facilities and above mentioned targets provided a base and context for this research.

The research used both primary and secondary data collection techniques, such as literature review, case studies and a questionnaire survey. The later phases of the research highlighted a clear need for immediate actions on existing healthcare facilities, if government targets related to energy consumption and overall performance are to be achieved. Thus, redevelopment of existing healthcare facilities to support the 21st century (modern) technologies to reduce environmental impacts and improved users' satisfaction was considered as priority areas. One of the key challenges for existing healthcare facilities is the presence of occupants during refurbishment in adjacent spaces, which may not be a problem for other types of existing buildings; there is also a lack of information on existing healthcare buildings.

The research findings revealed that refurbishment lacks broad perspective, for example, issues related to mechanical systems, aesthetic considerations and redesigning facilities have never been given a sufficient importance. A Healthcare Energy and Refurbishment (HEaR) framework and decision making process was developed as part of this research to enable healthcare organisations to adopt modern methods for re-designing of existing facilities, and to exploit refurbishment practices with consideration to energy consumption. The framework was validated by demonstrating it to professionals; experts from the industry.

Keywords: *Building Information Modelling, energy, existing healthcare facility, framework, refurbishment.*

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ACRONYMS AND ABBREVIATIONS

ACHA	American School of Healthcare Architects
ADB	Activity Data Base
A+DS	Architecture + Design Scotland
AEC	Architecture Engineering Construction
AEDET	Achieving Excellence Design Evaluation Toolkit
A&E	Accident and Emergency
ASHE	American Society for Healthcare Engineering
ASHRAE	American Society of Heating, Refrigeration, & Air-conditioning Engineers
ASPECT	a Staff and Patient Environment Calibration Tool
BEES	Building for Environment and Economic Sustainability
BEMS	Building Energy Management System
BI	Building Information
BIM	Building Information Modelling
BMC	Blake Medical Centre
BPS	Building Performance Simulation
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
BRITA	Bringing Retrofit Innovation to the Application
BSM	Building Simulation Modelling
CAD	Computer Aided Drawing
CAII	Cost Analysis of Inadequate Interoperability
CDM	Construction Design and Management
CEN	European Committee for Standardisation
CHP	combined heat and power
CMS	Common Minimum Standards
CO_2	Carbon dioxide
CRC	Carbon Reduction Commitment
CRS	Carbon Reduction Strategy
CSB	case studies from book
CSL	live case studies
CSW	case studies from website
DBWG	Design Brief Working Group
DD	Desk Based Development
DIAG	Directive Implementation Advisory Group
DoE	Department of Energy
DoH	Department of Health
DTM	Dynamic thermal modelling
EB	Existing Buildings
EBD	Evidence-based Design

EC	Energy Consumption
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPIQR	Energy Performance, Indoor air Quality, Retrofit
EPSRC	Engineering and Physical Sciences Research Council
FM	Forward Modelling
GBC	Green Building Council
GBCA	Green Building Council Australia
gbXML	green building Extensible Markup Language
GDP	gross domestic product
GGHC	Green Guide for Health Care
GHG	greenhouse gas
GJ	gigajoule
GP	General Practitioner
GSA	General Services Administration
HaCIRIC	Health and Care Infrastructure Research and Innovation Centre
HBN	Health Building Notes
HEaR	Healthcare Energy and Refurbishment
HPH	Health Promoting Hospitals
HTM	Health Technical Memorandum
HVAC	Heating Ventilation Air Conditioning
IAI	International Alliance for Interoperability
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IES	Integrated Environmental Solution
IFC	Industry Foundation Classes
IG	Integrated Group
IPD	Integrated Project Delivery
ISA	Integrated Sustainability Assessment
KPA	Keep Performance Indicator
kWh	kilowatt-hour
LCA	Life–cycle Assessment
LEED	Leadership in Energy and Environmental Design
LIFT	Local Improvement Finance Trust
LR	Literature Review
M&S	Modelling and Simulation
MEP	Mechanical Electrical Plumbing
MHRA	Medicines and Healthcare products Regulatory Agency
MtC	Million tonnes Carbon
$MtCO_2e$	Metric Tonne Carbon Dioxide Equivalent
MtDG	Maintenance to Demolition Group
NAO	National Audit Office
NC	new construction
NCM	National Calculation Method

NEP	Nottinghamshire Energy Partnership
NHS	National Health Services
NHSBSA	NHS Business Services Authority
NEAT	NHS Environmental and Assessment Test
NIBS	National Institute of Building Sciences
OEG	Operational Energy Group
OFEE	Office of the Federal Environmental Executive
OFM	Operational Facilities Manager
OGC	Office of Government Commerce
PA	Positional Analysis
PAG	Positive Action Group
PASA	Purchasing and Supply Agency
PCE	Post-construction Evaluation
P&CG	Production & Construction Group
PCT	Primary Care Trust
PFI	Private Finance Initiative
POE	Post-occupancy Evaluation
PPP	Public Private Partnership
PNH	Piedmont Newnan Hospital
PuBs	Public Buildings
PVC	Polyvinyl chloride
QS	Questionnaire Analysis
QSA	Questionnaire Survey Analysis
RFI	Request for Information
RIBA	Royal Institute of British Architects
SBD	Sustainable Building Design
SBEM	Simplified Building Energy Model
SDAP	Sustainable Development Action Plan
SDM	Sustainable Development Manager
SDU	Sustainable Development Unit
SHA	Strategic Health Authority
SIA	Sustainability Impact Assessment
SPeAR	Sustainable Project Appraisal Routine
SOGE	Sustainable Operations of the Governments Estate
SUI	System Under Investigation
USGBC	United States Green Building Council
VB	Virtual Building
VE	Virtual Environment
VFD	Variable Frequency Drivers
WHO	World Health Organisation

CHAPTER ONE. INTRODUCTION TO THE RESEARCH

1.1 Introduction

The healthcare sector is broad and complex. Its operation and management is a major issue in the UK, as it is for other countries. The reason for this is the number and scale of healthcare facilities, and their environmental impact due to (significant) energy consumption, thus significant carbon footprint. All the above mentioned points have been important motivations for this research. This chapter introduces the research background, questions, aim, objectives, justification, scope, and the structure of the thesis. The need for a research on existing healthcare facilities is also discussed.

1.2 Research context

In the UK, the National Health Services (NHS) trust was formed on July, 5th 1948, (Perry, 2007) as part of the Department of Health (DoH) to provide healthcare related services with a primary aim "*good healthcare should be available to all, regardless of wealth*" (NHS, 2009). In the late 20th century, the NHS started major restructuring of all the services, which is continuing to date. Also, until the mid 1990s, before commencement of Private Finance Initiative (PFI), Public Private Partnership (PPP) and Local Improvement Finance Trust (LIFT), the NHS was principally responsible for investment into the healthcare sector. However, its re-structuring and certain strategies resulted in poor levels of investment in its existing buildings. In 2005, it was estimated that there was a backlog in maintenance worth £3.5 billion. In the same year, the £115 billion estimated budget of the NHS, just 20 per cent was related to estates (Perry, 2007); the reminder divided between Acute Care, Ambulatory Care, Mental Care and Primary Care services.

The DoH have developed and initiated many policies, guidelines and standards (see Chapter Two and Appendix B for details) to achieve the NHS's aim. However, changes in the construction industry and innovation in medical science has resulted in changing demands from healthcare facilities. Most healthcare premises operate round-the-clock and comprise of several buildings types with varied characteristics similar to other building types (for example, hotels, houses, warehouses, factories); in addition it consumes a significant amount of energy compared to other sectors (PAHO, 2000, Sheth *et al.*, 2008). Moreover, various researchers and studies (Sheth *et al.*, 2008, Bristol, 2007, Bizzarri and Morini, 2006) reported that healthcare facilities are responsible for more energy consumption than other building types and need to be considered urgently for refurbishment with a key consideration to energy. Various researchers (for example, Dascalaki *et al.*, 2009, Dascalaki *et al.*, 2008, Balaras *et al.*, 2007, Vittori, 2002) have reported indoor environment quality (IEQ) as an area for concern and responsible for a significant impact on the well-being of occupants and users in healthcare buildings. Also, the USA Environmental Protection Agency (EPA) has reported IEQ in healthcare facilities as a major risk in the USA. Most of the UK's NHS facilities were built in the 20^{th} century and, thus need to be modernised to support current (the 21^{st} century) standards, user demands, industry demands and minimise their impact on environment.

A study by Perry (2007) related to facilities for primary care shows that only 40 per cent of premises are purpose-built and 80 per cent of them are below the recommended size. Also, it is reported that 60 per cent of all the buildings which will be standing in 2050 are already constructed (Carbon Trust, 2008); thus a need to focus on existing facilities. Hancock (1999) and Gann and Whyte (2003) argued that until recently, the hospital industry has ignored the built environment and its impact on health; the hospitals were understood as – "*facilities (only) associated with wellness*".

It is reported that existing healthcare facilities in the UK consume a significant amount of energy generated mostly by burning fossil fuels. Burning of fossil fuels leads to indirect effects, accumulates greenhouse gas (GHG) and carbon dioxide into the global atmosphere resulting in total 21.21 $MtCO_2e$ in 2007 (NHS SDU, 2010). The UK government has agreed to develop and implement strategies to reduce carbon emissions by at least 34 per cent by 2020 compared with 2005 levels (Webb, 2010). In England, a set of mandatory targets on energy consumption and carbon emissions for healthcare facilities have been set as mentioned below (Perry, 2007):

- to achieve a target of 35-55 GJ/100 m^3 energy efficiency performance in new healthcare estates and major redevelopments or refurbishments;
- a target of 55-65 GJ/100 m^3 energy consumption in existing facilities; and
- to reduce the level of primary energy consumption by 15 per cent or 0.15 million tonnes carbon (MtC) from 2000 to 2010.

Until recently, it was reported that only one PFI project, the Cumberland Infirmary at Carlisle had achieved these targets (Perry, 2007), but huge number of healthcare facilities exist in the UK; currently, there are more than 1200 hospitals, 3000 GP practices and several other proposed and under development facilities (Perry, 2007). In April 2002, the NHS in England had 300 Hospital trusts, 300 Primary Care Trusts (PCT) and 28 Strategic Health Authorities (SHAs), so there is an urgent need to address the problem of existing healthcare facilities.

1.3 Research sponsor

This research was undertaken as a sub-project of the work undergoing as part of the HaCIRIC Research Group *'Theme Three: Innovation in Facility Design and Construction Processes'* at Loughborough University. The group is funded by the Engineering and Physical Sciences Research Council (EPSRC) and the collaboration between existing research centres at Imperial College London and the Universities of Loughborough, Reading and Salford with the following four key objectives (HaCIRIC, 2010):

1. to shift care between different settings, often closer to home;
2. to use technological and physical infrastructure creatively to support that change;
3. to develop new organisational and funding models to make that infrastructure work; and
4. to generate clear evidence showing what really works and how it can be embedded.

1.4 Research problem

The purpose of this study was to explore buildings refurbishment in the healthcare sector. The research started with the question '*how does refurbishment benefits the healthcare sector and its users?'* This inquiry led towards a deeper understanding of the refurbishment, healthcare sector and construction to formulate the research aim and seven attendant objectives presented in the next section. The study was oriented towards investigating energy efficiency and performance of existing buildings, which can be addressed through refurbishment projects.

One of the major concerns for refurbishment in healthcare facilities compared to other types of facilities is healthcare premises host numerous buildings with various conditions and often, construction occur adjacent to occupied buildings. Also, most of the NHS facilities from the 19th and 20th century have evolved into campuses due to increasing demand and expansion projects. Most functions within (the NHS) healthcare facilities are interdependent, and it is difficult to isolate any part of the facilities to perform refurbishment. This imposes additional challenges with refurbishment, which may not be the case with other types of facilities. Moreover, ill people occupy these buildings most of the time compared to facilities from other sectors. Characteristics of (NHS) healthcare facilities are explained also in Section 3.2, which represent additional challenges associated with refurbishment of these facilities.

1.5 Aim and objectives

Aim

The aim of this research is "*to develop a framework that supports and facilitates refurbishment of existing healthcare facilities with an emphasis on improving their energy consumption and overall performance*".

Objectives

To accomplish the above aim the following objectives were formulated, to:

1. explore the healthcare sector and existing facilities in regards to sustainable development;
2. examine refurbishment trends for healthcare facilities with the help of primary and secondary data collection;
3. review quantitative tools used for modelling and simulation of buildings and, to facilitate their integration during refurbishment;
4. review qualitative tools, such as LEED, BREEAM, etc., used in the industry to analyse performance of buildings and their applicability to existing facilities;

5. identify drivers related to existing buildings, refurbishment and energy consumption in the healthcare sector through investigation;
6. develop a framework to support refurbishment of existing healthcare facilities and identify the components for management and design team to be included within the framework; and
7. evaluate, validate and enhance the framework through interviews with experts from industry.

As part of this research, various methods were used to collect data, such as interviews and site visits. The rationale behind conducting primary data collection are, to: explore current trends; verify the outcomes of the literature review; collect data from the key sources; avoid duplication of work; and link the academic research with industry.

1.6 Research questions

A set of research questions use throughout this project have been discussed below. These were used to assess the applicability of current trends and to develop a new framework to minimise energy consumption and carbon emissions through refurbishment of existing healthcare facilities.

1.6.1 Refurbishment of existing healthcare facilities

Jochelson (2003) stated, the NHS owns land equivalent to size of 64 Hyde Parks (a 350 acre park situated in London) and has a floor space equivalent to 140 Canary Wharfs (a huge modern commercial development in London). There is also evidence of increased hospital-acquired infection cases and errors committed by healthcare professionals in the literature. These issues lead to the first research question.

Research Question 01. *How are existing facilities considered in the healthcare sector?*

- Is equal importance given to the new facilities and existing facilities?
- What are the current refurbishment trends in existing buildings?
- Why are existing facilities important?

1.6.2 Energy consumption and carbon emissions in healthcare facilities

There is a constant pressure from the government and respected authorities to reduce energy consumption in the NHS facilities. Moreover, a need to consider existing NHS building stocks to minimise 82.9 pJ of primary energy consumption, costing more than £400 million per annum is reported (Perry, 2007). Also, a pressure on all existing facilities to reduce their energy consumption to a level of 55-65 GJ/100 m^3 is reported.

Nevertheless, not only the UK but also worldwide most countries are facing problems such as non-renewable energy, oil crises, global warming because of increasing demand for energy. Throughout the world, significant amount of healthcare facilities have been constructed and they are responsible for significant amount of energy consumption. Also, often healthcare facilities are in the list of most energy intensive buildings.

Considering patient, staff and visitor safety, energy consumption, and quality in an existing facility lead to the first part of a second research question.

Research Question 02.A. *How is energy considered during refurbishment?*

- How can we satisfy the principles of energy refurbishment?
- How to provide a good working, healthy environment?
- What methods or approaches are used to reduce post-refurbishment energy consumption through refurbishment?

Ren *et al.* (2007) highlighted that carbon emissions need to be considered beyond a minimum specified limit in building regulations '*Part L*' (see Section 2.3 for more details). Considering the NHS's massive carbon footprint (543.7 million tonnes a year) and issues such as indoor and outdoor built environmental quality, their impact on the users, etc., leads this research to formulate the second part of this research question.

Research Question 02.B. *Do current practices and approaches consider carbon emissions during refurbishment?*

- Is it during all types of refurbishment?
- If yes, then up to what level?
- What methods are used to address this issue?

1.6.3 Modern methods for refurbishment

Energy consumption and carbon emissions are priority areas, and there are many new tools, methodologies available to tackle the same. These tools and methodologies can help to predict a level of energy consumption and carbon emissions during a proposal development and design stage of a refurbishment project. This helps to assess the strengths of the refurbishment proposal from energy consumption and carbon emissions point of view even before the execution stage, which leads to a third research question.

Research Question 03. *What current energy and carbon assessment methodologies are used to develop healthcare facilities?*

- What current methodologies are applicable during refurbishment?
- What needs to be done, so that current methodologies can be used during refurbishment?
- Are any methodologies from other sectors applicable?

1.7 Significance of the research

The research is based on methodologies used for development of new facilities in the construction industry and healthcare sector. The project results will allow a reappraisal of the methods for energy refurbishment of existing healthcare facilities and can be used during a development of new healthcare facilities. Moreover, it is an approach that seeks to establish a competency framework for improved practices in refurbishment, renovation and/or extension of existing healthcare facilities. The procedure will allow goals, commitments and priorities areas set by the government and the DoH to be addressed more effectively in practice.

1.8 Scope of the research

The existing building stock owned by the NHS and its focus towards development of new healthcare facilities provides a good potential for (this) research related to existing healthcare facilities. Moreover, most existing healthcare facilities are energy inefficient and responsible for a significant amount of carbon emissions (Vittori, 2002, Adderley *et al.*, 1987). Nevertheless, newly constructed facilities in this and coming decades will need refurbishment in the future. Hence, the outcome of this research can be used now and in the future to improve the overall performance of healthcare facilities.

Within this scope, the thesis does not strive to develop technical solutions or an assessment tool for mechanical and electrical improvements related to energy performance and carbon emissions from the existing facilities. Rather, the physical aspect of architectural design is considered as a key focus, priority area to improve existing refurbishment processes. The research focus, contribution of the objectives and expected output are presented in Figure 1.1.

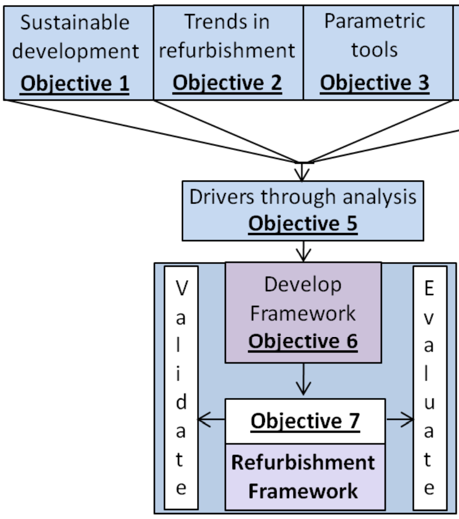

Figure 1.1. Research focus and data input

A very specific group of existing healthcare facilities are the focus for this research. Considering the fact that facilities in use now span from before the First World War to the current day, in this research the existing buildings under considerations are only those constructed after the 1980s. A justification for this is given in Chapter Six.

1.9 Research process

Figure 1.2 (presented in the remainder of this chapter) shows the steps taken in the research process for this project to accomplish its aim. It illustrates the relationship between the key research stages: i.e. introduction; literature reviews; methodologies; data collection and analysis approaches; research findings; development and validation of framework; and discussion, conclusions and recommendations.

1.10 Research contribution

In general, this research considers the specific practices that should be adopted during the refurbishment of existing healthcare facilities. The research provided a theoretical understanding of the problems related to refurbishment, especially in healthcare facilities. An approach for refurbishment based on theory and parametric modelling is suggested through this research. Most of the collected data is focused on the refurbishment of the NHS facilities because it operates and owns the huge stock of healthcare facilities. As much of the available research and work have focused on the construction of new healthcare facilities, this research fills an important gap by considering existing healthcare facilities.

1.11 Research output

This research presents a refurbishment process, the Healthcare Energy and Refurbishment (HEaR) framework, to support modern and improved practices within the healthcare construction industry through the following.

Improved integration between the various refurbishment processes by:

- promoting refurbishment with consideration to available standards;
- providing an unified approach for refurbishment process;
- providing a framework that details and clarifies various refurbishment stages; and
- developing a mechanism for co-ordinating and organising refurbishment processes.

Improved collaboration between the various participants involved in refurbishment projects:

- to support each party involved in the process by suggesting tools and support systems for them;
- to introduce intermediate processes which ensure the smooth running of the entire process; and
- by providing a framework that allows problems to be addressed.

Improved understanding of refurbishment practices:

- allowing the client and project team to visualise and understand refurbishment processes;

- expressing the phases, stages, activities, and ideas of processes required during refurbishment; and
- by providing a refurbishment process map to understand and inform the whole process.

Throughout this research, the outputs from the literature review, a conceptual framework, the framework components, and the research approach were presented in various publications, as shown in Appendix A. This helped with the intermediate validation of the research projects and sought experts' feedback (especially during the early phases of the research), which helped this research to progress further.

1.12 Overview of thesis

Chapter One introduces the main themes and justifies the rationale behind the work. Thesis aim and objectives are stated and a summary of the chapters is given together with a diagrammatic representation of the research and thesis structure (see Figure 1.2).

Chapter Two presents an extensive literature review on the sustainable development and healthcare sector, gained knowledge that defined the nature of the sustainability and the characteristics of the same. This chapter also provided early direction for the research.

Chapter Three is part of the literature review. The healthcare sector and refurbishment is characterised, discussed and is a key focus of this chapter. It highlighted various areas and practices in the healthcare sector. Possible solutions for the existing facilities from the literature are also discussed.

Chapter Four presents various national and international assessment tools, including parametric tools related to sustainability, energy and carbon emissions. This chapter provides an overall idea of the current situation in the healthcare sector. Ideas and initiatives taken by respective authorities are the key considerations of the chapter and, it also forms a part of literature review.

Chapter Five presents the philosophical position of this research. This chapter presents the ontological, epistemological and empirical consideration relevant to this research. Also, the importance of selecting an appropriate methodology for research is presented. The research design, theoretical considerations and research position are outlined. A range of research methods are reviewed and their strengths and weakness are highlighted. It describes the adopted methodologies used to accomplish the research aim and comprises two hypothetical sections. The first section reviewed fundamental concepts of qualitative, quantitative and mixed methods and the second provides details about the methodology used in this research project.

Chapter Six presents the findings and analysis of the case studies, a questionnaire survey, and other collected data. This chapter along with literature review provides most of the data required for the framework development. The collection of the empirical data as part of this research is also presented. Qualitative, quantitative as well as some comparative data has been discussed in this chapter.

Chapter Seven presents the development of the proposed framework to achieve the research aim and addresses possible problems from the literature. The need for a framework is justified in this chapter. It also validates the framework through interviews with professionals working on healthcare refurbishment projects. A summary of the research findings is also presented.

Chapter Eight presents a discussion in the light of the literature review, brings together the findings of the research and draws conclusions with specific reference to the research objectives. The chapter concluded by stating the limitations of this research, and providing recommendations for the healthcare sector and further research.

Appendices are presented in the remainder, which presents a material supporting this research. The interview schedules, sample questionnaire, the HEaR framework, user manual, etc., are provided in this section.

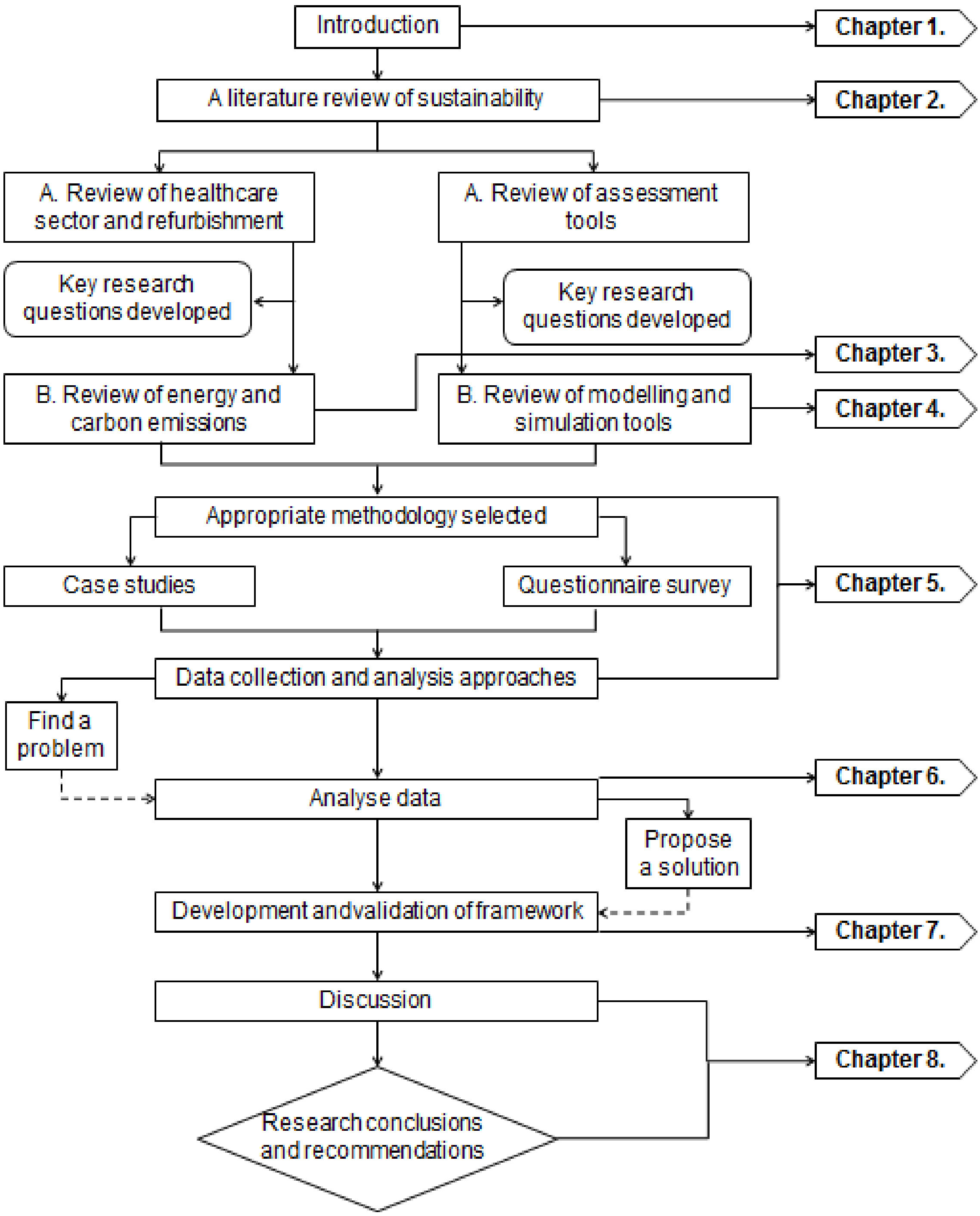

Figure 1.2. Research process flow chart

CHAPTER TWO. SUSTAINABLE DEVELOPMENT AND THE HEALTHCARE SECTOR

2.1 Introduction

Current concerns about natural resources, energy consumptions, increasing oil prices and other such factors affecting the global environment have put pressure on any development to be sustainable. At the same time, issues pertaining to global warming and carbon emissions make sustainability a priority area for concern. Thus, much attention is now devoted towards sustainable development; it is now an area of evolving research and a new dimension for the construction and healthcare sector. There are different opinions and definitions of sustainability because it is a multidimensional concept; a simple database search relating to sustainability presents a tremendous amount of literature gathered over the past few decades.

This chapter reviews previous work on sustainable development related to the construction industry, healthcare facilities and refurbishment of existing facilities. Although this is not an exhaustive review, it presents the nature and level of complexity associated with this research area. A set of questions, which guided the production of this chapter are listed below.

- What is sustainable development?
- What are the key considerations/themes to achieve sustainability within a (healthcare) project and an existing healthcare facility?
- How do we measure and account for sustainability?
- What is the relation between sustainability and healthcare sector?

2.2 Sustainable development

Sustainability is a fuzzy, vague term, and there are many opportunities for debates and disagreements (Adetunji, 2005, Pearce *et al.*, 1990): the widely used internationally accepted definition of sustainability proposed by Brutland (1987) is:

"*a development which meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

The last three decades have seen an increasing promotion of sustainability by researchers, experts and governments. For example, Short (2005) reported sustainability should be at the core of designing and development of healthcare facilities. Many other authors also concentrated on sustainable development, for example, Turrent (2007), Holtz (2005), Van der Flier and Thomsen (2005), Burgess *et al.* (2001). As a result, the substantial amount of literature and information has been generated with a few focussing on healthcare facilities (Hancock, 1999) and refurbishment (Sheth *et al.*, 2008).

2.2.1 Key issues and benefits

Holtz (2005) highlighted a need to create individual strategies to adopt sustainability within the process of designing a (healthcare) facility. A report by the Surgeon General in the USA on '*Healthy People*' in 1979 and re-confirmed in 1991 stated that inadequate healthcare facilities were responsible for 10 per cent of preventable disease (Hancock, 1999).

The literature indicated that stakeholders, managers, medical practitioners are not aware of the benefits of sustainability to the construction industry, especially to healthcare facilities. Also, the healthcare industry is largely uninformed about the explicit benefits of sustainable building strategies to human health (Frumkin, 2007). Construction cost, operational cost and a complexity level in healthcare facilities tend to be high and people responsible for making decisions assume sustainability means an increase in cost and complexity (Hancock, 1999). However, the main annual operating cost in any type of a healthcare facility is employees' salaries, which can be up to 90 per cent of the total operating cost. Thus, incorporating sustainability can help to improve productivity, well-being, satisfaction and retention of employees, resulting in greater economic benefits.

A study of green buildings by Turrent (2007) reported improved energy performance and savings in operational cost as common benefits of incorporating sustainability while designing buildings. Vivian *et al.* (2006) suggested that sustainability should be considered with a broader perspective and not merely limited to energy, water and material resources. Holtz (2005) argued that sustainability is not a part of the operation phase (building life-cycle) due to various reasons, for example, design team does not inform a facility manager about their assumptions/considerations related to sustainability.

2.2.2 Indoor environment quality

Roulet (2001) studied the environments inside the buildings and impact of the indoor environment on the outdoor environment. Often, users and stakeholders assume that reduced energy consumption is responsible for poor indoor air quality (IAQ) and, advanced (21st century) technology and more energy consumption can help to achieve high comfort levels within buildings. To prove that buildings consuming lower energy can have better IAQ, a comparative study of energy efficient facilities with energy inefficient (poorly designed) facilities was performed. Roulet (2001) reported that the energy used during the whole life-cycle of a building has a significant impact on the outdoor environment, hence responsible for a number of building-related syndromes. In existing buildings, the level of thermal insulation and its impact on thermal comfort is also a major cause for energy loss and unacceptable IAQ.

Omer (2008) reported that in the past, the provision of adequate indoor environment conditions meant a more energy intensive building through air conditioning. The author suggested that a pleasant indoor built environment and reduced needs for mechanical heating/cooling could be achieved through utilising daylight and ventilation. Energy efficiency and optimum indoor environmental quality (IEQ) depend on minimising emissions of avoidable pollutants caused from indoor and outdoor environment. Some studies reported by Omer (2008) claimed 20-40 per cent savings in artificial lighting use and additional environmental benefits by exploiting daylighting. Omer (2008) reported a possibility of 43 per cent reduction in energy use by employing a combination of well-established technologies, such as glazing, shading, insulation and natural ventilation to create an energy efficient building. Omer (2008) found a key challenge related to indoor environment that the users' expectation of better indoor conditions are rising. It is very important to discuss here because often, indoor environment in existing healthcare facilities are poor and very less efforts are being spent to improve the same through refurbishment.

2.2.3 Definition of sustainability in the healthcare context

A review of academic and professional literature resulted in several issues, themes, and concerns related to sustainable development, which are applicable to the healthcare sector (see Table 2.1). The literature revealed that built environment, mechanical hazards and poor air quality inside the buildings have a significant impact on the users, especially patients (Dickerman and Barach, 2008). Thus, the highest safety, environmental and ecological standards should be adopted to reduce the impact while proposing a hospital (Hancock, 1999). Also, a facility should be an active member of a health community, healing environment for patient, healthy workplace for staff, and an environmentally responsible citizen.

So, considering sustainable devolvement in a healthcare context, some widely accepted definitions found in the literature (and applicable to this research) are mentioned below.

According to Office of the Federal Environmental Executive (OFEE), USA, it is *"the practice of designing, constructing, operating, maintaining and removing buildings in ways that conserves natural resources and reduce pollution"* (Frumkin, 2007). In other words *"sustainable buildings that are safe, healthy and productive for their users and owners, make a positive contribution to their local surroundings and have a minimal impact on the local and global environment, both today and for generations to come"* (SHINE, 2008).

The common definition agreed by various experts from industry, academic, healthcare practitioners during *'the Green Healthcare Institutions; Health, Environment and Economics'* workshop was *"green healthcare facilities are; asprational, economical, prudent, long-term and contextual and meets high standards in sitting, orientation, design, construction and energy efficiency and all these elements are measurable"* (Frumkin, 2007).

2.2.4 Measuring sustainability

While reporting on financial operations of an organisation is a statutory requirement and addressing sustainability is voluntary; economic benefits are direct and accountable, whereas social benefits are indirect and unaccountable (Turrent, 2007). However, taking a sustainable approach can result in broader benefits. For example, assessment of the Great Western Hospital in Swindon reported more than 20 per cent reduced energy consumption, and additional unaccountable benefits because of sustainability measures (Stanger, 2003). A sustainable facility can have a positive impact on the various factors, such as community, staff social terms and conditions; quality of wastewater discharged; and GHG emissions into the environment (Turrent, 2007).

It is, therefore, important that a link is made between sustainability and healthcare operational performance to strengthen the relation between sustainability and facilities. A need to measure sustainability in facilities demands re-thinking of many traditional approaches. In the current market, various approaches are available to measure/assess sustainability, such as LEED, BREEAM as discussed ahead in Section 4.2. Measuring sustainability helps to assess and reduce resource consumption as well as environmental impact due to construction of facilities.

2.2.5 Proposed concepts

The review of literature revealed several concepts that can be used to promote sustainability within healthcare facilities. Although the concepts below discussed were derived for new facilities, their adoption during refurbishment will help to deliver improved existing facilities.

Concept 1: The Nucleus Hospital Department Programme (Boswell, 2008)

The early 1970s saw the development of the '*Nucleus hospital*' to support future expansion. The DoH promoted this concept as a template for hospital developments and designed hospital policies and technical data around it (Boswell, 2008). As a result, 80 schemes were built and 50 reached the planning stage during 1975 and the early 1990s. In the 1990s, the PFI procurement process superseded the *'Nucleus'* system. The principles of designing the *'Nucleus hospital'*, such as flexibility and future proofing can still be applied in the current context and should be developed into a set of guidelines for future use. It was concluded that the buildings based on this concept had a good future because flexibility and future proofing were inherent in their planning. Smith (1984) argued that in the *'Nucleus hospital'* facilities and space for patients are ample, but inadequate for staff (lack of offices, storage space, changing rooms in theatres, etc).

Concept 2: Health Promoting Hospital

Hancock (1999) and later Pelikan (2007) promoted the concept of a *'Health Promoting Hospital'* (HPH). The concept was a key focus of a workshop held by the World Health Organisation (WHO) in Ottawa, Canada in 1998. Representatives from the healthcare sector (owners, managers, practitioners, nursing personnel and other such professional groups), health promoting organisations, experts as well as national and international health policy makers were part of this workshop. It was argued that healthcare facilities and re-orientation of healthcare services were worthy challenges and priority areas in the 21st century. The WHO identified a need for socio-ecological models and socio-political strategies to address healthcare related issues and sustainability. It requires healthcare to satisfy at least following five key action areas (Pelikan *et al.*, 2001):

1. reorientation of healthcare services;
2. health-promoting hospital setting;
3. health-promoting workplaces and provision of health related services, training, education and research;
4. hospital as an advocate and *'change agent'* for health promotion in its community/environment; and
5. healthy hospital organisation.

Concept 3: Evidence-Based Design (EBD)

The Centre for Health Design in California, USA defined EBD as the process of establishing credible decisions and research to achieve the best possible outcomes for the development of effective built healthcare environments (Carr, 2010). Wagenaar *et al.* (2006) illustrated the integration of an EBD approach in a hospital to provide improved physical space and environment for patients, staffs and visitors. It includes a range of ergonomic methods including tasks and user-needs analysis to explore knowledge relating to work processes within a defined space that produces a research-based or user-centred design (Rutter, 1996). The principles of EBD have become a key aspect of mock-up simulations and evidence-based tools, and (EBD) guidelines can aid decision makers during briefing, design and evaluation stages.

Concept 4: Safety-driven facility

Reiling (2006) presented a set of safety-driven facility designs and principles to guide the development of new hospitals with consideration to patient safety. It was reported that ‘‘*the study of the inter relationships between humans, the tools they use and the environment in which they live and work*’’ is a base for designing a hospital and it affect the performance of the people, equipment and technology. Often, decisions made by a management, architect and (equipment) designer are responsible for latent conditions because of non-standard equipments, procedures, poor visibility, high noise levels and excessive movement of patients and staff within a hospital. Although a significant amount of money has been spent annually on development of healthcare facilities, there are inadequate design principles for healthcare organisations, whether they are building a new or remodelling/expanding an existing facility (Reiling, 2006). Designers and healthcare decision makers can contribute significantly to patient safety if, safety-driven innovations and strategies within the process of designing a facility (especially with consideration to environmental factors) are introduced.

2.2.6 Key issues

Table 2.1 presents the key themes for refurbishment set against a number of issues and benefits of environmental, economical and social sustainability based on the literature. The issues presented in the table are mostly for existing facilities and refurbishment of a major scale.

Table 2.1 Key themes, principal issues and benefits for existing healthcare facilities with consideration to sustainability

Key themes related to refurbishment	**Principal issues, benefits for existing hospitals**
Economical value of the healthcare facility and surroundings (Economical sustainability)	
Benefits to patient, user Refurbishment delivery time Material, labour, etc., required Existing buildings Environment	Whole life-cost Better return Shorter patient stay Reduction in pain killing drugs consumption Users' satisfaction Minimising defects Consideration to future Maximum use of existing buildings Less consumption of new materials Reduced project cost Monitoring of refurbishment process
Protection of the environment and prudent use of natural resources (Environmental sustainability)	
Footprint (environmental & physical) Staff/user Waste Energy usage Carbon emissions Harm to nature Renewable resources Pollution control Local community Environment	More virgin land Healthy atmosphere, less global warming Accountability of energy usage Less consumption of natural resources Safe environment Less consumption of non-renewable resources Less harm to local community Less harm to environment Controlled built environment Maximum reuse of resources
Social progress which recognise the needs of everyone (Social sustainability)	
Environment for all Knowledge (exemplar project) Local community Users Existing buildings	Less impact on society Safe and healthy environment Responsible corporate citizen Creating exemplar projects Increased awareness Sharing good practices Healthy community

An important report on the '*Green Healthcare Institutions: Health, Environment and Economics'* workshop held during early 2006 presented by Frumkin (2007) is discussed below, because it is particularly relevant and very influential source of direction for this research. The main goal of the workshop was to address "*how research could help and guide the transition towards green healthcare*" and discussed the following issues.

- What is green healthcare?
- Why pursue green healthcare?
- What is the evidence to support green healthcare and what further evidence is needed? and
- How is green healthcare implemented?

Various aspects of green healthcare facilities such as increasing workplace productivity, ethics of green buildings, and areas for further studies, design principles, and health related benefits were discussed. It was supported by a 600 person peer review study on physical environments in green buildings and their relationship with patients. The study revealed several benefits of sustainability, such as reduced operational costs, reduced user stress and fatigue thus consequently, effective delivery of a care, improved patient safety, health outcome and quality of healthcare. Also, green healthcare supports the sustainability concept of '*triple bottom line; people, planet and profit*' and optimises social, environmental and economical outcomes. The biomedical and ethical reasons for pursuing green healthcare are based on the principles of autonomy, beneficence, non-maleficence (not doing harm) and justice. A need to protect health at three level building occupant, surrounding local community, and global community was identified (Frumkin, 2007).

In 2003, the release of the *'Green Guide for Health Care'* (GGHC) filled a gap in the market by providing a toolkit for healthcare facilities (Frumkin, 2007). The GGHC has been discussed ahead in Table 4.2. The guide provides the healthcare sector with a self-certifying toolkit for designers and operators to evaluate their progress towards healing environment. It was first quantifiable design toolkit to promote and integrate environmental and health related principles (with consideration to planning, designing, construction, operation, and maintenance). Source control, ventilation control, building commissioning and maintenance are also associated with designing healthy buildings. The need to consider aesthetic, sunlight, noise reduction, positive sound stimulation, connection to nature, social interactive spaces and increased behavioural control in healthcare facilities was identified in the GGHC. Many (untouched) areas for further research were proposed, such as good air quality and design for healthcare facilities, key environmental factors and their impact on the patients, etc (Frumkin, 2007). Hence, these documents provide an important basis for this research and several other studies since 2003 relating to sustainability, especially healthcare facilities.

The objective of the USA-based '*Summit for Massachusetts Health Care Decision Makers*' was to address '*hospital design and operation*' with a goal to promote green practice while enhancing patient healing, staff retention, staff productivity and feasibility of a hospital (Karolides, 2005). The addressed issues were relating to environment, health, healing, IAQ, energy, water, community, products and waste streams. One of the major areas for a discussion was healthcare premises host numerous buildings with various conditions and often, construction occur adjacent to occupied buildings. Moreover, ill people occupy these buildings most of the time. Other proposed key areas for concern were implementation strategy and mission, education, resource efficiency, purchasing, construction, collection of evidence and data collection policies (Karolides, 2005).

2.3 Designing sustainable healthcare facilities

As understood from the literature, traditionally designing a facility can be defined as means to fit and arrange all the spaces and requirements with consideration to circulation, physical site conditions, client, budget, schedule, etc (AFUH Design, 2006). Unlike most industrial mass production processes, designing a building is a complex process as no two buildings/projects are identical in all aspects and it varies from a building-to-building, or a project-to-project (Matthiessen, 2004). Designing sustainable facilities is important because "*you never get a second chance to make a good impression*" and "*a facility conveys a message and communicates about the organisation and medical care being provided*" (Carr, 2008). Gesler *et al.* (2004) mentioned there is a definite relationship between patient, staff, visitor and the built environment of the hospital (also confirmed by Frumkin (2007)), thus, the sustainability and patient/user safety is a key consideration while designing.

Vakili (2007) defined Sustainable Building Design (SBD) as "*a construction that weaves together the ethical, human, scientific, aesthetics and other aspects of nature, culture and technology*". It is "*a complementary dynamic mechanism of contemporary design*", which helps to rethink and revise the current practices. Designing is a key driver and a process that involves a three-step modelling '*inform, reform* and *give form'* responsible for sustainability, physical strengths and spiritual durability of physical environment. However, building design can determines sustainability approach and promotes, creates and maintains the value of asset (building) throughout its life-cycle. Four main contexts that influence value creations in design are passive design strategies; customer values and designer's responsibilities; commitment towards the existing society; and commitment towards the environment.

Various parameters are involved in the design of sustainable buildings, and these are changing constantly; it is a complex dynamic concept. Vakili (2007) proposed a theoretical eco-indicator model based on the principles of integrated design process, core values, existing contextual frameworks and certain assumptions to improve whole life-cycle value of the asset.

The theoretical paradigm of the model representing the flow of design value throughout the life-cycle of a building is illustrated in Figure 2.1. The four-stages of process preparation, pre-use, use, and obsolescence are clear, as is a need for exchange of information throughout the process. The study is discussed here to understand the value of the asset throughout the life of building. The below figure shows that building starts losing its value on occupancy. It was found that with further studies it would be easy to predict when buildings would require refurbishment. Also, there is a need to analyse post-occupancy building's life and its impact on the value. This study could be extended further to explore flow of design value post-refurbishment in facilities. Also, Figure 2.2 provided the directions to be considered with this research during initial phases.

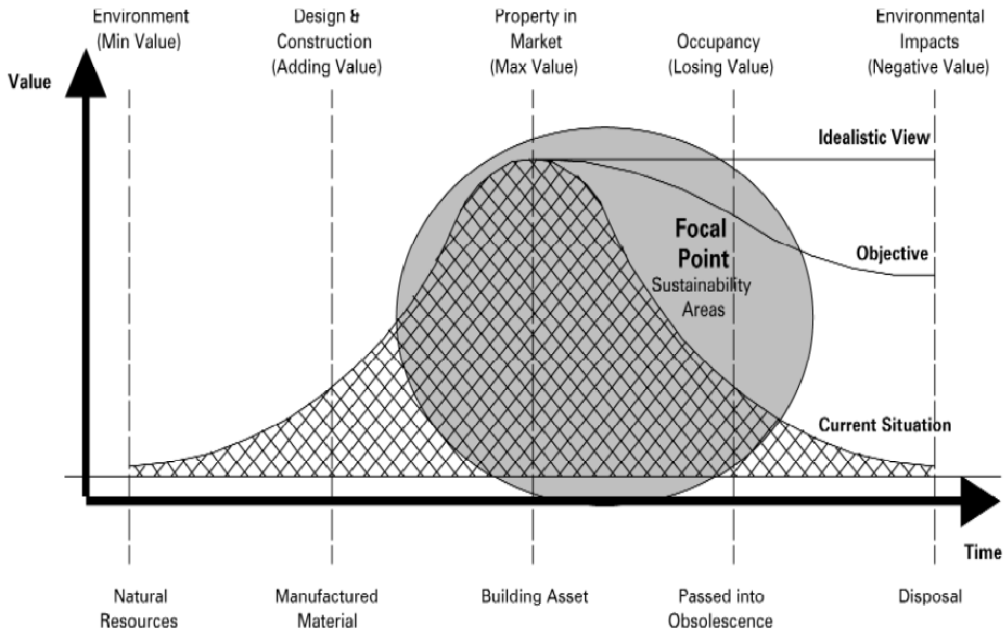

Figure 2.1. Flow of design value in the building process
(Source: Vakili, 2007, p. 87)

The SBD approach proposed by Vakili (2007) considers human needs addressing all existing values and contexts of sustainability; Figure 2.2 depicts the SBD approach. Vakili (2007) identified four key factors; building design, environmental profile, energy and resources consumption, and socio-economic aspects, which are also reflected in Ren *et al.* (2007) studies.

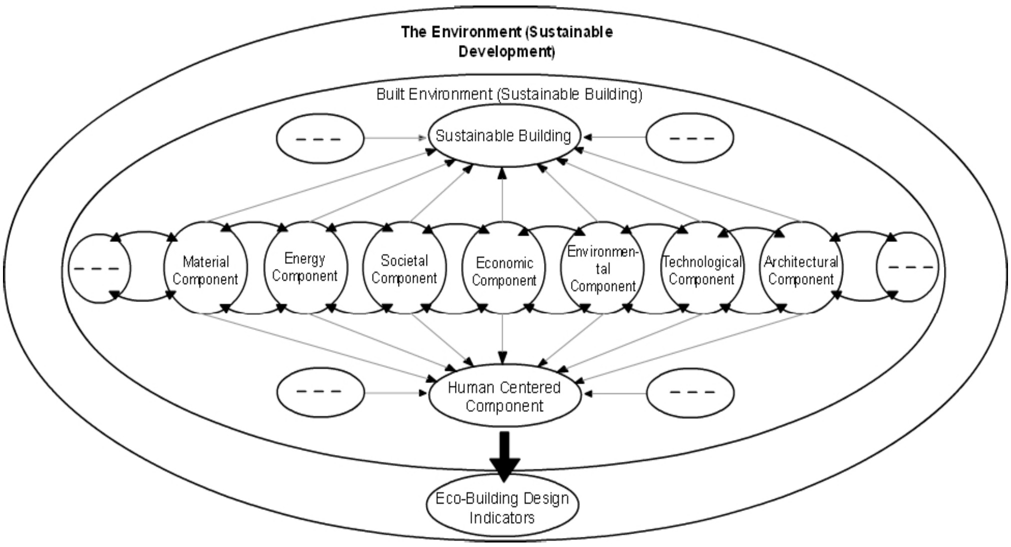

Figure 2.2. The Sustainable Building Design model
(Source: Vakili, 2007, p. 90)

They identified energy, water, material, waste and carbon emissions and, a need to address the following (at least):

- energy efficiency and carbon emission beyond minimum specified limit in '*Part L*[1];
- utilisation of onsite renewable technologies; and
- targets to achieve a *'very good*' BREEAM rating.

Overall, from the above discussed literature it is clear that hospitals need to re-consider their strategies and approaches to play an effective role in promoting health as they are workplaces (office), healthcare facilities, and community centres (Sheth *et al.*, 2008, Ren *et al.*, 2007). Vivian *et al.* (2006) reported some health related benefits to be gained from taking such approach to building performance, because it offers: the highest air quality; thermal control, maximum use of daylight; ergonomic from user point of view; access to natural environment; and reduced climate stresses.

Several case studies of green buildings presented by Turrent (2007) indicated that better insulation levels and selection of materials with minimum environmental impact are key steps while designing green buildings, and argued:

"*much has been written about the benefits to business of procuring more sustainable buildings but there is little factual evidence to back this up and it is commonly held belief that sustainability adds capital costs but even in that opinions are divided*".

The importance of (good) design was further expressed in a report *'the Better Health Building*' published by the NHS Estate (Centre for Healthcare Design, 2002). Good design is "*not an optional extra, but it has to combine fitness for purpose with whole-life costs to deliver value for money*". It helps to provide a safe and secure environment for patients, meet rapidly evolving medical technological advancements and supports social changes. A facility based on '*good design'* supports staff to deliver their health-related objectives and long-term best value resulting in overall sustainable solutions. Hence, a growing

1. The legal framework and approved government document that describes conservation of fuel and power as part of the Building Regulations 2010. The Regulation contains new energy performance requirements for work notified to building control bodies.

body of literature that supports the importance of addressing sustainability in the healthcare design process is found.

2.3.1 Design considerations

Vittori (2002) highlighted building facets which have an impact on occupant health, such as natural lighting, roof garden, indoor landscaping, outdoor landscaping, solariums and atria; Rao (2004) also cited design as an essential component of infection control strategy.

However, Gangemi *et al.* (2000) reported complexity, multi-disciplinary and unavailability of information as one of the key challenges to incorporating sustainability while designing and developing a facility. They performed a comparative study of frameworks and policies related to sustainable design to understand the role of environmental consultants, and their contribution towards designing energy efficient sustainable buildings. They concluded that the following strategies were necessary to develop an environmental responsive design:

- involvement of an environmental consultant and environmental features from (inception) early stages of designing;
- legal and contractual codes of practice from environment point of view that allocates responsibility to everyone;
- co-operation amongst the various members of the design team; and
- equal involvement of the client and design team.

Pushkar *et al.* (2005) established a methodology for a building (mainly office buildings) to adopt during its design stage to overcome the disadvantages of prescriptive tools, while keeping the environmental optimisation procedure simple and amendable during the design process. Pushkar *et al.* (2005) also showed that design variables can have an impact on the environment throughout a building's life-cycle, such as production, construction, maintenance, service life (including operational energy usage), repair, rehabilitation, demolition, dumping and recycling. However, involvement of an entire project team makes it difficult to apply the direct life-cycle assessment (LCA) on construction projects and there is a need to modify the existing LCA method. Pushkar *et al.* (2005) considered a comprehensive performance-based methodology to implement within the building design process and proposed a three-step environmental optimisation methodology for a building design with consideration to principles of grouping (see Figure 2.3). A two-step life-cycle, pre-occupancy and post-occupancy to ensure that individual decisions lead to an optimal environmental solution was suggested. The proposed methodology is divided into: 1) analysis and investigation; and 2) synthesis and grouping.

The suggested basis for the groupings in Figure 2.3 was electricity consumption, CO_2 emissions, or an environmental score. The proposed method was analysed, and synthesis was performed on a 3m by 4m and 3m high hypothetical building.

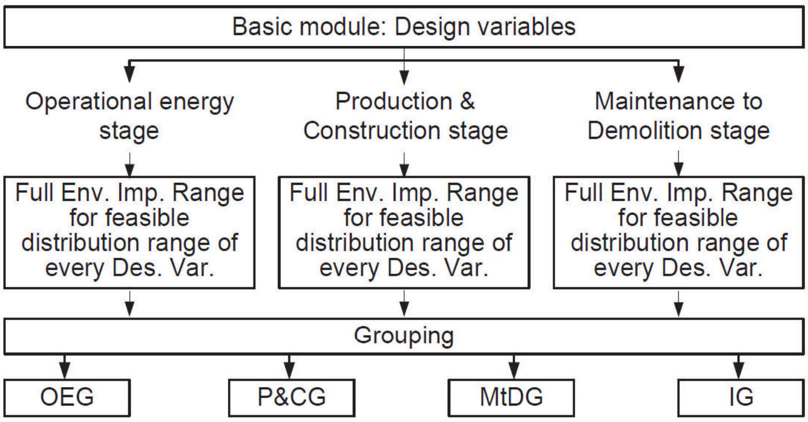

Figure 2.3. Schematic of grouping procedure (Pushkar et al., 2005)

Note: Operational Energy Group (OEG), Production and Construction Group (P&CG), Maintenance to Demolition Group (MtDG), and Integrated Group (IG)

It was concluded that in the future, the tool would be developed further, to: includes post completion activities, such as dumping, recycling, land filling and incineration; extend and deepen sensitivity studies; deliver optimal environmental solutions; and integrate a tool with an ongoing building project. Indeed, to implement sustainable development strategies, a planner must be aware and should consider the above issues from the outset and initial stages of the planning process.

The issues relating to design of sustainable healthcare facilities are discussed above because they helped to identify the associated themes and areas to be considered. Also, the literature shows that design process and refurbishment are govern by the issues related to cost and sustainability. The above discussed issues guided this research during the early phases and laid a platform to move this research further. Later in the process, when there was a lack of primary data the literature review helped significantly while developing a questionnaire and interview protocol.

2.4 Policies and framework affecting the design of healthcare facilities

One in every 100 tonnes of domestic waste in the UK comes from the NHS, with majority of it going to landfill (New Economics Foundation, 2007). The healthcare sector ranks first among all activities in the UK (and hence worst), in terms of energy consumption, resource consumption, building stock, and contribution towards (construction) waste. So understandably the UK government has set several commitments and targets relating to these concerned areas through the DoH Sustainable Development Action Plan (SDAP) (see Appendix B); BRE and other not for profit organisations such as SHINE, Nottinghamshire Energy Partnership (NEP) are also active in providing guidance and support in these areas.

2.4.1 The role of UK government

Mandatory sustainability targets have been set for the DoH by the UK government. Consequently, the DoH, a health services regulatory authority is responsible for development of several policies and guidance notes for the NHS and the wider healthcare sector. Some of the actions taken by the government are discussed below and in Appendix B.

The DoH has developed an advice note through the Design Brief Working Group (DBWG) for the NHS trusts for development of a new (healthcare) project. The document provides advice to the trusts on the main components of the design brief for healthcare buildings (Burton *et al.*, 2002). On other hand, the Office of Government Commerce (OGC) has been working to set the '*Common Minimum Standards'* (CMS) and mandatory use of either BREEAM or equivalent for all types of construction projects (DEFRA, 2007). At the beginning of the 21st century the DoH has also developed a *'BREEAM for*

Healthcare' which replaced NEAT and, the DoH is planning to developed NEAT Part-II for existing buildings (Perry, 2007).

DEFRA (2007) proposed a strategy to address design quality, sustainability, post-construction evaluation (PCE) and post-occupancy evaluation (POE). The purpose of this draft strategy was to make existing regulations better and to introduce new legislation including priority areas and milestones/targets for the industry. The strategy covers various areas such as means to enhance sustainable construction performance (procurement, design, innovation, people and better regulation), resource conservation (climate change, water, biodiversity, waste and material), and assessment of other strategies. It was reported that there are variety of policies, regulations and standards for sustainability, but a common action plan applicable to government and industry was lacking (DEFRA, 2007).

Key legislations and directives related to buildings and their energy performance as revealed during the literature review are listed below. The list is not exhaustive but provides an overview of the legislations.

- Building Regulations Approved Document '*C*'- '*Site preparation and resistance to contaminate and moisture*'.
- Environmental Liability Directive (2004/35/CE).
- Environmental Assessments of Plans and Programmes Regulations, 2004.
- Sustainable and Secure Buildings Act, 2004.
- Building regulations, 2006.
- Energy End-Use Efficiency and Energy Services Directive (2006/32/EC).
- Energy Performance of Buildings, England and Wales Regulations, 2007.
- Climate Change Act 2008 (discussed below).

The climate change act was introduced during late 2008 to set minimum targets for all the sectors (including NHS) related to carbon emissions and GHG to be achieved by the year 2050. It focuses on activities that encourage carbon reductions and considers buildings energy consumption and performance. The act is for all type of facilities i.e. new as well as existing buildings and functions (NHS SDU, 2010). In 2010, the DoH has proposed amendment in existing NHS’

Sustainable Development Management plans to adopt the Climate Change Act. This act is found important because the NHS is the largest public sector organisation and can influence other sectors too. It is also anticipated that adopting this act will help to prevent a large amount of ill health, thus reducing a need for healthcare facilities.

It is very important that to achieve government targets related to carbon emissions, current building performance data is available. Table 2.2 presents average carbon emission rates for a range of buildings to demonstrate scale of the problem based on energy usage per m^2 in these buildings. The table indicates that health buildings are responsible for the highest impact of all types of buildings.

Table 2.2. Average emission rates for a range of buildings (Source: NHS Cambridgeshire, 2010)

Kg CO_2/m^2 per annum and types of buildings	**Heating**	**Cooling**	**Auxiliary**	**Lighting**	**Domestic hot water**	**Equipments**	**All end users**	**Total**
Commercial offices	20	06	04	20	03	26	78	157
Communication and transport	16	12	05	22	04	28	87	174
Education buildings	10	N.A*.	02	15	06	15	48	96
Government buildings	20	06	04	20	03	26	78	157
Health buildings	***17***	***N.A.***	***12***	***27***	***09***	***62***	***127***	***254***
Sports and Leisure	N.A.	30	15	22	31	14	112	224
Other services	13	10	07	27	09	31	97	194
Average of all sectors	***12***	***8***	***07***	***28***	***05***	***16***	***76***	***152***

*N.A. Not available

Despite a lack of data related to carbon emissions due to cooling in healthcare facilities, the above table clearly indicates that these facilities are responsible for significant amount of carbon emissions. The table also indicates that healthcare facilities are responsible for maximum carbon emissions almost in all the areas thus, demands urgent attention towards these facilities. It is important to discuss the above table in this research because it clearly indicates nonavailability of performance related data of various types of building, including healthcare. From the above table and available literature the extent of carbon emissions and problems associated with the same are not clear and indicate a need for more studies.

The UK government and the DoH worked on the Sustainable Development Plan for the year 2007-08 (Davis *et al.*, 2008). An objective of this work was to involve people from the DoH to promote sustainability throughout the NHS and life-cycle of its buildings. Although consideration of sustainable development by NHS trusts is typically limited, it was anticipated that it would be implemented across the NHS. In addition, the NHS executive agencies Purchasing and Supply Agency (PASA) and Medicines and Healthcare products Regulatory Agency (MHRA) are working on their SDAP (Davis *et al.*, 2008).

Scholte and Rich (2010) developed an action plan and associated Carbon Reduction Strategy (CRS) to support the Government's Sustainable Development Framework for the healthcare sector in the UK. This work can be used as a foundation for sustainable development because it focuses primarily on providing value-for-money and service excellence to the customers. Mentioned below are the key themes in response to government's overall SDAP, and as part of the above mentioned work (Scholte and Rich, 2010).

Considering the focus of this chapter (sustainable development) as well as the overall research focus (energy), Themes One and Three out of seven themes have been selected for particular attention and are presented in Table 2.3.

Table 2.3. Action plan for NHS Estates
(Source: Scholte and Rich, 2010, pp. 9-11)

No.	Action	Outcome	Accountability
Theme One. Sustainable Development			
1.1.	Approval of revised SDAP and performance monitoring arrangements	Agreed plan and monitoring arrangements	NHSBSA Board/ Leadership team
1.2.	Establish a Positive Action Group (PAG) at the senior management level within each authority work stream	Terms of reference agreed PAG launched	Sustainable Development Manager (SDM)

No.	Action	Outcome	Accountability
1.3.	Provide further inputs into the sustainable development implications of business cases and proposals in partnership with senior management	Engagement via PAG and assistance provided as required	SDM
1.4.	Maintain and further improve the NHSBSA ISO 14001 Environmental Management System (EMS)	First year of authority-wise ISO 14001 certification and improved local documentation	SDM
1.5.	Continue to engage with key stakeholders to work in partnership and share best practice, for example, the Carbon Trust, NHS Sustainable Procurement Forum, local authorities, DoH Estates Forum, etc.	Links established, meeting attended, best practice shared and partnerships formed	SDM
1.6.	Establish a regular sustainable development update process for staff, giving details of performance against targets, initiatives, etc.	Relevant information regularly distributed to NHSBSA staff	SDM
1.7.	Produce a Sustainable Development Annual Report (2009-2010)	Report produced and agreed	Director of Finance
1.8.	Benchmark the NHSBSA against the NHS Good Corporate Citizen Model and use the results to make further improvements	Benchmark score established and saved on Good Corporate Citizen Model website	SDM
Theme Three. Energy use in NHS Buildings			
3.1.	Install energy efficient equipment during all planned maintenance/ refurbishment works, for example, point-of-use, water heaters, energy-efficient hand dryers	Energy efficient equipment installed and operated	Operational Facilities Manager (OFM)
3.2.	Establish procedures and processes to ensure compliance with the requirements of the Carbon Reduction Commitment Energy Efficiency Scheme, and work towards achievement of Early Action Metrics	Established CRC Energy Efficiency Scheme processes and procedures, compliance with scheme requirements	SDM
3.3.	Engage with One North East to undertake CRC Energy Efficiency Scheme simulation project	Data to enable further development of CRS	SDM

No.	Action	Outcome	Accountability
3.4.	Upgrade the Building Management System to enable better control of buildings, and implement a process of ongoing BMS maintenance, aligned with operational hours, holidays, etc.	Improved building controls and established routine of Building Energy Management System (BEMS) maintenance	OFM

Nevertheless, the DoH has announced and sponsored several policies for procurement, staff training, development of skills and tools, and construction, like AEDET, ASPECT, BREEAM, NEAT, SHAPE because it is under pressure to achieve its Sustainable Operations of the Governments Estate (SOGE) targets (Scholte and Rich, 2010).

2.4.2 The NHS role in sustainability and design

As an integral element of the NHS-Sustainable Development Unit (SDU), the NHS commissioned a consumption-based carbon footprint analysis of all NHS England activities. Based on this analysis, the NHS-SDU outlined the following targets under the CRS for all NHS bodies to take actions to reduce their carbon emissions (NHS Cambridgeshire, 2010).

- Based on 1990 levels, 26 and 80 per cent reduction in carbon emissions by 2020 and 2050 respectively, where the data exists.
- A Board-approved SDAP containing a commitment to reduce each organisation’s 2007 carbon footprint by 10 per cent by 2015.
- Signing up to the Good Corporate Citizenship Assessment Model.
- Monitoring, reviewing and reporting on carbon.
- Raising carbon awareness at every level of organisation.

However, despite the set targets to be fulfilled in coming decades, it is not sure if, the data exist for the past decade and their accuracy (for e.g. see Table 2.2). Thus, the biggest challenge for the NHS would be to compare performance of the facilities and satisfying the government targets.

NHS Scotland (2007) has issued an updated version of an *'advice note developed by the Architecture + Design Scotland (A+DS)*' to undertake all design processes within NHS-Scotland. This is a non-mandatory advice note within the context of the Scottish Executive Health Department’s Policy for various stages of design. The process offers an advice and a constructive criticism, but not a detailed comment or approval on physical space standards, clinical adjacencies, construction techniques and other technical aspects. The review provides a report to the client team with areas for immediate attention, consideration, and development. Any outcome of this review is shared only between an assessor panel and the client team (NHS Scotland, 2007), hence it had limited impact overall.

The DoH proposed the Achieving Excellence Design Evaluation Toolkit (AEDET) to assess NHS healthcare buildings and to acquire and represent knowledge relevant to hospital designs. As part of the tool, there are 10 dimensions under the three main headings; Functionality, Impact, and Build Standard as presented in Figure 2.4 (Gesler *et al.*, 2004).

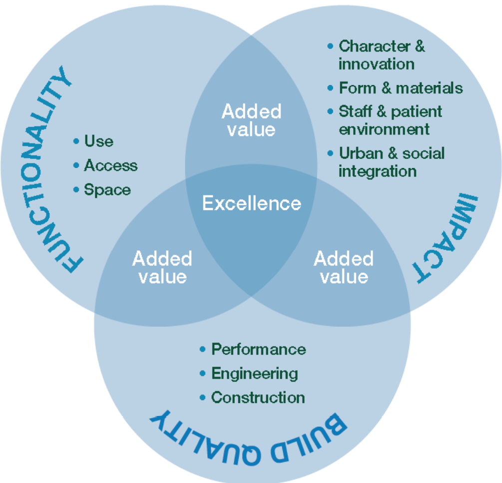

Figure 2.4. AEDET toolkit - the framework (Gesler et al., 2004)

The AEDET tool scores against each of the 10 dimensions to produce measurable performance indicators for every aspect of the design. Every dimension presents several specific questions for evaluation. For example, under '*Impact*' one question asks, "*is the building therapeutic for patients*". It is based on the successful approach devised by DQI (www.dqi.org) in the early 21st century, which became the Design Quality Indicator (DQI) and grounded in Vitruvius' firmness commodity and delight maxim.

DQI is use to evaluate and improve the design and construction of new buildings and refurbishment of existing buildings. The key aim behind this method is to measure the performance. The focus of this method was mainly on public buildings to address issues related to environmental impact(s) (Gann *et al.*, 2003). Gann and Whyte (2003) reported that in social research often designers and clients/occupants evaluate buildings differently; however, the DQI should:

- assist in informing choice in design decisions;
- be user friendly- including professional designers and lay users;
- raise public awareness of the importance of design;
- be capable of measuring individuals' view of design quality against their own chosen intent for the buildings;
- allow to compare and contrast different options;
- be flexible, multipurpose and generic nature, and useable on many different types of buildings;
- be useable at different phases in a buildings' life-cycle; and
- be swift to use, with a simple and clear interface.

Although, Ecclest (2007) reported that the NHS would have saved £50 million by 2010 if, it would have achieved its energy consumption targets, an audit of the NHS facilities by the BRE in 2004-05 for the National Audit Office (NAO) concluded that the NHS could not meet its targets especially related to energy consumption (Perry, 2007).

2.4.3 Other organisations

A Sustainable Project Appraisal Routine (SPeAR) is a tool to turn sustainability from a theory to practice developed by ARUP (Bourke *et al.*, 2005). The tool (see Figure 2.5) demonstrates the sustainability of a project, manages information, and can be a part of the design team.

This is a four quadrant (economic, social, natural resources, and environmental) tool for sustainability appraisal and indicator for a project and highlights the strengths as well as weaknesses of the project. It is based on the key elements, such as environmental protection, social equity, economic viability and efficient use of natural resources. It is relevant here because it was used on a hospital project in Arizona, USA and proved beneficial (Bourke et al., 2005).

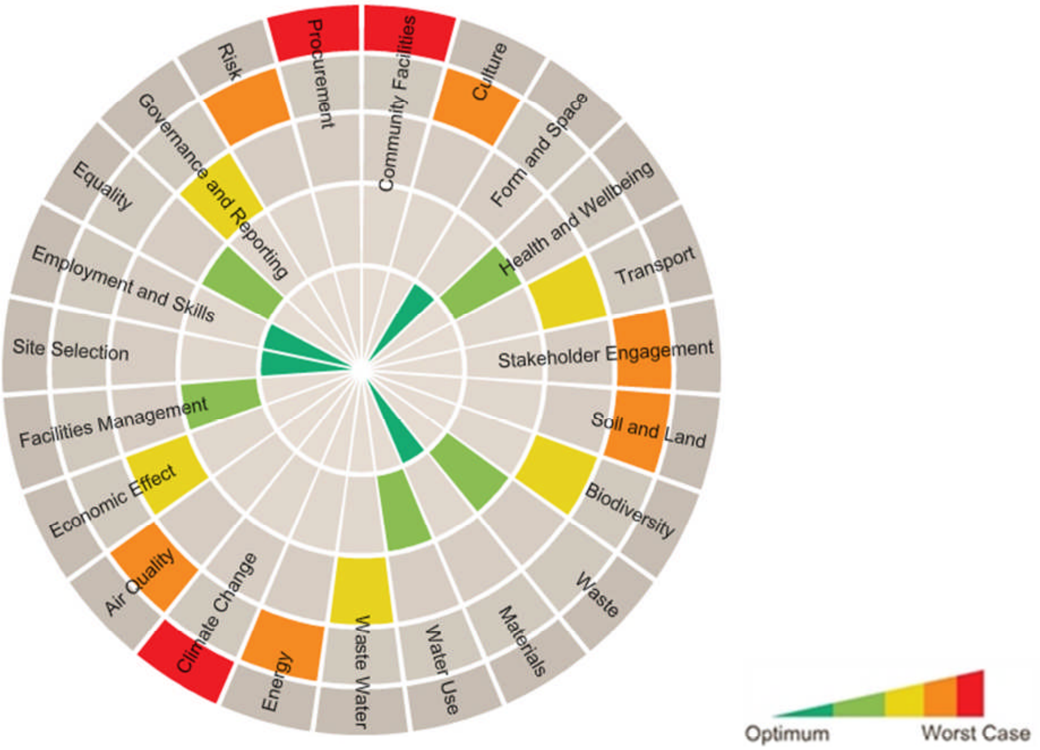

Figure 2.5. An overview of SPeAR (Bourke et al., 2005)

In fact, Bourke *et al.* (2005) discussed 67 tools from the construction industry mostly related to sustainability, some of which are presented earlier and in Table 2.4. However, 90 per cent of the tools presented by Bourke *et al.* (2005) are for new buildings, with an inherent assumption that they can also be used for existing buildings; although the distinction is not clear and remains un-discussed.

Table 2.4. List of selected tools to assess sustainability
(Source: Bourke et al., 2005)

Tools	Audience				When will it be used?					B/I
	Designer	**Client**	**Contractor**	**Other**	**Inception**	**Appraisals**	**Construction/Handover**	**Operation phase**	**Decommission**	**Buildings (B) / Infrastructure (I)**
BREEAM Provides guidance on minimising adverse effects of buildings on the local and global environments. The assessment is based on credits awarded for set of performance criteria. There are different versions for existing and new offices, dwellings, superstores, retail, healthcare facilities, etc.	√	√	√	√	√	√				B
Building for Environment and Economic Sustainability (BEES) An interactive computer design aid for users to select building products in commercial, housing projects to balance environmental and economic criteria.	√			√		√	√			B
Dashboard of sustainability Free software tool & presents complex relationships between economic, social, & environmental issues aimed at decision-makers interested in sustainable development.	√	√		√	√	√	√			B, I
NEAT A checklist based approach for assessing any new development or refurbishment projects for NHS buildings. It aims to raise environmental awareness within the NHS and scores on a scale from fail-to-excellent.	√	√			√	√	√			B

There are many other relevant tools developed by various organisations, such as SigMa by HOK, DeLta by BDP, CEEQUAL, EcoProp, Envest (Bourke *et al.*, 2005); an in-depth consideration of some leading tools can be found in Chapter Four.

2.5 Chapter summary

This chapter reviewed sustainability at a broader level and demonstrated the nature and complexity associated with it. The literature review confirms the importance of sustainability in the context of the healthcare sector and demands that it should be at the core whilst refurbishing existing buildings. The design of a new healthcare facility should cover a number of concepts such as HPH, EBD, but considering much of existing UK building stock dates back to the 20th century (and in some cases 19th century) innovative solutions, and specific tools are needed to address their particular challenges.

To achieve sustainability in the NHS and the healthcare sector, there is a need to have common aims and objectives across the sector and for the entire estate. The evidence suggests a shift from traditional construction to sustainable construction, however, the construction industry and healthcare sector is far from achieving sustainability. If the construction industry wants to appreciate sustainability, then it is not possible only via new developments, but it should also focus on the existing building stock. Through this chapter the available data and set targets by the governments are challenged. The investigation revealed that sustainability is dynamic, and includes several characteristics and, thus, subsequent chapters narrow down to existing hospitals and energy; the field of this study. This focus is essential to achieve the overall aim of the research.

CHAPTER THREE. HEALTHCARE FACILITIES AND REFURBISHMENT TACKLING ENERGY AND CARBON EMISSIONS

3.1 Introduction

With an increasing awareness of energy efficiency, carbon emissions, and healthy indoor and outdoor environments there is a need to reduce impact not only from new construction projects but also from existing buildings, especially in the healthcare sector on the environment as explained earlier.

This chapter reviews the main types of existing and new healthcare facilities, refurbishment, drivers, theories, energy consumption and carbon emissions due to the healthcare sector and the construction industry. Selected methods used for refurbishment in other sectors are also discussed, because there is a lack of adequate literature and approaches related to refurbishment in healthcare sector. A set of questions that guided this chapter are listed below.

- How is healthcare facility refurbishment different from other building types?
- What is the relation between healthcare facilities, refurbishment, energy consumption and carbon emissions?
- What current researches and trends exist related to energy and carbon emissions along with refurbishment in (healthcare) construction sector?

3.2 Healthcare sector

The healthcare sector is one of the biggest UK industries occupying tens of thousands of acres land for several purposes, for e.g. to provide healthcare related services to various age groups (children, old people), emergency services, transportation of patient and staff, storage of medical equipments. The NHS employs more than a million people, which makes it the World’s third biggest governmental organisation after the Indian Railway and the Chinese Army (Lister, 2004). Every year the UK government spends significant amount of money (i.e. £90 billion in 2007-08 rising to £110 billion in 2010-11) to provide healthcare services, resulting in more than 7 per cent of total Gross Domestic Product (GDP)

(Jeffreys, 2009, Appleby, 2005). Also, through Private Finance Initiative (PFI), the government has redeveloped around 25 per cent of existing healthcare buildings in the last 10 years (Gesler *et al.*, 2004).

The healthcare sector is also one of the highly professional and highly paid labour-intensive industries, where 60-75 per cent of hospital expenses are labour cost with total operational costs rising up to 90 per cent of spending (Michael, 2005). Thus, a need for a well-designed, energetic and encouraging built environment to make optimum use of staff was identified. Increasing recognition of whole life-cycle cost, economic efficiency, environmental impact and sustainability of existing facilities has attracted attention of the research communities, industries and experts (Sheth *et al.*, 2008, Kapoor *et al.*, 2006). Standard definitions of frequently used terminology related to healthcare sector and refurbishment, based on the review of literature and understanding of the subject are stated in Table 3.1 and will be used throughout this thesis as well as research.

Table 3.1. Standard definitions of frequently used terminologies (Source: Ali et al., 2009, Heng, 2003, Jaggs and Palmer, 2000)

Terminology	Definitions
New building	A building in the process of being built, or a less than three-year old
Existing building	Total existing building stock, excluding the new buildings
Healthcare building	A health facility where patients receive a treatment
Refurbishment	The state of being restored to its former good condition
Renovation	The act of improving by renewing and restoring
Extension	Where any new part is being added to an existing facility
Retrofit	Building or building elements being upgrade and improve to a higher standard than was originally planned for earlier

NB: A construction project can be hence categorised from the above list or using a combination of above types of project, for example, a refurbishment and extension project.

3.2.1 Types of cares and buildings

There are various types of healthcare buildings, which can be classified depending on their function, role in the society, etc., this is an important discussion in the context of refurbishment and to understand the levels of complexity associated with healthcare building projects.

3.2.2 Definition of a healthcare facility

A healthcare facility is a building or campus with several buildings depending on the purpose and a level of the care provided. In the 19th and 20th century, many hospital buildings were developed, which have evolved into campuses due to increasing demand and expansion projects.

There are several characteristics (as presented below) of healthcare facilities revealed from the literature (Sheth *et al.*, 2010a, Jeffreys, 2009, Dascalaki *et al.*, 2008, Joseph, 2006, Centre for Healthcare Design, 2002), which may or may not be similar to other sectors, such as housing, offices, hospitality, warehouses, and industries, it:

- deals directly with public health;
- accommodate physically/mentally ill people;
- consumes significant amount of money (GDP) in most countries;
- mostly funded through government or are not-for-profit organisations;
- includes/deals with entire population irrespective of their gender, age;
- mostly sits within the community/society and an essential part of the same;
- should be operational during emergencies, for example, earthquake, flood, etc.;
- more possibility of having contaminated air spoiling IEQ; and
- air change regulations are stringent in healthcare, for example, in some areas 12-15 air changes required per hour.

3.2.3 Type of healthcare facilities

Often, cities have different hospitals and facilities of varying sizes for various purposes, such as acute care, Accident and Emergency (A & E), maternity, rehabilitation and teaching. A type of a hospital can be classified depending on either a treatment/care, or length of a patient stay. Considering the length of patient stay, a hospital can be classified into '*inpatient*' and '*outpatient*' (Alabama Hospital Association, 2006). The former admits a patient for more than a day, whereas the later is a medical facility smaller than a hospital, where only diagnosis and/or therapy is given for a short period, sometimes over several visits. Another kind of a hospital is based on the length of a treatment, i.e. '*long-term care*' hospitals. In this, medical and skilled nursing services are provided to patients with long-term illnesses that are not in acute phase, but require a level of service not available in a general hospital. Also, hospitals can be differentiated on the basis of types of medical facilities and treatments as discussed below.

General facilities

A well-known type of hospital is a '*General (Community) Hospital*' found in almost every town. These hospitals are also known as a '*City hospital*' or '*Nursing home*' as nurses look after patients mostly (compared to less time spent by doctors treating patients). These hospitals are set up to deal with many kinds of diseases and injuries and include specialised facilities for surgeries, such as childbirth, bioassay and laboratories (Alabama Hospital Association, 2006). The NHS definition of community hospital is "*a service which offers integrated health and social care and is supported by community-based professionals*" (NHS, 2010a). Generally, a city hospital is a major healthcare facility in a region with a large number of beds for intensive and long-term care.

Specialised facilities

A facility for selected age groups or a specific health-related needs fall under this category. It includes trauma centres, rehabilitation, children's, geriatric, psychiatric and certain diseases categories. Also, specialised hospitals include acute care, which treats patients in the acute phase of an illness or injury. Rehabilitation hospitals provide medical, health-related, social and/or vocational services to disabled individuals. Whereas, '*addiction/substance abuse treatment centre*' provides assessment and treatment to individuals with addiction (Alabama Hospital Association, 2006).

A teaching hospital may or may not provide a special treatment, but includes additional requirements, such as classrooms, labs, teaching facilities, etc., and so it is categorised under a specialised facility. It combines assistance to patients, and is linked to a medical school providing teaching and training to students thus also known as University Hospitals.

3.3 Refurbishment

Gesler *et al.* (2004) reported that many hospitals in the UK have been developed with prime consideration going to costs and clinical functionality. In the healthcare sector attention is given to the development of new buildings, but refurbishment is a neglected area (Sheth *et al.*, 2010a, Sheely, 2008, Hancock, 1999, Smith, 1984), although many opportunities exist in current hospitals to reduce energy consumption and carbon emissions (Wilson, 2009, Heng, 2003). A need for healthcare facilities to accommodate a new, more cost-effective medical technologies not supported by some of the NHS existing facilities demand refurbishment (re-development) (McKahan, 1999). Smith (1984) reported continually funds allocated for maintenance has been used to provide clinical needs, and planners and the government were focused on building new hospitals rather than remodelling existing facilities. The literature revealed that refurbishment have been considered as an expensive, time-consuming option; Smith (1984) argued it is not necessarily an easy option but more ingenuity and hard work to find a good solution can deliver improved existing buildings.

In the past, it was anticipated that existing hospitals will be replaced in the near future, resulting in more focus on new development and downgrading existing facilities and maintenance (Wilson, 2009). The DoH reported a backlog of £4 billion of maintenance works in England (BBC News, 2007) and Wilkinson and Reed (2006) stated that this is worsening in some facilities. The '*Guide for Low Carbon Refurbishment of Buildings*' reported that most existing buildings cannot support modern medical needs, but they are inefficient in energy performance and are being replaced at very slow rate (Carbon Trust, 2008). However, very limited data are available on building turnover rate in the NHS and healthcare sector, so this is impossible to corroborate.

It is difficult to fulfil modern clinical requirements and medical needs within buildings from the mid 19th to late 20th century, including Victorian hospitals (Penoyre and Prasad, 2006). Considering 21st century buildings and their standards, many buildings constructed in the 1960s and 1970s consume more energy because of their outdated heating system and/or inadequate level of insulation (Penoyre and Prasad, 2006, Wilkinson and Reed, 2006). The hospital wards, tower blocks and podiums from the 1960s and 1970s are expressed as "*the match-box on the muffin, relying heavily on mechanical ventilation*"; they only comply with the now inefficient standards of 30-40 years ago (Smith, 1984).

During refurbishment, the entire building needs to be considered and provided with overall diagnosis options. Burton and Kesidou (2005) claimed that refurbishment of buildings comprised physical and functional components, energy consumption, pollutant emission, operational waste, users' comfort, and quality of air. There are several possible and feasible alternatives, which can be considered from various perspectives for refurbishment, but there is a clear need to carry out in-depth investigation and analysis of any proposed solutions (Burton and Kesidou, 2005, CADDET, 2005). Finally, patient expectations, new treatments and medical advances are some of the common areas to be considered while developing a new or refurbishing existing healthcare facility (Milburn, 2004, Department of Health, 2000). Currently, this is lacking up to a certain extent in the industry as explained ahead in this thesis.

3.3.1 Refurbishment models and methodologies

Until recently, most refurbishment-literature focused on the housing sector and commercial (office, hospitality) buildings with healthcare being one of the least considered areas. The focuses of these studies were on economical aspects of refurbishment, for example, Juan *et al.* (2009), Gieseler *et al.* (2004), Caccavelli and Gugerli (2002), and Wittchen and Brandt (2002) reported that very limited consideration is given to technical solutions, or the pros and cons of existing buildings/designs. Houses and hospitals similarly accommodate healthy and ill people respectively, so literature has also been gathered related to refurbishment of housing. The current approaches towards hospital design has been evolved over the years and witnessed pattern change almost in every decade, for instance hospitals recently started adopting designs from non-clinical settings including hotels and '*trendy bars*' (Gesler *et al.*, 2004). Thus, the information related to refurbishment from few other sectors such as offices and hospitality is also presented here.

Studies on the effects of a hospital environment on patients were initiated in the early 19th century (Payne and May, 2009), but still there is limited literature available; Gesler *et al*. (2004) found that hospital designs are complex. Payne and

May (2009) reported that *'comfortable and homely'* refurbishment reduced the treatment time by up to 14 per cent and suggested following minimum requirements for hospital refurbishment projects. It was suggested that refurbishment projects should aim for a physical improvement in areas especially used by patients and provide evidence suggesting involvement of perspective users. The refurbishment approach should be align with the trust's strategic direction and must be well conceived and aspiring to the highest design standards, thus delivering attractive or at least pleasant end product to the eye. Overall the project should be value for money and design should contribute towards the local environment.

An example of this can be found in the expansion and renovation of Blake Medical Centre (BMC) located in Bradenton, Florida (Schoenleber, 2003). From the beginning of this project, aim was to develop and implement project goals, promote a tracking system for reuse, recycling and green purchasing, and program to reuse and recycling during construction phase.

It was reported that many contractors would like to reduce construction impacts on the environment, but the alternatives take time to research and design, thus they are not considered. Sustainability is not often explored because new construction materials have not been field-tested and a concern for project deadline, budget, product appearance, durability and safety or sometime clients think sustainability is not worthwhile. A new process included following strategies related to material selection, waste minimisation, design features, mechanical systems, infrastructure, and operation and maintenance to minimise impacts on the environment by:

- involving healthcare administration and representatives to incorporate green building initiatives within the process;
- working with contractors to minimise consumption and depletion of material resources;
- minimising and recycling waste generated from the construction process;
- purchasing materials with recycled content;
- considering impact of materials on the environment; and
- better management of waste.

Schoenleber (2003) proposed the following four steps to incorporate above strategies and to adopt sustainable practices: (i) develop task force and convene meeting; (ii) develop green building strategy plan; (iii) building construction strategies and analysis; and (iv) final reporting.

Jaggs and Palmer (2000) proposed an '*Energy Performance Indoor air Quality, Retrofit*' (EPIQR); this is a computer based methodology which demands a comprehensive survey and generates a report through visual observations and interviewing occupants. The tool assesses information for refurbishment and retrofitting needs of apartment buildings; by providing measures to achieve better indoor environment and lower energy consumption, by establishing the building conditions and to carry out the physical and functional state diagnosis of the building. They also assist with understanding nature of work to carry out and cost involved with it, study post refurbishment energy consumption to develop options for retrofit and to perform a comparison of refurbishment options.

Balaras *et al.* (2000) used the EPIQR methodology on 38 apartment buildings in seven European countries. The focus of this study was to explore overall energy consumption in European buildings. Their survey considered energy systems, indoor environmental conditions and building envelope (which provided an overview of the conditions, construction characteristics, installations, energy systems and energy consumption). It was concluded that the thermal envelope plays a vital role in maintaining indoor temperature and quality, and performance of most studied buildings is inadequate and the authors highlighted that it is a possibility in most existing buildings in Europe.

Kaklauskas *et al.* (2005) developed a framework '*Multivariant Design and Multiple Criteria Analysis of Building Refurbishments*'. The framework was part of 'the *Bringing Retrofit Innovation to the Application* (BRITA) for *Public Buildings* (PuBs)'. A need to determine significances, priorities and degree of utility was suggested through the framework. The framework assesses and identifies the extent of physical degradation of the built environment during renovation with consideration of multiple design criteria (e.g. technological, ecological, social, comfortable, aesthetic) (Kaklauskas *et al.*, 2005). For instance, energy performance is a complex function in buildings which depends on form, structure, heating systems, occupancy pattern, operating schedule and external climatic conditions.

Kaklauskas *et al.* (2005) identified a need for quantitative information based on criteria systems, subsystems, units of measures, values and initial weights of the alternative design options for the projects. They concluded that conceptual information was too flexible and not sufficiently accurate to cope with an energy performance assessment.

Mickaityte *et al.* (2008) explored several studies (such as Siller *et al.*, 2007, Sitar and Krajnc, 2006, Caccavelli and Gugerli, 2002) in the field of sustainable refurbishment development, with a key focus on public buildings. They proposed a conceptual model for sustainable refurbishment of buildings, illustrated by means of a pollution map. The model was divided into phases for analysis, and mapped the level of environmental pollution in buildings under refurbishment and their effect on human health.

Burton and Kesidou (2005) considered refurbishment projects of non-domestic buildings in relation to energy performance and indoor environment. They found IEQ in existing buildings to be poor, below acceptable levels despite consuming more energy compared to new buildings and proposed the following research questions:

- Can we reduce energy consumption to current standards?
- How can we improve cooling, ventilation and comfort without increasing energy consumption?
- How can we make best use of the existing structure, such as thermal mass?
- How can we use the higher ceiling heights?
- How do we retain the existing appearance of architecturally important buildings while improving energy and comfort?
- Can we make changes with occupants in place?
- Is the life-cycle CO_2 assessment positive compared with demolition and rebuilding?
- For multiple building owners, how do changes affect the overall CO_2 emissions of their buildings stock?

Although Burton and Kesidou (2005) found that some offices refurbished 10 years ago in Greece were not performing well, they speculated that a 50 per cent reduction in energy consumption could be achieved through successful refurbishment. But Wilkinson and Reed (2006) denounced any research considering just energy efficiency as out of date; they highlighted a need to explore user comfort, environment, sustainable development, and GHG emissions while developing existing buildings.

Caccavelli and Genre (2000) proposed TOBUS, a decision-making tool for office building improvement projects because these buildings are often affected due to lesser life span than residential buildings, changing users requirements, brand value and highest energy consumption; retrofitting is cheaper than new construction if performed successfully. An overview of TOBUS is shown in Figure 3.1.

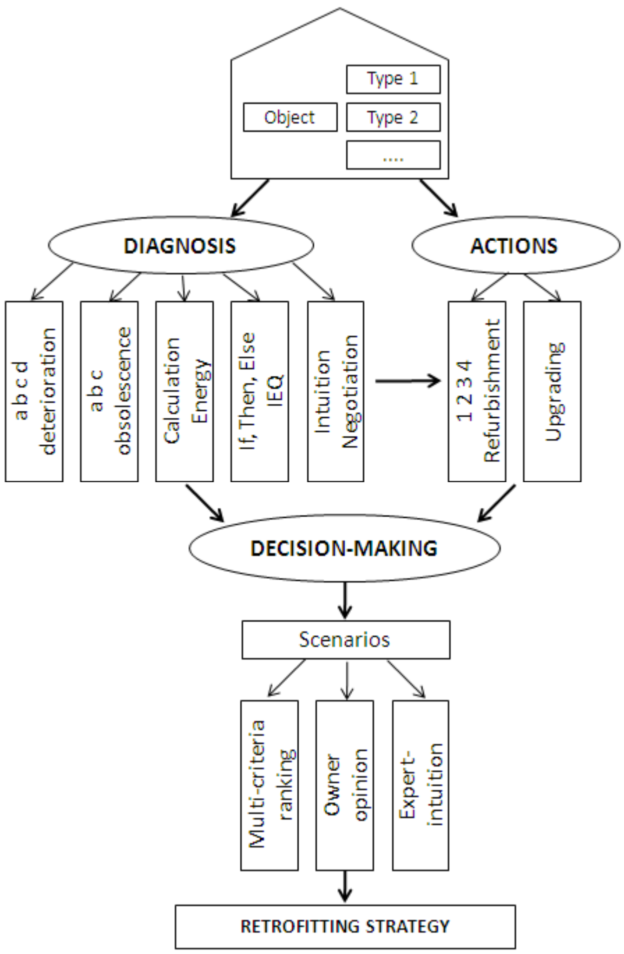

Figure 3.1. An overview of the TOBUS process (Caccavelli and Genre, 2000)

The objective was to estimate cost with consideration of energy performance and indoor environment. The tool addresses the initial stages of retrofitting projects with consideration to owner and user, assists with a diagnosis (evaluation of the general state of office buildings) and provides actions for retrofitting and corresponding costs. TOBUS considers the physical state of building elements, building services, energy consumption and IEQ. It divides existing objects into four degradation codes to review every action for retrofitting into four intervention codes. The actions are classified with consideration to building elements and their feasibility. Five criteria (i) users' needs, (ii) flexibility, (iii) divisibility, (iv) maintainability and (v) compliance with regulations were explored as part of the functional degradation. The main modules of TOBUS are heating, cooling, ventilation, hot water, lighting, equipment, mechanical installation and water use, but it does not include energy simulation or an auditing tool. Indoor environment is addressed with respect to thermal comfort, air quality, lighting and noise. A checklist and a questionnaire were proposed to collect various data required for this tool. The output produced using this tool is the most suitable refurbishment and retrofit actions considering the maximum possible energy saving and improved IEQ within the budget constraint of the owner.

Following this initiative, Wittchen and Brandt (2002) conducted a survey of European buildings using the TOBUS methodology. Physical conditions, actions to improve those conditions, extent of the work and the budget for buildings were part of the survey. TOBUS surveys were divided into four categories; degradation, functional, energy and IEQ (see Figure 3.2).

An output from the survey of 15 buildings was used to refine the tool and, concluded that it is difficult to gather data to perform an energy analysis of existing buildings which had undergone (several) renovation(s) (Wittchen and Brandt, 2002); energy related data questionnaires, energy bills, checklist and a visual inspection were all thought to be needed.

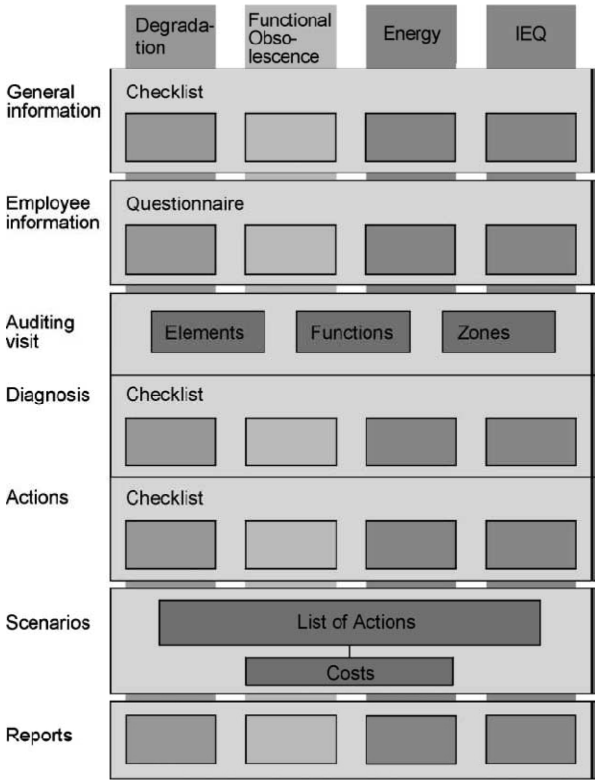

Figure 3.2. Overall structure of TOBUS method (Wittchen and Brandt, 2002)

There are many other proposed frameworks and tools, which are not discussed here, for example, Atkinson *et al.* (2009), Juan *et al.* (2009), Barlow and Fiala (2007), Hong *et al.* (2006), Yan-chuen *et al.* (2000); because these differ significantly in their scope and area of consideration.

3.3.2 Building regulations related to refurbishment and rebuild

In 2007 '*Part L*' of the Building Regulation was revised to introduce '*Part L2B*' for existing buildings with a total surface area over 1000 m^2 to set maximum carbon dioxide emissions. The following sections are introduced as part of the revisions.

Section 1: Improvement in energy efficiency with a '*consequential improvement*' to buildings and the advice on feasibility of the same.

Section 2: Guidance on the efficiency measures for large extensions when there is a change (in terms of up-gradation or expansion) of material, use, alteration and lighting, heating, cooling and ventilation.

Section 3: Guidance to deal with envelope (wall, roof and floor) to take reasonable steps to control heat gains and losses.

This shows some initiative taken by the government to reduce energy consumption and carbon emissions, however situation is more complex and further development is needed (Davies, 2009, Wilson, 2009). A review in 2006 undertaken by Directive Implementation Advisory Group (DIAG) reported that *'Part L'* is not linked to the Sustainable Building Code and needs further developments. Also, DIAG requested further amendment in *'Part L2B'* in order to achieve improved lighting levels.

3.3.3 Drivers

Several drivers can influence planning, execution and refurbishment. These can be divided into resource drivers, productivity drivers, economic drivers, technological drivers, political drivers, and brand and image (marketing) drivers (McKahan, 2006), but several other challenges and drivers exist specifically related to healthcare premises. User profile, infrastructure age, development in medical technologies, in addition to drivers presented by Sheth *et al.* (2010c) are all important. Nevertheless, the need to keep facilities in good working condition during major works imposes particular challenges for refurbishment project as discussed further.

For healthcare Sector

Drivers can be divided based on the principles of sustainability, such as strategic drivers and sustainability drivers (Sheth *et al.*, 2008). In addition drivers can be categorised based on a refurbishment needs and a key focus such as user's drivers, construction drivers, future drivers as proposed by Sheth *et al*. (2010a). Future flexibility is best accommodated by identifying a *'future technology zone'*, rather than developing detail plans for the future (Sheely, 2008). Health and productivity are drivers because they can promote visionary thinking, connect sustainability and help with pollution prevention in healthcare sector (Frumkin, 2007).

For refurbishment

Reducing vacancy rates, improving rental levels, upgrading assets and offsetting obsolescence are reported as key drivers for refurbishment (Martinaitis *et al.*, 2004). Building age is an important driver (Payne and May, 2009) and the building envelope is a major area for concern along with physical constraints and air tightness (Sustainable Building, 2007).

3.3.4 Refurbishment versus demolition (new construction)

There is a lack of effective environmental standards for refurbishment in the current market (Sustainable Building, 2007). Careful planning will preserve an existing building's fabric to minimise the use of raw and non-renewable resources and it can help to achieve better quality with minimum capital, compared to new construction. Often, the decision to demolish is taken without accounting for environmental and social impact, as refurbishment is not always a straightforward option. However, careful planning and the best design practice can match the performance and quality similar to new build at greatly reduced cost (Sustainable Building, 2007).

With many refurbishment projects, because of time and budget constraints sustainability is not always considered. It is also difficult to standardised refurbishment procedures in existing buildings because of various constraints, such as building owner objectives, economical limitations, and physical boundaries. The literature suggests following areas to be considered while developing objectives for works related to refurbishment and existing buildings (Genre *et al.*, 2000).

- A diagnosis of the building elements.
- An overview of the worst deterioration problems.
- An energy balance of the building with possible improvements.
- Improved indoor air quality.
- The nature of refurbishment work and possible actions.
- A definition of the degree of intervention.
- The cost of refurbishment work.
- A simulation of possible investment schemes.

Wilkinson and Reed (2006) argued that refurbishment often involves changes in an unpredictable manner. Penoyre and Prasad (2006) performed a feasibility analysis of '*Dulwich Community Hospital Refurbishment Project'* comprising various buildings from the late 19th and early 20th century. The cost and efforts to achieve adequate contemporary standards were significantly higher or equivalent compared to new construction cost. However, rather than being '*unpredictable*' they found some specific factors that proved to be challenging in the refurbishment of Victorian buildings and the late 19th century facilities:

- 25 per cent extra built volumes (because of more floor-to-floor height);
- solid masonry walls;
- lack of insulation;
- lack of adherence to contemporary standards;
- sub-optimal layouts;
- remote storage;
- poor cross ventilation and compromised external view;
- long-term maintenance cost;
- lack of emergency exist;
- technically insufficient; and
- lack of access for disabled.

Lee and Gilleard (2002) argued that building maintenance has been neglected and demanded more studies related to existing buildings. They claimed that additional skills are required for refurbishment compared to development of new facilities (Sustainable Building, 2007, Lee and Gilleard, 2002).

3.4 Energy consumption and existing buildings

NHS existing building stock is responsible for significant energy consumption and an associated carbon footprint. Caccavelli and Genre (2000) reported energy performance of healthcare buildings is inefficient compared to other buildings.

Adderley *et al.* (1987) reported buildings designed after 1973 are fuel efficient compared to buildings built before 1970s and, even today, many poorly constructed energy-inefficient post war facilities are operational. Around 50 per cent of buildings are more than five years old; almost 40 per cent are at least 80 years old and five per cent built in the mid and late 19th century. Their study concluded that the NHS is responsible for consuming more energy because of a general state of dilapidation of its buildings and associated equipment within those buildings.

Santamouris (1994) conducted an energy audit of 33 healthcare buildings (24 hospitals and nine clinics) in Greece. The main aim was to propose several intervention scenarios for increasing energy efficiency; occupants, building envelope, HVAC and lighting system (including occupants' opinions about thermal comfort) were all considered. Orientation of the building, natural cooling techniques, insulation, energy conservation from cooling, ceiling fans, night ventilation were significantly responsible for energy consumption. A series of simulations were performed using software for building thermal analysis to reduce the overall heat transfer coefficient and the energy consumption for heating. Several energy conservation options were applied in each case to identify low energy options, for example, use of fluorescent lamps was proposed after investigating 26 different types of lamps. Santamouris (1994) found that HVAC and lighting were key compared to equipment and other systems. Reduction in energy consumption using alternative building elements including heating and cooling systems by 50 per cent was reported.

Vittori (2002) reported passive cooling, energy efficiency and natural ventilation can play a major role in reducing overall impact by the healthcare facilities on the society and environment. Frumkin (2007) went on to report that many healthcare facilities are low in thermal mass, depend heavily on artificial HVAC and their indoor environment is not satisfying. Also, these facilities are energy inefficient as they heat up rapidly during summer and cool down quickly during winter.

The Department of Energy (DoE) in the UK estimated new buildings would consume 50 per cent less energy and existing buildings 25 per cent less energy through appropriate intervention of design (Clarke and Maver, 1991) and the design phase determines most (up to 90 per cent) of the issues related to energy consumption (Azhar *et al.*, 2009). Nevertheless, reduced energy consumption figures should not be achieved by compromising comfort and IAQ (Clarke and Maver, 1991).

Fangting (2007) studied energy efficiency of buildings and concluded that a lack of data, international methods, and shortcomings in the building science literature related to energy consumption are most relevant. A new methodology (see Figure 3.3) to analyse energy consumption for large-scale building was proposed by the author and was tested on two Chinese and two French office buildings, which highlighted a need for (to analyse a large-scale commercial building) an appropriate set of indices. Fangting (2007) reported energy efficiency of lighting, and heating and cooling as the most important drivers.

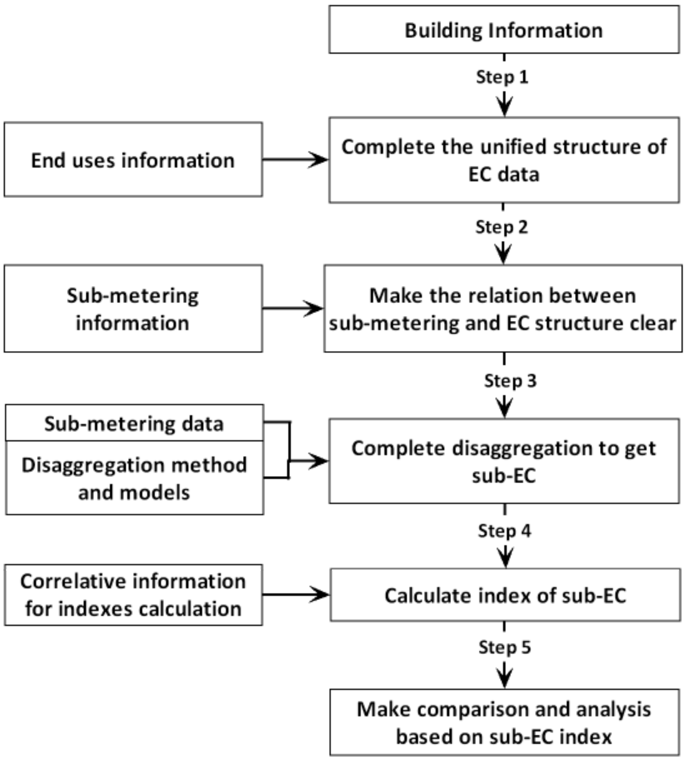

Figure 3.3. Building energy consumption analysis methodology (Fangting, 2007)

Chwieduk (2003) reported great potential for energy savings in the housing sector, describing a three-step design process. The first step was to develop an economically feasible standard method related to energy efficiency; the second step to explore energy saving measures from environmental point of view and, finally, the third step to find equilibrium between present and future energy needs keeping environment and other aspects in mind. Depending on the above steps, building can be categorised into energy-efficient, environment friendly and sustainable building. The need for environmental sensitive construction practices to address the issue of rising energy cost and growing environmental concerns were identified.

Literature suggests that from the inception of a project, the hospital should plan to be a green hospital with development of new philosophies, whole system thinking, front loaded design, end user consideration and teamwork. Also, possible design solutions should be compared with the current situation and for the future (Azhar *et al.*, 2009).

3.5 Carbon emissions in the healthcare sector

Carbon dioxide (CO_2) in the atmosphere is increasing steadily since the beginning of the industrial revolution and is set to increase even more rapidly with the growth of global economy. One recent study revealed NHS buildings consume over £410 million worth of energy and produce 3.7 million tonnes of CO_2 every year (NHS, 2010b). This contributes towards 22 per cent of the total NHS carbon footprint, thus presents an opportunity for savings, which can result in improved patient care. Considering domestic as well as commercial sectors, most buildings will be operational at least for the next 30 years and to improve quality of existing buildings, upgrading their fabric is a vital consideration (Davies, 2009, Wilson, 2009).

3.5.1 Relation between carbon emissions and energy consumption

The energy consumed in the UK comes from various sources, such as coal (34 %), oil (1 %), gas (43 %), nuclear (15 %), hydro (1 %), imported (1.5 %) and other fuels (4.5 %) (Fenwick, 2008). Burning fossil fuels such as gas, coal, or oil releases carbon dioxide into the atmosphere.

Fossil fuels are burnt directly (in a boiler or car) or in a power station to drive turbines which generate electricity and at various stages in the process of creating food, products and services for day-to-day consumption. Carbon footprint is the total carbon emissions that individuals or organisations are responsible by consuming energy. In the process, not only carbon dioxide is generated but other gases (such as methane) responsible for global warming are also generated. Collectively, they are known as GHG emissions (The Carbon Account, n.d.) and are the subject of tough targets for the NHS and other UK public sector bodies, as described next.

3.5.2 Carbon emissions challenges and targets

Hancock (1999) argued, there is a need to consider Environmental Management System (EMS) and '*3Rs*' of *Reducing, Recycling and Re-using* in hospitals to achieve zero-emission policy and minimise the ecological footprint. This concern was raised because the existing building stock remains largely untouched, many refurbishment projects have missed the opportunity to reduce carbon emissions (because until recently the focus was on new buildings/developments) (Chlela *et al.*, 2009, Davies, 2009). Refurbishment of existing buildings is important because this plays a vital role in meeting targets related to emissions in the UK (Wilson, 2009) and elsewhere.

Payne and May (2009) conducted a comparative study of carbon emissions from new and old office buildings in Melbourne, Australia. One of the reasons for this study was to examine replacement/turnover rate of existing office building stock. There is an average gap of 17-years between construction and refurbishment, and every 20-25 years offices require a major refurbishment. Also, targets related to CO_2 emissions are not possible to achieve relying only on building regulations and the targets should be achieved beyond minimum level of regulations. Payne and May (2009) proposed two approaches for refurbishments: high-tech and low-tech. A high-tech approach depends on technology to deliver energy efficiency and consumption from a source to facility, and a low-tech approach for an energy efficient refurbishment includes artificial lighting, heating, cooling, and ventilation within buildings. Also, for measuring energy consumption and CO_2 emissions, following different methods based on total energy consumption and building size were used.

- Mega-joule (MJ) per m^2
- MJ/person/year
- m^2/person
- Kg-CO_2/year

Wilkinson and Reed (2006) revealed that large buildings are more efficient because of higher degree of flexibility and level of occupancy compared to smaller buildings. Also, when compared more than a 50-year-old building with less than a 50-year-old from emissions and energy consumptions point of view, drastic changes were reported. It was concluded that energy and CO_2 emissions are directly related to age of the building and both increase with time. The proposed way to measure energy consumption and carbon emissions in offices was to calculate office space per employee against energy consumption and carbon emissions.

Jenkins and Newborough (2007) proposed a method for estimating carbon emissions associated with electricity consumption for several categories of buildings, such as office, domestic and retail buildings. To support the UK's 2030 target of reducing carbon emissions by 50 per cent and to calculate building demand for energy in 2030, building energy consumption for 2005 was considered as benchmark. For a six-storey office building, by changing lighting specification in accordance with predicted daylighting for year 2030, a possibility of annual energy savings by 56–62 per cent in lighting energy and a reduction in CO_2 emissions by nearly three tonnes was anticipated. The approach was designed to provide first-order estimates of carbon-savings and lighting interventions and the method was not a substitute for sophisticated simulation tools.

Figure 3.4 presents the NHS England emissions from the 1990s to projected emissions up to 2020; the target emissions for the year 2050 with consideration to the current NHS and governmental targets are also presented.

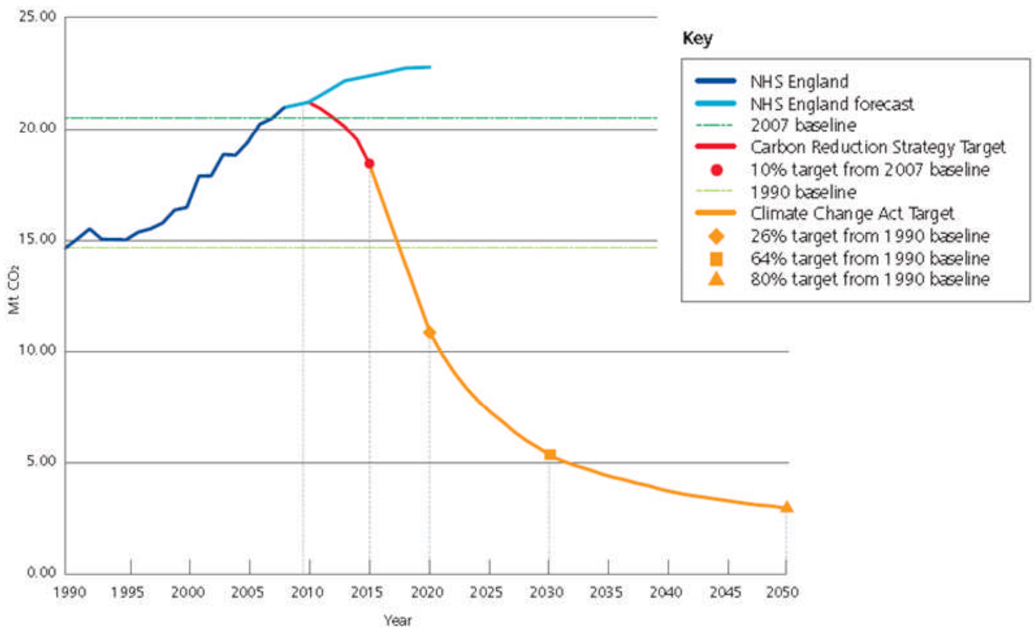

Figure 3.4. The NHS England CO_2 emissions (Sustainable Development Unit, 2008)

The UK government has defined the Carbon Reduction Strategy (CRS) and Carbon Reduction Commitment (CRC) for the NHS. The strategy indicates the scale of reduction in carbon for the NHS to meet the Climate Change Act requirements set by the government and, recommends key actions for NHS to be an exemplar organisation for sustainability and low carbon. As part of the CRS for England, the key strategies are proposed (Sustainable Development Unit, 2008). These strategies include energy and carbon management review at board level in every organisation, integrated use of renewable energy where appropriate, consideration to whole life cycle cost and to ensure individuals as well as the organisations are following CRS.

3.6 Chapter summary

The literature revealed an increasing demand for refurbishment of existing buildings, although it is not a straightforward option and it is driven by certain critical characteristics that determine appropriate actions. The review of literature suggests that often, energy consumption, carbon emissions and refurbishment of existing facilities are considered from a narrow point of view, i.e. a mechanical (HVAC) point of view. Several studies concluded that measures, such as advance planning, development of strategies and policies could help to deliver successful refurbishment of existing buildings.

The review indicates that energy and carbon emissions are often measured per hour or per person basis. However, considering the characteristics of healthcare facilities, such as 24-hour nature of operations and significant variation in the occupancy during day-time, night-time and weekends, the more appropriate way to measure energy consumption and carbon emissions would be per hour per m^3 considering that both the values are constant and do not depend on occupancy.

The literature suggests that focusing only on one area, for example, energy will not help to achieve entire sustainability in existing facility, but all the areas; environmental, economical, and social sustainability should be considered. Thus, from the literature discussed in this chapter it can be summarise that with the NHS building stock, it is better to consider facilities built in the late 20th century for refurbishment if, experts agree. Moreover, in some cases it is better to change use or demolish facilities and build a new healthcare facility to fulfil modern standards and building regulations. In this chapter various studies related to existing buildings, healthcare sector, energy consumptions and carbon emissions are discussed and found that more research and development is required to reduce overall energy consumption and carbon footprint of the NHS. The next chapter presents a review of tools use in the construction industry, and applicable to existing facilities, for planning and refurbishment proposal for healthcare facilities, and for the consideration of different energy performance options in the design process.

CHAPTER FOUR. EXISTING ASSESSMENT AND PARAMETRIC TOOLS FOR BUILDING PROJECTS

4.1 Introduction

The focus of this chapter is on existing assessment methodologies related to sustainability with consideration to energy consumption, carbon emissions and modern tools such as CAD, BIM and simulation for built environment. Most of the tools considered in this chapter are related to sustainability and/or energy assessment of buildings. Some of the tools and approaches adopted in the construction industry for housing, offices, hospitality, etc., are also discussed. Key questions, which guided this chapter, are listed below.

- What current methods are available in the market to assess sustainable development and existing facilities?
- What (interoperable/parametric) tools are available in healthcare and other sectors?
- How can BIM based methodologies be used for refurbishment?

4.2 Tools to assess the performance of buildings

A range of tools can be employed on a project prior to construction to assess possible impact on the environment, community (social impact), and economy depending on the scope of the tool(s) being used. Tools are required to achieve efficient ways of working and to minimise project length, construction waste, money, and resources, yet literature suggests that 20-40 per cent of resources in the construction industry are wasted due to a lack of advance planning (Doran *et al.*, 2009, p. 2).

In the 1970s, to explore complex designs and energy consumption, a need for energy simulation and computer aided design (CAD) was reported (Clarke and Maver, 1991). The European Parliament in the 1980s highlighted a need to have defined standards to promote technical quality checks in a building, such as using computation to determine performance (Van, 2009, Henk *et al.*, 2009). Towards the end of the 20th century, an increasing interest in performance assessment of built environment and their sustainability resulted in the development of several assessment tools (Shi, 2008) such as NEAT, AEDET, ASPECT, LEED.

Several tools now exist to assess performance of a building from various points of view, such as environmental, economical, social, sustainability, resources, procurement. These tools are employed on a construction project for various reasons (Sheth *et al.*, 2010a), such as, to: speed up construction; study environmental performance; predict energy demand; assess overall performance; reduce construction waste; and make optimum use of resources.

The performance of a building can thus be assessed and accredited employing a '*points-based system*' or with the help of benchmarking on a scale of 01-100 using certification schemes, like BREEAM, LEED, GreenStar. Often, the focus of these tools is not limited to energy performance of a building, but also considers a level of sustainability and whole life cost of buildings too. The certification schemes based on benchmarking perform relative and absolute comparisons of a building's performance against similar buildings to issue credits related to (energy) performance (Olofsson *et al.*, 2004, Heng, 2003). According to Rorarius (2007), the following points define a competent sustainable assessment process:

- consideration and linkage between the three dimensions of sustainability;
- multi-stakeholder participation and individual ideological orientation;
- provide conditional conclusions;
- be an ex-ante assessment (capable of involving an evaluation of the conditions for the launch of a project);
- flexibility and innovative (challenge current paradigms);
- consideration to spatial (cross-boundary) and temporal dimensions; and
- combine various existing assessment tools and indicators to help decision-making.

The primary users of the performance assessment tools are controlling authorities, architects, designers, researchers and consultants whereas, building owners, investors and contractors being potential users. Depending on their approaches, project requirements, and local/national regulations the project team may or may not apply any energy performance assessment/certification tools. However, from the beginning of the 21st century, these tools are commonly found on building projects in the UK and in several other parts of the world.

4.2.1 Types of tools

Considering all three key dimensions of sustainability (Environmental, Economical and Social), the assessment tools can be divided broadly among these three categories. In construction, tools for environmental and/or economical assessments are used more often, compared to social assessment tools.

Tools can be divided in to two categories, qualitative and quantitative or based on their focus, '*ecosphere'* or '*technosphere*' (Forsberg and Von Malmborg, 2004). Qualitative tools consider scores and criteria for individual categories, whereas, depending on the focus of a tool, quantitative tools use a physical life-cycle approach with quantitative inputs and outputs related to energy consumption, and overall sustainability. A need for tools to be used at three levels (simple, advance and expert) with respect to projects was reported by Mazzarella and Pasini (2009). Tools to assist with accreditation/certification with the help of point based system or benchmarking are discussed below.

Rorarius (2007) defined three types of tools: sustainability impact assessment (SIA), integrated sustainability assessment (ISA), and positional analysis (PA).

1. The SIA is described as "*a systematic and iterative process for the ex-ante assessment of the likely economic, social and environmental impacts of policies, plans, programmes and strategic projects, which is undertaken during the preparation of them and where the stakeholders concerned participate pro-actively"* (Berger, 2007).
2. The ISA is "*a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers*" and use to study past or future performance (Lai *et al.*, 2008).
3. PA is a method, which "*considers certain network and aims to find similarities between actors in those networks*" (Tuan-Fang *et al.*, 2007).

A '*hybrid*' method where building design standards and modelling software are employed simultaneously for benchmarking with consideration to the European Committee for Standardisation (CEN) was proposed by Heng (2003).

This is a benchmarking approach considering minimum indoor environmental conditions "*for estimating the minimum energy required to meet a set of basic functional requirements*". The approach ensures that only the best energy performing building/option is certified regardless of the quality of the existing building being assessed, which could not necessarily satisfy the need of the healthcare refurbishment sector in which user needs have been identified as an important factor. A simulation model to integrate computer based testing procedure is shown in Figure 4.1.

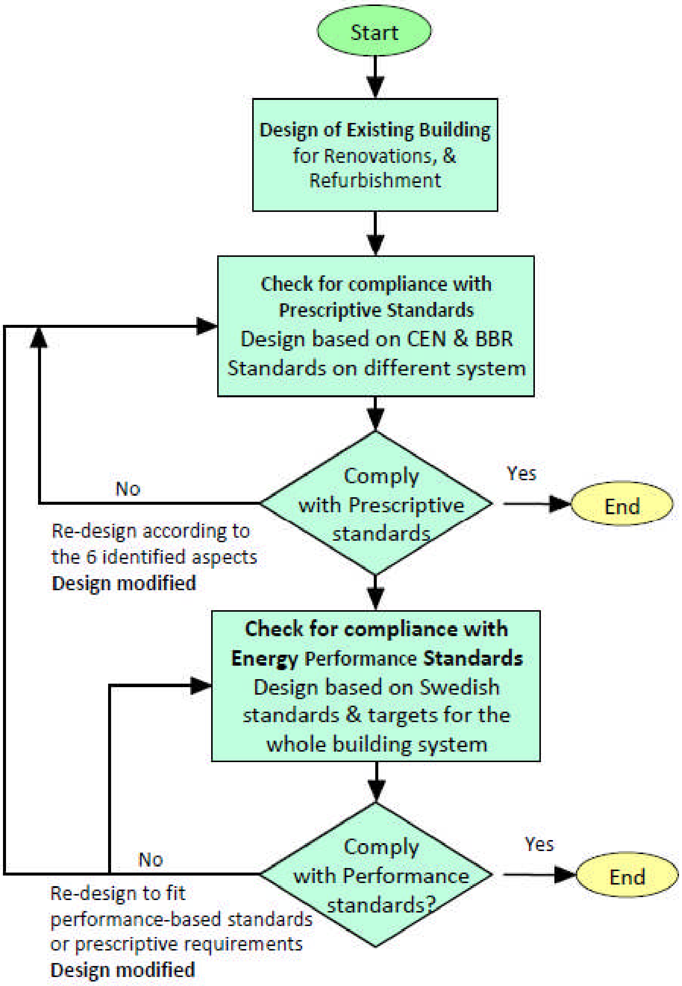

Figure 4.1. Verification process for simulation model (Heng, 2003)

4.2.2 Leadership in Energy and Environmental Design (LEED)

Matthiessen (2004) reported that LEED is "*useful for gauging level of sustainability or greenness of a building*". LEED-EB introduced in 2004 is a widely used assessment tool in the USA and elsewhere for existing buildings (EB), based on the LEED Green Building Rating System. LEED-EB is "*a set of performance standards for the sustainable operation of existing buildings*" (Smith, 2003). It awards credits upon compliance of certain performance standards and the final score is compared with a scorecard. A facility considered for LEED-EB must satisfy at least two prerequisites out of 17 available under the section '*Energy and Atmosphere*' to ensure a minimum energy performance (Heng, 2003). The accreditation involves the verification and assurance of "*building elements and systems are designed, installed and calibrated to operate as intended*". The prerequisites are benchmarked on existing requirements based on the USA EPA and the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE). LEED-EB addresses the areas of operation, performance, whole building cleaning and (interior/exterior) maintenance, including chemical use, IAQ, energy efficiency, water efficiency, recycling, system upgrades to improve energy, water, IAQ, and lighting.

However, the public version of this assessment standard is significantly detailed than that of the BREEAM pre-assessment checklist (Heng, 2003). The focus area of this scheme is building operation with relation to 'green' performance standards. LEED EB focuses on ongoing sustainable building operations, alterations as well as extensions to existing buildings.

Energy performance is typically measured in kilowatt-hour (kWh) of energy consumption per square metre of net building area against cost. Requirement for compliance of LEED involves the provision of calculations showing that the actual energy efficiency and performance of the building as described by ASHRAE. Nevertheless, LEED-EB focuses on ways to reduce use of non-renewable fuels and to minimise environmental impacts associated with excessive energy use. Other than above mentioned points, LEED-EB also considers: establishment of IAQ; provision of an adequate level of lighting and ventilation; temperature control; minimise use of hazardous chemicals; and CO_2 monitoring for occupant's health and comfort.

It is suggested that energy efficiency and low energy use should not be achieved at the cost of user comfort; hence a review of the indoor environment is important while assessing the energy performance of a building.

4.2.3 BRE Environmental Assessment Method (BREEAM)

BREEAM for Healthcare was commissioned by the DoH and the Welsh Health Estates as the preferred environmental assessment method for healthcare buildings in the UK (see www.breeam.org). BREEAM focuses on the following nine categories; management, energy, water, land use and ecology, transport, materials, waste, pollution, and innovation.

As announced by the DoH, from July 2008, new buildings should achieve an '*Excellent*' and major refurbishments a '*Very Good*' rating under BREEAM Healthcare assessment (Cinquemani, 2009). Under BREEAM accreditation, a facility should achieve a minimum number of credits under the above nine categories as mentioned in the BRE checklist (Pendry, 2009).

The Building Research Establishment (BRE) is a non-governmental organisation that helps government, industry and business to meet the challenges of built environment in the UK. It is a research-based consultancy, testing and training organisation. BRE Global launched BREEAM Healthcare XB in 2009 as a means of assessing and offering solutions for existing operational buildings. This new tool complements BREEAM Healthcare developed for new and major refurbishment projects (Pendry, 2009). It is a credit based, self-assessment tool substitute for NEAT and can be sought only on appointment of a BREEAM assessor to carry out a formal assessment and on submission of a BRE Global compliant report. The scheme helps NHS Trusts and other healthcare organisations by (Pendry, 2009, Cinquemani, 2009):

- improving efficiency of existing building portfolio;
- improving indoor environment of occupied buildings with the result of increasing staff and patients' wellbeing;
- reducing energy waste and consequently reduce utility bills; and
- demonstrating commitment to sustainable development.

Table 4.1 presents a comparison of LEED versus BREEAM, both developed for healthcare facilities. A further comparison of two common matrices, LEED-NC and GGHC is presented in Table 4.2; both developed to measure performance of a development from sustainability point of view. The United States Green Building Council (US-GBC) promotes LEED for New Construction (LEED-NC) and

American Society of Healthcare Engineering (ASHE) promotes Green Guidelines for Healthcare Construction (GGHC).

Table 4.1. LEED - Healthcare versus BREEAM - Healthcare (Source: Cinquemani, 2009, Pendry, 2009, Wendt, 2008)

LEED Healthcare	BREEAM Healthcare
Assesses medical offices, assisted living facilities, medical education centres and research centres	Assess specialist hospitals, general acute hospitals, community and mental health hospitals, GP surgeries, health centres, clinics
Need to follow integrated design process develop by the GGHC	Need to follow a New Green Guide for Specification develop by the BRE
The project team must set goals, conduct a design charrette, state the health mission statement of the project, and outline the owner's requirements	Should target to improve conditions for patients, operational savings, better staff working conditions and encourage community use
Offers up to two points for meeting specific acoustic requirements	Credits for providing natural (day) light and outside view
Credits are issued under the Materials and Resources for considering human health	Credits are screened at early stages in project using a screening tool provided by the BRE
Credit for not using harmful materials (for e.g. PVC)	Credits for reusing facade and existing structure

Table 4.2. Comparison of LEED-NC with GGHC (Source: Holtz, 2005)

LEED - New Construction (LEED-NC)		Green Guidelines for Healthcare Construction (GGHC)	
Pros	**Cons**	**Pros**	**Cons**
Third party Validation	Not specifically for healthcare	Healthcare specific	No third-party verification
Formal certification process	Registration and certification fees increases cost	No registration or application fees	No plaque or other formal recognition
Broad industry acceptance	Does not address operation issues	Self-certifying, voluntary process	Not widely known, limited acceptance
Marketing advantages through the USGBC	Requires extensive experience with certification process	Addresses healthcare operation and maintenance issues	Limited guidance available on issues related to operations and maintenance
LEED certification as recognition	Online application process	ASHE award as recognition	Team decides documentation

The next section discusses some additional tools and is followed by a more detailed discussion of the available tools for healthcare.

4.2.4 Energy assessments tools

Simplified Building Energy Model (SBEM) is a software tool, developed by the BRE, to perform an analysis of energy consumption and CO_2 emissions in buildings. The tool is for non-domestic buildings, and is based on the National Calculation Methodology (NCM) and the Energy Performance of Buildings Directive (EPBD) (www.energyassessorslondon.com). SBEM evaluates CO_2 emission rates for new buildings in compliance with 'Part L' of the Building Regulations (England and Wales) and equivalent Regulations in Scotland, Northern Ireland, the Republic of Ireland and Jersey. The SBEM considers building construction, geometry, use, lighting equipment and HVAC to calculate the monthly CO_2 emissions and energy used by buildings. This method is also employed to generate Energy Performance Certificates (EPC) during selling or letting of non-domestic buildings. SBEM ratings are scored on the scale 01 to 100; one being the worst energy use and 100 being a zero usage of energy. Considering the focus of SBEM and its applications in the industry a very limited consideration is given to the same in this research. Also, it is important to note that SBEM follows mostly Part L1B, which is for new buildings and not Part L2B developed for existing buildings. If, SBEM is used for a conversion project, thermal elements, such as, walls, floors, glazing need to be upgraded to a minimum level specified as per the standards.

4.2.5 Dynamic thermal modelling

Dynamic thermal modelling is a technique based on a package of specific software to enable the thermal behaviour of a building in the designing or retrofitting phases (http://www.bureauveritas.com.au). Building thermal simulation is important for two key reasons; first to decide size and select mechanical equipment, and second, to predict the (annual) energy consumption of a building. The former is important to predict peak hourly load during cooling and heating and, the later to predict the energy consumption in terms of quantity.

Energy analysis programs have varying levels of accuracy intended to be used at different phases of the design process and, thus require different levels of effort, information and cost. There are also various categories of tools such as architectural design tools, engineering design tools. For example, a tool such as Energy-10, has been developed for the designer or project manager during the earliest phases of a project to provide immediate feedback and they are known as architectural design tools. While tools such as DOE-2 or BLAST demand more inputs, time and details, are engineering design tools. Therefore, they are often reserved to be used later in the design process when most architectural decisions have already been made. EnergyPlus is a simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows; develop on the widely accepted features and capabilities of BLAST and DOE-2.

4.2.6 Other tools and methods

At the beginning of the 21^{st} century, throughout the world a significant development in tools to assess the greenness and quality of the buildings were observed. A formation of the World-Green Building Council (GBC) by 13 members in 2002 promoted means to measure facilities performance and sustainability. The council comprises Australia, Brazil, Canada, Germany, India, Japan, Mexico, New Zealand, South Africa, Taiwan, UAE, UK and USA with additional 35 countries are expected to join, such as Argentina, Chile, China, Colombia. Currently, the World GBC is a federation of global GBCs. The investigation suggests that existing GBCs in many countries are under development to suit specific categories (such as offices, homes, healthcare) and specific types (such as new and existing/operational buildings).

The GBC of Australia (GBCA) released a GreenStar for Healthcare in mid 2009 to support sustainable planning, design and construction of high-performance of healthcare facilities (www.gbca.org.au). The expected audience for this tool are the owners and operators of healthcare facilities in Australia, to; minimise the environmental impact of facilities, improve patient health outcomes and staff productivity, receive recognition for green leadership, and reduce operational cost.

However, several other GBCs, such as India, South Africa, Korea, and Israel are also said to be in the initial phases of development of similar tools.

Chlela *et al.* (2009) used Design of Experiments (DoE) method with an aim to setup a meta-model for parametric studies of a low energy building. The DoE is a widely accepted statistical method use to perform parametric studies to reduce the number of experiments in the process of designing low energy buildings. The authors explored three buildings to establish the proposed meta-model. The outcome shows that the proposed DoE based meta-model is capable of representing significant errors with the help of complexity of modelled output. In the future, the development of meta-model could replace (complicated) simulation tools often used while designing low energy buildings (Chlela *et al.*, 2009). Meta modelling is the analysis, construction and development of the frames, rules, constraints, models and theories applicable for modelling a predefined class of problems (Cheng, 2009).

De Wilde *et al.* (2002) described decision theory as "*a concerned with making rational choices amongst the options by applying mathematical model*". A proposed framework for the selection of energy saving options includes:

- analysis of components and appropriate specification of performance indicators;
- optional space development by combining building design with energy saving components of a building and parametric combination of the same;
- determination of performance of above options; and
- appropriate selection of options.

To choose an energy analysis tools for existing buildings in order to develop/propose energy saving components, the following key observations were made by De Wilde *et al.* (2002). A significant development in tools to assess performance of a building, and involvement of experts' knowledge to analyse any of the conditions was reported. Consideration to multiple performance assessment tools as there is a lack of tool in the market that covers all the aspects of energy saving components and performance indicator. Nevertheless, it was suggested that application of more than one tool is possible considering differences due to physical and computational modelling.

4.2.7 The debate on leading tools

Despite various developments discussed in this chapter, even today widely accepted tools are not fully qualified to perform required technical checks on a building from (entire) sustainability point of view. The UK NHS Sustainable Development Unit's (2008) position that "*it does not seem clear at present how BREEAM will be managed to ensure its adoption*" clearly indicates lack of strategies to achieve sustainability in the construction industry. Until recently, most of these tools were developed for new facilities and it was assumed that with few amendments the tools could be used for existing buildings.

Rorarius (2007) explored existing assessment tools and indicators with consideration to sustainability. He found that current assessment tools lack practical implication and there is a need to do further research and development in order to prove their applicability.

Although assessment tools such as LEED, BREEAM, GreenStar are accepted widely, the experts raised some concerns because they believe that these tools do not perform beyond a certain extent. Kibert (2007) raised a concern, there is a very little difference between the performance of a LEED certified building and a standard building. Even the best green building (as per LEED) consumes more energy as "*the practice of benchmarking is limited by the performance of the current existing building stock*" (Heng, 2003, p. 64). Thus, even the best building as per LEED may not reflect efficient performance as it is based on current energy-inefficient building stock. Therefore, Heng (2003) suggested a need for further developments in current benchmark approach.

Schenkel (2009) reported that as a predictive system, LEED has no performance requirement (one of the least known flaws) and the "*healthcare industry's unique needs may not be best served by adopting the dominant green building standards in the USA*". He concluded that LEED certified buildings consume 29 per cent more energy than non-LEED buildings.

Roderick *et al.* (2009) tested three widely accepted assessment methods; LEED, BREEAM and GreenStar from USA, UK and Australia respectively with the help of energy modelling and simulation of a building using Integrated Environmental Solution-Virtual Environment (IES-VE). The results show that, the proposed building failed to get a LEED certification as it lacks a significant improvement in energy consumption compared to a baseline building. Under BREEAM, the building achieved a performance rating of 49 on a scale of 01 to 100, (thus Good). However, the improvement in energy consumption under GreenStar rating is lower when compared to the two other assessment methodologies. Based on the study it is highly recommended that the simulation of HVAC system along with any of the assessment methodologies should be performed. Moreover, this study also indicated that there is a lack of common approaches for assessing sustainability in buildings, despite development of World GBCs and other above mentioned efforts.

Nevertheless, many governmental as well as non-governmental organisations are developing in-house tools (such as Spear by ARUP, DeLTA by BDP), which is creating some confusion in the market.

4.3 Computer Aided Design (CAD)

The integration of BIM and modern tools during refurbishment offers potential benefits, so CAD is considered briefly within this chapter and research. The introduction of CAD based tools in the late 20th century helped construction industry to upgrade from handmade drawings (see Figure 4.2). Until recently, before introduction of BIM and simulation based tools, CAD was the most widely adopted system in the construction industry throughout the world. The transition from handmade drawings to CAD helped designers/planners spend more time at the early phases of designing exploring different layouts rather than spending most of their time at producing drawings (Smith, 1984).

Cyon (2003) reported that traditional construction processes (for example, CAD) involve numerous documents at different stages resulting in overlap and inconsistency of information. Also, all these drawings are maintained separately by various project participants at several locations making buildings designs a complex process. Nevertheless, a lack of updated drawings and inconsistency during design phases of a project leads to expensive construction errors (see Section 4.6) resulting in a late delivery of a project.

Bailey *et al.* (2008) reported that 2D drawings are still a key focus of the construction industry and are responsible for conflicts, poor documentation and cost the industry billions of dollars each year, due to interoperability related issues.

Ahead, in Section 4.6 interoperability is discussed. The problems with 2D drawings are manual coordination, level of detailing, and creation of construction documents by separate disciplines each with their own concerns. Cyon (2003) reported that unlike CAD, in BIM, objects are not collection of points, lines and curves, but contain information, specification, details and hold data related to manufacturing and sustainability.

4.4 Parametric modelling tool

According to Bentley, one of the developers of BIM based tools, parametric modelling "*captures and exploits the critical relationship between design intent and geometry*" (Bailey *et al.*, 2008). Parametric software facilitates complex designs in two respects, firstly, it allows users to generate complex forms and secondly, for rapid changes by adjusting the variables and testing efficiency, aesthetics and performance. Modelling is defined as "*the act of describing a system by extracting, organising and representing in some unambiguous way, the knowledge gained upon the system under investigation (SUI), by building a conceptual model*" (Mazzarella and Pasini, 2009, p. 638).

The need for a virtual building model was identified by Popov *et al.* (2009) and Bailey *et al.* (2008). The object-oriented nature of the model makes it easier to exchange, insert, or extract information related to the project throughout the process (Bailey *et al.*, 2008, Revit, 2007). Virtual Building (VB) is defined as "*fully tested building solution with confidence not just in constructability of the building but also in its long term operational performance*" (Bailey *et al.*, 2008, p. 15). VB stands where "*design, construction, environmental performance and operational problems are visualised, solved and optimised by adopting integrated computer simulation*" (Dix, 2009). In addition to the above benefits, VB helps stakeholders in the following areas.

Exploration: to explore new design and construction directions.

Communication: helps project team to communicate quickly and accurately; explains design forms, functions and behaviours to other team members and stakeholders.

Integration: enables design and facility team members to share and co-ordinate project information quickly and efficiently.

Optimisation: to optimise performance, sustainability and costs to meet short-term as well as long-term goals.

VB helps with quick comparison and assessment of different design options considered from an environment point of view, if required. Bailey *et al.* (2008) asked "*would not it be powerful to be able to experience the space before it is built in order to refine design choices and provide more certainty in the outcome?*"

A parametric study involves consideration of various factors, such as insulation, orientation, glazing (facade), type of envelope, equipment efficiency; all these contribute towards building energy demand. Tools such as BIM and VB model support and integrate principles of sustainable buildings. VB has the potential to go beyond building design and is capable of assisting with master planning, construction planning, urban planning, traffic simulation, and so on at various levels, hence could be extensively valuable in a complex healthcare refurbishment project.

4.5 Building Information Modelling (BIM)

The need for tools to prepare conceptual and final designs along with a centralised file system to save information and reduce overall time related to construction project was noted by Bailey *et al.* (2008) and the development of object oriented CAD resulted in BIM, filled the above gap. The purpose of BIM is to support and explore design concepts and building forms from the earliest possible design stages of the project and, to maintain a project vision through construction documentation.

According to the National Institute of Building Sciences (NIBS), BIM is "*a digital representations of physical and functional characteristics of a facility*" (American Institute of Architects, 2008, p. 536). Succar (2009) defined BIM as "*a methodology to manage the essential building design and project data in digital format throughout the building life-cycle*". Hill (2007) noted that BIM had emerged as a critical catalyst for interoperability and often, used for 3D visualisation and clash detection. Revit was developed on the principles of BIM as "*a complete,* *discipline-specific building design and documentation systems platform supporting all phases of design and construction documentation*" (Revit, 2007). It is reported as a critical cornerstone for the exchange, management and integration of project information across diverse platforms (Han, 2005). Table 4.3 presents the benefits and limitations of BIM, as revealed from the literature.

Table 4.3. BIM benefits and limitations
(Source: Sheth et al., 2010a, Azhar et al., 2009, Higgs and Stokes, 2008, Hoover and Schubert, 2007)

BIM benefits	BIM limitations
Maximises flexibility in use and location of spaces throughout design process	Handling of a fully loaded central BIM project file represents a major challenge
Gives comprehensive coherent understanding of a project as a whole, while controlling each individual departmental area	Difficult to share complete model because of quantity of available construction related information
Enhanced visualisation and data management	Need increasingly sophisticated data management at the building objects level
Model can be used for simulation and visualisation at any stage	Rarely single technology is used across the project by consultants, design team
Data is stored centrally and automatically updated	Sometime BIM does not provide the flexibility needed by the engineers
Better co-ordination as all the data is available in one file	Design file size and complexity of data management in BIM is tedious
Good as-built model can support a maintenance and renovation at any stage	Hard to predict the future of the construction sector thus future of the BIM
A new area for research and development	Need trained BIM experts
Increased collaboration, auditability and maintainability	BIM being new technology, there are limited legal and contractual framework in regards to BIM liability

The interoperable nature of a building model helps to increase collaboration amongst stakeholders and provides information required by a facility manager throughout the life-cycle of the facility.

Bailey *et al.* (2008) described BIM not only as a 3D geometric modelling tool, but also supply construction related information into the process of design and development of a facility, with the advantages such as; automated quantities and scheduling on time, provides information required for planning construction process, automating the fabrication process, and provides information required for facilities managers.

4.5.1 Development of BIM

Azhar *et al.* (2009) reported that to perform any kind of building performance analysis in the early design stage, a comprehensive set of building knowledge related to a form, materials, context and technical systems is required. Exchange of project-related, trustworthy building information is important for integration and collaboration purposes as part of a building designing and development process (Van, 2009).

Dix (2009) presented the development of BIM from drawing board (see Figure 4.2) in the construction industry in chronological order and predicted that by 2020 BIM will be fully developed, however, it is difficult to estimate the percentage of BIM utilisation and adoption in the industry.

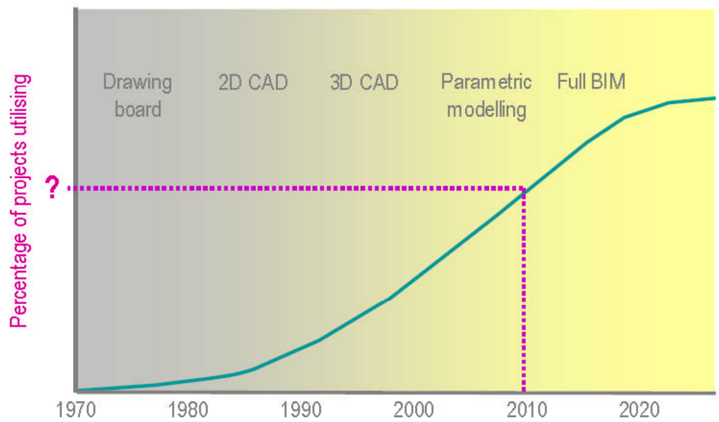

Figure 4.2. Development of BIM from drawing board (Dix, 2009)

Figure 4.3 presents comparison and understanding of 2D lines in CAD with 3D objects (lines) in BIM (Dix, 2009).

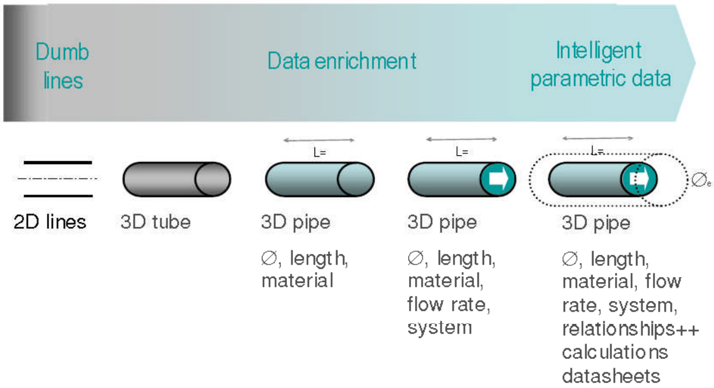

Figure 4.3. The BIM pipeline
(Dix, 2009)

4.5.2 Applications of BIM

The literature related to construction industry highlighted various possible applications of BIM. Cyon (2003) reported that BIM offers a level of management control, typically ignored by the conventional construction processes, such as handmade drawings, CAD. BIM helps to apply additional knowledge such as information related to occupancy, operational hours to the building process and a 3D model, whereas a study by Azhar *et al.* (2009) concluded that BIM facilitates very complex process of sustainable design, such as daylighting, solar access, material takeoff, estimation, scheduling and energy modelling.

BIM based software tools can support sustainable design and export building information and data related to materials, room volumes, furthermore, into green building extensible markup language (gbXML) and Industry Foundation Classes (IFC). To perform energy analysis using Green Building Studio (GBS) and to study building performance employing Ecotect Analysis software by Autodesk developed on the principles of BIM (www.usa.autodesk.com) is less time-consuming process. Whereas, using 3D Studio Max (www.autodesk.com/3ds-max/) helps to evaluate indoor lighting analysis in support of green building accreditation, such as LEED, BREEAM.

BIM assists professionals (such as architects, designers) in predicting the outcome(s) of a building before construction to minimise its impact on the environment throughout its life-cycle. A model developed on the principles of BIM is data rich, object-oriented, intelligent and parametric digital representation of the facility and can provide appropriate data on demand to several users for various analysis purposes (Azhar *et al.*, 2009). Also, it links virtual building model, project life-cycle information, and physical and functional characteristics of a project. These characteristics make BIM a highly interesting option for complex building projects, thus suitable for healthcare facilities as well as refurbishment.

4.5.3 Existing methodologies using BIM

Previous studies on communication between designers (architects) and simulation experts, (for example, Sanguinetti *et al.* (2009), Dunsdon *et al.* (2006), Ellis and Mathews (2001), Morel and Faist (1993)) often refer to the need to integrate design data with virtual models to predict performance of a facility, or the presentation of simulation results to evaluate the design process. In Appendix D, a brief list of publicly available guides and reports related to BIM in various countries is presented.

A conceptual framework for BIM-based '*Sustainability Analysis*' developed by Azhar *et al.* (2009) for construction companies is presented in Figure 4.4. The left hand column indicates the project phases, the middle column depicts the various sustainability analysis features, and the right hand indicates the interaction of external entities such as customers or project partners.

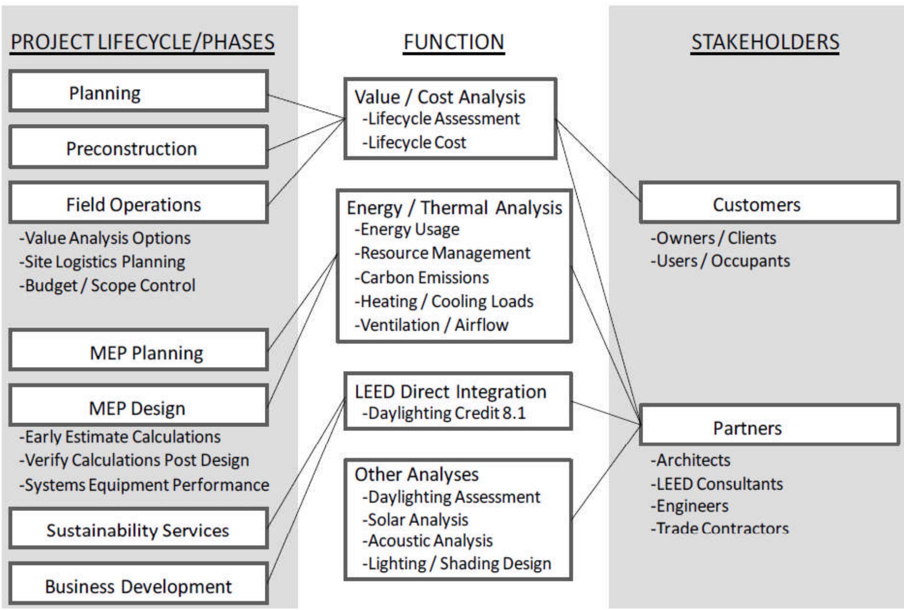

Figure 4.4. Conceptual framework for BIM-based sustainability analysis (Azhar et al., 2009)

The above framework was proposed to facilitate design process and to provide integrated energy analysis in the process. It is interesting because, it is one of the ongoing studies relevant to BIM in relation to sustainability analysis. This indicates that BIM can facilitate tedious process of sustainable design. This study explores the capability of BIM in performing various tasks, such as solar studies, material takeoffs, and cost estimation.

Sanguinetti *et al.* (2009) tested an automated energy analysis framework (see Figure 4.5) on two courthouses at the preliminary concept design stage and presented to General Services Administration (GSA) in the USA. The aim was to explore issues involved with a '*BIM-driven concept design process*' that integrates building simulation to evaluate design.

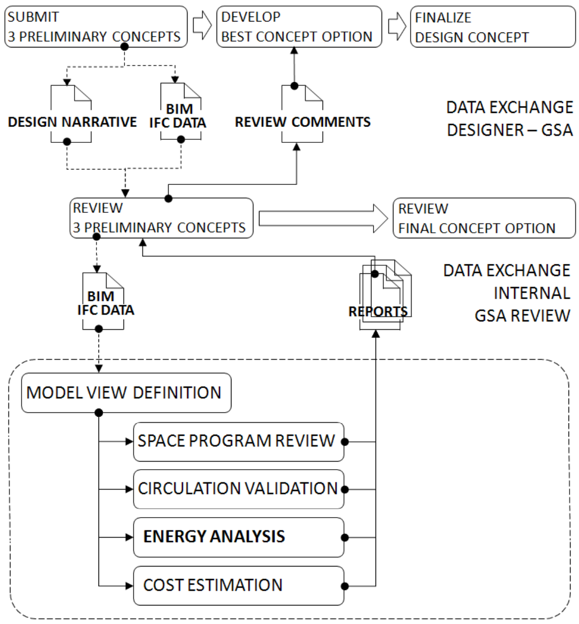

Figure 4.5. Automated assessment for USA courthouses (Sanguinetti et al., 2009)

The study was conducted in two phases, first, to map BIM for building simulation modelling (BSM) and second, to analyse impact of design options on energy performance. The authors concluded that to support design evaluations and decision making during the concept design stage, BIM provides explicit information with the help of early integration of energy simulation by assessing conceptual design. The plug-in developed by Sanguinetti *et al.* (2009) as an energy evaluation module is presented in Figure 4.6.

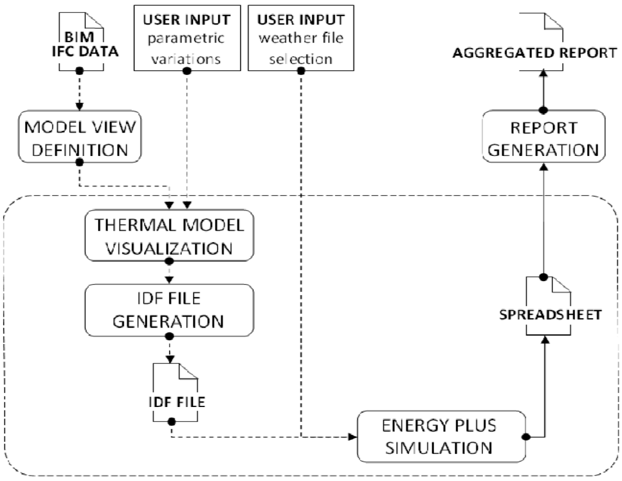

Figure 4.6. Automated energy analysis (Sanguinetti et al., 2009)

Succar (2009) proposed three '*BIM fields*' and several participants (actors) associated with those fields (see Figure 4.7).

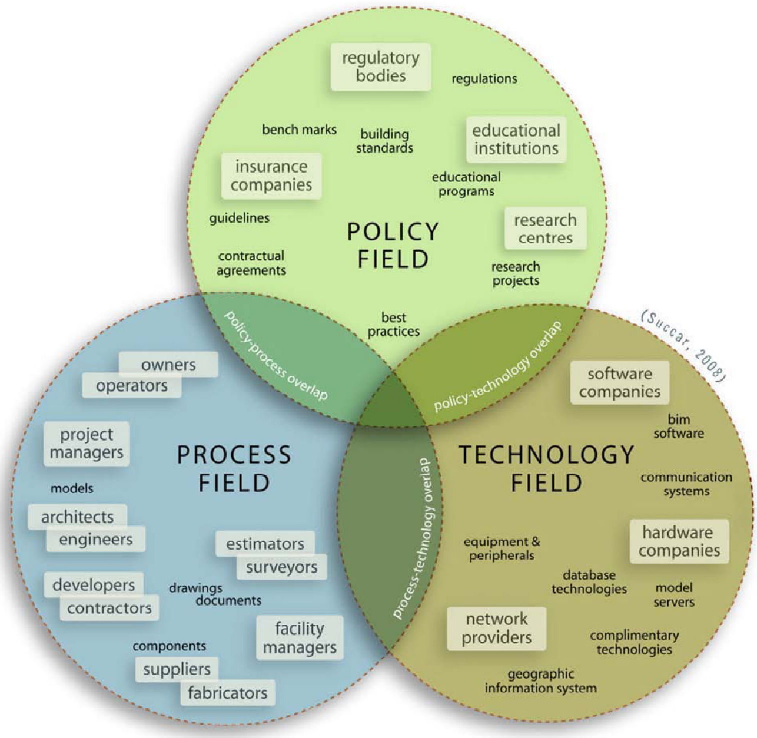

Figure 4.7. Three interlocking fields of BIM activity - Venn diagram (Succar, 2009)

As part of the study, the integration of BIM is divided into the following three key steps.

Technology step: migration from drafting based to object-based workflow.

Process step: model based collaboration.

Policy Steps: involves integrated practices.

A linear view of BIM is presented in Figure 4.8; it shows life-cycle from pre-BIM to Integrated Project Delivery (IPD).

Figure 4.8. Three stages of BIM maturity - linear view (Succar, 2009)

4.5.4 Success

A BIM can optimise overall construction time by highlighting bottlenecks and site constraints during construction work. In the USA, since 2007, it is mandatory to use BIM within design process on any project funded by the GSA (Revit, 2007). Bailey *et al. (2008)* reported that integration of BIM within the process may not reduce design and documentation time, but can minimise the effort, time, and money required during the various construction phases. Moreover, good BIM improves participants' efficiency and effective collaboration, thus speeding-up the entire process (Van, 2009) and produces operative information (the information relevant to and which allows design decisions to be made).

Huang *et al.* (2008) reported that 28 per cent of design firms in the USA are using BIM and projected that the number will increase by 200 per cent in the near future. A study by Hill (2007) in regards to implementation of BIM in New York revealed that 80 per cent are using BIM for 3D rendering and half of engineers use it for interference detection. Also, around 50 per cent of experts use BIM for parametric manipulation of designs; and 46 per cent use for structural analysis.

Importantly, many organisations working in the healthcare construction sector have reported several benefits due to adoption of BIM on projects as explained earlier and further.

Higgs and Stokes (2008) reported application of BIM on a newly designed 136 bed 350,000 ft^2 Piedmont Newnan Hospital (PNH) in the USA to help the design team and client. The use of the (delivery) tool increased team collaboration, improved schedule, cost reliability and reduced rework on site. It has also helped to make decisions during the design process by providing updated 3D model for visualisation, expedite the project schedule while controlling the cost, and provided a 3D closeout document to stakeholders, facility manager, etc.

Barista (2007) shows how Revit, a BIM based tool, was used for several healthcare projects and reported benefits such as simulating process, reduced project cost, shortened schedules, better project quality, improved material distribution, better patient and staff flow and co-ordination between mechanical, electrical and plumbing (MEP) activities. The use of BIM helped off site co-ordination to resolved problems before construction and reported a 20 per cent reduction in MEP and fire-protection labour cost because of fewer revisions and errors.

Cooper (2008) found BIM can address the hospital's changing infrastructure needs with consideration to human issues. Barista (2007) stated, "BIM is a perfect fit for healthcare because of the complex nature of these buildings, the repetitiveness of the activity within the building, and the need to really nail the process".

The benefits cited above for BIM on healthcare projects are also confirmed by various experts such as Bovey, (2008), Cooper (2008), Manning and Messner (2008), Oberlin (2008), Howell and Batcheler (2004).

4.6 Interoperability

Traditional methods often divide the delivery of construction projects into several phases as work is handed from one member to next throughout the process. Also, in the past because of difficulties such as switching from handmade drawings to CAD, the architect used to ignore client's demands for design data to take forward for building operations; soft copy/CAD (Hecht, 2008).

Hill (2007, p. 4) defined interoperability as "*the ability to manage and communicate electronic product and project data among collaborating firms" and "ability to implement and manage collaborative relationships among members of cross-disciplinary build teams that enables integrated project execution*". Young *et al.* (2007) reported several benefits of interoperability such as reduced project delivery time; reduced infrastructure vulnerability; greater reliability of information throughout the life-cycle; expanded markets for companies; decreased supply-chain and communication costs; and improved value for customers.

Also, interoperability helps eliminates (Young *et al.*, 2007) re-entry of data manually, duplication of business functions and continued reliance on paper-based exchange of information.

The International Alliance of Interoperability (IAI) believes that up to 85 per cent of (trust worthy) information related to construction projects can be obtained from a virtual model and the information is trust worthy, provided the inputs supplied to the model are correct (Young *et al.*, 2007). Virtually hosted buildings in BIM with the help of interoperability can promote visual and calculated checks. Also, together BIM and simulation approaches provide an opportunity to test a building virtually from all aspects (except air tightness, water tightness, which are associated with physical/actual buildings) (Hecht, 2008).

Forward Modelling (FM) along with interoperability can compare design options to arrive at energy-efficient design with consideration to costs. FM is data-driven design optimisation approach, such as modelling based on energy use of existing buildings for establishing baseline and calculating retrofit savings, and to simulate and predict energy consumption (Pan *et al.*, 2008). FM involves geometry, geographical location, physical characteristics, type of equipments, etc., relevant to a project.

Until recent, communication related to design, construction projects consist of the back and forth translation of ideas between the 2D representations versus 3D space in the reality. This has resulted in widely recognised problem of interoperability in the construction industry. In response to this problem, an emerging concept of BIM has been seen as a promising solution. Interoperability is a problem associated with not only new construction projects, but also with refurbishment projects. In the previous section BIM has been discussed in greater details.

A work related to Building Energy Performance Simulation Tools as part of Stanford University, Lawrence Berkeley National Laboratory, etc., focusing on interoperability (Maile *et al.*, 2007) is briefly discussed ahead. Energy performance simulation programs are powerful tools to study energy performance and thermal comfort during the building's life-cycle; today, numerous such tools are available. Usually, these tools are developed to be used during the design phase of the building life-cycle. Recent developments lead to a broader use over all phases of a building's life. Most simulation tools are use for prediction of energy use, but can be used to calculate differences in energy consumption for different design alternatives. Accuracy of simulation results is determined by the quality of the data input given to the same. A major benefit of energy simulation in design today is the comparison of architectural design alternatives.

4.6.1 Interoperability impact on cost

In a report on 'Cost Analysis of Inadequate Interoperability' (CAII) 20 to 50 per cent possible reductions in delivery time through improved communication between all the stakeholders in the industry and by avoiding conventional processes was highlighted (Gallaher *et al.*, 2004). As mentioned by the CAII large Oil Company reported savings of 11 to 14 per cent in operations and maintenance cost in 1980s through interoperability. Ineffective communication in construction industry's is reported as responsible for tremendous waste and inefficiency and accumulating up to 30 percent of the total cost of each building project. Also, during the construction phase around 10 percent saving by improving scheduling is reported. According to the CAII report in 2002 savings of $15.8 billion in costs were quantified for the U.S. capital facilities supply chain by addressing interoperability related issues (Gallaher *et al.*, 2004).

During the construction phase due to request for information (RFI), it cost $55.7 million to architects and engineers (based on available data), which could have been reduced by effective interoperability in the USA. Inefficient business process management accounted for nearly $400 million, with mostly (89 percent) was during the design phase. Below table presents some of the major cost due to inadequate interoperability during 2002 in the USA by Stakeholder Group by life-cycle phase.

Table 4.4. Costs of Inadequate Interoperability (Gallaher et al., 2004)

Stakeholder Group	Planning Engineering, and Design Phase	Construction Phase	Operations and Maintenance Phase	Total (in US$ millions)
Architect and Engineers	1007.2	147	15.7	1169.8
General Contractors	485.9	1265.3	50.4	1801.6
Specialty Fabricators and Suppliers	442.4	1762.2	-	2204.6
Owner and Operators	722.8	898	9027.2	10648
Total	2658.3	4072.4	9093.3	15824

Even lack of interoperability costs extend beyond life-cycle phases in which it cost architects and engineers $15.6 million to transfer information between different entities during post-construction phase.

4.7 Simulation

Simulation is a tool "*credited with speeding up the design process, increasing efficiency and enabling the comparison of a broader range of design variants leading to optimal design*" (Augenbroe, 2002, p. 6). Mazzarella and Pasini (2009, p. 640) explained it as "*the act of performing experiments on the model to make predictions about how the real system would behave; that is how the real system under investigation (SUI) would react when subjected to such stimulating conditions*". Moreover, simulation provides a better understanding of design consequences, thus increases the effectiveness of the engineering aspects of the design process. It offers potential for healthcare refurbishment in terms of energy modelling and analysis, which can improve IAQ and patient satisfaction by a significant amount.

4.7.1 History

In the late 1960s, an attempt was made to apply computer-based simulations to study building behaviour, and in the 1970s some development in application of software for building design was observed. In the 1980s, it was reported that it is difficult to develop a model which includes all the data needed, thus it becomes very tedious and putting off to perform any kind of simulation study. Despite extensive developments in simulation tools, Augenbroe (2002) reported the pace is slowing down and there is a difficulty in predicting the direction they are progressing (see Figure 4.9).

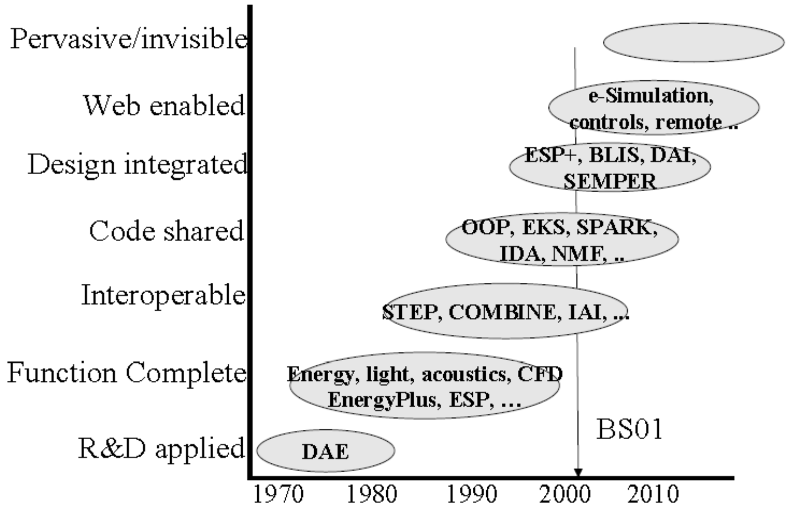

Figure 4.9. Trends in building performance simulation tools (Augenbroe, 2002)

The current simulation tools are very advanced and not well suited to early design stages. The two suggested areas by the author to improve applications of simulation tools are development that respond better to design requests and development embedded in the process of design for managing and enforcing the role of analysis tools in a design project. In Figure 4.10, the evolution of building energy models is presented.

1st Generation	Handbook oriented Simplified Piecemeal	Feedback loop	Indicative Application limited Difficult to use
2nd Generation	Dynamics important Less simplified Still piecemeal		Increasing Integrity Vis-a-vis The real world
3rd Generation	Field problem approach Move to numerical methods Integrated view of energy sub-system Heat and mass transfer considered Better user interface Partial CABD integration		Leading to
Next Generation	CABD integration Advanced numerical methods Intelligent knowledge based Advanced software engineering	?	Predictive Generalized Easy to use

Figure 4.10. The evolution of building energy models (Clarke and Maver, 1991)

4.7.2 Application

Integrated simulation tools are required to support the new building regulations and to develop innovative responsive element, such as plant system, new material, and strategic building future. Fewer than 20 per cent of energy saving building components are selected with any consideration of an alternative option (De Wilde *et al.*, 2002). Application of computer based simulation to compare and optimise the best design solution and component is most effective at conceptual design phase (Lain *et al.*, 2009, Azhar *et al.*, 2009). Mazzarella and Pasini (2009) reported simulation as the only approach for the designer to explore the complexity between design and environment in the early phases of the building design.

Clarke and Maver (1991) reported that the first stage towards simulation is to model a proposed or existing design using a 3D geometry along with constructional and operational attribution. The climatic responsive design of high efficacy and optimum combination zones is possible to achieve with the help of simulation. Simulation can help to determine the effects of design strategy, glazing system, or sophisticated building controls. However, rather than selecting a simple design tool because more data input is required, it is better to gather the data and adopt integrated design tools to obtain better results. Clarke and Maver (1991) explored simulation tools and concluded that more importantly simulation improve quality of the environment within buildings, it increase awareness of designers regarding energy conscious design; and provide value of the case material in education and training.

Though many simulation tools exist in the market with different aims, still the predicted results should not differ significantly if, they are used appropriately in the right context (Heng, 2003). So, a need to have a user driven, sensitive, and case-specific process to increase support during building design was found in the literature.

4.7.3 Limitation

Huang *et al.* (2008) explained that the limited adoption of simulation tools in the construction industry was majorly due to; large amounts of data inputs required, time consuming, difficulty in interpreting outputs especially to make decisions related to design, experts to embed the information in the designing process, and difficult to ascertain level of accuracy.

Whereas contemporary (lighting) tools have following shortcomings (Huang *et al.*, 2008).

- Hard and frustrating to learn many tools;
- Geometric input is tedious and error prone;
- Limitation on modelling;
- Level of accuracy and validation;
- Difficult to interpret;
- Does not support integrated, concurrent design process;
- Difficulty in transferring data between domains; and
- Difficulty in conducting parametric analysis.

De Wilde *et al.* (2002) and later Harputlugil *et al.,* (2006) argued that the application of simulation based tools is yet to be prove in real life, and to enhance the current applications, there is a need to have a process based approach. The starting point for the selection of energy saving options is not completely developed and, though the detailed model allows better analysis, they do not reduce the gap between analysis and design. Fully automated exchange can improve and support design strategies. Moreover, rather than statistical data modelling, any interface should make it easier to integrate data from different players involved on the project. This can be improved by addressing issues related to interoperability.

The functions of many available tools are not clearly understood and often, they are used without proper understanding (De Wilde *et al.*, 2002). Also, there is a lack of a framework which helps designers with their selections of a specific tool (Harputlugil *et al.*, 2006). Based on the review of literature presented in this chapter it can be concluded that there is a need for functionality and performance based data to validate widely accepted tools. Mazzarella and Pasini (2009) reported development of various Building Simulation codes in past 30 years, but Modelling & Simulation (M&S) approach is not yet properly defined in the Building Performance Simulation (BPS) field (also confirmed by Harputlugil *et al.*, 2006). Finally, BPS can be expressed as a performance predictions technique of the buildings prior to construction.

4.8 Chapter summary

Through this chapter, the importance of BIM and simulation based tools especially for existing buildings and certification tools, such as LEED, BREEAM are discussed. This chapter highlighted a need to identify tools at the beginning of the project to be implemented during the project to get an idea about data input needed throughout refurbishment projects and to understand resources required throughout the process. Also, it is required to get an idea about data output obtained throughout the project and to predict energy consumption throughout the life-cycle of the facility being refurbished.

If an assessment scheme requires some unique data not supplied by the modelling tool employed on the project, then during the project there will be a need to employ some additional tools resulting in price escalation, delay in project, quality of project, etc. Also, having analysis tools in different domains make it difficult to coordinate the data related to a project. The tools such as LEED, BREEAM can be applied for energy assessment certification, but there is a need for further development to comply with energy based performance standards.

Nevertheless, to facilitate use of simulation, BIM is a necessary part of the process.

Although there is continuing development in simulation tools, the applications of these tools is not user friendly and there is difficulty in sharing data between two or more domains. However, in the construction industry (to reduce losses due to inefficiency), there is a demand for interoperability and many experts are promoting it. In reality, design simulation tools are used towards the end of the process for optimisation and verification, but not to support decisions made during the design phase. Often, interoperability and BIM is considered from very narrow perspective; a tool for easy data sharing, 3D modelling, scheduling, estimation of cost, etc.

In Chapters Two, Three, and Four the data collected from secondary sources (literature review) has been presented, and in the next chapter the methodologies employed in this research to further accomplish research aim, objectives and to collect primary data are discussed.

CHAPTER FIVE. RESEARCH METHODOLOGY AND APPROACH

5.1 Introduction

A research methodology, data collection and data analysis sections are one of the key features in a thesis, which provide insight of the research and are driven by an aim or a thrust to the subject under investigation. These justify the chosen methodologies and provide the research environment. They comprise the activities such as acquiring and compiling information (means collection of data) from different sources enabling a researcher to connect the empirical data (means data analysis) with the research questions and objectives. The collected data are analysed to develop and/or to verify a theory, a framework, or a tool. The process of analysing data is very important because the validity and rigour of a research depends on it.

This chapter describes the research design, theoretical orientation, and various tasks and methods adopted to facilitate the aim and objectives of this project. Issues related to research designs, strategies, approaches, types, methods, and data collection and analysis adopted in this research are also presented.

5.2 Research philosophy

A number of considerations exist in the literature that could underpin the philosophical position of a research, but there is no clear view on deciding an appropriate research design and approach (Easterby-Smith and Lyles, 2003). The key issues behind understanding a research philosophy suggested by Easterby-Smith and Lyles (2003) are discussed below, also considered in this research. These key issues are: to clarify research designs; to help researcher to recognise which design will work and which will not; and to explore and create designs that may be outside the researcher experience/knowledge.

Due to the complexity associated with the fundamental concept, research area, construction processes, including perspectives and motivations of the individuals, a '*nested*' approach presented in Figure 5.1 has been adopted for this research project. This approach was preferred because most available philosophical considerations have pros and cons, as discussed ahead. This enabled the researcher to establish the philosophical position, approach, and consequently, a selection of appropriate techniques for this research (see Figure 5.1). Three interrelated themes (philosophy, approach and technique) had been identified in similar studies, such as *'the Development of Generic Process Protocol for Construction'* (Kagioglou *et al.*, 2000), *'the Development of Continuous Improvement Framework for the Procurement of Primary Healthcare Facilities'* (Ibrahim, 2007).

Figure 5.1. Nested approach of research methodology

Bryman (2004) named '*ontology*' and '*epistemology*' (also considered as part of the research philosophy) as two key philosophical considerations in social and most construction management researches. Oliver (2004) suggested the use of ontology and epistemology to discuss varying degrees of theoretical issues in a thesis/dissertation. However, some experts criticised ontological and epistemological considerations within the construction management research. For instances, Seymour *et al.* (1997) criticised positivist (epistemology) approaches in the built environment research because of the need for greater proximity between a researcher and a real life problem. Susman and Evered (1978) stated "*the positivist model of science when applied to organisations produces a knowledge that may only inadvertently serve and sometimes undermine the values of organisational members*". Whereas, with the interpretivist (epistemology) approach it is difficult to create a generalisable theory as two individuals observing the same phenomenon could arrive at different conclusions because of the preconceived ideas and beliefs (Harriss, 1998).

To overcome the above issues, empirical philosophy is found to be an evolving direction for research projects related to the construction sector (Yang *et al.*, 2010), including this research. The key philosophical aspects of the empirical research methodology is ‘*a research supported by evidence’* (Manor College, 2006) and it involves a case study based approach to overcome the boundaries between the phenomenon within its real-life context (Seppanen, 2009). Thus, the nested approach involving three philosophical considerations was considered in this research. Below these three considerations are explained in more details and justification have been provided how they benefitted this research.

5.2.1 Ontological considerations

Ontology involves “*the logical investigation of the different ways in which the different types of things are thought to exist and, the nature of various kinds of existence*” (Ibrahim, 2007 p. 31). Fitzgerald and Howcroft (1998) highlighted two broad ontological positions, realist and relativist discussed in Table 5.1. For example, one of the basic ontological distinctions is about the possible nature of the entities, which a researcher seeks to measure.

5.2.2 Epistemological considerations

Epistemology means an attempt to create knowledge and a development of theories to explore its nature (Knight and Ruddock, 2008). Oliver (2004) suggested that with a case study approach there should be a discussion of epistemological issues to explain the ways in which the collected data are expected to reveal knowledge about a research area. Epistemological issues deal with a question of knowledge acceptability in a discipline; are concerned with ‘*how we know*’ and the methods through which knowledge is acquired (Bryman, 2004).

Epistemologically positions of the research are grouped as a positivist and interpretivist presented in Table 5.1 (Ibrahim, 2007, Bryman, 2004, Love et al., 2002). A positivist epistemology suggests the use of survey methods such as questionnaire, and data to be analysed quantitatively (Oliver, 2004). The interpretivist epistemological position in a research is critical to the application of a scientific model in a social study.

Table 5.1. Summary of philosophical considerations
(Source: Ibrahim, 2007, Oliver, 2004, Bryman, 2004, Fitzgerald and Howcroft, 1998)

Ontological consideration	
Realist	**Relativist**
External world comprises pre-existing, hard and tangible structures	Holds to the multiple existence or realities as subjective construction in mind
Existence of structure is independent of individual's ability to acquire knowledge	Perceives reality directed by socially transmitted terms and varies according to language and culture
Epistemological considerations	
Positivist	**Interpretivist**
Application of natural sciences methods to the study of a social reality and beyond	Absence of universal truth and emphasis on realism of context
World conforms to the laws of causation and, complex issues can be minimised through reductionism	Understanding and interpretation come from researcher's own frame of reference
Empirical consideration	
Interventionism	**Integrative**
Teaching methods, student learning are backed by quality data and educational theory	Integrate professional knowledge to inform instructional developmental decisions
Results reflect/support a theory	Demonstrate relevance to context

5.2.3 Empirical research considerations

Empirical research methods are supported by quality data and learning with the help of an educational theory. They build a relationship between intervention and behavioural response for the area being researched. Objectives behind empirical considerations in a research project are, to (Manor College, 2006): capture contextual data and complexity; learn from the collective experience of the field; identify, explore, confirm and supply advance theoretical concepts, and enhance educational design.

An integration of the empirical approach provides benefits to a research, such as moving research beyond recordings of '*observations'* only; provides nurture environments for enhanced understanding; combines rigorous research through case study; and relevance of a theory is proved by ability to work in a real context

(Manor College, 2006). In above Table 5.1 ontological, epistemology and empirical philosophical positions for a research are summarised.

In the research world there are two key methodologies, qualitative and quantitative, which can be adopted to collect the type of data to fulfil the research aim and objectives as discussed ahead. In some research projects, both the methods are adopted simultaneously known as triangulation or mix-methods. Philosophical considerations helped to design the research approach and guided this research. Also, the research strategy was designed on the basis of the philosophical considerations mentioned earlier. Table 5.2 presents characteristics of two key research methodologies, qualitative and quantitative as revealed from the literature review.

Table 5.2. Qualitative research versus quantitative research (Source: Knight and Ruddock, 2008, Ibrahim, 2007, Brewer, 2007, Levy and Ellis, 2006, Ruikar, 2004)

Qualitative research	Quantitative research
Inductive, subjective, impressionistic	Deductive, objective, conclusive
Holistic, interdependent system	Independent but dependent variables
Purposeful, key informants	Random, probabilistic sample
Not focused on generalisation but on words and is probing	Focused on generalisation, numbers and is counting
Aims to understand new perspectives	Aims at truth, scientific acceptance
Considers case studies, content and pattern analysis	Considers statistical analysis
Involves in-depth interviews and focus group	Involves surveys and scientific sampling
Asks questions such as: Why? Through what thought process? In what way? etc.	Ask questions such as: How much? How many?
Interviewer needs to think critically and quickly to frame questions	Interviewer needs only be able to read scripts
Highly trained professionals required	Little training needed
Sequence or phrasing of questions may vary during the process	No variation in sequence or phrasing of question during the process
Fewer interviews but of more duration	Many interviews but of less duration
Help to develop a hypothesis, gain insights, refine concepts, add numerical data and provide diagnostics for advertising copy	Test hypothesis, arrange factors according to priority, furnish data for mathematical modelling and projections

5.3 Research approaches

The complex nature of this project demanded number of approaches to meet the objectives. This was necessary because the early stages of the project reviewed the healthcare sector on a broader scale, with a consideration to sustainable development (in Chapter Two) and narrowed down to existing facilities (in Chapter Three). As the project progressed, the research focused on the refurbishment of existing healthcare facilities thus, a '*whole to parts*' approach (see Figure 5.2) combining different methods was adopted.

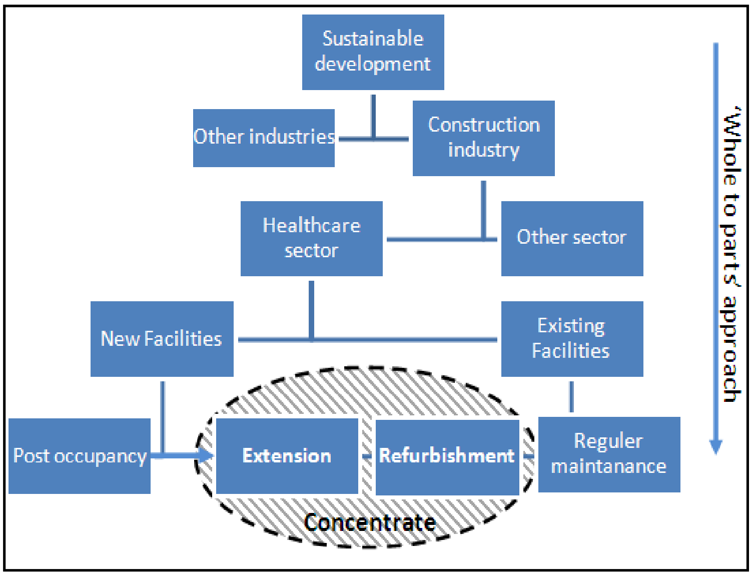

Figure 5.2. A 'whole to parts' approach

The research aim and objectives were synthesised with the help of secondary data collection, such as the review of (relevant) literature and case studies from books and the internet. This highlighted the existing theories relevant to refurbishment and current as well as some traditional practices within the (healthcare) construction industry presented in the previous chapters. The review helped to clarify the complex nature, a lack of previous studies and guided primary data collection. Substantial evidence of cross-sectoral practices with appropriate contextualisation was recorded. It was found that the appropriate integration, contextualisation of the lessons and knowledge generated during the refurbishment phase of a project could be reused in the future phases and projects, without being influenced by a proposed framework. The rationale for the research strategy was justified with regards to the characteristics of the framework within the healthcare sector. The literature revealed that a wide range of methodologies had been used in the construction, refurbishment and healthcare sector researches to date. Also, in the near future recently constructed facilities will need refurbishment, it is thus, considered as a key focus in this research. Considering the current healthcare building stock and focus of the government and industry on the same, refurbishment of these facilities will continue in the future.

5.4 Research strategy

In order to accomplish the research aim and objectives (set out earlier in Section 1.5), it was important to consider how refurbishment processes are characterised within the construction industry. Thus, the qualitative approach was adopted for the exploratory aspects of the research as it satisfies the research needs and to answer to '*how*' and '*why*' questions (Knight and Ruddock, 2008). The key challenges were to determine the characteristics and variables; these challenges have been identified through the literature and confirmed using primary data collection. Also, characteristics of the subject are have been explored further through an in-depth investigation with the help of diverse participants to understand contexts of the research area.

A need for an in-depth study, relating to refurbishment processes, through which the perceptions within organisations could be fully explored and described was identified. Qualitative data were collected compare to the quantitative as an overreaching research strategy. Qualitative data formed the main source of information supported by the quantitative research approach. Having identified the characteristics and variables, the quantitative methods were employed to answer '*how much*' and '*how many*' questions, where necessary and applicable. The combination of qualitative and quantitative is suited to the case study approach, which, as Bryman (2004) reported, entails the detailed examination of one or a small number of cases.

As an outcome of the literature review, rather than a deductive approach where the existing theory guides the research, an inductive research approach was adopted; consequently, theory has been developed as an outcome of the research. An inductive approach uses detailed readings of raw data to derive concepts and themes and interpretations of the same (Thomas, 2006). Bryman

(2004) suggested that an inductive approach involves *“the process of drawing generalisable inferences out of the observations”*. Also, data analysis was performed with consideration to the principles of grounded theory, for example, allowing issues to be emerged from the data; is an inductive approach. Glaser and Strauss (1967) stated that an inductive approach linking data and theory is generally associated with a qualitative research. Thus qualitative research approach was a key to this project.

The data collection and its analysis were performed simultaneously, helped with the collection of a finite set of data. Constant comparison and theoretical sampling during the research supported the discovery of refurbishment processes, and theories remained grounded throughout the observations rather than generating separately in the process. Throughout the process, efforts were made not to move from a specific towards general area and focus was restricted to bring changes and improvement in existing practices. Below, the steps taken to minimise the impact of the shortcomings of the research approaches are discussed.

Limited generalisation potential samples: the interview samples were relatively small, but very experienced participants and in-depth nature of interviews helped to obtain quality, diverse and reliable data.

Subjectivity: considering the vast, less researched, complex subject under investigation, to simplify the process, a structured form for the overall research and semi-structured interviews asking open-ended questions to satisfy the principles of qualitative research methods were used. Also, a protocol based on the principle of qualitative methodology was developed, which helped to stick to the subject.

Replications of data: the semi-structured interviews with open-ended questions and protocol development helped to avoid any replication of information in the process.

Transparency: random, but filtered sampling helped to collect pure data, which means sampling was not influenced by the researcher. Participants with certain characteristics, such as registered members of the American College of Healthcare Architects (ACHA), were included in the questionnaire survey.

Type of data: collected using open-ended questions was analysed to obtain qualitative, quantitative and comparative data. This helped to reduce the time and resources by a significant amount as it could provide required information for analysis.

Non-response limitation: a variety of precautions were taken in the administration of the questionnaires, such as before sending a questionnaire, a brief about the research project and type of data expected was informed to participants. Nevertheless, piloting helped to improve questionnaire and response rate.

Errors during data analysis: to avoid duplication and organisation of data, spreadsheets were used. Considering the characteristics of qualitative data, it was analysed manually, although, a few (data analysis) software were tried in the beginning of the process.

5.5 Research tasks

Appropriate selection of research methods ensure the success and validity of any research (Fellows and Liu, 2008). Research is defined as *"the search for knowledge or any systematic investigation to establish facts"* (Akhtar, 2010) and methodology as *"the systematic study of methods that are, can be, or have been applied within a discipline", or "a particular procedure or set of procedures"* (Kirst, 2008, p. 15).

A typical research cycle is theory - hypothesis - data collection - analysis and back to theory for modification or corroboration (Knight and Ruddock, 2008, p. 85). Table 5.3 is a research road map with the indication of the related objectives, tasks and chapters. Figure 5.3 is a flowchart of the research process indicating various key stages involved in this research. The aim and objectives set in Chapter One have been incorporated in the research map and flowchart. Together, Table 5.3 and Figure 5.3 present a comprehensive overview of this research.

Table 5.3. Research road map

Objective	Task	Method	Chapter
One	Investigate healthcare sector and their buildings to present overview Identify relation between healthcare facilities and sustainable development	LR	1, 2
Two	Review others works to get direction for this research Review and collect data related to refurbishment trends, designing of healthcare and other facilities Study historical context of refurbishment	CSL CSB LR QSA	2, 3 & 6
Three	Review various respective measures such as modelling, which can be used for existing buildings Establish tools used for development of new facilities	LR CSB D QS	4
Four	Review assessment tools related to energy and environmental impact of buildings Enlist and discuss shortcomings of assessment tools Categorised existing tools to use later in this research	LR CSW INT QS	4
Five	Investigate drivers for existing buildings and refurbishment Identify challenges for existing healthcare buildings and refurbishment Collate case studies from healthcare sector to explore practical issues related to the framework	LR CSL CSB QSA	6, 7
Six	Design and develop prototype framework to emphasis energy efficiency and overall performance Develop key components for the framework to reduce energy consumption through the refurbishment to achieve low carbon building	QSA D CSL	7
Seven	Validated the framework with the help of interviews and refine	INT, D, CSL	7

Key: LR: Literature Review, CSB: Case Studies from Books, CSW: Web-Based Case Studies, CSL: Live Case Studies, D: Desk based development, INT: Interviews, QS: Questionnaire Survey
QSA: Questionnaire Survey Analysis.

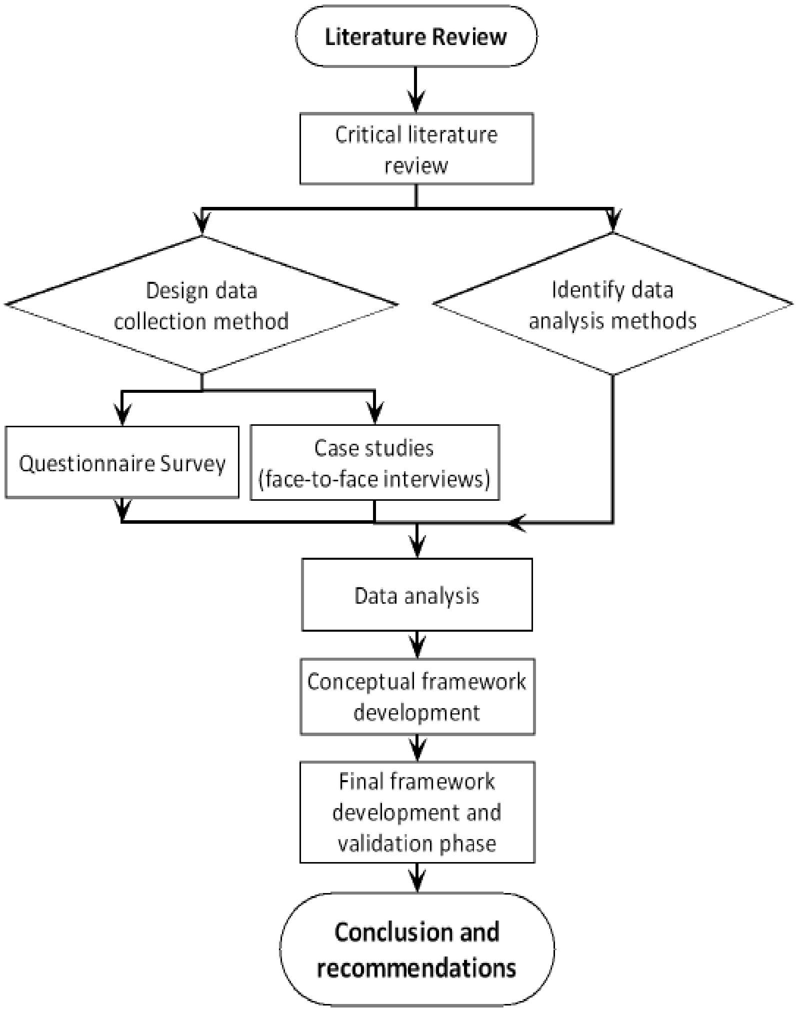

Figure 5.3. A flowchart showing the various stages involved in this research

5.6 The research framework

Research framework design is important to lay a foundation and to understand the overall research context. The first step in understanding the research tasks is to outline the sequence of research events (illustrated in Figure 5.3 and Table 5.3). The methods used to deploy the research tasks are discussed next.

Data collection was performed simultaneously in two key parts, a questionnaire survey and case studies involving in-person interviews. These two key parts as parallel phases, form an interpretative framework to render processes/techniques adopted in the construction industry and applicable to existing healthcare buildings' refurbishments. Based on the aim and objectives drew in Section 1.5 and the above process, expected key outputs from the overall research are defined as:

- importance of refurbishment versus new construction;
- reasons behind less attention towards existing facilities;
- refurbishment practices observed in the industry;
- tools, frameworks and methods related to refurbishment;
- possible drivers for refurbishment, especially existing buildings; and
- improved refurbishment practices in the future.

Broadly, there are two types of data collection approaches, qualitative and quantitative and, often, both the methods are employed in a research depending on the context. The collected information can be classified mainly into primary and secondary data, depending on their sources. Most of the primary data in this research were collected using two key procedures, case studies and a questionnaire survey. However, some ad-hoc data was also collected as explained further.

The research was concerned with a systematic and logical collection of data to accomplish its aim and objectives (drew in Section 1.5) and, using the following strategies to underpin data collection approaches:

- collect data/information at a detail level which justify the adopted methods;
- consideration to resource prioritisation, planning, implementation, documentation, leading to continuous improvement of the data sets used in the inventory;
- review data collection approaches and methodological needs on a regular basis to guide progressive, efficient and inventory improvement;
- introduce data sources to support consistent and continuing information flows; and
- data collection to provide qualitative as well quantitative information.

The above steps assisted the progress of research and linked it into the framework as presented in Figure 5.4. Within the interpretative framework, several methods of data collection were employed to accomplish the pre-defined aim, objectives and, to collect a combination of qualitative and quantitative data.

The research framework was designed to allow an investigation of a broad range of refurbishment and healthcare related issues, tools and approaches (see Figure 5.4). The specific elements to be investigated through primary data collection were identified from the research questions developed with the help of secondary data collection.

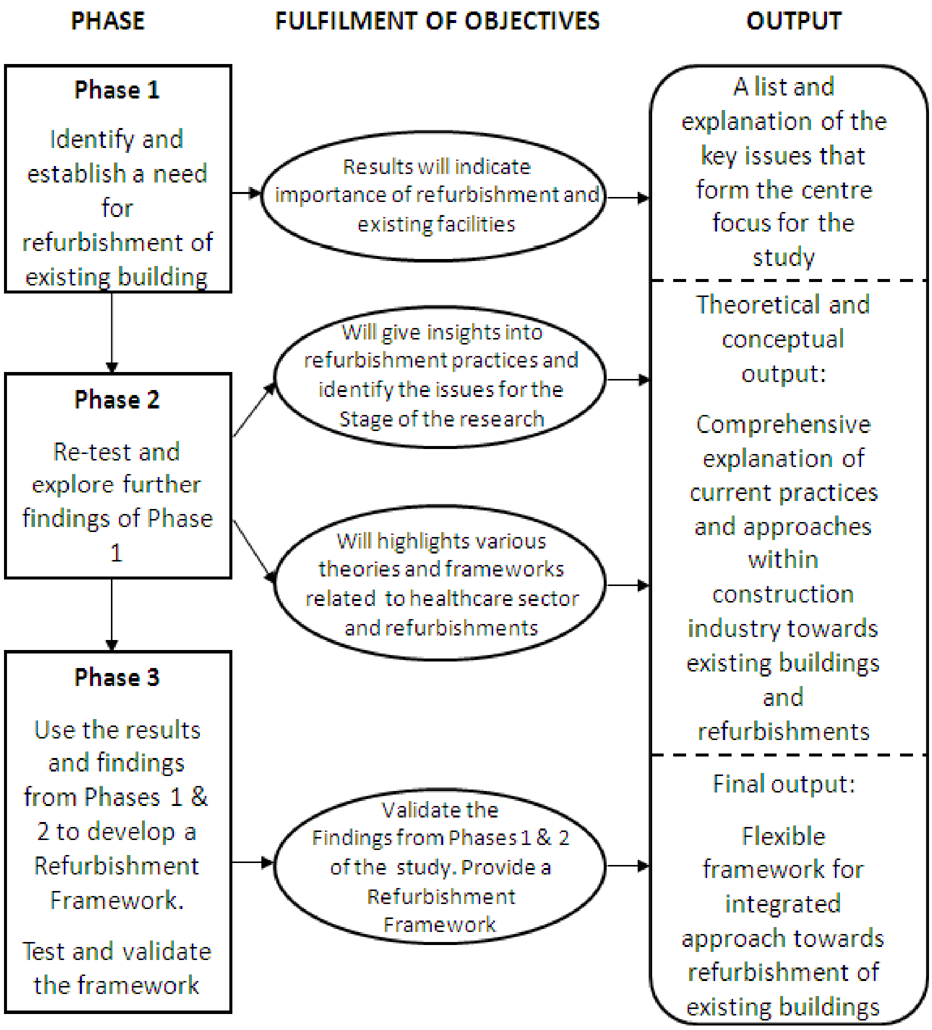

Figure 5.4. Research interpretative framework

5.7 Data sources

The secondary and primary data collection sources adopted in this research are presented below in Figure 5.5. Every data source has positive and negative characteristics and no single source is more valuable than any other. Thus, multiple sources of data collection are adopted as they can complement one other (Fellows and Liu, 2008).

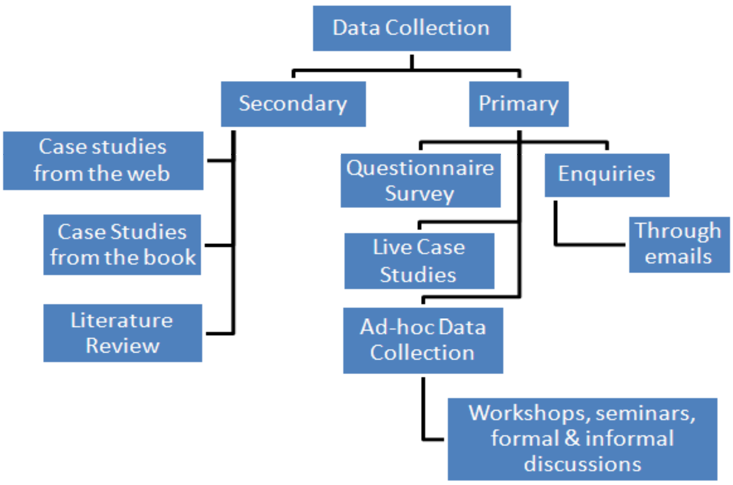

Figure 5.5. Data collection process in this research

The underlying principles and fundamental reasons behind data collection are to check if the existing system can support sustainability and their applicability to healthcare facilities and to explore methodologies applicable to refurbishment and development of new facilities. Also, the collected data helped to identify energy consumption and carbon emissions due to healthcare facilities, especially existing buildings and to verify constraints and limitations of available methods in relation to existing facilities. The process of data collection provided inputs based on the review of currently adopted standards/tools and analysed field data helped with the development of an improved integrity methodology. Nevertheless, validation, testing of a proposed methodology/framework was guided by collected data.

5.8 Secondary data collection and their sources

Data collected by someone else for a different purpose to that of a researcher need is secondary data (Tesch, 1990). During the early phases of a research, expert judgments or opinions may be the only available source of information in the form of reports, research papers, books, etc., which represent the extreme aggregate and soft end of the spectrum. Secondary data provides thresholds and guides primary data collection. Well-known sources of this kind of data are archives, libraries, museums, repositories and databases. However, in some cases it is difficult to identify and trust the source of data and their reliability as origins of information is unknown or inadequately presented. Since it is largely impossible to validate secondary information, more than one opinion should be considered, if possible. Again, these tendencies point to a manual, creative, labour intensive effort in the early stages of a research. Ahead data collected from two key sources in this research have been discussed.

5.8.1 Literature review

A process of reviewing literature was found important to search for the influential researches and groups in the research field (Randolph, 2009). It was commenced by reviewing theories and practices applicable to the area under investigation and can be explained as gathering information from existing knowledge. Literature review is defined as "*the use of ideas in the literature to justify the particular approach to the topic, the selection of methods, and demonstration that this research contributes something new*" (Levy and Ellis, 2006, p. 202).

A review of literature was considered because it helped to focus on a particular field of a study, including vocabulary, theories, key variables, phenomena, methodology and history (Randolph, 2009). Apart from these, it was found to be important because it:

- delimits the research problem;
- seeks new lines of inquiry;
- avoids fruitless approaches;
- gains methodological insights;
- identifies recommendations for further research;
- seeks support for grounded theory, if applicable; and
- guides the primary data collection.

An effective method to initiate the process is to identify if, proposed review fits into taxonomy of literature presented in Table 5.4 (Randolph, 2009). The goal of the literature review stage was to collect an exhaustive, semi-exhaustive, representative, or pivotal set of relevant articles.

Table 5.4. Taxonomy of literature review (Source: Randolph, 2009)

Characteristics	Categorise
Focus	Research Outcomes
	Research methods
	Theories
	Practices or applications
Goal	Integration
	Generalisation
	Conflict resolution
	Linguistic bridge-building
	Criticism
	Identification of central issues
Perspective	Neutral representation
	Espousal of position
Coverage	Exhaustive
	Exhaustive with selective citation
	Representative
	Central or pivotal
Organisation	Historical
	Conceptual
	Methodological
Audience	Specialised scholars
	General scholars
	Practitioners or policymakers
	General public

A set of keywords was identified as suggested by Levy and Ellis (2006), to search for a relevant literature during initial phases of the project, for example, refurbishment, refurbishment tools, BIM for existing buildings, existing healthcare facilities. This process is known as querying scholarly databases. In addition to keywords, small phrases such as *'refurbishment of healthcare facilities', 'tools to be used on refurbishment project', 'importance of refurbishment in healthcare sector'*, were also used while searching for the literature. These keywords and phrases helped while searching for literature in journals, books and on the internet. Precautionary measures were taken to not to miss *'buzzwords'.* Keywords are sometime known as *'buzzwords'* because they disappear from the literature over a period compared to more stable underlying hypotheses and theoretical constructs (Levy and Ellis, 2006). Thus, it was found necessary not to rely only on keywords, but also to deploy backward and forward approaches. Backward approach refers to review the references of the articles yielded using keyword searches, whereas, forward approach is reviewing additional articles that have cited the article (Levy and Ellis, 2006).

To gather secondary data, academic literature and published case studies from the books and the internet were used. Literature was gathered from books, e-books, journal papers, newspaper articles, interlibrary loans, statistical publications, government publications, MSc dissertations, PhD theses, internet resources, references, bibliographies and annotated bibliographies from national and international sources. Journal articles proved to be one of the best sources of information; it was easy to select current and specific journal papers and most of the important and groundbreaking researches are published there in. Journal articles were found using citation databases such as Zetoc, Science Direct, MetaLib, Emerald.

5.8.2 Case studies from books and web-sites

During the transition from primary to secondary data collection, web-based case studies were also used. With increasing use of electronic technologies, information is easily available and accessible in the form of e-books, e-reports, e-research e-papers, etc. Access to the internet makes it easy to obtain latest and updated information in a limited time (Islam and Panda, 2007). Thus, the research project was benefitted from this type of available information, although sometimes it was difficult to find trustworthy sources, however careful surfing (assessing trusted, widely accepted databases) provided very useful information. Most organisations and institutions have their online accessible database or website, which provided information about ongoing, completed and proposed projects. Various online usable case studies related to refurbishment, BIM, modern tools and new constructions of hospitals were studied and analysed. The available literature was considered for its rigour, credibility, relevance and validity. Most of the online case studies were gathered from leading architectural and construction organisations' websites in the healthcare sector. For example, Skanska, a construction company which used BIM, palmtops, e-drawings on the £1 billion Barts and the Royal London new Hospitals programme. Moreover, some databases have additional information, which date back to the 19th century and available irrespective of researcher and database location.

In addition, E-books and the internet are found to be one of the inexpensive, less time-consuming data sources providing organised and (mostly) validated data, which will be available in the future, provided its e-address is known. Electronically available data are easy to store as most researchers have access to the internet and computers. Now days, with advanced technology, this form of data can be commented, marked, or highlighted before saving for future references (avoiding the need for photocopy, print, or handmade notes) and, thus, easy to store, share, present, and handle.

5.9 Primary data collection and their sources

Primary data can be defined as data collected by a researcher or someone else following researcher's instructions. To collect this type of data various key methods are available; such as questionnaires, interviews (face-to-face, postal, telephonic, focus group interviews, etc), observations, case-studies, diaries, modelling and simulation, critical incidents and portfolios.

A mixed method approach was used on multiple projects to obtain an overview of certain areas, to collect data related to refurbishment procedures and to study experts involved in the industry. To collect primary data various approaches (such as case studies, questionnaire survey, enquiries through email, etc) were considered and adopted. One of the key reasons for primary data collection was to corroborate findings from the literature review and to overcome any shortcomings. Most of the data were collected simultaneously using two key methods: a questionnaire survey and case studies.

Figure 5.6 is an overview of the process used to collect primary data. In the figure the process which started with primary date collection leading towards data analysis is presented. The analysed data is presented in the next chapter.

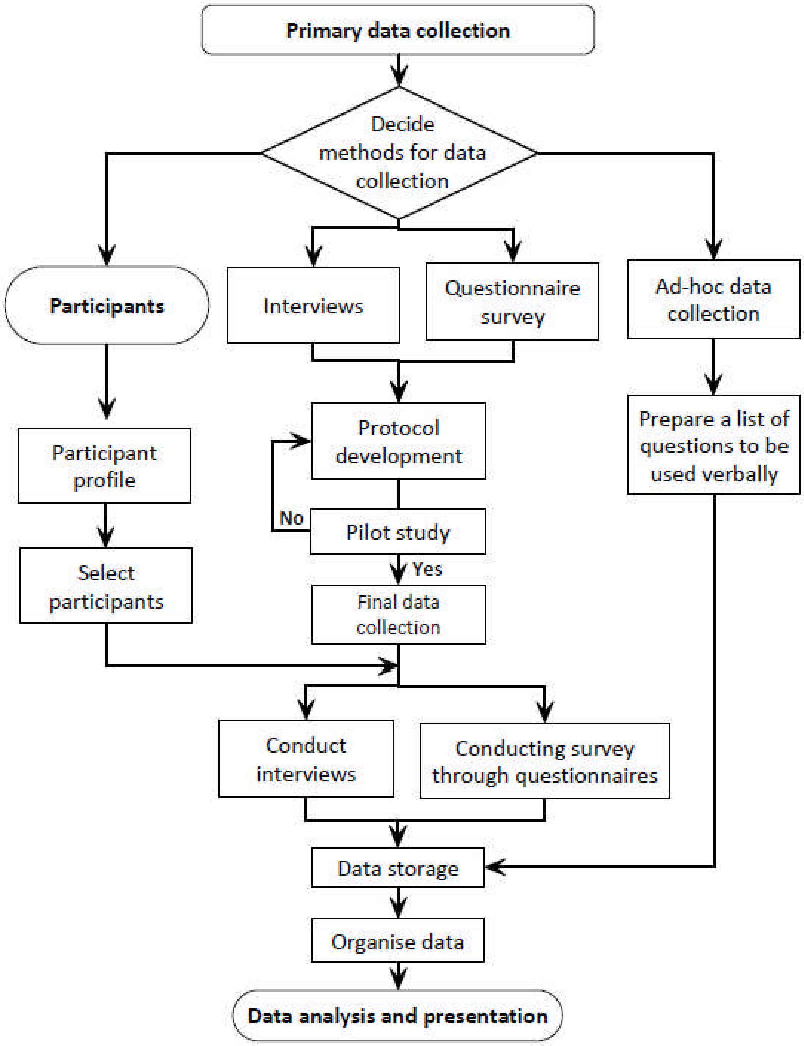

Figure 5.6. Overview of primary data collection

5.10 Instruments and procedures

Various instruments and procedures are available and required to collect qualitative as well as quantitative data depending on a research project need. Sampling, protocol for case studies and questionnaire survey are considered as instruments (Yin, 2009). Procedures to complete a research cycle included a problem formulation, collection, evaluation, analysis, interpretation and presentation of the data (Randolph, 2009).

5.10.1 Protocol development for interviews and questionnaire survey

Depending on the research needs, a protocol can have open and/or closed ended questions. It is very important to consider phrasing and sequence of questions in the manner they are posed to respondents thus the following points should be considered to receive quality information through the survey (Ali, 1998, Gill and Johnson, 1991).

- Ensure increased probability of respondents' co-operation without biasing subsequent responses.
- Clear, simple and unambiguous instruction along with jargon free, understandable questions.
- Respondents should not feel any question or entire questionnaire is offensive, sensitive, or embarrassing.
- Wording of the questions should lead respondents to a particular answer avoiding any misleading assumptions.

A need for detailed design of the email based questionnaire and interview protocol was identified to collect the data. To develop a protocol, it was useful to refer back to the subject matter of the research questions as stated in Chapter One. The content of the questionnaire was designed to investigate a wide array of refurbishment projects and processes. The design of the questionnaire, including outline of the interview protocol was carried out with due attention to the following considerations.

Research area: was explored through a critical literature review, which helped with the development of the protocol.

Introduction to respondents: the research and rationale behind the data collection was introduced to respondents. During the questionnaire survey, additional guidance about the research context and other relevant information was provided in email. Similarly, with interviews the extent of information/data to be collected was explained through email in advance (for example, by including the phrase *"all the questions are not compulsory, and you can skip any questions, if it is not relevant to the area of your research/expertise")*. In addition, a guarantee was given about confidentiality of information and privacy of the respondents.

Respondent profile: while conducting the questionnaire survey and interviews, only a selected group of respondents was considered. As part of this research project, respondents with certain qualifications or experience were involved through filtered sampling, for example, all the participants from the USA were registered (professional) members of the American College of

Healthcare Architects (ACHA), which helped to reach architects and experts working mostly on healthcare projects. To select interview participants, NHS Estate department employees or experts who worked on or with a NHS healthcare project were considered. More details about respondent profiles are provided in Chapter Seven.

Questionnaire focus: was maintained by framing questions with consideration to the research focus (refurbishment and existing buildings) identified early in this research. The questionnaire was focused on the objectives of the study, and efforts were made to link individual questions with respective objectives.

Interview focus: was maintained with every question, and highlighted keywords in the protocol helped to pose the questions. The focus was maintained through objectives and semi-structured nature of interviews.

Question phraseology: was kept as simple as possible and piloting helped with this. Instead of one long question, two shorter questions were introduced. Also, considering the fact that data being collected in the UK and USA, synonyms were provided for complex words to avoid any confusion.

Question sequences: with the protocol, the sequence of questions was critically analysed to avoid duplication of data and to collect original data in an organised manner. The protocol was divided into four key parts, (i) a section asking background information about participants followed by (ii) a section on refurbishment, (iii) involvement of client (NHS, DoH, etc), and (iv) a space to provide feedback, notes or any additional information. The first section comprised of three questions, second section (which is a key section) comprised 10 questions, third with two and fourth was for feedback.

Response: to ensure a better response rate, following a pilot study, the questionnaire was redesigned. Also, during the process after receiving and reading (brief analysis) first seven responses, a question was added and small changes were made. However, again after receiving 10 responses a questionnaire was revised, which helped to receive final 26 responses; 43 in all together. Table 5.5 presents details about revisions made to the protocol.

Table 5.5. Feedback received during piloting of questionnaires

Area of feedback	Phase 1	Phase 2
Number of questions	Question on occupancy pattern was added	Re-order and re-wording of questions (2.2, 2.5 and 2.7)
Phrasing	Re-wording of few questions and change in number of sections	Highlighted keywords in every questions
Purpose of section	Provided purpose of section at the beginning of every section	Considering participants from the USA & UK, synonyms provided
Number of sections	Reduced number of questions in Section One	4 distinguish sections; participant background, refurbishment, client and government role, feedback
Change in section	Added three questions from Section One to Section Two	Key focus on Section Two
Introduction to questionnaire	Reduce length of introduction at the beginning of the questionnaire	Added objectives and used bullets to mark every objective in the introduction

Section Two of the protocol was divided into seven hypothetical themes and several sub parts relevant to this research; existing buildings, challenges, types of projects, users (occupancy pattern), re-design, tools, guidance, frameworks, etc., and existing trends.

The overriding aim behind the questionnaire and interview protocol was to understand drivers and challenges for refurbishment, which could help to simulate an overall refurbishment process. The questions along with the protocol were piloted and discussed with the researcher's colleagues and supervisors before sending to experts via email, and requesting their participation either by filling a questionnaire or through an interview. The final questionnaire and the covering letter are presented in Appendices E and F respectively.

The only difference between the protocols used for questionnaire and interviews was, with the former, a self-completion questionnaire format and guidelines were provided; with the later, respondents were informed verbally about interviews, agenda, etc., at the beginning of interviews. Nevertheless, this helped to gather information not only related to social aspects of refurbishment but also related to business decisions.

5.10.2 Case studies

Case study method is *“a strategy of research that aims to understand social phenomena within a single or small number of naturally occurring settings”* (Bloor and Wood, 2006, p. 27). Case studies are suitable to gather data from experts, who provide descriptive detailed examples to generate theories, or to test particular theories (Yin, 2009). Knight and Ruddock (2008) suggested that this approach is suitable to build a theory in a relatively new research area or to obtain a different perspective for existing areas by providing information through data collection. Brewer (2007) suggested a case study based approach where there is a need to study current practices and to illustrate a new and potentially innovative approach adopted by an organisation. Also, the approach is suitable for research which examines problems faced while implementing any new techniques in an organisation and where there is a lack of theorisation and knowledge.

The following characteristics of a case study based approach are reported by Knight and Ruddock (2008, p. 90), thus this approach was found to be more suitable for this research too.

- a story;
- multiple sources of evidence;
- integrated triangulation approach;
- meaning in context;
- display in-depth analysis of the central issue being explored and a broad understanding of related issues and contexts;
- clear focus; and
- reasonably bounded relation with a data collection and a research.

Yin (2009) and Knight and Ruddock (2008) suggested the following major considerations for a case study approach, also, taken in to considerations as part of this research.

Time limit: will depend on whether a case study is longitudinal or cross-sectional. The former monitors a single activity throughout its life period, and later focuses on a particular situation (snapshot) or a process from several cases.

Availability of documentary evidence: depends on confidentiality of matters, sensitivity of the topics and any difficulties in getting access to this type of information. Often, participants are not keen to discuss financial issues or certain documents with confidential information about a project or person involved with the project.

Access to person involved: people are a key source for gathering information and an important aspect for a case study approach. Interviews provide detailed insight into the subject. Often, open-ended questions and a degree of flexibility (semi-structured interviews) examine and manage issues as they arise during interviews. A structured approach is preferred when quantitative data or information is needed. How to conduct interviews is explained in detail in the next section.

Number of cases: is a complex issue and it is difficult to decide required numbers in a research. However, this is balance by the distribution of available resources, which affects the depth of investigation and validity of the research findings to some extent. The number of cases required will depend on available time, and whether research is focused on a longitudinal or cross-sectional study.

Case studies can provide documents, archival records, direct and indirect observations, participant observations, and physical artefacts, but the collected data will vary in relevance and reliability (Knight and Ruddock, 2008). Multiple case studies results are always compelling (assuming they support each other) and are therefore easier to defend.

Archival records: provide history of a company, an organisation, or a project and their importance will depend on the aim and subject of a research.

Documents: help to lay foundation for a study and provides basic information about the case at hand in the form of letters or correspondence, minutes of meetings, drawings, contractual documents, etc.

Qualitative observations: is a form of data collected through detached observations in the context of a research.

Participant observations: involves '*watching (observing a case) from the outside*'. This approach provides a valid form of information as it represents what people actually do, rather than they mentioning what they do (Knight and Ruddock, 2008). This can be used to observe an employee, a person, a group, or application of a (construction) technique, etc. Typically, information is recorded with the help of a template, which provides organised data.

Physical artefacts: are considered for anthropological research and can be observed as part of a site-visit, or collected as an example to scrutinise later in the laboratory.

The case study based approach was considered appropriate for a number of reasons, most particularly, to get answers to the type of qualitative research questions, such as, '*how*', '*why'* refurbishment is necessary. A case study explores more variables, and conducting multiple case studies has similar benefits to performing several experiments. Although there is no rule of thumb to decide an ideal number of cases to be explored, seven interviews involving 11 experts were selected to provide multiple case studies. The semi-structured type of interviews were used in preference to structured or unstructured interviews to enable the researcher to probe further insights and clarification as part of the approach while maintaining the overall structure of this research. By using a semi-structured approach, the participants were encouraged to talk in their terms around subjects/themes predefined by the researcher.

The case studies helped to obtain a clear picture of current trends during a refurbishment and redevelopment of existing healthcare facilities. Also, they helped to establish the shortcomings and to highlight problems while refurbishing hospitals. Given the limited time and few other factors (such as resources, budget), the questionnaire survey was conducted simultaneously to gather more qualitative data. Both, the questionnaire survey and interviews were conducted using a protocol developed as discussed earlier. Carrying out the case studies in parallel to the questionnaire survey helped to explore incomplete or adequately explained areas during the survey, such as a lack of post-project survey or evaluation with refurbishment. Also, the semi-structured nature of case studies helped to discuss and explore issues or criteria reported by the survey participants.

5.10.3 Interviews

Interviews are "*an exchange of views between two persons of mutually interested subject*" and "*are a method of collecting data that can stand on its own or be a* *follow-up process to another method*" (Swetnam and Swetnam, 2007, p. 1). It is one of the key sources for information in research by case study (Yin, 2009). With this approach, it is assumed that people are honest and share similar views. A typical role of an interviewer is to pose questions and collect the best possible data; listen to respondent; and follow the process, sequence, and manage within the time.

Interviews are often applied in the case study to address a specific situation, a person, or an institution (Brinkmann and Kvale, 2009, p. 116). It is one of the widely accepted methodologies in built environment research. They provide flexibility from highly structured in-person gathering of information in quantitative studies to semi-structured interviews to get insights and generate concepts, rather than generalising about a research (Knight and Ruddock, 2008, p. 111). The following guidelines to be followed for an interviewer are suggested by Swetnam and Swetnam (2007, p. 68):

- be friendly but formal;
- treat all interviewees similar;
- prompt but not directing;
- do not volunteer answers;
- avoid insinuation/irony;
- never be patronising or pompous;
- be tolerant and patient
- follow schedule; and
- develop status.

More standardised consultations provide a significant amount of quantitative data, whereas, the less structured and freer ranging interview provides qualitative data (Knight and Ruddock, 2008, Swetnam and Swetnam, 2007). Qualitative interviews focus on the subject, interviewee perspective and context based on their knowledge and experience, prior to a scientific explanation. Seven stages involved with interviews as suggested by Brinkmann and Kvale (2009, p. 1) are; thematising an interview project, designing, interviewing, transcribing, analysing, verifying and reporting.

Types of interview questions

There are several types of questions to be used during various stages of interviews, depending on the type of data needed. It is better to identify types of question early in the process because it helps to define approaches and methods to be used for interviews and their analysis. Below, few commonly used types of questions, used in this research, are discussed.

Introductory question is an opening question, which provides aspects of the investigation.

Follow-up question helps to extend the subject area through the curious, persistent, and critical attitude of the interviewer. Sometime it is also called as *'specifying question'*.

Probing question focuses on the content without stating what dimensions are to be taken into account, and interviewer peruses the answers.

Direct question introduces topics and dimensions through the interviewer.

Indirect question involves enquiries, for example, "*how do you believe other pupils regard…..*" and the answer reflects the attitude of others.

Structuring question is introduced to follow the subject/agenda, and to break the long answers by asking questions, such as "*I would now like to introduce another topic…*"

Silence is not a type of question but important to avoid cross-examination by continually firing off questions. Pause/silence during the process will give a time for the subject to provide significant information.

Interpreting question explains or interprets what pupil had said. The degree of interpretation involves merely rephrasing an answer, or relating it to an example based on researcher knowledge or interviewee.

Data collection through interviews

Through interviews mainly two types of data can be collected; quantitative or qualitative as explained ahead.

Quantitative data collection through interviews: asks a set of pre-selected questions related to the topic in a formal or semi-formal manner in a structured approach (Bloor and Wood, 2006, p. 105). This always provides predicted answers as a respondent supposed to choose an answer from available options, thus not considered in this research. Interviews are conducted using an interview schedule and can be in-person, telephonic, over a videophone, or through the internet. These interviews are predefined hence not led by the data. The data collected through a standardised format, for example, using a protocol, are organised up to a certain extent thus easy to analyse and can be presented in numbers, charts, graphs, etc.

Qualitative data collection through interviews: using unstructured or semi-structured interviews, the concept emerges as the interviewer explores the area with respondents and provides rich inputs. The nature of these interviews makes it a complex process and demands more skills compared to structured interviews. This is a tool for a researcher and allows a respondent to elaborate research area through open-ended questions prepared in advance (Bloor and Wood, 2006, p. 105). The interviews can also be focus group with a purpose to collect a set of data or to validate a research output. With this approach, the data are shaped partly by the interviewer's pre-existing topic guide and by concerns that are emergent during an interview (Bloor and Wood, 2006). Before an interview, the interviewer should explain about the project, particular questions, or specific lines of questioning and ask for the permission to record the interview, if applicable.

Brinkmann and Kvale (2009) reported qualitative interviews can be expensive, if a study seeks to predict the behaviour of a large group, such as voting behaviour. In this scenario, a questionnaire survey with pre-coded answers is beneficial rather than going for a qualitative approach.

Types of interviews

Interviews can be divided depending on their subject and the way they are conducted. Brinkmann and Kvale (2009, pp. 147-150) reported various methods of interviewing, such as in-person, computer-assisted, focus group, factual, conceptual, as presented below.

In person interview: involves a bodily presence with access to non-linguistic information expressed in gestures and facial expressions.

Computer-assisted interview: are being widely practiced in recent years. They can be in the form of e-mail correspondences, or messenger. These are self-transcribing ready for analysis but demands high writing skills from an interviewee as well as an interviewer.

Focus group interview: involves a group of six to ten experts led by a moderator. It is characterised by a non-directive style of interviewing, where the prime concern is to encourage a variety of viewpoints on the topic focus by the group.

Factual interview: are useful for doctors, police, lawyers, etc., to obtain information about a particular fact or event.

Conceptual interview: explore the meaning and dimensions of central terms as well as their positions and links within the conceptual network.

Narrative interview: asks participant to narrate a story relevant to its life, work, etc.

Discursive interview: focuses on how knowledge and truth is created within the discourses and on the power relations of discourses. All interviews are discursive by default and imply different discourses.

5.10.4 Observations during site visits

Research by observation has two sides, to gather quantitative data and qualitative descriptions (Sapsford and Jupp, 1996). In observations-based research a major influence on the accuracy of field notes depends on when they were made (Sapsford and Jupp, 1996). Notes prepared as soon as possible after the observations are very useful. With any delay in preparing notes, there is a possibility of losing some information or having inaccurate and biased data. Sometimes an object or any non-living thing is considered for observations. It helps to collect data in addition to the information being gathered through primary research methods such as interviews, questionnaire survey.

Observations are made with or without a standard template. Observations using a standard template have similar benefits to close-ended question whereas, observations without a template but knowing what to observe are similar to open-ended question.

5.10.5 Questionnaire survey

Questionnaires are considered as one of the key research instruments. The information obtained using questionnaires is pre-arranged and organised thus is relatively easy to analyse (Brewer, 2007).

Often, open and/or closed ended questions are part of a questionnaire. Open-ended questions can have infinite numbers of responses, whereas, close-ended will have a fixed number of responses as explained further. The nature of open-ended questions is similar to close-ended questions except informant has the freedom to answer in his/her own way, rather than selecting answers from predefined categories. With close-ended questions, fixed set of options or answers *('strong to weak', 'attractive to ugly', 'cool to warm'*), or sometimes on a Likert scale (strongly agree, agree, neutral, disagree and strongly disagree) are provided.

The questionnaire survey in the UK and USA helped to investigate the characteristics of refurbishment projects. The limitations of the survey through email were considered carefully when decision was made to collect the data using a questionnaire. The questionnaire was of a minimum length, with adequate space for a participant to provide their responses. Also, it was understood that in the construction industry people are extensively using computers, and there is an attempt to make a minimum use of paper thus, questionnaires were sent through email. Moreover, the characteristics of the internet based and postal questionnaire mentioned in Table 5.7 were taken into account.

Designing a good questionnaire is a difficult exercise because it influences the validity and reliability of the data. Table 5.6 presents some key advantages and disadvantages of a questionnaire survey, considered in this research.

Table 5.6. Advantages and disadvantages of a questionnaire survey

Advantages	Disadvantages
It is a method in its own right	Designing is challenging
Can be face-to-face or through post, e-mail, fax, or over a phone	Questions have to be relatively simple and short to receive more responses
Can reach a large number of people or organisations	Responses will depend on methods used to design and circulate questionnaire
Wide geographic coverage	Requires a return deadline
Relatively cheaper	Need to wait for responses
No prior arrangements required	Several reminders may be required
Difficult to give reminders	Assumes no literacy problems and no control over who completes it
Avoids embarrassment on the part of the respondent	Difficult to give assistance, if not face-to-face
Responder may remain anonymous	Problems with incomplete questionnaires
No interviewer bias	Replies not spontaneous and independent of each other
Researcher can predict the type of responses	Need clear and unambiguous instructions
There are fixed number of question	Respondent may not participate if, too long, complex, uninteresting, or personal

Questions and questionnaire should be based on common sense, knowledge, experience, brevity and relevance, and need to be unambiguous, specific and objective based (Knight and Ruddock, 2008). There are various methods to distribute questionnaires depending on the quality and quantity of information to be gathered. The benefits of two widely practiced methods, internet-based versus postal surveys are presented in Table 5.7.

Table 5.7. Comparison of internet-based versus postal questionnaire (Source: Knight and Ruddock, 2008, Sapsford and Jupp, 1996)

Questionnaire	Internet based	Postal
Cost	Less cost involved if, access to internet and computer is easily available	A traditional methods and suppose to have good success rate, comparatively costlier
Access	Can reach more number of participant accessible through internet only	Can reach more number of audience but requires more time, resources, etc.,
Identity	Difficult for user to remain anonymous but not impossible	User can remain anonymous
Time required	Less time consuming	More time consuming
Storage	Easy, can be stored using a computer or electronic device	Depends on a number of responses, if in thousands, then may be difficult to store
Space for answers	Flexible, because more space available to provide answers	Limited but overleaf can be attached
Quality	Always, easy to read	Handwritings can be challenging
Data recording	Always machine readable	Sometime possible to have machine readable responses
Analysis	Comparatively easy to analyse	Need to transcribe or prepare notes manually

There is a limited database relevant to refurbishment projects in the healthcare sector. Probably, until recent the focus of the industry and government was on new development. Hence, the questionnaire survey was administered among professionals from the UK and USA as explained further. The particular characteristics of the survey and data collection were:

- a significant construction in the healthcare sector of both the countries;
- a diverse approach towards the healthcare sector; in UK, through DoH and, in USA, not-for-profit organisations, private organisations and state governments;
- the USA is already witnessing increasing refurbishment projects in the healthcare sector;
- in the UK, it is expected that the present and coming decades will observe more refurbishments;
- initial stages of investigation revealed good qualitative response rate from the participant based in the USA;
- many experts (participants) work in both the countries;

- it was easy to locate more professionals working in the healthcare sector through ACHA in the USA;
- initial investigation including review of literature revealed the wide application of BIM and simulation based tools in the USA;
- a huge number of regulations related to healthcare in the USA;
- a significant considerations to health promoting designs, EBD in both the countries; and
- the healthcare sector is in the priority list of development in both the countries.

Key tasks to complete any questionnaire survey are design, administration, entering data and data analysis procedures.

Advantages of the survey questionnaire to this research

Adopting questionnaire survey method in this research helped in various ways. This provided adequate time for participants to respond thereby increasing the reliability and accuracy of the same. The questionnaire protocol helped to extract qualitative, quantitative and comparative data through analysis. The survey method helped to obtain organised and consistent information. This method proved to be one of the simplest and most direct approaches to obtain qualitative information from a wide array of experts and professionals. More importantly, it gave the indication how existing buildings and refurbishment is perceived by the industry and proved inexpensive, less time consuming and required minimum resources.

5.10.6 Piloting

Piloting is defined as *"a small-scale trial before the main investigation, intended to assess the adequacy of the research design"* (Sapsford and Jupp, 1996, p 103). According to Forza (2002) the reliability and robustness of data collected through the survey methods will depend on the rigour of the piloting. It is performed simultaneously with questions and the questionnaire to ensure overall success of the survey. The well-known methods for piloting are a peer review, cognitive interview, or focus group discussion:

A peer review *involves asking a number of people, research colleagues, who are involved with the survey subject or with the questionnaires to review it.*

Cognitive interview *is a method of interviewing how experts respond to questions, a questionnaire and whether they can answer it correctly. The questionnaire is completed with the help of a test-respondent, and exploring how or why the respondent answered the question in this particular way. The test-respondent should represent the survey population and number of pre-tests should be performed.*

Piloting through a focus group *is similar to a cognitive interview but in a group situation managed by a discussion leader and a dedicated note-taker. However, a researcher or a researcher's colleague performs most of the roles. Five to eight participants who represent the survey population are selected. The participants are expected to complete a questionnaire, while a moderator observes the process, make notes, and addresses any difficulties or query during the piloting. This is followed by debriefing the respondents asking pre-planned evaluation questions based on the moderator observations. Typically, debriefing questions are asked to know participants' interpretation of questions, a questionnaire and their answers.*

In this research the above mentioned first two types of methods were considered, however, due to time constraints, limitation, piloting using a focus group method was ignored. Brinkmann and Kvale (2009, p. 190) highlighted a need to established analysis methods at the beginning of data collection as this guides a protocol or questionnaire development. To consider the validity of the questions and overall questionnaire, the following factors were considered during piloting.

- Clarity of instructions.
- Length of questionnaire.
- Significant topic omissions.
- Any other comments.
- Unclear or ambiguous questions.
- Questions which a respondent was uneasy about answering and comments.

To address the above areas, a two-stage piloting process was arranged. In the first stage, a draft copy of the questionnaire was given to the four colleagues in the researcher’s department. In the second stage, the questionnaire was sent to the seven industry respondents select for data collection. In addition to the above efforts, the protocol was discussed with the researcher's supervisors during every stage. Feedback was received from the selected participants, and subsequently, modifications were made to the questionnaire. During the piloting the questionnaire was checked for clarity, flow, length, questions, etc. Post piloting, some changes were made to the draft questionnaire. No substantial modifications were made, except a few changes specified in Table 5.5. The process to develop the questionnaire format and pilot study is shown in Figure 5.7.

To avoid collection of undesirable data and to improve success rate the participants were told that data related to capital cost etc., is not required as part of this research (this was established during the piloting).

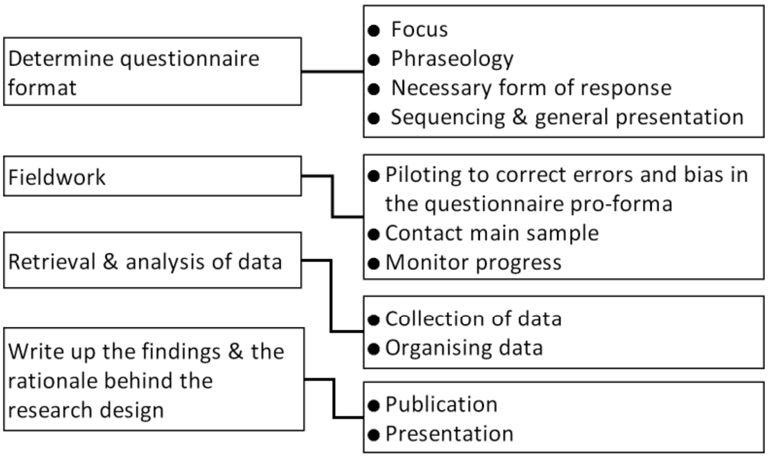

Figure 5.7. Overview of the questionnaire survey

5.11 Sampling

Sampling can be defined as *"obtaining a manageable part of an object or population that supposedly possesses the same qualities as the whole"* (Swetnam and Swetnam, 2007, p. 42). In most research projects, it is difficult and impractical to collect data from the entire population or area being studied, hence sampling is considered. The key focus behind this is to explore experts and experienced people's views in relation to the area under investigation. Swetnam and Swetnam (2007, p. 33) referred sampling for surveys as an attempt to produce an output based on the information collected from the entire user group and to generate a logical conclusion to develop an appropriate policy. It is very important because the information may be gathered in several ways, but poor sampling and ambiguities will invalidate it.

Collecting samples from the physical world compared to the social is easier (Swetnam and Swetnam, 2007, p. 42). For example, obtaining a gram of sample from a tonne of limestone is less complicated compare to get an accurate representative sample of 100 unemployed people from a group of 1000. There is no definite method to decide, "*how large should a sample be*". During sampling predictability, judgement of feasibility and cost against representativeness should be considered. Collecting huge samples can be a waste of time, money, resources, etc., when a smaller sample is capable of producing the same results. With sampling, the researcher should satisfy the following minimum facts (Swetnam and Swetnam, 2007, p. 43); the sample is a large enough to be significant, it should represent an entire group, its defects are acknowledged, and a rationale for the same is produced. Probability, non-probability and opportunity are types of samples often use in the research world (Swetnam and Swetnam, 2007).

Probability (random) sampling assumes every part of the sample has an equal and calculable probability of being selected.

Non-probability sampling includes a selection of firms based on researchers' knowledge, which are considered to be experts in their field.

Opportunity (snowball) sampling considers the only reachable samples and is circumstances based.

Non-probability, filtered sampling was used, which means selected firms thought to be experts based on the researchers' knowledge. As it was hard to find a definitive database of experts involved in healthcare refurbishment projects, a '*long-list*' was generated from several sources, such as NHS Estates websites, business directories, trade listings, construction magazines, internet searches, the ACHA website and personal contacts. Even the ad-hoc data collection helped to gather a few samples to be used for primary data collection. This helped to identify a sample of 415 experts suitable for possible inclusion in the study. Given a qualitative research approach, this is a huge number, but it was necessary because literature revealed the possibility of a low response rate. Also, it is rare that all the respondents will participate and answer all the questions, therefore, a larger sample was targeted.

The experts were contacted through emails, where eight emails remained undelivered and from the remaining 407, only 62 agreed to participate either with the survey or personal interview. It also included seventy-four experts contacted to conduct face-to-face interviews of which 11 interviews (with seven individuals and a group of four experts) were undertaken in the UK. Five site visits were made to ongoing refurbishment projects with the help of the interviews' participants. This helped to explore refurbishment and to experience the level of noise, construction dust, etc., with it. Also, three further site visits were made during conferences, attended by the researcher. The list of sites visited is presented in Table 5.8.

Table 5.8. Site visits conducted in this research

Title	Details
As part of the case studies	
Mansfield Community Centre, Nottinghamshire	Extension cum refurbishment projects, BREEAM certified
Addenbrookes, Cambridge	Campus with mix buildings and projects
Royal Infirmary, Leicester	Part refurbishment completed and occupied
Royal Victoria Hospital Redevelopment Project, Belfast, Northern Ireland	Campus with Victorian and modern buildings with ongoing and recently refurbished buildings
Imperial College Building Refurbishment, London	Ongoing refurbishment and partly occupied
As part of the conferences, seminars	
Hove Polyclinic, Brighton	New development, operational hours are eight hours a day, five days a week
Kingsway GP surgery, Braunstone, Leicester	Recently re-decorated buildings and occupied, eight hours a day, five days a week
Chicago Family centre, IL, USA	Recently refurbished and occupied

Finally due to time restrictions, commitments, etc., only 54 participated in this research (11 for the interviews and 43 for the questionnaire survey), representing an overall response rate of 13 per cent. Though the response rate was low, it was found to be adequate due to various reasons. The data collected was significantly qualitative in nature, and could highlight the number of themes, challenges, and overall complexity in refurbishment projects. Towards end of the data collection stage, the most of the responses were repetitive and the researcher could predict the type of responses, thus the researcher decided to conclude this stage. It was also discussed with the researcher's supervisors before concluding the data collection process. Mason (2010) reported that generally a sample in a qualitative research is smaller compared to quantitative research; as more data does not necessarily lead to more information of the qualitative nature of data. Mason (2010) studied 560 different qualitative researches employing various approaches (such as action research, grounded theory, content analysis) from various backgrounds and it was found that the most common sample sizes were between 20 and 30. The most researches employed interviews or case studies based approach to conduct qualitative data. Also, it was concluded that there is no rule of thumb to decide the required number of sample, but in a PhD research, a researcher and the supervisors can decide the same depending on the saturation point and research limitations. Thus, 13 per cent response rate involving 54 participants was found to be adequate.

The selected participants (for interviews as part of the case studies) and respondents (for questionnaire) were working on either a development or an implementation of new or refurbishment proposals within the healthcare sector. At the time of data collection, most of the participants had more than 10 years of professional experience. Also, most of them were working at least in two countries; the UK and USA. The participants were considered to have a practical understanding of working or managing a refurbishment project, especially related to healthcare. In addition, some participants from academia were included in the questionnaire responses and for formal discussions to understand the approach towards existing facilities, refurbishment, etc., within the academic world.

During the data collection, two respondents asked for telephonic interviews, but the researcher requested them to participate in the questionnaire survey to avoid additional needs. Interviews were conducted in the UK, including Northern Ireland, and the questionnaire survey in the UK and USA. During the data collection stage, the researcher contacted 250 registered architects with the ACHA and collected 35 responses from the USA and eight experts working on PFI and NHS projects from the UK, out of 91 selected for the survey.

5.12 Ad-hoc data collection

Neither a researcher nor a participant influences this type of data. Although a significant amount of ad-hoc data was not collected, some data, not exaggerated by participants, was collected as explained here. The data were collected through various formal and informal discussions during conferences, seminars, lectures, and workshops. Unlike questionnaire surveys or interviews, with ad-hoc data neither a researcher nor a participant controls the process. The researcher can generate more contacts, sources for case studies, references, provide additional information, or gain some lessons from industry through these discussions.

To facilitate site visits, a snowball sampling was used because the researcher could access appropriate projects with the help of interviews' participants. Also, the interviewees had knowledge about the selected sites which they shared with the researcher. Through case studies and site visits (other than responses to the interview protocol) the researcher managed to collect drawings, photographs, etc., which provided more information about the projects. Considering the focus of this research on refurbishment of existing buildings, archival records, such as historical information about the project drawings were collected during the case studies and were very useful.

Discussion during conferences, seminars, etc.

Although this approach did not provide a significant amount of data, it helped to establish links between theory and practice. Some of the case studies were gathered with the help of discussions. These could not help to talk about entire project, or questionnaire, but a specific area or a question, for example, conversions about BREEAM for Healthcare, and BIM for healthcare buildings.

Observations during site visit

Various site visits were conducted with the help of the interviews participants. In this research, a standard template was not adopted to collect data during site visits because every case was unique, diverse. For example, some facilities were occupied, some empty, few soon to undergo refurbishment. Table 5.8 shows sites and their condition at the time of the researcher's visits.

5.13 Data analysis

In this section, the methods for analysing collected data in this research are presented. The key focus behind the data analysis was to explore experts' and experienced people' views on refurbishment related processes in the (healthcare) construction industry. This was necessary to develop a framework for refurbishment. The analysis was performed in two phases. Firstly, secondary data were analysed simultaneously as a whole. Secondly, the researcher analysed primary data in parts (in two major divisions) as explained further. The collected data were analysed to reveal qualitative and quantitative findings related to existing facilities and refurbishment. Nevertheless, comparative analysis of data from the UK and USA was performed to understand the differences.

The process of data analysis is explained as "*the interplay between the researcher and the data*" (Knight and Ruddock, 2008, p. 89). Analysis focuses on understanding and interpretation of a data collected in a systematic, logical manner to arrive at reliable conclusions. The type and source of the data decide the analysis techniques to be employed. Secondary data are organised and pre-analysed by other researchers, thus involves less effort, whereas primary data is rich, fertile and requires additional efforts to organise, code, analyse and present.

Analysis is an important task because ineffective data analysis can negate entire data collection resulting in failure of the project (Knight and Ruddock, 2008). It should be a continue process in conjunction with data collection to identify areas of interest to ensure the methods and research approaches are well suited. It was suggested that the use of computer software is more suitable for storage and retrieval of data than for analysis (Knight and Ruddock, 2008).

Computer programmes were not used for the data collected through the literature review, as it was manageable and could be analysed using traditional methods. The data were de-contextualised physically and assigned particular categories and certain themes (Easterby-Smith and Lyles, 2003, Tesch, 1990), such as energy, BIM, simulation, refurbishment policies, modernisation, NHS. The data extracted from the literature review were segregated and developed throughout the analysis process before being used to study similarities and differences (Huberman and Miles, 2002, Dey, 1993). The themes were descriptive and conceptual, which enabled a basis for comparison between them (Dey, 1993). To analyse the data collected through the literature review, the following criteria were used; summary of each work, a possible relationship between various works, highlighted short comings (if any), conflicts between previous research, differing arguments, linking the rationale and purpose of the study, and generating a base for this research.

However, during the analysis of primary data, a computer programme was used, but only to a certain extent. Many qualitative and quantitative data analysis software packages are available and have been reviewed by Basit (2003), Seidel (1998), Tesch (1990), etc. The best way of selecting an appropriate and up-to-date software package is to assess the specific needs of each research or a phase. However, a criticism is that computers can limit the emerging new direction and diversity of approaches available for qualitative research. Brinkmann and Kvale (2009, p. 198) reported that computer programmes can facilitate the analysis of interview transcripts but people should do the actual analysis and not the computer. It is said that "*computers are not substitute for thought but they are a strong aid for thought, computers do not analyse data; people do...*" (Brinkmann and Kvale, 2009, p. 198).

Due to a large number of expected interviews and detail primary data to be collected; the '*NVivo qualitative data analysis*' software package was considered for data management. However, an extended search related to tools for qualitative data analysis revealed software packages, such as Microsoft Excel enables a researcher to complete the required tasks in a qualitative and quantitative data management if, used effectively (Bolboaca, 2009, Leahy, 2004). Considering several tasks performed by the researcher, the knowledge about Excel and time required to learn new software package(s), MS Excel was selected for data management and to assist with analysis. With spreadsheets (MS Excel), it was found easy to manage partially pre-organised data and, thus, other software packages were not considered further. Also, MS Excel was inexpensively available, and even the researcher's colleagues possessed experience of using advance features of MS Excel.

Most computer-based methods enhance the validity of the qualitative research outcome in a number of ways. Firstly, with management, manipulation and exploration of a significant quantity of a larger and wider quality data compared to traditional methods of manual analysis (Dainty, 1998). Secondly, it helps by providing facilities, such as coding, searching, counting, retrieving large quantities of qualitative data, which are cumbersome with a manual approach (Basit, 2003). Thirdly, they reduce time required for data management and presentation by a significant amount allowing a researcher to perform tasks related to data analysis (Leahy, 2004). However, advance features of MS Excel, such as '*data validation', 'conditional formatting', 'macros', 'formulas'* and '*if then statements*' provided the above advantages and benefited this research.

Coding with the help of keywords and categorisations is a more systematic conceptualisation of a statement, opening it for quantification. The open coding is "*the process of breaking down, examining, comparing, conceptualising and categorising data*" (Brinkmann and Kvale, 2009, p. 202).

As a major primary data collected from both the methods (interviews and the survey) was similar in nature, the principles applied for each method during analysis was similar. The only difference between the data was that the questionnaires were saved electronically using Word Processor and later transferred in to spreadsheets, whereas interviews were in the form of audio recordings which researcher transcribed into Word Processor for the analysis purposes. As the semi-structured interviews asked questions whose content and sequence were not fully specified in advance but outlined with the help of the protocol, a large amount of rich, fertile and partly organised data was collected. However, the collection of the data was performed simultaneously, which means the questionnaire survey responses were received at the same time from the UK and USA participants along with case studies in the UK. Accordingly, the data was organised in spreadsheets and used for analysis purposes. The data was segregated and arranged into the following 11 key themes identified from the literature review and a brief analysis of primary data.

1. Refurbishment Cycle.
2. Importance of Refurbishment.
3. Driving Factors.
4. Risk and Challenges.

5. Types of Refurbishment.
6. Occupancy.
7. Tools, Guidance, Framework, etc.
8. Consideration to Energy Consumption and Carbon Emission.
9. Opinion about Current Refurbishment Practices.
10. Clients (NHS, DoH, stakeholders) Role.
11. Current Standards and Legislations.

Accordingly, the process of assigning themes became an interactive process of determinant identification, thus the data analysis for all the phases followed the principle of grounded theory, as explained below.

5.13.1 Grounded theory techniques

This method is recognised as a systematic approach to explore processes even with a smaller sample size thus, getting popular in various research areas (Ibrahim, 2007). It is an approach towards analysis which integrates a set of specific techniques in flexible and different ways to give theoretical insights of the research area using qualitative data (Bloor and Wood, 2006) thus it is the qualitative approach (Tesch, 1990). The technique is suitable for fields with vague or a lack of existing theories, which cannot offer guidance (Macpherson *et al.*, 1993) and it can be tested by further research. The key difference between this research method and other methods is the evolving theory is based on a researcher's observations and grounded in the collected data. The theory is at the "*interpretivist, post-positivist end of the philosophical continuum*" noted by Knight and Ruddock (2008) and Glaser and Straus (1967). Grounded theory gives more control and understanding of a situation as it is based on the set of data, its illustration, and not merely hypothesised/conceptual ideas.

This method was developed by Glaser and Straus (1967); Corbin and Straus (1990) described it as *"a theory that is derived from data, systematically gathered and analysed through the research process"*. It demands systematic data collection and analysis allowing a theory to emerge from the data. Grounded theories are drawn from a finite set of data and offer insights, enhanced understanding of a research area providing a meaningful guide to action. The approach attempts to discover regularities through the categorisation of elements and exploration of their connections.

This approach does not begin with a theory to be tested, but allows it to be emerged with an area for the researcher without any preconceived ideas of output. The theory is a combination of literature, observation, common sense and experience (Knight and Ruddock, 2008). Three main categories considered under this approach are field data (notes), interview data (notes, observations, recordings and transcripts) and available literature.

The main data for this type of analysis is gathered from interviews, observations, documents, historical records, videotapes and anything else of potential relevance to research questions (Knight and Ruddock, 2008, Ibrahim, 2007). Glaser and Strauss (1967) outlined the following benefits of a well-constructed grounded theory:

- faithfulness and induced from diverse data;
- relevance to both, who are studying and those who are practising in the area;
- wider application to a variety of contexts related to that phenomenon; and
- to provide control with regards to action towards the phenomenon.

The grounded theory approach is criticised in the literature, as it is difficult for a new researcher, a very subjective process, and relies on the researcher’s abilities. Nevertheless, the literature gives some guidance on analysing data using grounded theory (Carvalho *et al.*, 2005).

Thematic analysis

Thematic analysis focuses on recognisable themes, patterns, behaviours, and often used by research-clinicians (Aronson, 1994), for example, to analyse conversations happened during a therapy session. With thematic analysis, audiotapes should be collected to study the conversions. Quotes and paraphrasing from the transcribed conversations are explored to list the patterns of experiences, and the data is searched for themes that relate to the listed patterns. Themes are defined as units derived from the patterns (Aronson, 1994). From a single transcription, various patterns can be identified, such as conversation topics, vocabulary, recurring activities, thoughts, meanings, feelings, proverbs. Alone themes can prove to be meaningless, however, identified themes by linking them with components or experiences are useful in an analysis process (Aronson, 1994).

Transcribing interviews

Brinkmann and Kvale (2009, p. 177) defined transcribing as "*an interpretative process, where the differences between oral speech and written text are the reasons for the practical and principal issues*". Now-a-days often, audio, or video recordings of interviews are made depending on whether a body language and gesture are important, or only verbal information shared by the participants will be the key to a data analysis. Audio or video recordings are effective and efficient in the research world because it enables an interviewer to focus on the subject. With this research, all possible interviews were recorded using an electronic device in the form of audio. Later, these recordings were used for analysis purposes. Intensive note taking during interviews can be distracting and interrupt the free flow of a conversation (Brinkmann and Kvale, 2009). Thus, during interviews, the researcher spent limited time making notes and concentrated on probing the questions. Nevertheless, transcribing interviews and making it available into a written format is itself an initial analytical process leading towards the overall analysis of data (Brinkmann and Kvale, 2009).

Qualitative data requires specific analytic techniques to avoid the problem of a researcher being bias, data overloaded, or uncorroborated or misleading conclusions drawn (Huberman and Miles, 2002). The codification of qualitative data demands a process describing findings, classifying or coding it, and linking the data as presented in Figure 5.8.

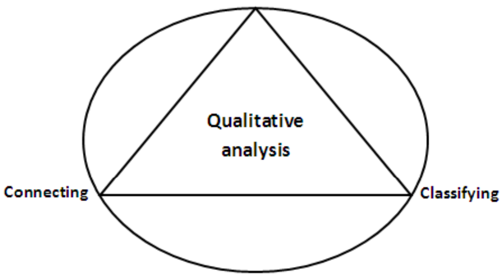

Figure 5.8. Qualitative analysis process (Dainty, 1998)

There are greater analytical challenges with a diversity of data collected in research (Huberman and Miles, 2002). Some researchers have addressed issues of diverse data by applying content analysis techniques use for the quantitative data analysis (see Dainty, 1998, p. 107). Coding based data analyses are particularly suited to unorganised, text-based data, where a researcher has theoretical concerns about the research (Dainty, 1998). Accordingly, the partially pre-organised data were broken into chunks, assigned under conceptual themes, and then studied as part of the qualitative data analysis process. Data can be loaded into a spreadsheet manually or automatically if an optical readable questionnaire is used (Knight and Ruddock, 2008, p. 128). As the data was partially pre-organised because of adoption of the protocol, it was categorised and arranged with the help of a spreadsheet and a conceptual label.

Knight and Ruddock (2008, p. 126) argued that coding is most suitable for close-ended questions, therefore, the collected data was not significantly coded. Computer-aided qualitative data analysis has a potential to enable the researcher to manage increasing sample sizes and facilitate the need to compromise the number of cases investigated with a number of dimensions that could be studied (Dainty, 1998) and produce a result with confident in it. Brinkmann and Kvale (2009, pp. 205-06) suggested following five stages of analysis for the data collected through interviews.

Stage 1: Thorough reading of the interviews transcript.

Stage 2: The natural '*meaning units*' of the text, as they are expressed by the respondent and determined by the researcher.

Stage3: The researcher understanding from the respondents point of view, and themes should not dominate a natural meaning unit during thematising.

Stage 4: The interrogation of the data in relation to specific purpose of the study.

Stage 5: The essential, non-redundant themes generated through interviews are tied into a descriptive statement.

The above stages were adopted during the analysis of data. Firstly, the researcher transcribed all the audio recordings, which involved thorough reading of the interview data. Again in the process, during management and organisation of data the researcher went through the entire data, which helped to highlight certain key areas and themes within the data. Secondly, the data were understood by reading again from respondents' point of view with consideration to refurbishment and existing buildings. Thirdly, data were searched for any new theme, direction, or critical issue that the researcher might have missed. Fourthly, the data were interrogated with consideration to the main purpose of the study. Finally, through data analysis descriptive statements were extracted. The outcome of these five-step analyses is reported in the next chapter. Also, where necessary, the data were discussed with the researcher's supervisors and colleagues.

The adoption of grounded theory does not test existing hypothesis but helps to develop it inductively. With this approach, comparative study of the collected data for its similarities and differences leading towards sampling and theoretical memoranda was performed (Brinkmann and Kvale, 2009). Also, rigorous or more focus on a coding of data, moves analysis from descriptive to more theoretical levels resulting in a saturation of the information through the coding process. Thus, primarily importance was given to searching for themes within the collected data compared to coding. The strength of an opinion can also be indicated with a single number on a scale. The categories as part of the theory can be developed in advance, arise as ad hoc during the analysis, derived from a theory, or extracted from interviewees' own idioms (Brinkmann and Kvale, 2009). Also, while analysing the data, principles of thematic analysis were considered. The data was explored further, which represented a common theme under every category and diverse theme, if there is any.

Knight and Ruddock (2008) stated software packages, such as SPSS are more appropriate for statistical analysis. A limited quantitative data was extracted from interviews' transcripts and the questionnaire responses, such as to determine how many experts reported when facilities should be refurbished, or how many participants thought building age was a key factor in refurbishment. However, as explained earlier, MS Excel was used to analyse and present data quantitatively in the form of charts or graphs (see Chapter Six). Also, the analysis of collected data using the questionnaire helped to established recommendations and areas for further research as presented in Chapter Eight.

5.13.2 Analysis of secondary data

To use secondary data in another research project or a purpose it needs to be analysed again, despite being pre-analysed. Below a method used for analysis of secondary data, meta-analysis is discussed. Meta analysis uses existing data from the literature and various sources, such as books, journal papers, etc. In this, data from existing research studies are extracted, encrypted and understand using statistical methods. Meta analysis is defined as an "*analysis of analyses*" (Brewer, 2007, p. 41) and involves:

- analysis of research methods used in the other relevant studies to know their rigour;
- analysis of the valid and acceptable data;
- reduce collected data using appropriate statistical techniques; and
- adoption of new samples to explore a relation between variables.

5.14 Data collection errors

A lack of reliability due to subject error may arise when a participant is influenced by external factors, such as working environment or a work load. In this research, the potential for error in the data is probably related to the workload of participants, complex nature of healthcare projects, or existing buildings. The questionnaire survey and interviews demanded participants' time, and if they feel that was an unreasonable use of their valuable time, it might have had a negative effect on the completeness and accuracy of the findings. To overcome this issue, the phraseology of the questions was improved and made simpler by reviewing questions with the researcher's colleagues and supervisors for relevance focus and ease of combination.

5.15 Validation

The establishment of appropriate operational measures for the context being measured was achieved using multiple sources of evidence in the collected data. Triangulation is a combination of qualitative and quantitative approaches adopted to explore multi-perspective and complex research areas. In triangulation each employed method is equivalent to a tool, which helps to exploit research in several ways, for example, qualitative methods refer to '*what kind*' and quantitative methods refer to '*how much of a kind*' (Brinkmann and Kvale, 2009, p. 116). Three key approaches suggested by Knight and Ruddock (2008) behind a multi-strategy research are mentioned ahead. In Table 5.9 reliability and validity measures addressed by the research design to accomplish overall aim and objectivise are presented.

Table 5.9. Reliability and validity measures addressed by the research design

Issues	Measure used
Reliability	Implicit case study and survey protocol established and adhered to it throughout
Construct validity	Evidence gathered using multiple sources and collection of additional documents
Internal validity	Cases gathered from wide array of sample and analysed using tactics suggested
External Validity	Case comparison undertaken at common theoretical analysis and simultaneous analysis

Corroboration: qualitative research to support quantitative research and vice versa.

Facilitation: strategies to aid research.

Complementarity: two strategies dovetail different approaches of an investigation.

Knight and Ruddock (2008) emphasised that quantitative method should be a part of research design in the built environment because '*hard*' data are require to uncover relationships between the various parts of the research. Whereas, qualitative methods are require to collect '*soft*' data and to explain their relationships. Theoretically, a combination of multiple methodologies is attractive as it can handle problematic situations with a need for effective linking of judgement and analysis.

Thus, multiple sources of evidence were sought to triangulate perspectives within the collected data set as discussed below. Validation of the results of Objectives One and Two were tested via critical literature review, web-based case studies (see Appendix C) and during early phases of the data collection. Objectives Four-Six were tested via semi-structured interviews with 11 participants during the later phases of the research. These interviews and research works (Sheth *et al.*, 2010a, Sheth *et al.*, 2010c) presented during the conferences provided feedback on the development of research and the conceptual framework. This in turn allowed the refinement of the Refurbishment Framework. In addition to interviews, 43 questionnaire responses were used to accomplish the aim and objectives.

Validation of the final framework, Objective Seven was achieved through piloting and final interviews as part of the validation process.

5.16 Ethical considerations

A qualitative research approach is preferred in a research related to the social sciences, which involves the action and reaction of individuals. In research ethics, moral principles for a researcher are to identify various findings in a given setting. The ethical considerations will decide the quality and quantity of the data being collected. Collected data can be based on two typologies, first, either experience or education of the participants and second, a combination of both.

In this study, the participants were given the option to decide the settings of the interview and location, thus, mostly the researcher travelled to the participant's office. A participant should feel safe throughout the interview process or while completing a questionnaire survey. During face-to-face contact with participants, a sensitive researcher should perceive an uncomfortable response and change the direction of investigation (Brinkmann and Kvale, 2009). The researcher's inexperience meant that the researcher was unable to anticipate some situations or know what was likely to happen while interviewing the participants, such as phone calls, unplanned works, and ongoing projects. The effect of such situations were minimised by allowing flexibility up to a possible extent, for e.g., informing participants to discontinue, opt out at any time, or to skip any question.

It is difficult to anticipate everyday life and this meant the researcher had to account for all sorts of factors and unanticipated conditions. For example, some experts did not attend a group interview because of an unforeseen situation, though the interviews were pre-planned and scheduled with consideration to their requirements. Also, to suit the participants' schedule and everyday work life, the researcher reached the predefined location of interviews well in advance and kept some free time post-interviews to allow flexibility. In the beginning of every interview and discussion, a brief background of the research project, a researcher, researcher's university and HaCIRIC were given to the participants. Also, permission was sought from the participants to make an audio recording of the conversation, where applicable (except one all the participants agreed to do audio recordings). Also, the following points were considered before approaching experts to participate in this research.

- Explaining the intended use of the data.
- Agreeing in writing to the level at which information will be made public.
- Identifying the increased accuracy that can be gained through its use in inventories.
- Offering cooperation to derive mutually acceptable data sets.
- Giving credit/acknowledgement in the inventory to the data provider.

As with interviews, the above mentioned ethical issues were considered during a questionnaire survey, enquiries through email, and in personal communication at various conferences, seminars, etc., attended by the researcher. Before the questionnaire survey, all the participants were informed that they could skip or revise any question, if necessary.

In this research, the researcher was careful while publishing any personal details or other information, which can disclose participants' name or details. The participants were assured that their name or information that will encroach on their privacy would not be made publicly available. Thus, the collected data used for publications are in the form of a qualitative and/or quantitative analysis and none of the individual responses or answers are disclosed by any means. Participants' privacy was safeguarded with code names such as using A1 to A26, B1 to B10 and C1 to C7 for questionnaire responses. An alphabet represents a version of the questionnaire, whereas numbers represent respondents. With interviews, they were given letters, such as Interviewee A, Interviewee B... Participants of the group interviews were represented using Interviewee A1, Interviewee A2...

The collected data in the form of hard copies (in lockers) and soft copies (in hard disk) is stored in a secured space, which can be accessed only by the researcher and supervisors using passwords.

5.17 Rejected research methodologies

Various research methodologies were considered in this study, however, a few methods were rejected due to their characteristics as explained below. It was established that qualitative literature reviews conducted using a phenomenological method gathers data from an empirical research report instead of interviews.

However, the data from empirical research reports were used as secondary data and not primary.

A protocol for the questionnaire and interviews was developed with consideration to various methods (see Section 5.10.1), but structured interviews, Likert scale, etc., were not considered because they did not have the '*right*' combinations or characteristics to satisfy the research aim as discussed ahead. During the development of the protocol, close-ended questions were not considered. A close-ended question lacks the characteristics of the qualitative approach and measures certain situations/topics into *'strong to weak', 'attractive to ugly',* or on a five point Likert scale *('strongly agree, agree, neutral, disagree and strongly disagree')*, which was not a requirement of this research. Also, data collected using close-ended questions produces quantitative data, significantly, which was not a key to this research.

With data collection, a probabilistic method was not considered for case studies or questionnaire survey. Sampling using this methodology assumes that every part has an equal calculable probability of being selected as part of data collection (Knight and Ruddock, 2008).

Verbal methods during the questionnaire survey were not employed on this research project because they are suggested for gathering data from general public and suitable for types of survey collected on the street, over a telephone, etc (Knight and Ruddock, 2008). Also, they demand close-ended questions and a minimum length of questionnaire (since most of the data is collected during rush hours with an expectation of a huge number of participants). A questionnaire survey conducted over a phone would also need to be as short as possible and simple, for example, *'do you use this product...Yes/No*', and consequently, this method was not adopted.

Postal questionnaire survey is known to have a good success rate in the research world, however, due to advancement in technologies and additional benefits of other types of survey methods mentioned in Table 5.7, postal questionnaire were not considered in this research.

There is an increasing demand and popularity in an organisational research to employ computer-based simulation as a research method. LANL (2008) suggested two ways to test/validate proposed design solutions first, using '*physical to scale model*' and second, with the help of a computer generated virtual building model through simulation studies. Other research methods rely on several assumptions related to (exact cause and effect nature) research area; such as, in survey research, a researcher should "*define the form and content of cause and effect*" to develop learning based on the data (Baum, 2005). Whereas, a researcher performing simulations inherit existing organisational data and conditions in his study. In most cases, a simulation-based research method helps answer the question *'what if'* and it enables more complex studies by moving forward into the future, compared to the other research methods, which consider history to determine what happened, and how (Baum, 2005). Also, the nature of living systems is to either increase in entropy (disorder) or complexity (order), looking backwards is inherently more difficult than moving forwards except in case of existing facilities. There are three main schools of simulation (Baum, 2005), which can be employed as part of a research method, are mentioned ahead. Discrete event simulation involves modelling the organisational system as a set of entities evolving over time according to the availability of resources and the triggering of events. System dynamics involves identifying the key *'state'* variables that define the behaviour of the system, and then relating those variables to one another through coupled, differential equations. Agent-based simulation, which involves agents that attempt to maximise their fitness (utility) functions by interacting with other agents and resources; agent behaviour is determined by embedded schema which are both interpretive and action-oriented in nature. However, none of the above simulation method was considered as explained ahead.

As part of the research, modelling and simulation (M&S) were considered (Sheth *et al.*, 2010b) in the beginning, but later in the process, because of time and resource constraints it was excluded. Considering the fact that there is a lack of research related to refurbishment and existing healthcare facilities it would be very difficult to explore different systems, scenarios, organisational behaviours, etc., associated with them. Furthermore, it is very difficult to get access to data required and it would require extended time-period to test a proposed framework longitudinally on an ongoing project. As mentioned earlier computer simulation is growing in popularity as a methodological approach for organisational researchers, however, due to limitations mentioned in this section, this methodology was not considered as a key to this research. There are several challenges associated with refurbishment such as lack of data, expertise, tools, etc., thus computer simulation was avoided and a validation and evaluation of the framework were performed through interviews with experts.

5.18 Chapter summary

This chapter presented and discussed the methodological approaches adopted for the research to meet the aim, objectives and research questions. The methodology has been linked with the research objectives to clarify the whole picture of this research. The research design was that of the case study, questionnaire survey and the unit of analysis was the themes (discussed in Chapter Eight). However, some of the rejected methodologies are also discussed in this chapter.

The ontological, epistemological and empirical considerations applicable to the research relating to refurbishment practices were outlined and discussed. Given the characteristics of methodologies and the research considerations a mixed approach was selected to accomplish the aim and objectives. The various research instruments such as interviews, questionnaires, etc., supporting the research methodology are presented in this chapter and a typical research cycle and the steps to complete the same are also discussed. The research cycle starts with literature review and ends with validation of the research.

The use of the questionnaire survey and protocol through emails and face-to-face interviews has been discussed as main data collection methods and proved to be an important data source for this project. All the data collected using questionnaire survey were organised using spreadsheets for analysis purposes. At the beginning of data analysis software, such as NViVo was considered, but later the data was analysed manually. The development of the protocol enabled the management of the collected data during the course of this research. The organised data were reduced by analysing to draw conclusions. As explained earlier, many of the ideas in this research have been developed through the literature related to existing buildings in healthcare, and other sectors such as housing, hospitality, etc. Also, at the beginning, literature related to sustainable development was considered to establish a relation between sustainability and the healthcare sector.

Together Chapters Two, Three and Four present the literature review of this research. The following chapter presents the analysis of collected data using above mentioned methodologies. Further to data collection and analysis, progress was made to propose a conceptual refurbishment framework (Sheth *et al.*, 2010a, Sheth *et al.*, 2010c, Sheth *et al.*, 2010b) and a final framework in Chapter Seven, which is one of the key outputs of this research.

CHAPTER SIX. ANALYSIS OF INTERVIEWS AND QUESTIONNAIRE SURVEYS

6.1 Introduction

This chapter presents qualitative and quantitative findings relating to refurbishment and existing hospitals collected using an in-depth investigation. The collected data were also related to current development in modelling and simulations to partially satisfy the objectives of the research. The primary objective of the questionnaire survey and interviews was to determine the refurbishment processes observed in industry. Both (questionnaires and interviews) sought information on issues related to energy and carbon emissions in existing buildings. Nevertheless, they also investigated what decisions are made during refurbishment with regards to re-designing and impact on energy consumption of existing healthcare facilities.

Due to the exploratory nature of the survey and interviews, the collected (primary) data allow comments and conclusions to be made along with the results. The findings and analysis are presented under conceptual headings and themes, which together helped during development of the Healthcare Energy and Refurbishment (HEaR) framework. Representative quotes from the raw data are used to provide rich insights into the research topic.

6.2 Respondent’s profile

In the protocol, Questions 1.1 and 1.2 were related to the respondent’s profile. These questions gathered general information, such as participant's name, age and associated projects. Table 6.1 presents the overview of the participants' profiles. In total, 43 experts participated in the questionnaire survey and 11 in the interviews (see Appendix G). All the participants in this research were working exclusively on healthcare projects, as explained earlier Chapter Five.

Table 6.1. Overview of participants for the survey and interviews

Years of experience	Questionnaire respondents	Interview participants
Maximum	50	30
Minimum	10	6
Median	30	18

6.3 Refurbishment cycle

This was Question 2.1 in the protocol. Qualitative characteristics of refurbishment, such as when, after how many years, a facility should be refurbished, and their importance is discussed through this question. However, there are several reasons when refurbishment can occur in existing healthcare facilities, and it was difficult to find a single solution or trend for refurbishment. Sometimes a client controls the refurbishment cycle and sometimes when there is a need for facility extension, existing buildings receive refurbishment.

In Figure 6.1, the vertical axis is a number of respondents, and the horizontal axis represents after how many year refurbishments cycle occurs in healthcare facilities. Eleven experts reported refurbishment is ongoing; whereas, 16 mentioned that it typically occurs every 11 to 20 years. The figure clearly demonstrates it is difficult to predict when there will be a need for refurbishment, especially with consideration to age.

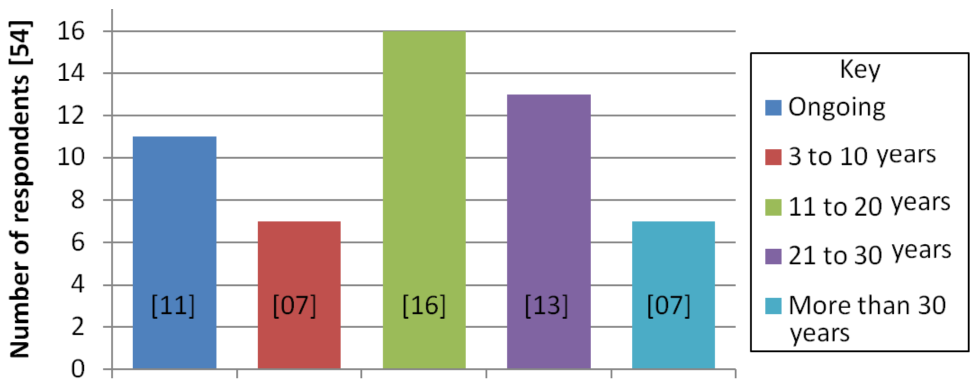

Figure 6.1. Refurbishment cycle in years

Some experts stated, recently constructed facilities will not demand significant refurbishment because of a consideration to flexibility, adaptability and future proofing during planning stage. Moreover, selection of building elements with a consideration to their life-cycle, and a design brief as part of the project can give an indication of when refurbishment will occur in the future.

The average age of a facility was found to be approximately 40 years, with refurbishments occurring at varying locations and scales throughout its life. However, some recently constructed facilities had observed refurbishment in less than four years after inception. The occurrence of refurbishment in healthcare facilities depends on goals and objectives of the organisation. However, it can occur within five years or after a decade because of equipment obsolescence and changing technology, such as an introduction of new smaller equipment with added functionality.

Refurbishment is important to support new service lines or equipments and to improve current systems. There is no fixed governing pattern for refurbishment and many drivers exist, such as accessibility, look and feel (see Section 6.4 for more details). Large facilities with more functions have noticed ongoing minor refurbishment and major refurbishment on an irregular basis. The investigation revealed that buildings should be considered for minor refurbishment in 5-10 years and for major work in 25-30 years, but it will depend how it has been maintained post-construction.

With existing buildings, which are more than 30-year-old, refurbishment is triggered because of maintenance and or operational issues. Also, the trend in NHS refurbishment is to act after three-year, but in some cases nothing has been done for more than two decades. If facilities were refurbished in the past then eventually only the facade is treated and not the core. Interviewee D, associated with one facility for more than two decades stated, *"he does not recollect any significant refurbishment in the past*". Post-refurbishment patients and users report an improved indoor environment in many facilities, which is often a key behind refurbishment. Also, a well designed clean building attracts more patients and users feel secure inside this facility.

Sometimes facilities have been refurbished within a decade or two decades, as it is difficult to remove older structures because of their dependencies on adjacent facilities, vice versa, or economical issues. The frequency of the refurbishment can depend on the functional and elemental life-cycle. Parts of a hospital with important (life-saver) medical technologies may be refurbished in three years, along with its architectural finishes. Irrespective of age, some facilities demand refurbishment depending on their utilisation (less or more) compared to other facilities. However, refurbishment is important to replace worn-out finishes or to accommodate more patients/users depending on the age and condition of the buildings.

The varying life-cycle of the equipment, buildings and finishes are often reasons for refurbishment at different times. For example, a mechanical system with 15-20 year life in a building with 40-50 year life span will require different types of refurbishment throughout its life-cycle. New service lines parallel to new technology can influence refurbishment of the built environment. Sometimes hospital areas, such as inpatient and outpatient demand refurbishment at different times, for example, former needs frequent refurbishment to maintain the environment (and quality of care), whereas later needs refurbishment because of new advanced/improved technology.

One of the respondents from the USA described refurbishment cycle as follows. For skilled nursing homes, a five-seven year cycle is optimum, but usually they are refurbished in 10-year time. In assisted living facilities, a seven-year cycle is optimum however; usually it is bigger than 10 years. Similarly, wards in geriatric facilities are often refurbished every decade, although five year is recommended for a partial refurbishment, or maintenance in the USA.

6.4 Reasons and driving factors for refurbishments

This was Question 2.2 in the protocol used for the interviews and survey. The pervious section presented when and why refurbishment occurs in existing facilities and this section discusses drivers behind the same. A brief list of drivers to be considered with a refurbishment project has been extracted from the collected data, grouped under common themes and presented in Table 6.2. It is very important to identify the drivers at the beginning of the project, as this defines the aim, objectives, and challenges for the project.

Several driving factors have been identified in Table 6.2, but due to their complex nature, it was difficult to categorise these drivers. However, efforts were made to categorise these drivers into users, construction and future drivers (see Sheth *et al.,* (2010a)).

Table 6.2. Types of drivers for healthcare facilities and refurbishment

Type of drivers	**Number of respondents citing this driver**
New regulations, codes, and government policies	33
New technology updates	32
Expansion, more demand for space	32
Building age and aging infrastructures	24
Upgrades/end of building's life cycle systems; electrical, HVAC	22
Degraded building fabrics	18
Lighting and operational cost including staff salary	17
Energy consumption	17
Improvement to patient rooms	16
Outdated or worn finishes	14
Improvement to outpatient areas	11
Infection control measures and privacy issues	11
Change in use	11
New medical procedures	9
New clinical requirements	9
Standard of care	8
Competition	8
New operation models	8
Change in demand	8
Dependencies of adjacent structures	8
Staff retention, aging population, complexity issues, changing priorities, value for money and assessments	6
Outdated space	5
Maintenance cost	4
Scheduled activities	3
New staffing ratio, staff recruitment, demographics change, functional obsolescence, seismic deficiencies, new leadership, and diagnostic updates	1

The developments in the healthcare such as departmental policies, moving pressure to acute hospitals, operational costs and demand for new/improved facilities are key drivers for many recently completed refurbishment projects. Also, new diseases, increasing population, fewer beds, new standards and requirements, and demands are some of the well-known drivers for major refurbishment projects or new developments. New technology, privacy issues, infection control, healthcare organisation and government targets are reported as drivers, with a significant impact on the life-cycle of the existing buildings. Refurbishment is also observed during the implementation of a master plan, which has impacts on all existing facilities and infrastructure as reported by Interviewee C.

Often, changing regulations for healthcare facilities put pressure on existing buildings to perform updates to comply with new regulations. With some projects, construction cost or efforts associated with developing a new facility are less compared to refurbishing an existing facility. However, refurbishment is a preferred option due to the difficulty in replacing existing facilities, such as the level of complexity associated with them, day-to-day function, limited access, and dependency of adjacent facilities. Also, changing or expanding services can result in an existing facility being replaced or extended. In some cases, a facility begins to downgrade because of constant use, a need to update technology, poor performance of envelopes, or changing (physical, social, or economic) demands.

With Victorian buildings, there are several critical drivers when compared with recently constructed facilities; for example, accommodating a new mechanical system, required number of air changes, infection control, increasing capacity and current regulations. Also, some of the existing buildings are difficult and expensive to maintain because of their scale. Interviewee D reported a Victorian building being used only for archives, as is the case with several NHS trusts. During an interview with a site manager responsible for marinating buildings built in the mid 20th century onwards, he noted how difficult and complex it is to manage a site comprising of buildings with varying characteristics, such as age, construction details, materials. However, certain departments demand refurbishment sooner compared to other areas in a hospital due to unforeseen conditions, which can be hard to predict.

Towards the end of the 20th century, a lack of improvement in glazing in existing buildings will become a driver for refurbishment in the future. For example, a hospital refurbished during the late 1980s that remained single glazed will be responsible for problems like air leaks. Until the end of the 20th century, carbon emission was not a priority area for a concern, thus some projects have not addressed this issue and will result in a refurbishment in the coming decades.

Another interview participant reported PFI hospitals would be a driver for the healthcare sector in the coming decades. These projects were only planned for 35 years, and they will be handed over to NHS trusts in '*Condition B*' at the end of this period. Thus, in the future, hospitals will need significant refurbishment because the owners of PFI hospitals will have to satisfy '*Condition B*' classified by the NHS Estates. Although the definition of '*Condition B*' demands facilities to be sound, operationally safe and allows for minor deterioration. One interview revealed that in the past, some governments promoted PFI projects, which resulted in degraded existing buildings but this is changing now and, there are fewer PFI schemes under development.

As with Victorian buildings, several problems are reported in modern buildings. During a case study, ongoing problems were discovered in a modern facility because of the radiant heating panels installed in the false ceiling, thermostat near the windows (easily influenced by external weather) and the facility being controlled by the Building Management System (BMS) installed half a mile away. Some users reported that the building is not performing the way it was predicted. Also, a few offices were using (additional) electrical heaters despite central heating being operational, and some areas and floors were extremely hot, with a need to open windows at the same time. In some areas, even on a sunny day, a requirement for round-the-clock heating was reported. Also, the poor acoustics was a concern; during site visit one user stated he could hear what was being said in the next (meeting) room. Another interview participant reported that investigation and simulation are being performed to address heating and acoustics related issues. However, Interviewee C, a site manager, reported that there is a strong demand for local controls against central controls (BMS). Certainly, all these above issues will be drivers in the future.

Though many experts are anticipating that 21st century buildings will not have problems quite like Victorian stock in the future, certainly there are going to be drivers for refurbishment because of their complex nature and inadequate planning. With many existing projects, master planning is inadequately considered as explained ahead. For example, one case study revealed, in an existing facility, five wards were refurbished, but post refurbishment only three were considered for utilisation. Also, in reality, the trust occupied only two wards resulting in three empty (refurbished and furnished) wards, which shows a lack of master planning.

Various procurement models (for example, ProCure21, ProCure+, etc) are being used to maintain Key Performance Indicator (KPI) and to justify the proposal are some of the well known driving factors for refurbishment. Certain targets by government and local authorities to establish the hospital’s indoor conditions to provide a healing environment will drive existing buildings towards refurbishment.

6.5 Advantages of existing facilities

The investigation revealed several problems and challenges associated with refurbishment because of available ceiling heights, existing layouts, and lack of open space in existing facilities. However, it is a preferred option over new construction due to various reasons as discussed further. Although throughout the investigation various criticisms are noted related to existing facilities, during the analysis, efforts were made to reveal advantages of existing facilities and refurbishment in the healthcare sector.

In overcrowded cities, refurbishment is preferred over a new construction because of inadequate availability of land and/or it is difficult to segregate existing functions, which are in existence for several decades or more. To build around existing ward acting as a service feeder, to retain the same for administrative purposes or develop a new facility for clinical use are some of the common suggestions revealed from the investigation. Strategies such as dual services, feeding a building from both the sides can help during refurbishment and future construction related activities. Isolated services at the building as well as site level will be very helpful during refurbishment and other construction related activities. Also, satellite units can be developed, which may act as a feeder for existing buildings and support modern medical needs. The investigation revealed that part refurbishment is a better option compared to full because with full refurbishment only structural elements are untouched and it is expensive. Although during the investigation, there were mixed opinions about complete (major) refurbishments versus new construction, all the participants suggested, partial refurbishment of hospital is effective as it keeps a system operational/live. While commencing any new construction or refurbishment, similar strategies throughout the site (master planning) is very important. Post-refurbishment (due to improved layouts, circulations, internal planning) the number of staff required can decrease or vice versa. With many refurbishment projects, users have reported improved access on completion, which is often a goal of the refurbishment.

Successful refurbishment may not provide more beds, but can reduce treatment time. Refurbishing a facility for a similar purpose can be quicker because of low risk associated with the planning. It is also important from sustainability point of view to save open land and to recycle existing space. To meet the DoH targets related to energy reductions and CRC there is a need to address issues associated with existing buildings performance; refurbishment provides the opportunity for the same. If refurbishment is completed in effective ways then it can be cheaper option to provide a new technology at lower construction cost.

6.6 Risks and challenges associated with refurbishment

This was Question 2.3 in the protocol used during the investigation, as presented in Appendix G. The investigation highlighted risks and several challenges associated with refurbishment due to the complex nature of the facilities in the healthcare sector. Some participants mentioned these projects are challenging, tedious, time-consuming, whereas, a few mentioned "*interesting and unique projects involving (real) great level of engineering*". One interviewee stated that because refurbishment is not a 100 per cent new build it is difficult to achieve new standards, even if it involves substantial work. Whereas, Interviewee C mentioned that the design team needs to negotiate with local councils and a planning approval authority against stringent building regulations.

During the analysis, efforts were made to identify themes within the collected data. Seven major themes mentioned in Sections 6.6.1 to 6.6.7 were identified. Also, the data were analysed with consideration to the overall focus of this study, refurbishment of existing facilities, which is also one of the themes. Structurally sound buildings, but degraded envelopes and degraded internal spaces are reported as a common problem in many existing buildings from the late 20th century.

6.6.1 New facilities versus refurbishment of existing facilities

Although, there was no specific question on a development of new facilities, while analysing the data, efforts were made to characterise the reasons for new construction and demolition of existing facilities.

Development of new projects is a straightforward option, whereas with refurbishment many assumptions have to be made. For example, while comparing different options for new windows it is easier to change parameters such as air gaps, '*U value*', '*R value*', colours, but in existing buildings, these values are based on assumptions and vary from a component-to-component. A huge backlog from the past is also responsible for a significant amount of new constructions. Existing buildings cannot support new clinical requirements, such as a need for more isolation rooms.

It was reported that some buildings have run out of life, especially Victorian buildings are exhausted and no amount of redecoration, or minor refurbishment could fulfil modern clinical requirements and increasing demands. Many participants stated that refurbishment is not the preferred option for clinical and medical areas in the early and mid 20th century buildings because of inadequate height. For example, Interviewee A stated that with existing buildings it is difficult to achieve 4800 mm floor-to-floor height, including 1200 mm in the false ceiling for ancillary services (as per modern regulations), thus the preferred option is new construction. Also, in some cases, the available space in a ceiling cavity is 800 mm but HVAC systems, and new equipments demand 1800 mm.

If clients or stakeholders are not satisfied with the payback period of green (sustainable) technologies, new development is considered. For example, with smaller life-cycle of refurbishment projects, more than five-seven year payback period is not acceptable. Thus, advanced technologies with 20-30 year payback along with new construction are considered. Stripping down an existing facility to the level of structural frame built in the 1970s is expensive thus, new build is considered. Also, heating systems and glazing are not efficient and existing buildings cannot support modern regulations related to number of air changes per hour and required air quality within hospitals. Nevertheless, sometimes new development is observed because conditions of existing systems are beyond use or at the end of their life-cycle, which should be assessed in every refurbishment project before deciding on the scope of work.

6.6.2 Energy savings in existing buildings

One respondent mentioned reducing energy in existing hospitals is a simple option, which starts with efficiency at the source to micro scale, such as from CHP to use of low energy bulbs and better insulation. Works related to infrastructure, updating mechanical systems and electrical lighting provide significant energy savings along with reduced challenges during refurbishment. To achieve the maximum possible energy saving sometimes there is a need go beyond the scope of work, such as replacing an entire building infrastructure, but this may not be a cost effective solution. In some facilities, additional equipment results in increasing demand, consequently replacement of mechanical, engineering plumbing (MEP) to support more energy loads, however, a lack of adequate space can change refurbishment scope significantly. In the industry, ongoing developments of equipment and lighting to conserve energy are reported, which needs to be considered during refurbishment. Existing building constraints can limit the integration of different options to improve the built environment's performance and to reduce energy consumption. Poor building envelope is reported as challenge mainly associated with reducing energy consumption and improving IEQ.

To achieve energy saving in an existing facility, close working with the infection and quality control department is required. Also, disruption to patients, site restrictions and structural conditions are noted as a problem for saving energy due to restricted or limited access to infrastructure. In Victorian buildings, 90 per cent of the time heating is operational and users open the windows to control the excessive heat, which is a significant driver for energy savings. One interviewee, a site manager, reported new buildings with many temperature controls, lopping, air conditioning and air handling plants are responsible for a significant gas and electricity consumption equivalent to Victorian buildings. During one case study, a participant reported that some of the energy saving features are responsible for more energy consumption in reality because of their inefficient design. Moreover, during refurbishment efforts should be made to reduce unnecessary volumes (such as excessive height) to minimise the heating or cooling load. Also, post refurbishment some projects have reported increasing energy consumption due to more number of single-bed rooms, stringent regulations, etc.

6.6.3 Refurbishment of existing facilities

Several participants reported even today 30-40 per cent of buildings used by the NHS were constructed in the 1970s, 1960s, or during the Victorian era. The key challenges with existing facilities are privacy and infection control in multi-bed rooms or wards. A congested site is one of the biggest challenges for current and future developments. Phasing is very important for large-scale projects involving several facilities, and it can have a positive or negative impact on the project cost, quality and overall success. It was mentioned that services are often depend on centralised facilities, and unforeseen conditions in existing buildings are challenges for refurbishment and demolishing, as the entire building/site is dependent on the same. Stand-alone mechanical (HVAC) systems with minimum or no dependencies on adjacent facilities are less challenging while developing and implementing phasing plans. Infrastructure such as existing grids, storm water drainage, building structure, and so forth can be challenging, if not considered properly.

Staff and patient safety, code compliance, indoor air contamination and operation hindrances during refurbishment are unique problems when compared with the development of a new healthcare facility. However, if it is not possible to construct a new facility, then with very advanced planning and engineering existing buildings can be used for medical/clinical purposes. The investigation revealed that refurbishments involve more manual work, and it is important to protect deteriorating existing spaces, improved IEQ and to update technology within the existing buildings.

The major risk reported by all the participants is trying to accommodate construction works/requirements where occupants are within the hospitals throughout the day and night, and any construction activity nearer to the patient area or clinical space can disrupt ongoing works. Often, vacating building and shifting patients from a building under refurbishment is a risk and challenge; also, shifting patients and vacating some areas result in loss of beds and clinical services. Considering this fact, facilities under refurbishment are partially occupied air born infection and dust, noise and vibrations due to construction are additional challenges. Based on the analysis of collected data the following key points are listed related to existing buildings and refurbishment.

a). ***Initial cost:*** is challenging because sometimes the expected life of a refurbished building is less than the payback period of the investments.

b). ***Minimising dust and keeping noise down:*** is important because facilities are occupied partially and can interrupt medical activities.

c). ***Disruption to patients:*** from construction is unsettling and can result in a feeling that building is not suitable for the purpose.

d). ***Access:*** to facilities for patients and users should be unobstructed from any construction related activities.

e). ***Infections and disruptions to services:*** should be minimal because it can be irritating for users, especially patients.

f). ***Physical constraints:*** such as existing structure and mechanical systems can limit the possibility during refurbishment and should be considered throughout the project.

g). ***Hidden conditions:*** of walls, ceilings, and height in existing structures are responsible for increasing cost in refurbishment projects.

h). ***Lack of updated drawings:*** is a common problem in most 20th century buildings, thus a detailed pre-project survey should be considered of a prime importance.

i). ***Space required for BMS and modern services:*** should be accounted before proposing the same, if applicable.

j). ***Required number of air changes per hour:*** can be difficult to achieve in existing buildings because of degraded building envelopes.

k). ***Unknown conditions of the existing facilities:*** can result in unintended shutdown, users' dissatisfaction and is difficult to manage during refurbishment.

l). ***Disruption to daily functions:*** can be avoided by investigation before starting any construction related activities, by advance planning and involving users.

m). ***Phasing:*** should be considered for refurbishment projects with a longer duration and to minimise the impact of changing prices because it can make refurbishment unsuccessful.

n). ***Hazardous materials:*** in some 20th century facilities, presence of asbestos, PVC, galvanised iron, cast iron are reported as one of the major concerns and a reason for refurbishment.

6.6.4 Existing building envelopes

Internally, it is easier to change/improve heating systems but difficult to make the existing structure airtight. Also, a lack of information related to insulation, envelope, site, etc., and facility managers being not aware about the insulation conditions result in additional challenges. Another issue in existing buildings is air tightness and an unpredictable air leakage rate resulting in cold bridges, even if the buildings are refurbished and maintained regularly. In existing hospitals, floors need to be checked regularly for wear and tear, and windows as well as roofs can be challenging because of their dilapidated conditions.

6.6.5 Refurbishment of modern buildings

Unlike 19th century hospitals, modern facilities are easier to refurbish due to an optimum planning grid. Structural bays in recently constructed buildings can accommodate multi or a single bed ward easily make refurbishment relatively less complicated option compared to buildings from the past century. Interviewee E, a healthcare architect, suggested that buildings from the mid 1990s onwards are better and reliable for refurbishment because of their appearance and the ability to fulfil new standards and building regulations. Another participant reported that a building refurbished in the 1990s was successful because of adequate floor-to-floor height and space.

Refurbishment will be relatively a simpler issue in the future as new buildings are less components oriented and they can support a need to replace windows, alter envelope, or changing layouts due to regulations. For example, a need for triple glazing replacing double pane windows due to developments in regulation in the future will be easier in recently constructed buildings. However, difficult it is to build a future-proof project, design briefs do insist on considering future demands and requirements, especially for healthcare projects.

6.6.6 Refurbishment of buildings from the 1960s-80s

Healthcare facilities built before the 1980s impose particular challenges during refurbishment as discussed further. Concrete cladding used in some NHS buildings is described as “*2000 version of the 1960s buildings*” with a similar look and characteristics. In recent years, a lot of work especially related to improvement of envelope and IEQ happened with hospital buildings built in the 1980s. Single pane windows were replaced by double glazed but still their performance is poor and similar to that of single glazed windows due to the poor envelope; thermal bridging. With many former buildings, their envelope is thermally broken, lack proper insulation, windows have metal frames and aesthetically they are not appealing.

Interviewee E reported some buildings from the 1960s and early 1970s are not worst, at least their structural concrete frames are solid and a new skin can improve their IEQ significantly. This is a straightforward process when compared with the 1980s buildings, which are difficult to refurbish. Investigation revealed that with buildings constructed during the 1960s had some similarities (influence) to Victorian buildings, but buildings from the 1970s-1980s only have “*cheap, thin*” structure.

When asked about refurbishment of existing buildings, Interviewee F said that buildings from the late 1970s are beyond refurbishment, worn out and their life is over as these buildings were not built like Victorian buildings. Also, buildings from the late 1980s were fine and 1990s buildings are appropriate for surface refurbishment, but the buildings from the late 1970s are not suitable at all. If, with the late 1980s buildings doors, mechanical plant is being replaced, then with the late 1970s buildings significant refurbishment is needed because of the inadequate performance of envelope.

Also, in the 1970s, some buildings were constructed for temporary use but even today the NHS is using those buildings due to increasing demands, which are beyond their functional life. It was agreed that Victorian buildings are better than 1970s and 1980s buildings.

6.6.7 Refurbishment of Victorian buildings

When compared buildings from the 1970s and 1980s with Victorian buildings, it was reported that Victorian buildings are aesthetically pleasant but "*the 1980s buildings are shabby*" as reported by Interviewee E. Victorian buildings are at least suitable for administrative use but not for clinical purposes. For example, Interviewee D stated if, the administrative people are provided with the choices of a Victorian building and a building from the 1980s, then most of them would go with the former option. During an interview with a facility manager from one of the NHS trusts reported that it is hard to achieve space standards and quality standards in an existing hospital building. Also, the net usable area is less because of more thermal mass (thick walls and large structural columns). Whereas, due to development in construction technologies in new buildings thermal mass (walls/envelope) is relatively lesser, providing flexible and more usable areas. In some of the older buildings, the available (less or more) floor-to-floor height is difficult to manage. Also, for Victorian buildings to support new requirements, a significant investment is needed, equivalent to a new construction.

6.7 Change in occupancy patterns during refurbishment

This was the fifth question in Section Two of the protocol. At the beginning of the data collection, there was no question relating to impact of refurbishment on occupancy patterns. However, during a pilot study a brief analysis of the first seven responses indicated a need to investigate it. An analysis of data collected from the survey and case studies related to occupancy patterns in existing buildings and during refurbishment are presented below.

A cosmetic refurbishment has no impact on a change in capacity or patient volume, and it is driven by previous function versus proposed function of the refurbished areas. Most refurbishment projects lack re-designing, re-planning and deal with only aesthetics of the buildings, thus there is no change in occupancy pattern. Post-refurbishment facilities have reported quality of indoor environment as a pleasant and welcoming hence increasing number of users. In buildings, depending on the degree of refurbishment, a significant improvement in patients' satisfaction is reported. Improved indoor environment due to refurbishment can help to retain staff, increased productivity, fewer accidents and medical errors. Consequently, with the scope of a project limited to energy and mechanical equipments upgrades, occupancy patterns remain the same. Likewise, exterior refurbishment (such as envelope, landscape, parking) will not change building capacity.

Improved efficiency of staff was reported in refurbished facilities because of bigger, airy, brighter facilities and optimum use of the available spaces. One of the case studies revealed an increase in a number of clinical activities in terms of outpatient and rehabilitation, but no significant change in a number of users. In some projects, the internal space is remodelled to handle more traffic and increased number of users. Also, the geometry of recently constructed modern buildings is different thus overall space for users remain same. Deeper floor plates and more column free space in modern buildings allow flexible and better usage along with improved occupancy, compared to Victorian buildings with narrow floor plate.

Post-refurbishment increase or decrease in occupancy patterns depend on the types of department or area within a refurbished facility. For example, refurbishment to outpatient areas will not improve occupancy pattern, but improving a Nightingale ward can reduce occupancy significantly. Also, Interviewee B reported that "*refurbishment is driven by a change in occupancy and not the other way around*". Some projects with the specific goal of increasing number of beds have reported up to 15 per cent more occupancy post-refurbishment.

6.7.1 Multi-beds to single-bed ward through refurbishment

Refurbishment as part of a code compliance may reduce patient volume because of the stringent regulations related to health and safety, etc. In refurbishment, the most significant factor, which has an impact on occupancy pattern of the existing buildings, is transforming multi-bed wards into single-bed patient rooms to achieve privacy and reduced spread of infection. Thus, a decrease in the number of beds or occupancy is observed in inpatient areas. To comply with regulations, often, facilities have to be rebuilt or remodelled to provide at least a few single-bed rooms responsible for a decreased number of beds. Also, with converting semi-private rooms to private rooms, there can be a reduction in patient occupancy by up to 50 per cent. Some nurses criticised this trend stating a lack of sight and contact with patients, as reported by Interviewee A.

Sometime there is pressure on refurbishment projects because of expected increased intake on completion and a minimum number of beds throughout the refurbishment. If the scope of the work includes expansion, and an objective behind the refurbishment is to increase a number of beds or consultation rooms, then there can be a significant improvement in the capacity of the facility. In some refurbishment projects there might be a significant reduction in patient volume due to demolition of part of the facilities.

The lack of studies relating to occupancy patterns in refurbished hospitals was reported by 70 per cent of the respondents. A lack of and need for official information and formal surveys to study or observe the occupancy pattern in existing hospitals was revealed during the investigation. However, refurbishment should not be judged based on pre and post refurbishment number of beds or occupancy but the quality of space.

6.8 Types of refurbishment projects

Question 2.4 in the protocol investigated types of refurbishment projects observed in the industry. The approach towards refurbishment depends on its purpose and a type of project is driven by characteristics of building. The analysis highlighted the three major themes considering current building stock: modern (21st century); 1960s-1990s (late 20th century); and Victorian (pre-1960s) buildings.

Based on aesthetic of the facilities, it is easy to distinguish 20th century onwards facilities from Victorian facilities. However, facilities from 1960s and 1970s can be divided based on the regulations they followed when they were developed. A significant development in building regulations towards the end of the 20th century differentiated buildings from 1960s-1980s, Victorian and modern buildings. For example, Interviewee F stated, the new *'Part L'* came out in the early 1990s with massive changes and additions, like stringent *'U value'* and glazing requirements, which divided buildings into the above mentioned categories. Below in Figure 6.2

major types of refurbishment projects observed in the industry, as revealed from the data analysis, are presented.

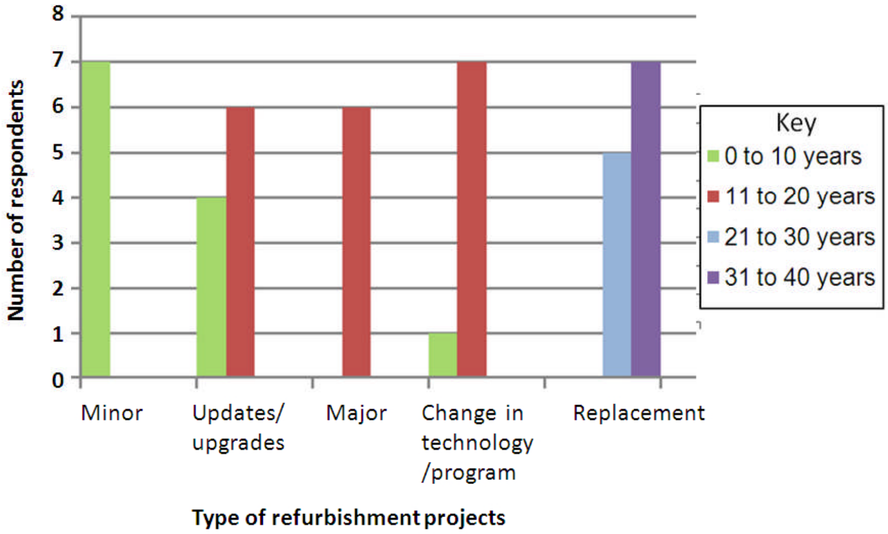

Figure 6.2. Type of projects and their refurbishment cycle in years

Interviewee B reported that refurbishment can be divided on the scale of one to 10. Where one is minor (lighting related work), three being non-structural and 10 is major refurbishment. The later involves structural work and modification to almost the entire facility. Briefly, all refurbishment projects can be categorised into energy, interior re-planning, built environment, mechanical up-gradation, extension and scheduled work. The level of complexity in refurbishment projects increases with the age of the building. During refurbishment new infrastructure, built environment, relocation of services, MEP and equipment up-gradation is often considered. With major refurbishments change of use and improvement to inpatient units, X-ray rooms, and laboratories are considered.

6.8.1 Existing buildings

An aesthetical (decoration) refurbishment occurs more frequently compared to work related to fabrics and building services. However, the degree of refurbishment depends on the type of contract. Major refurbishment projects use design and build, or traditional tendering approach. The advantage with design and build contract is a project team gets an early opportunity to visit the site, but the problem is a lack of information from an architect and designer. With traditional method of refurbishment, an architect or organisation is responsible for a project management and provides most of the project related information.

It is hard to predict the direction in which medical technology is moving. In the future because of advancements in technologies, there might be a lightweight smaller machine and, thus, a need for reduced space, or vice versa. The same problem with building services equipments is also reported, they might get heavier or lighter. In some areas there is a demand for natural ventilation, so regulation related to it in the future will demand replacement of fixed windows by operable ones. Refurbishment can involve insulating an envelope as part of the building updates because of poor envelope (windows), thermal leakage and safety regulations.

Work related to car parks, landscaping, signage, lighting (for technical reasons), and energy are a few possible types of refurbishment in existing facilities. Also, improving poorly lit spaces, the colour temperature and ballast should be considered during refurbishment. Operational issues such as clinical demand for more procedures, and new departments result in shifting of existing facilities, interior re-planning and some changes having a *'knock on effect'* demands a wider scope of work during refurbishment. With some projects, due to the lack of budget for periodical replacement of equipment, energy and mechanical upgrades tend to be cyclical. One of the participants proposed following two scenarios for refurbishment.

Scenario one; the vast majority (75 per cent) of the project is referred as "*gut and remodel*". This kind of a project demands complete demolition of existing space, including finishes, partitions, ceilings, fixtures, caseworks, ductworks, electrical distribution systems, insulations, and so forth. These projects are usually driven by a need to add capacity, change in an operational care model, introduction of new equipment, service line, etc.

Scenario two; remaining refurbishment projects (25 per cent) fall into this category of redecorating or finishes upgrades. The scope of the projects is limited to floor finishes, wall treatment, ceiling, lighting, and furniture/speciality accents. In this kind of projects generally existing mechanical and electrical systems remains intact. Also, partitions and caseworks remain in place but may receive some re-facing.

In both the scenarios, almost all exterior envelopes remain untouched. Also, windows replacement, re-roofing, restoration amongst others and any upgrades related to boilers, and chillers are separate initiatives depending on their replacement schedule. Rarely structural systems are part of any of the above scenarios, but it is very important to improve the same.

6.8.2 Refurbishment types in modern (21st century) buildings

A less than 20-year-old building is easy to refurbish and the typical scope of work would be new finishes, energy saving lightings and better ventilation. All the interviewees reported significant construction of new healthcare facilities in recent years, which will be due for refurbishment in the coming decades. An interview with two experts responsible for a PFI hospital site development reported a strategy in the future for refurbishment is that the structural frame will stay untouched and the skin will be replaced. Often, refurbishment is preferred option for structurally sound buildings, or where infrastructure is capable of supporting new needs. Also, the trend in refurbishment is changing and now-a-day it deals with function, technology, government targets and not only a facelift, which used to happen in the past. Functional planning is re-considered to improve patients' movements and to reduce staff travel time.

One of the participants mentioned that with existing buildings, most scope of work involved 50 per cent re-planning, 30 per cent interior work and MEP up-gradation 20 per cent. Often, a proposed renovation cycle with an interim evaluation for public areas is considered but whole life cost is neglected. Typical scope involves new envelope, MEP and most projects relate to removal of the finishes, partitions, walls, ceiling and flooring.

6.8.3 Refurbishment of 1960s to late 1980s buildings

Refurbishment of buildings in existence for 20-40 years is complicated work, with a need for the improvement of infrastructure along with re-planning of layouts. Two types of approaches are suggested, consideration to improvement in frontline services, and ancillary support functions (usually considered later). In these types of buildings, often focus of the refurbishment is on aesthetic to achieve an improved environment, such as to provide a comfortable, pleasant environment for patients and users. However, if the use of a department has been changed then a level of refurbishment; minor or major, will depend on a degree of changes. In future work related to structural frames of the buildings to support loads of new equipments, cosmetic refurbishment, facelift, replacing carpet, liner, re-paint will be constant, as revealed from the investigation.

In some cases interior re-planning, HVAC, plumbing along with exterior skin/envelope is reported. Depending on the conditions of the buildings and other systems, either technology is upgraded, or replaced. The scope of the work in these buildings is trying to achieve *'Condition B'*, and work is related to floors, walls, lighting, and layouts of the wards. In buildings from the 1970s, many things need to be considered, such as replacing and changing air handling plant, mechanical equipment, fire alarm systems, water supplies, hot water storage, electrical fixtures, replacing boilers with modern specification, including energy efficiency.

6.8.4 Refurbishment typology in Victorian buildings

With more than 40-year-old buildings, replacement of a facility is considered, unless it has heritage value. A few participants noted that listed buildings are being refurbished to be used for administration, clerical purposes and, new buildings are developed for clinical use. Considering the age, dilapidation survey plays a major role while developing a refurbishment proposal for these types of buildings. Most refurbishments are because of new technologies, for example, Victorian buildings that cannot hold MRI machines. Also, the addition and replacement of ageing equipments and periodic updates of interior finishes are reported.

Sometimes during major refurbishment, windows are considered along with roofs and lifts. Some projects involve finishing upgrades (providing sustainable finishes) along with the replacement of lighting fixtures in these buildings. One interviewee stated that the refurbishment of a Victorian hospital involved improvement to corridors, lighting fixtures, flooring, and furnishing. Often work is related to improvements in existing layout to provide assess for physically challenged people.

6.9 Energy consumption and carbon emission in existing facilities

Question 2.7 in the protocol investigated two key factors: energy and carbon and their impact. The responses on energy consumption and carbon emissions in healthcare facilities varied from *"not at all"* to *"these considerations are core of the projects"*. Below Figure 6.3 is based on the responses received as part of the investigation. It was found that around 71 per cent of the participants agreed that considerations to energy and carbon related issues are important.

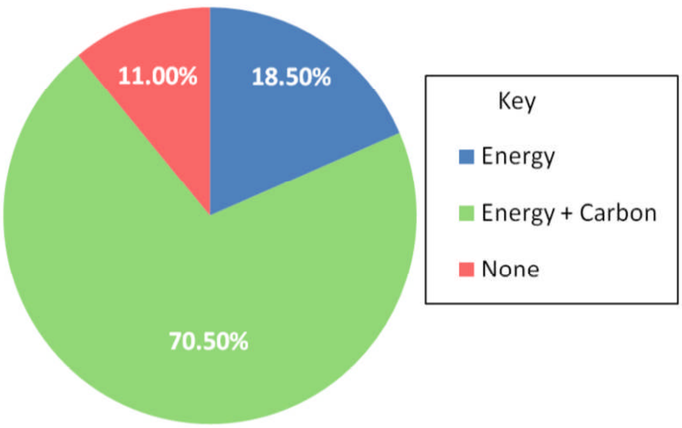

Figure 6.3. Consideration to energy consumption and carbon emissions

Energy consumption is a driver, because many authorities want to reduce their consumption and carbon spending. A survey of 21 hospitals in the USA as reported by one of the participants indicated a need to focus on a healing environment, aesthetic (finishes) and physical plant along with infrastructure to decrease energy usage significantly.

Introduction of natural light has two fold benefits, energy savings and faster recovery for patients, thus lighting levels must be considered during refurbishment. One interviewee mentioned that considerations to energy targets and measures reduce energy consumption and carob emissions on a refurbishment projects were part of NEAT since BREEAM was under development. The participant reported, it was difficult to accomplish targets and certain assumptions were made during modelling using a BIM, like curtains on south and east façade, but in reality, they were not part of the contract thus there was a variation in actual and predicted results.

Most participants reported the considerations of energy consumption and carbon emissions during design stage and refurbishment and stated there is no escape from it. If energy consumption is extensive and mechanical plant is inefficient, then refurbishment costs more. For example (as explained by a participant), during refurbishment of a hospital, client does not wanted to implement Phase II. However, power failures due to the new mechanical systems with a requirement for additional electricity forced them to commence Phase II. Some projects reported because of adoption of sustainable materials minimal efforts would be required in the future during refurbishment.

One interviewee, a project manager, reported energy consumption and carbon emissions are targets for a design team and not for a site team, thus the interviewee is not aware about specific targets but agreed that there are targets. Also, the energy targets set by the government are possible to achieve, but then the DoH needs to explore the current targets, as they are not clearly presented or explained. If, during refurbishment there is a significant change in the area or volume, then energy consumption can reduce or increase extensively. Also, the main guiding factors in construction of healthcare are defined by temperature ranges, relative humidity ranges, air quality and quantity; all have an impact on energy cost and savings.

Many participants reported energy consumption is not a driving factor for refurbishment, but considered in the design process. In existing buildings, consideration of daylight and HVAC system has a significant impact on energy consumption and carbon emissions. It was established that during design stage, energy consumption and environmentally responsible design are key factors, irrespective of a green certification scheme. The designers' goal is to test design decisions against potential environmental impact before arriving at any conclusion. Also, the conclusion should be based on sustainability to meet the users' requirements. The challenges during refurbishment to reduce energy consumption are depend on material reuse, exterior skin performance, natural light, hours of operation, insulation, and occasionally natural ventilation. The driving factors for energy consumption on a project can vary because of:

- a demand for expanded or new services;
- a need for more space as delineated in a detailed functional space program;
- facility upgrades due to regulatory requirements; and
- ageing infrastructures.

To address energy consumption and carbon emissions during primary planning, the carbon footprint and infrastructure should be assessed. During a planning and design stages analysis, energy model and daylight models are of more importance. Considering the fact that hospitals are a major consumer of electricity, it is important and challenging for the designers to maintain quality and function while reducing energy usage. Nevertheless, healthcare facilities are used for long time, thus maximising operational performance is an added advantage.

Sometime, the focus is on reduction of electrical costs, lighting, and air conditioning. One of the respondents noted that low carbon is a marketing tool use to achieve better yield or to attract users, especially in the USA. Refurbishment of existing structures can provide the most carbon, energy and environmental sensitive solutions. Many existing buildings have a poor energy profile, thus overall larger institutional footprint.

Solutions related to refurbishment, energy consumption and carbon emissions for existing facilities are noted as "*more engineering, specification driven versus planning and programming*". Significant technological advances and changes in building regulations result in efficient existing buildings. A refurbishment process re-evaluates the building potential as it relates to optimum performance of the entire structure.

In some refurbishment projects, energy and carbon emissions are considered throughout all the stages of the projects and beyond compliance, but more often, with mechanical upgrades, equipment is improved to achieve minimum energy standards. Design team members consider energy only from costing point of view and carbon emissions is determined on specific demands from the client.

Energy analysis is commonly performed to fulfil the Building Regulations or Standards. If a project team decides to opt for a building certification such as LEED or BREEAM, then either energy consumption or carbon emissions is assessed as per a need of the certification scheme. Compared to smaller (interior) projects, with larger infrastructure projects there are many opportunities to save energy. Sometimes the design team encourages clients to employ an energy manager or use critical energy analysis. Some clients are willing to engage sustainability but without spending money on any certification scheme.

One participant reported, during refurbishment energy consumption is a key priority, but not a cause for renovation. Often, an architect and design team considers energy consumption and carbon emissions against current regulations. However, extra efforts to reduce the emissions are driven by the client. Another respondent mentioned that carbon emissions have not been a factor for decision making while designing but energy consumption is always a factor for the same. Designing for the reduction of carbon emissions is reported as forward thinking, but this will change in due course. In some projects, most elements considered during refurbishment are based on their energy and carbon factors, and the guidelines related to emissions. Also, one respondent mentioned alternative systems are presented to the client with the pros and cons to make an informed selection. However, several respondents reported in existing buildings energy should be considered, but it demands a committed effort, and incentives.

6.10 Tools for refurbishment

The data presented in this section was collected using Question 2.6 of the protocol. The investigation revealed that various tools are adopted throughout refurbishment projects, including construction phase. More often parametric tools are employed for visualisation, energy analysis and improved coordination, and assessment tools to assess a building performance, especially from energy or carbon emissions point of view.

6.10.1 BIM for refurbishment projects

During the investigation, a question about BIM and simulation based tools was posed to the participants. The responses varied from *'adapting slowly'* to *'100 per cent of the projects are using BIM'*. Also, many BIM users are using the maximum strengths of BIM for various simulations, for example, to calculate travel distance. Often, BIM based tools are used for larger and complex projects. Some interviewee reported BIM is a 21st century tool and engaged on all the projects, irrespective of scale. It is reported as diverse and disparate due to capabilities of the team and vested parties. Figure 6.4 shows the applications of BIM based tools for various purposes in the (healthcare) construction industry as revealed during the primary data collection.

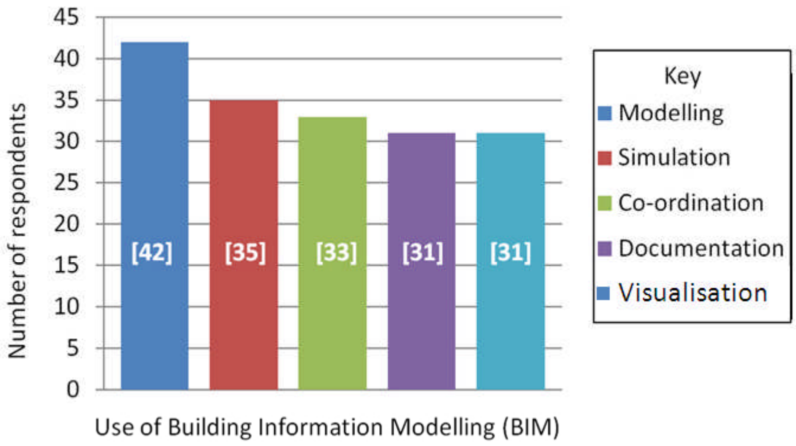

Figure 6.4. Applications of BIM in construction projects

Benefits of BIM

Often, BIM is engaged for documentation and to generate architectural plans on the projects to obtain updated and revised information in one place. Furthermore, models generated using BIM are utilise for managing data created by various consultants and resolving conflicts while overlapping models from various disciplines. BIM being in 3D makes process easier and provides various opportunities discussed earlier. The model is used as a base for energy simulation, performance prediction, etc., and for various other types of studies, including quantity take off, scheduling and phasing. Also, it is capable of generating high quality rendered images for visualisation and presentation purposes for staff, stakeholders and team members, especially from a non-construction background. Some interviewees suggested that BIM being database software, it can be used for benchmarking and various other planning purposes, such as a traffic study, urban planning. BIM and digital survey of existing conditions could improve documentation to identify problems while accommodating new systems.

Considering the characteristics of various BIM based software, they can be used during any stage of the project, including operation and maintenance. BIM can save a significant amount of money and time avoiding a need for physical mock-up by providing virtual mock-up. Also, it supports rapid prototyping required by the industry. A mock-up of the speciality rooms using BIM is reported as a great way to mitigate medical staff dissatisfaction. Also, it can work on several options and perform comparative studies between them. Furthermore, the tool can be used to present and study the proposed concept. In larger facilities with a lot of equipment, the BIM based tools assist with planning to ensure effective integration of medical equipment. In addition to above benefits, the tool can produce walkthroughs.

Some firms have progressed to such an extent that they use laser scanning to generate BI-model and rendition of the existing building model if a client agrees. In the later stage of the project, the model is used to develop a brief and justify the requirements along with studies related to patient flow. These kinds of studies help to understand the staff ratio and travel distance for nurses and other staff within the facility.

BIM is a process capable of assessing building envelope and performance, and makes a decision related to the same. Some firms have adopted BIM for master planning and for feasibility studies. Survey respondent A26 mentioned, *"we are using Revit quite a lot, but not entire BIM stuff"*. Often, designers produce BIM and shares with engineers, such as Mechanical & Electrical (M&E) consultant to generate energy model. Another participant reported use of a BIM for the project in North Hertfordshire to generate 3D drawings, electrical layouts, installation drawings, which helped to achieve high tech specification. Also, use of ADB with BIM based Revit software was reported for the work related to a patient room and scheduling. A BIM based Naviswork software package can present construction 3D model to a client. Interviewee B said he is "*a big believer in this (BIM) process*" because it helps to work on multiple options and provides all the factorial information at one place. In addition it offers great collaboration because information is generated mostly from one source and can be used for measurements, renderings and animation.

It has been suggested that BIM based parametric modelling tools are suitable for existing buildings with few or limited records. Also, fully coordinated model defines success of a project. Application of IES (energy simulation package) and 3D Studio Max for visualisation was reported during a development of the new hospital, and is suggested to be used with existing buildings. It was mentioned that for the planning of activities related to construction 3D approach is an easy and straight forward option.

Though engineers perform tasks related to energy modelling and simulation, a lack of energy simulation studies by design team was reported and a need for the same was mentioned for existing buildings. Also, when asked, a facility manager revealed that thermal imaging were used for a new building and at few places for an existing facility during refurbishment to resolve technical issues, such as to identify various cold spots and reasons for these.

Challenges and limitation of BIM

Sometimes tools are employed depending on the client requirements. However, they (BIM based tools) are very effective if, engaged from the beginning of the project (also confirmed by Harputlugil *et al.*, 2006) and the entire team uses tools with similar characteristic or BIM compatible tools. The development and implementation of BIM was found to be an emerging topic and requires attention because industry as a whole is not entirely on board with these technologies. Many suppliers, contractors, consultants, including some of the architectural design firms are behind compared to other construction management organisations that have adopted BIM.

Some interviewees reported that BIM and simulation based tools are not widespread because of their slow working nature, and they need more time to be at the core of the construction industry. In some of the offices, BIM is being adopted very slowly and simulation is used when operational practices are inefficient. Sometime, the clients and all other members ignore BIM because these kinds of tools demand advanced planning and early decisions related to a project. BIM based tools are capable of highlighting design disputes between different disciplines. However, because of the project management challenges this is not commonly used. M&E services design is very easy and straightforward, but energy modelling of existing building was reported as a difficult task. Also, it will take more research by the industry to come up with the right factors for a model, to understand types of buildings, and construction using BIM, especially existing buildings. Interviewee C mentioned that during redevelopment of a massive healthcare campus they used BIM and simulation for a new project. However, the same approach was effectively not considered during refurbishment due to lack of information and thinking it might not be suitable with existing facilities. This clearly shows a lack of awareness about implication of modern tools in construction industry, which needs to increase.

6.10.2 BREEAM and LEED for refurbishment

Certain targets imposed by BREEAM are reported for work related to existing buildings. During the investigation, it was found that it is easy to achieve BREEAM rating with new buildings. Also, with *'outstanding'* rating under BREEAM, a building performance needs to be maintained to preserve the rating and accreditation. Most respondents mentioned that BIM is a very useful to achieve (green) certification, such as BREEAM, LEED, and GreenStar.

However, some clients do not wish to go for LEED or BREEAM because they think it will increase the project cost, but architects, and designers convince the client to adopt the same. It is suggested that the LEED and BREEAM guidelines are very effective but their focus is on complete buildings hence it is difficult to apply a standard approach to a refurbishment/renovation project, especially for healthcare facilities. The lack of certification schemes for existing buildings is reported (see Figure 6.5). Also, most existing schemes need to be developed further to be used for existing buildings.

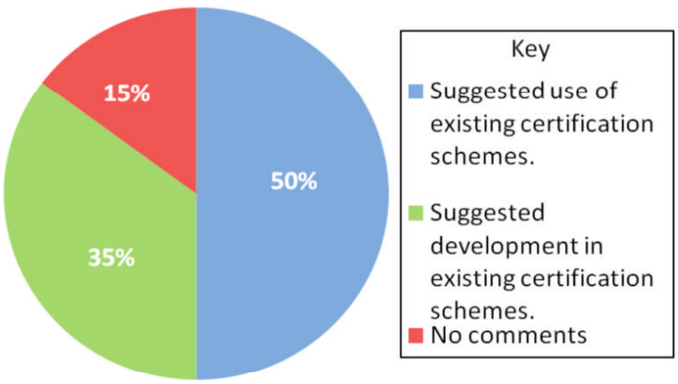

Figure 6.5. Application of green certification schemes for existing buildings

To achieve a good rating as per BREEAM assessment, it is necessary that the entire team is committed to the assessment from the beginning. However, the investigation suggested that a good rating does not mean the building is *'good'.* One interviewee cited, a building which achieved BREEAM *'good'* is a single storey building and partly new, despite significant refurbishment, demolition, and new construction; there was no drastic reduction in the gas and electricity bills. The interviewee stated that post-refurbishment the facility was also reduced by three wards, which clearly shows shortcomings in the existing approaches. Moreover, the majority of the users were not happy with the performance of the facility during winter as well as summer time.

6.10.3 HTM, HBN, and guidance notes

The investigation (through interviews and a questionnaire survey) revealed inadequate standards for existing facilities, and some agreements and disagreements about current standards, especially with consideration to characteristics of existing healthcare facilities. Three participants mentioned, HTNs and HBNs are updated, whereas four reported they are behind the time. One of the participants reported a lack of HTNs and unclear targets for a refurbishment project and it involves lots of detraction (shows disagreement). With some projects (as reported by two participants), it has been found that HTMs and HBNs are used without any interrogation shows agreement. Also, HTMs and HBNs are extremely applicable during refurbishment mentioned by a participant, and it is difficult to fulfil some of the guidance in existing facilities.

One participant stated that *"the design team must have used AEDET, ASPECT but I am not sure, because these tools are not mandatory, and it is the design team's responsibility to use them"*. Another interviewee reported difficulties in achieving 2800 mm floor-to-ceiling height required as per HBNs and HTNs in existing buildings. A survey respondent, A22 mentioned, in recent years, there have been a development of different regulations for new build and existing buildings, such as *'Part L 2B'* and new fire regulations.

Often, during construction and refurbishment *'Part L'*, HBN, AEDET, ASPECT, etc., are commonly referred to avoid any legal issues and not because they are mandatory. Most of the current tools in the market are not developed for healthcare and need to be re-considered from a patient and staff point of view. The list below presents commonly found healthcare related guidance notes as revealed from the data collection.

- HTMs
- HBNs
- British Standards
- Environment Agency
- Planning and Building Regulations
- Construction Design and Management (CDM) Regulations
- Counter Terrorism Advisor
- Radiation Protection Advisor
- Infection Control
- Fire Officers
- Security Officers

One participant reported that with refurbishment projects, there is an understanding between client and regulation authorities, and sometimes architects try to employ the best possible solution(s) because regulations are not achievable in existing buildings. Interviewee D stated, there is a difficulty in achieving the targets in existing buildings. It is balanced by achieving few standards in excess and few below a required limit; this is how refurbishment projects work. The investigation revealed that there is a lack of energy performance mandates for hospitals, and strict regulations related to air quality and energy related codes. Also, instead of refurbishment, maintenance work is considered because this type of the work does not require satisfying most regulations. However, the investigation revealed that a few guidance notes and limited targets are imposed by NHS or DoH on refurbishment projects.

6.11 Clients' involvement and role during refurbishment projects

All the participants were asked to provide information about client involvements and their role on refurbishment projects. It was reported that client's are involved throughout the process, which increases complexities with the projects. Their focus is on internal healthcare planning, space per building user, and they offer inadequate consideration to facility management or security. Also, because healthcare projects are complex, there are several participants during every stage, such as a facility manager, group of nurses, finance director, IT consultants and others.

The investigation revealed that the client is a key means to promote building performance and sustainability assessment methodology in any project. Client involvement is required on a project to make any decision related to programme and cost issues, but very few clients provide guidance notes. The client plays an important role during the preliminary design review, a complete documentation review, and inspection upon completion. The key role of the client is to sign off the design and to help establish goals during the initial stages of the projects. It was found that some of the larger institutes do have their own guidance notes and they adopt or aim for LEED or equivalent certification.

In healthcare facilities, often it is hard to achieve innovation with agencies, as they are slow to embrace new ideas and concepts. In the UK, the DoH requirements related to planning, design and building are very specific and detailed. It is reported that clients/stakeholders guide the process and government regulations control the process, though there are limited regulations related to refurbishment (except energy targets). Nevertheless, execution team, clinicians and department chiefs are always involved in the process. Guidelines and manuals for designing a hospital are used extensively in the planning and building processes. Also, clients are willing to opt for a certification scheme, such as LEED, BREEAM, but without spending money on them.

6.12 Opinion about current refurbishment projects

This was the third section in the protocol. The interviews and questionnaire survey asked all the participants to provide information about how healthcare refurbishment projects are completed and to provide any additional information.

The participants reported a lack of good policies for refurbishment, and it is difficult and expensive to upgrade and renovate out-of-compliance space without any defined approach. When enquired about strategies for 21st century facilities, it was reported that modern buildings are designed to support refurbishment and expansion in the future. However, some existing buildings were not designed to support expansion or cannot fulfil future demand.

The key players during refurbishments are MEP and structural consultants, but there is a lack of guidance on how and when they should be involved on a project. For example, one interviewee reported the following challenges during a recent work of transforming a ward in to an outpatient department in 23-week times. During designing stage, engineers were not involved, and later this resulted in several changes, such as adding supporting (structural) walls for a two-storey building thus redesigning layouts. However, the interviewee believed if, engineers had been involved from the beginning then a number of revisions would have been reduced significantly. Consequently, the entire proposal and design could have been different and more effective. The proposal involved more disruption to the existing facility, such as changing/adding walls to support the ward above, more re-work. The approach would have been different with early involvement of consultants, for example, to develop services around facilities to suit the existing space (thus least disturbance to internal spaces) and not the other way around.

It is difficult to predict the direction in which sustainability and current regulations are moving, but the industry is trying to go beyond the existing standards, which will benefit in the future. The investigation revealed that changing regulations, such as *'Part L'* is getting stricter, and hospital designers are trying to achieve the current regulation in excess minimum by a five per cent to make it easier in the future. A significant development in building regulations from the late 20th century onwards is reported and buildings built before the 1980s are significantly ineffective when assessed against those (new) regulations.

Various characteristics of refurbishment projects were reported by the participants, which are not mentioned earlier and not key to this research project, but can be useful for future research (see Chapter Eight). For example, one of the interviewees suggested lean construction for refurbishment because it is promising and can improve construction. A lack of communication between design, maintenance and construction team was also found. Refurbishment is controlled by three major factors: budget, conditions of the system, and clients' objectives.

It was reported that there are going to be more targets pass down by the government on to the public sector, including healthcare because of its characteristics. One respondent mentioned, "*many current legislations are focusing on carbon emissions issues, which is only a part of the story*" and certainly in the future, there are going to be more issues and not only carbon emissions. There will be issues related to reuse of buildings, reuse of material, is building adaptable, whole life-cycle value, etc. A lack of life-cycle cost approach and scrutiny of money being spent on healthcare tend to emphasise first cost. Also, the design team does not control the value engineering process. One interviewee mentioned "*if we put a bit more money on finishes of the building, it is going to last longer*" (and take a more environmental robust approach), but government needs to promote this effectively.

A need for strategic plans (rather than *"picking-up"* an existing plan) to consider the bigger picture, long-term vision, and a master plan which will save money over the period of time were reported. Utilisation of an integrated design process from the beginning is important, for example, considerations to automated building systems, which can monitor energy usage in a refurbished building. Most of the efforts are to maintain a clean environment within the hospitals and many of the proposals for offices cannot work for healthcare facilities. Incentives should be given to the trusts for saving energy in hospitals. Often refurbishment of healthcare facilities is reported as a lengthy process. For example, in the past, design review process used to last for a year involving many people and experts, but now it is getting organised, and it needs to be reduced further to make it simpler because most of the time client allocates a group of people to the process. Operational (functional) programming and analysis should occur prior to physical plant design. Over the period of time, energy and carbon issues will be in the priority list for concern. However, energy is not the only issue, these facilities are huge consumers of water and generate waste and though some progresses have been made in regards to this, it is not a significant development.

Policies and incentives that encourage better building fabric are lacking. The need for educating a client is reported, as issues related to energy consumption, carbon emissions, GHG are driven by the client and stakeholders. In some projects, usually the cost and effort for the refurbishment are underestimated. Also, before setting up the budget and scope of the work, the client needs to perform a brief review of existing conditions. An informed client with knowledge of sustainable buildings practices, who is willing to accept the guidance of Architectural/Engineering/Construction (AEC) professional advisors, is very important.

Moreover, incomplete information is a problem in existing buildings. It was explained that during one of the refurbishment projects, the estimated cost escalated from £100 million to £161 million because of surprises during the refurbishment. Like new construction, even in refurbishment project pre-planning is very important to achieve a successful project.

6.12.1 Post Project Evaluation

From the investigation (questionnaire survey and interviews), it was found that there is a limited consideration of post-project evaluation. Hence, Post-Project Evaluation (PPE) in existing buildings is explored.

It was found that many projects are not conducting any post-project evaluation although sometimes it is required, for example, as per Procure21[+]. It was reported that if the same team is involved throughout the designing and execution of the project, then it is easy to consider post-project evaluation. The PPE is important, but often healthcare organisations are scared to perform it because of the expected results, and they do not want to give away too much in terms of operational standards. Nevertheless, it is important from a patient or user perspective because it is a justification of the expenditure.

When asked Interviewee E, site manager, if PPE is performed, it was reported that nothing is planned but will be interested to see energy use and to know if, the performance has improved. Also, one participant explained that as a site manager it is easy to compare gas and electricity bills, but difficult to get any details or breakdown of their energy use. PPE and knowing details about energy consumption will help to understand any loss of energy and opportunities to save energy.

Interviewee E, site manager, reported that when the project is completed "*we move on to the next project and only as part of the retention period, our respective* *team visits the building in first 12 months, if there is any problem or complaint from client side*". Also, because there is a different department who look after project completion, it is difficult for an execution team or design team to conduct any PPE. There is an interest in pre and post project evaluation to see the performance and value, but often in the industry the site team move on to another, next project on completion.

6.13 Comments and suggestions

It was established that there are several possibilities with existing buildings, but due to challenges associated with them and restricted access to facilities, limited consideration is given to those possibilities. There is a clear relation between hospital environment and office buildings, hospitality industry, etc., and it needs to be explored further to achieve better IEQ in healthcare facilities. Working environment for nurses in existing hospital is considered as a secondary function and in most existing facilities nurses' stations are placed away from wards and natural light, which needs to improve. Also, administration facilities in the hospitals are often located in a clinical space and should be designed to fit for the purpose. While considering flexibility in healthcare facilities it should not be related only to clinical areas, but also the administrative areas.

In hospitals, considering several areas occupied by different age groups, heating control should be given to individuals instead of centrally controlled; there is a possibility that this will save energy and provide improved IEQ. In a recently constructed award winning healthcare facility, the huge glass facade in the front elevation was criticised by the users. It was explained that thermal imaging indicates a large glass façade from a floor-to-ceiling with metal frames creates cold spots in the lobby. The participant stated the glass area should have been reduced and of a different material. The interviewee reported "*the building looks fantastic in a picture, but lacks performance in reality*". All the interviews' participants agreed that there should be energy simulations and solar gain studies of every proposal. In a modern building, lighting with motion sensors was criticised by Interviewee B stating "*there is no distinction between day and night, and lights stay on"*.

It was suggested that refurbishment projects should be completed within a limited period because of changing medical technologies. A five-year refurbishment project will be less effective because there will be new technologies in the same time, and amendments with an ongoing project are expensive resulting in delayed project delivery. Also, small scale refurbishment projects are more effective compared to large scale.

Flexibility and sustainability are two key considerations for 21st century hospitals. All the participants reported (since formation of the NHS in the 1948), there has been more construction of hospitals in the last two decades due to formation of PFI and LIFT in early 1990s. It was suggested that consideration to cooling by passive methods and by exploring few energy saving features for example, energy saving lights, could minimise energy consumption. Also, providing passages on the periphery are a good option as they reduce solar gains and can be very helpful during expansion and refurbishment in the future. A brief overview of the refurbishment process suggested by one respondent is as mentioned below:

- a need to pre-plan all activities and compare with master plan and analysis of a total cost versus a first cost modelling;
- BIM should be adopted throughout the process, first as a planning and designing tool, second as a construction tool and then into a building maintenance model. This is a smart tool and will save lots of paper work, which goes into a project;
- no project should proceed without an energy analysis and daylight simulation;
- LEED is not important, but there is a need to have a standard process and a tool to drive energy saving;
- continue use of BIM will fine tune and refine BIM; and
- to integrate various energy, and daylight modelling programmes and BIM into a common easy to use package.

Some experts reported that LEED, BREEAM, etc., need to develop further, so they are using in-house tools. There is a need to incorporate following points, while implementing any tool:

- reliance on making a business case for strategy adoption rather than social responsibility;
- mandatory targets;

- educating a client;
- early involvement of engineers;
- integration of team members; and
- contractors' responsibilities.

The specific need for a tool for architectural, engineering and interior designer along with the client was reported. In refurbishment projects, every facility is unique and should be considered with additional needs, factors, etc. It was delimitated that hospitals are extremely difficult to plan because of the significant multiple overlaid requirements that often conflict with each other, and adding another required set of constraints further hamstrings the planner. For example, with a project in Canada, a number of windows were required to allow daylight into the hospital. Also, few departments needed several rooms with no windows (private exam rooms) and on the periphery for better circulation; however, the regulations prevented other rooms from being on the perimeter of the building. This resulted in poor designs as reported by the participant from questionnaire survey.

6.14 Comparison of USA and UK participants

As the data were collected from the participants based in the UK and USA, a comparative study was performed to understand the key difference between them. The major differences are explained ahead. In the UK, the central government provides the healthcare service at the cost of taxpayers' money, whereas in USA, most healthcare organisations are not-for-profit.

The data from the UK was used to explore the problems and the information gathered from the USA was used to identify possible solutions for refurbishment and existing healthcare facilities. Initial investigation including the review of literature revealed that in the USA there is already an increase in a number of refurbishment projects and some efforts have been made to improve overall construction process for e.g. development of NBIMS.

In the USA, it was established that during refurbishment even with the charitable trust they need to keep a minimum intake and, post-refurbishment they expect increased intake. Also, there are many local standards and regulations imposed by the state governments in addition to central government targets. However, in the UK most standards are from national government and very few county levels. In the USA, a green building assessment tool, LEED, is noted and widely accepted, comparable to BREEAM in the UK.

The major difference between the UK and USA healthcare sector is a competition among healthcare facilities, as explained ahead. In the UK, the government through DoH controls the healthcare sector thus, there is a limited competition. However, in the USA, within same region/locality there are multiple healthcare facilities (owned by state, private organisation, etc) resulting in competition and, thus, improved healthcare facilities to attract more patients.

A few participants from the USA stated hospitals, as a rule, are exempted from any energy saving standards. One participant stated, "*this makes sense because they provide life saving intervention that should not be compromised by energy use considerations*". In the USA, many experts challenged LEED but there is a lack of arguments in the UK against BREEAM. Few participants from the USA stated energy consumption and carbon emissions as a relatively new concerns and first cost, operational cost, and life-cycle cost are more important.

During the investigation it was found that there are no Victorian buildings in the USA unlike UK. However, there are considerable number of existing facilities, thus participants from the USA could provide information on refurbishment. Also, more than 50 per cent of the participants from the USA have worked in the UK, thus their responses were found to be very useful in this research. So the major difference between the participants from the UK and USA was, former provided data on traditional practices, whereas, later provided information about modern solutions, such as BIM, energy simulation.

Evidence-based Design (EBD) is found to be wide spread in the USA compared to the UK. It is explained as "*mainly using experience and implementing best practices into the planning and design of healthcare*". Another major difference is adoption of BIM in the process of designing healthcare facilities. The USA is ahead in terms of adopting BIM and simulation based tools within the process. However, application of BIM and simulation tools is limited in both countries for refurbishment of existing healthcare facilities.

6.15 Chapter summary

The investigation, including literature review related to refurbishment cycle of the facilities revealed several reasons for refurbishment to take place, but it is difficult to propose a single solution or trend to be used. Often, the scale of the healthcare refurbishment is bigger compared to refurbishment of buildings from other sectors, which imposes more challenges. It was observed that in existing facilities less importance is given to PPE, and formal comparison between two refurbishment projects, or between pre and post refurbishment project is lacking. However, PPE can help to improve and speed up the refurbishment process in the future and to validate the refurbishment proposals.

It can be summarised that the research in the area of refurbishment of existing healthcare facilities has been neglected. There is a need to develop approaches to improve their performance. Significant energy savings are easily achievable with more sophisticated planning and mechanical systems by reducing air volumes and using appropriate energy features. Several tools and approaches exist in the construction industry, but many need to be developed further to suit existing facilities. The trend in renovation of existing hospitals indicates that often, aesthetical (redecoration) refurbishments are performed more frequently compared to fabric or building services related work. Also, projects lack approaches related to re-designing and re-planning during refurbishment, resulting in no significant improvement in building performance through refurbishment. The investigation revealed a lack of a framework or a draft process to be used for the application of BIM on refurbishment projects, and for existing buildings. In this chapter, it can be de stated that there is a limited focus on existing facilities, which needs to be improved. Based on the data presented in this and previous chapters (Chapters Two, Three and Four), the next chapter presents a framework for refurbishment.

CHAPTER SEVEN. DEVELOPMENT AND VALIDATION OF THE FRAMEWORK

7.1 Introduction

The research findings highlighted the need for a number of advances, such as improved refurbishment processes and integration of tools to assess a facility's performance to satisfy government targets and users' expectation. This research was focused partially on identification of energy efficient aspects (providing maximum benefits to enhance the overall building performance) rather than assessing energy, which is often a focus of several current tools.

It is difficult to identify the most sustainable materials or processes for refurbishment and construction projects. Even computer programs and experts cannot give a definitive answer. The HEaR framework proposed in this research project is designed to complement current practices and achieve successful refurbishment. The framework stimulates a new way of approaching refurbishment projects as explained ahead.

This chapter provides the background for the framework, followed by the purpose, and a decision-making process showing the steps involved with refurbishment. The chapter then continues with the key features of the framework, the complexity level, the core of the framework, and elements (components). Also, benefits of the framework and implementation strategy for the proposed framework are presented. It ends with the validation of the framework and summary. The framework developed using MS Excel and user manual in MS word used for validation is presented in Appendices I and J respectively.

7.2 Background to the framework

The extant literature revealed multi-definitions of the term *'framework'*. Two common definitions provided by Fayad *et al.* (1999) are adopted in this research helped to outline the requirement for HEaR. The first is "*a reusable design of all or part of a system that is represented by a set of abstract classes and the way their instances interact*" and the second is "*the skeleton of an application that can be* *customised by an application developed*". The former definition outlines the structure and the later describes the purpose of a framework. The development and application of frameworks is becoming popular and often adopted by governments, organisations and researchers. In the construction sector, frameworks are principally implemented to reduce cost and time, to improve quality, to achieve sustainability, for resources management and so on.

The investigation of refurbishment practices discussed in the previous chapters indicated a variety of considerations and a range of current approaches in the healthcare sector. Refurbishment is understood as an approach to improve (or restore) existing facilities by the industry. Greater consideration of existing facilities during refurbishment, such as providing healing environment, user satisfaction, minimising impact on the environment, extended life of facilities, offer significant benefits. However, a lack of implementation of such ideas during refurbishment and uncertainty of who should do so has brought difficulties and created a complicated process. Effective guidance during the refurbishment can help teams think beyond financial performance and to focus on environmental performance.

An integrated framework for the refurbishment processes can help with these problems. A framework will help to build a refurbishment database and develop a strategy for any risk and problem that could cause difficulty in existing buildings or refurbishments, so is also applicable to future refurbishment projects.

The difficulties and challenges in implementing available practices and processes during refurbishment have been addressed by developing HEaR. The condition of existing healthcare buildings is uncertain and varied, thus the HEaR framework is proposed to allow flexibility in the process. It was clearly understood that there is a need for a structured approach to develop and implement a refurbishment proposal. Nevertheless, existing healthcare facilities have a larger impact than new buildings on the environment, which needs to be reduced, as discussed previously.

7.2.1 The needs and requirements of a refurbishment framework

The primary and secondary investigation revealed a need for approaches towards refurbishment and existing buildings. From the early phases of this research, it was clear that there has been a limited focus on existing buildings and refurbishment. Also, most research in the past has focussed on financial aspects of refurbishment or performance of existing buildings from an economic point of view. The case studies revealed that in the past the government was focused on the development of new facilities, but now it is shifting towards existing facilities, highlighted the need for this study. These, other (below mentioned) issues and various challenges discussed throughout this thesis, all justify the need for HEaR.

It was found that many post-refurbishment problems have their origin in pre-refurbishment and/or from the early phases of planning. Sophisticated planning during refurbishment can rectify errors from the past to reduce any future errors and impact, but there are several reasons, which contribute towards these problems as discussed earlier. In this chapter, the research attempts to address various issues discussed previously by proposing a new approach towards refurbishment; HEaR framework.

Work related to existing buildings can be classified in to two categories; refurbishment and expansion or a combination of both. Expansion/extension can be treated as a new construction, whereas refurbishment deals entirely with existing buildings. Although approaches for modern buildings can be adopted during refurbishment, there is a major difference between new and existing buildings, as explained further.

With new buildings, a top-down approach is adopted where design and development starts with overall form, and the main structure is followed by envelope, infill, etc. However, in most existing buildings individual elements receive initial refurbishments treatment leading towards a whole building, thus is more of a bottom-up approach. Also, the impact of refurbishment can be either vertical or horizontal and a combination of both. For example, with vertical impact, there is no adjacent part of a building affected by refurbishment but there may be upper or lower floors, which need to be considered. However, horizontal impact can significantly disrupt adjacent or surrounding functions. Nevertheless, there is a possibility where a core of the facility is being refurbished and there will be horizontal as well as vertical impact.

A need for improved pre-refurbishment planning that describes the activities related to it, supplemented with tools that measure progress and monitor improvement is required. This justifies the need to assess complexity associated with refurbishment and existing buildings. Baccarini (1996, p. 201) defined complexity on a construction project as *"consisting of many varied interrelated parts and can be operationalised in terms of differentiation and interdependency"*.

As revealed from the investigation, current practices for refurbishments or energy enhancement in existing buildings rely significantly on traditional methods, which involve more manual work. There is a lack of adequate, integrated, standardised approach in performing refurbishment and analysing modelling and energy performance of a building to satisfy the various targets and regulations. This proposal, therefore, presents such an alternative, where a systematic approach with an emphasis on energy efficiency and overall refurbishment is provided.

7.2.2 Objectives for the framework

The framework provides guidance, including a theoretical computational process to be followed during refurbishments to achieve possible energy savings and select a design option. Adoption of this framework will help to ensure consistency in maintenance and facility records. However, healthcare premises hold various buildings with different specifications, so integration of BIM and simulation tools can help here. The ultimate goal of the refurbishment process (in HEaR) is to determine the highest level of possible refurbishment solution and to fulfil the following recommendations by the DoH for NHS trusts (Boswell, 2008).

- Long-term strategic planning.
- Invest in quality generic healthcare estate.
- Master planning of the estate.
- Maximise the potential to expand and contract buildings.
- Zoning of activities and buildings.
- Creating clear and unobstructed communication routes.
- Design shape and form to maximise change over the time.
- Space used as a resource and not as territory.

Importantly, lower energy consumption should not be achieved at the cost of user comfort, especially patient.

To ensure the refurbishment process created in this research for development of existing facilities serves the user well, it should be comprehensive, flexible, easy-to-use, compatible and affordable. These attributes are elaborated upon in Figure 7.1. The attributes are based on a review of several other frameworks and tools (such as Davis, 2009, Burstein *et al.*, 2008) to understand the features of a good framework.

Comprehensive	Flexible	Easy-to-use	Compatible	Affordable
• Clear structure • Descriptive • Accurate output	• Adaptable to new or in exceptional situation • Can be followed for the duration of the life-cycle	• Customisable according to the needs of the users • User friendliness & reliability	• Compatible with other framework and process • Produces consistent results	• Consideration to project cost • Helps to reduce or save cost

Figure 7.1. The features of a good framework
(Based on Davis, 2009, Burstein et al., 2008)

During refurbishment, there is an opportunity to consider concepts related to new facilities, such as decentralised hospitals, multi-centre hospitals, nuclear hospitals, HPH and EBD. Therefore, components of the framework aim to combine different building systems and approaches in an integrated manner (in which existing codes and standards can accordingly be applied in order to renovate, refurbish, or retrofit an existing healthcare facility to achieve enhanced performance). Early in the process, every owner needs some guidance to develop an outline refurbishment proposal, so the HEaR framework supplies this. Also, it is important to achieve successful refurbishment to improve existing buildings and save energy because this tends to improve patient comfort and staff productivity, and consequently reduces cost.

A fundamental challenge was to propose a new design process that is in one or more ways superior to existing practices. It is important to note that the industry and healthcare sector is primarily interested in reducing challenges, operational cost and overall time associated with the implementation of refurbishment proposals and existing buildings. The components of HEaR are developed with consideration to the above requirement. Ahead, Figure 7.8 illustrates the interface of each object, the overall decision-making process, and relation with the other components.

7.3 Framework development process

The proposed integrated framework distinguishes between the two key areas of refurbishment processes; first, it identifies the associated degree of complexity and second, assists with development of a refurbishment proposal and reduces the complexity. The partial aim of this research was to provide assistance to end-users, who lack construction knowledge. Several standalone components that exist in the industry are also bounded together through this process. The development of HEaR encompasses various research processes. Firstly, the data were collected from literature and experts with knowledge of developing or implementing refurbishment proposals, especially within the healthcare sector. Therefore, the dataset included parameters such as development, implementation and/or managing the execution of a refurbishment proposal. Secondly, an analysis of the scenarios involved in refurbishment was conducted, which helped to develop a few components, such as guidance on the pre-project survey, types of project inputs required, and refurbishment scale. The framework can also identify existing facility's capability during refurbishment.

The proposed processes consist of phases and sub-phases known as stages (see Figure 7.9) that are performed to complete the activities associated with them. The process describes the working of the framework and is supplemented with the tools. The phases guide the refurbishment process, and assist in making decisions that are taken along through the review of purposes as part of the phases.

Importantly both quantitative and qualitative aspects underpinned the framework. The quantitative aspect is the complexity level, which quantifies challenges and risks associated with the project. Whereas, later, based on the complexity level, tools and support systems are proposed to use during various stages and refurbishment phases (a qualitative aspect).

The data collection and analysis exercise described in Chapter Five supported the formation of a solution for the problem. This arrangement was initiated based on the data presented in Chapter Six. To achieve this aim, the researcher designed a structured analysis of a refurbishment implementation process as highlighted through the conceptual framework in Figure 7.2, Sheth *et al.* (2010b) and Sheth *et al.* (2010c).

7.3.1 Methodology

The initial stages of development in the process involved a continuous review of academic and industrial material, including government reports with the focus on the refurbishment process and consideration to existing buildings. Semi-structured interviews and a qualitative survey were conducted, to: reveal current practices from the industry; make the framework relevant to implementation; use by the construction industry; and improve refurbishment practices. Apart from gaining data on current practices about refurbishment and existing buildings, the approach helped to investigate the gap in the development of new facilities and refurbishment of existing facilities.

A conceptual framework shown in Figure 7.2, Sheth *et al.* (2010b) and Sheth *et al.* (2010c) outlined possible courses of actions to present a preferred approach and an idea.

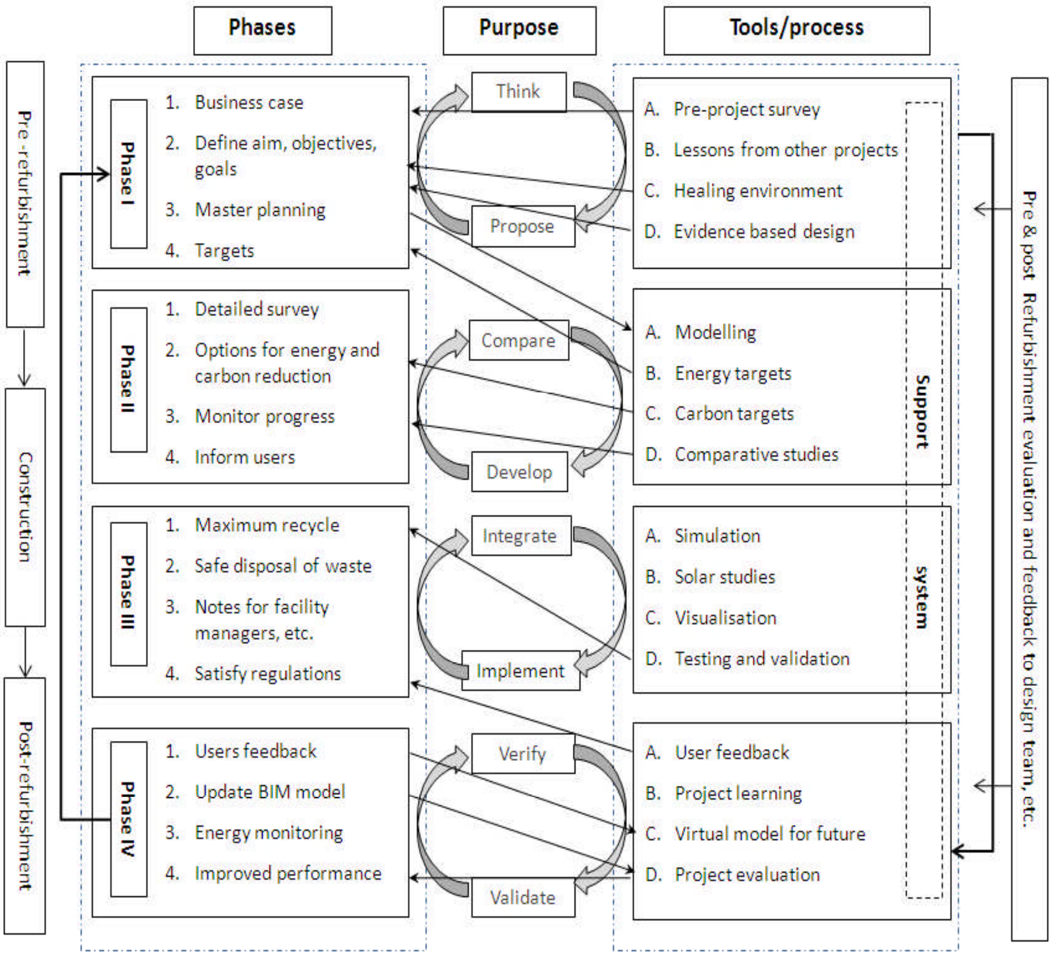

Figure 7.2. Conceptual framework for refurbishment

The phases and stages as part of the framework contribute towards refurbishment progress and success in a structured manner. The proposed process is developed to help an organisation to structure and organise refurbishment, and to provide guidance required for sophisticated refurbishment practices. It is also intended to be used as a tool to benchmark complexity levels associated with refurbishment of existing healthcare facilities.

The conceptual framework was divided into three columns; phases, purposes, and tools/processes. The left column helps to define the phase and stage of a project, the middle column (Purpose) denotes the purpose of the phase and the right column (Tools/Process) shows objectives of that specific stage and purpose. To understand the relation between the three columns, refer to Figure 7.2. For example, during *'Phase II'* of a project, at stage 2 *'options for energy and carbon emission'* the *'Purpose'* of that stage will be to *'compare'* the project status and *'develop'* the proposal with the help of *'Tools/Process'* such as energy and carbon related targets which is a *'support system'* for entire project.

The arrows indicated between *'Phases'* and *'Processes'* show the relation between them and tools to be employed during those phases. For example, the arrow between business case and pre-project survey indicates a need to conduct a facility survey before developing a business case. Moreover, the survey will provide various inputs for the business case to make it more exclusive which will ensure the success of refurbishment projects. Ahead the connections between the phases and processes are developed further. A brief list of activities and tools is presented which is developed further during the process to make it more exhaustive. Ahead, a matrix is presented which linked support systems and tools with the phases and stages.

To divide refurbishment into phases, the existing RIBA phases were studied (see Figure 7.3). These are divided into five parts (Preparation, Design, Pre-construction, Construction, and Use). Whereas, in this research, four phases (Pre-proposal, Proposal, Proposal execution, and Post-proposal execution) are proposed. With every phase there is a purpose, for example, the purpose of Phase-I is to think and propose, as explained ahead. The RIBA Phase V, '*Use*' is not considered for refurbishment because in most cases the building under refurbishment is already operational. In Figure 7.3, the purposes behind the phases are provided in the brackets.

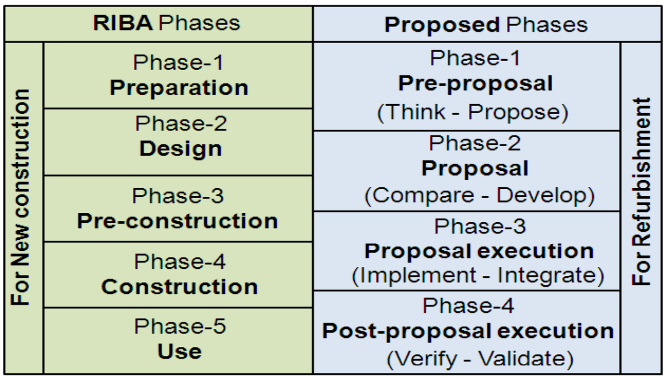

Figure 7.3. RIBA Phases versus proposed refurbishment phases

Phase One: Pre-proposal. The purpose of this phase is to propose and think; it consists of the following five stages: (i) Outlining Proposal; (ii) Business Case; (iii) Define Aim, Objectives, and Goals; (iv) Identify Project Team; and (v) Identify Project Targets.

Phase Two: Proposal. The purpose of this phase is to compare and develop; it is divided into the following five sub-processes: (i) Master Planning; (ii) Detailed Survey; (iii) Identify Level of Refurbishment; (iv) Design Concept; and (v) Develop Building Information Model. This phase is the foundation on which most of the proposal will be developed and helps to determine functions to drive the process.

Phase Three: Proposal execution. The purpose for this phase is to implement and integrate and is made up of the five stages: (i) Adopt Elemental Method; (ii) Overall Design Option; (iii) Refine Aim, Objectives, and Goals; (iv) Refine Proposal; and (v) Execution Planning.

Phase Four: Post-proposal execution. The purpose of this phase is to verify and validate and to execute the following four stages: (i) Handover; (ii) Update BIM; (iii) Project Evaluation and Validation; and (iv) Project Database.

Identifying the purpose behind every phase helped to propose tools and support systems for the same. It was very important because this can help to formulate the aim behind every phase and guide the process. For example, the purpose behind Phase I is to Think and Propose. Knowing this, the design team can identify the tools required to develop a proposal during any particular phase. Also, the design team is aware that this phase will involve thinking and proposing as two main criteria. Ahead in Figure 7.9 and Appendix I, the overall proposed process as part of the framework is presented.

The goal of the analysis was to arrive at an integrated methodology for refurbishment in healthcare facilities to improve existing facilities. Early in the process, a conceptual framework and few components were presented and discussed with experts through semi-formal interactions, for e.g. during conferences, which helped with the further development of the framework and sought people's perceptions about the framework. Below, in Figure 7.4, an overview used to develop the final framework is presented.

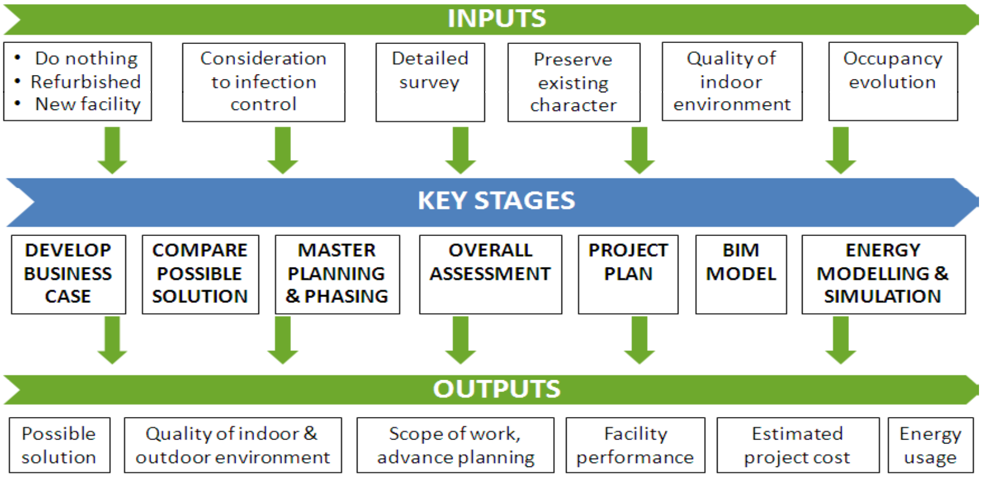

Figure 7.4. An overview of key steps considered in this framework

The framework is developed base on the '*components of an integrated process*' as presented in Figure 7.5 (Sarshar *et al.*, 1998).

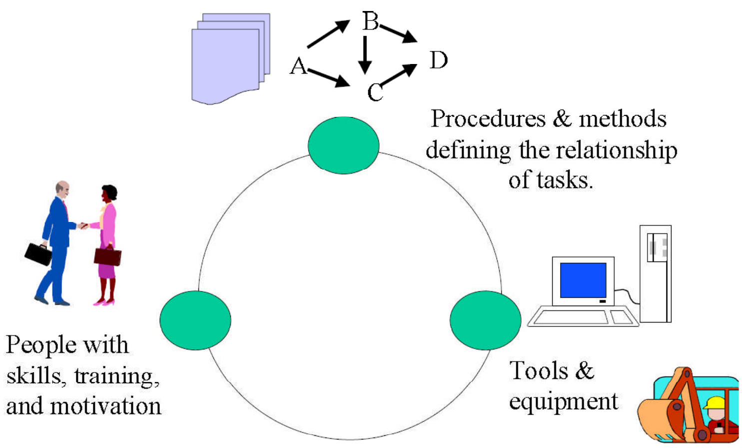

Figure 7.5. Components of an integrated process (Source: Sarshar et al., 1998)

The adoption of this existing model guided development of the framework as it was proposed for the construction processes and industry. The purpose of Sarshar *et al's* (1998) process was to improve quality, resolve difficulty in managing different experts and introduction of technologies within the process, which is similar to that of the HEaR framework created in this research. The proposed framework is divided into five key stages and an overview of the entire framework is presented in Figure 7.8. The stages move from the broad conceptual level during the pre-proposal stage to the very detailed design of every aspect in the refurbishment.

7.4 Framework components

Development of the framework started with identifying the key components. Below a list of components in the order they are integrated with the framework is presented. All these components are presented in Appendix I.

1. An overview of the decision making process.
2. Assessing the pre-refurbishment complexity level.
3. A guide for the process as indicated in Figure 7.9, which includes: (i) a matrix; (ii) details about phases; and (iii) support systems and tools.
4. Modelling and simulation that assess the design options from energy consumption point of view and to improve the overall performance.
5. A summary, comparison of pre and post-refurbishment complexity level. And
6. User manual (see Appendix J).

Through this framework and research, three key approaches (components) are proposed as part of the refurbishment process. First, the complexity level, second, the refurbishment scale and third, the adoption of elemental method as explained ahead.

The review of literature directly related to refurbishment patterns in healthcare construction revealed that little efforts are being made to categorise these types of projects. However, it is necessary to classify existing refurbishment projects' typologies to understand the possible scope of work and limitations. Thus, in the early phases of the research, efforts were made to categorise major types of refurbishment projects observed commonly in the healthcare sector. The collected data helped to propose a refurbishment scale indicated in Figure 7.6. All refurbishment projects can be divided into one of the three main categories, minor; average; and major. The key aim behind the development of such a scale is to provide a sensible way in which refurbishment can be considered during the design stages of a project. The proposed scale helped to divide and anticipate the degree of refurbishment associated with existing buildings thus a scope of refurbishment (also presented in Sheth *et al.* (2010b)).

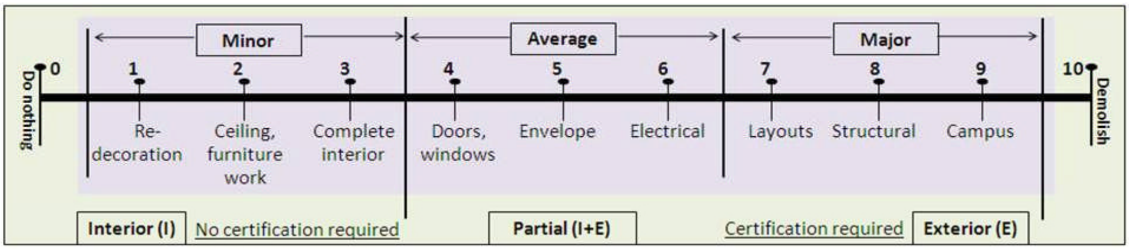

Figure 7.6. The proposed refurbishment scale

The elemental method was first proposed by Waters (2003), with the following characteristics. This method had the advantage that it avoids complex calculations and/or simulation. With this, every element of the building is treated separately and a minimum level of performance is expected to be achieved from each element. It allows more flexibility than other methods that require (energy) simulation of a whole building. Considering the above characteristics, it was found to be the most suitable method to integrate within refurbishment. Below in Figure 7.7, an example of elemental method is presented, which can be explored further to be used with other building elements considered for refurbishment.

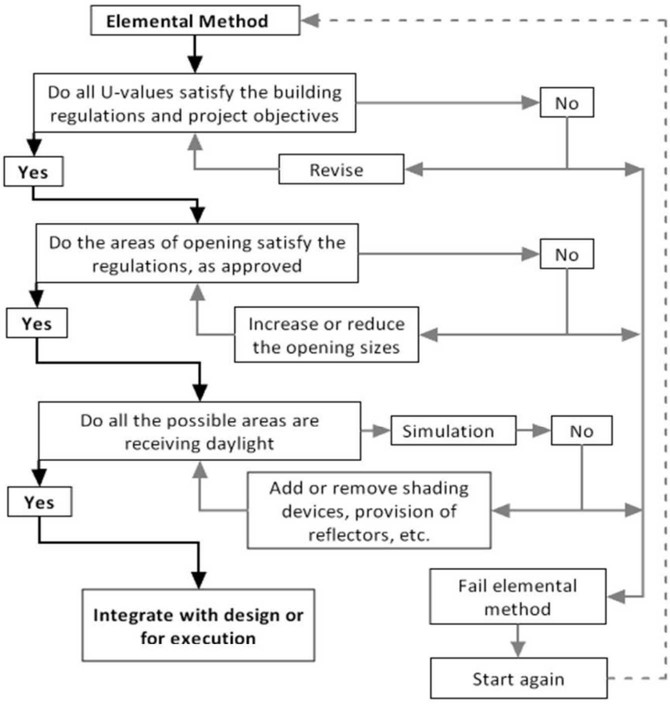

Figure 7.7. An example of the elemental method (Source: Waters, 2003)

The HEaR framework encompasses a structured process, tools to guide the process and an assessment criterion for measuring pre and post project complexity level. It is divided into three levels, phases and stages; support systems and tools; and modelling and simulation. All these levels are integrated through the proposed matrix. The matrix helps to bind the framework and its components with a complexity level as explained further. Different set of tools and support systems should be used depending on the complexity level, which can be obtained using the proposed matrix. Briefly, these levels can be named as Process level, Support level, and Assessment level. The three levels of the framework are illustrated in Table 7.1.

Process level: comprises the four phases and 19 sub-phases/stages (discussed earlier) as part of the project activities.

Support level: provides the list of support systems and tools that are implemented to guide the entire process.

Assessment level: comprises the modelling and simulation tools that measures and anticipate performance of the existing facilities.

Table 7.1. Types of levels integrated within the proposed framework

Levels	Details	Characteristics
Process Level	Phases and Stages	Divides the process into several manageable parts
		This involves planning, scheduling, designing
		It is a kind of process to be followed in a sequence
Support Level	Support system and Tools	Provides supports throughout process
		It is a kind of support or elements of the process
		Available throughout the process
Assessment Level	Modelling and Simulation	Help to assess the individual process, wherever possible
		It is a kind of resource
		This is a quantitative aspects

7.4.1 Overview of the framework

Figure 7.8 presents an overview of the framework; various terms presented in the figure are discussed below.

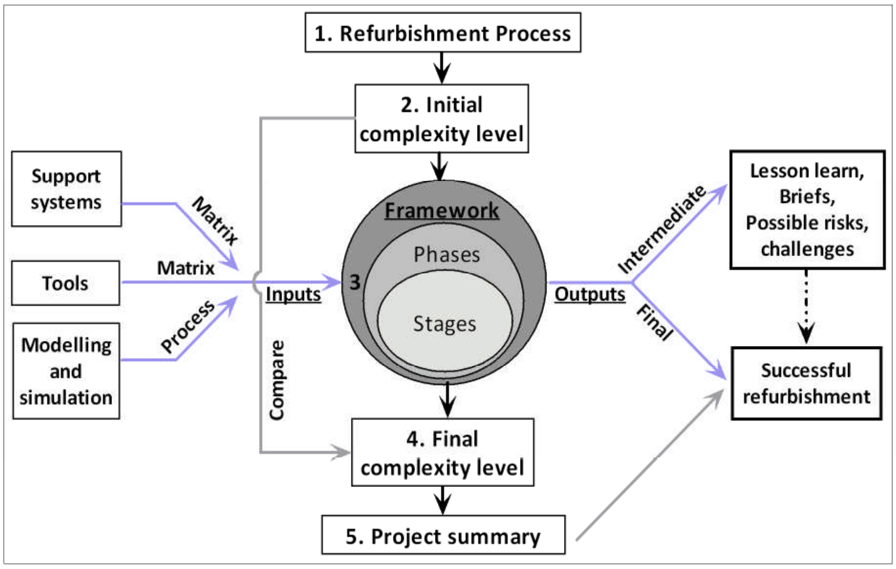

Figure 7.8. An overview of the entire framework

Refurbishment process: comprises of steps to be followed throughout the process and presents overall decision making process.

Initial complexity level: will be conceived through available information during the early phases of the process. It is important to know the complexity level because this will help to decide the overall project scope and success. However, to make the framework realistic, a relation was developed between the individual parameters used to predict the complexity level as explained ahead. For example, there are two sets of parameters. One is *'Building Operating Hours*' with options *'00-08, 09-16, and 17-24 hours*' and other being *'Types of buildings', which include 'Modern, 1960s-1990s, Victorian, and Other buildings*'. Depending on the option selected from both the parameters (see Table 7.3), a complexity level will be defined (e.g. refurbishment of a Victorian building operating round-the-clock will be more complex, whereas, a modern building, which is operational less than eight hours in a day will be less complex to refurbish). The complexity identified by each level will be added at the end of this stage, which presents overall complexity associated with the projects. Thus, an identified complexity level is not dependent on individual parameters, but rather a set of parameters. The final total indicates the level of complexity, which is divided into five categories as represented using colours shown in Table 7.2.

Table 7.2. Levels of complexities in the HEaR framework

Complexity level	Score	Colour code
Less Complex	Below 20	
Complex*2	21-40	
Complex*3	41-60	
Complex*4	61-80	
Highly Complex	Above 81	

Complexity: the level of complexity was identified from the set of collected data. At the beginning, the factors used in this framework such as type of projects, helped to identify building categories. To assign the complexity level for each factor, the data was analysed further and divided into chunks and for every part of the factor a complexity level from one onwards was assigned. Ahead in Table 7.3 the level of complexity assign for each level as part of the framework is presented. Also, at each level if nothing has been selected then a complexity level of one is assigned under each category. As revealed from the analysis of the collected data that work related to existing facilities is always challenging this framework indicates 13 as a minimum level of complexity during any refurbishment and produces minimum guidance and assistance required for a project. By assigning minimum level of complexity the framework ensures that before commencing any work in existing facilities there is a need for some pre-project activities such as pre-project survey, data related to existing facilities, assistance with selection of design tools. Knowing project details/ranges in advance helps to decide the approaches towards project during various stages. Depending on the project details/ranges provided at the project inputs stage the framework assigns level of complexity for each variables and entire complexity level towards end to produce complexity level as a whole for the project.

Table 7.3. Complexity index

Variables	Project details/Ranges	Complexity Level
Type of proposed project	New	2
	Extension	3
	Part refurbishment	4
	Full refurbishment	5
	Extension (New) + Refurbishment	6
Building operating hours	00 to 08	2
	09 to 16	3
	17 to 24	4
Type of building	Modern buildings	2
	1960s-1990s	3
	Victorian Building	4
	Others	5
Building layout	Shallow plan building	2
	Deep plan building	3
Scope of project	Interior (I)	2
	Exterior (E)	3
	Both (I+E)	4
Scale of refurbishment	Re-decoration	2
	Ceiling, furniture work	3
	Interior	4
	Doors, windows	5
	Envelope	6
	Electrical and mechanical	7
	Layouts	8
	Structural	9
	Campus	10
	Demolish	11

Variables	Project details/Ranges	Complexity Level
Total floor area (in M2)	900 to 90000	1 to 15
Total building volume (M3)	2700 to 270000	1 to 15
Project life-cycle	First refurbishment	2
	Second refurbishment	3
	Third refurbishment	4
Current phase	Phase I: Pre-proposal	2
	Phase II: Proposal	3
	Phase III: Proposal execution	4
	Phase IV: Post-proposal execution	5
Availability of drawings and information	Yes	2
	Partially	3
	No	4
Post-refurbishment building use	Same	2
	Partially same	3
	Different	4
Orientation	East or East-North	2
	North or North-West	3
	South or West-South	4
	West or South-East	5
Current energy use	Below 50 Gj/100 cu.m.	2
	51 to 60 Gj/100 cu.m.	3
	61 to 70 Gj/100 cu.m.	4
	Above 71 Gj/100 cu.m.	5

Framework: is presented in pictorial format (see Figure 7.9) and defines various phases, required inputs for the same and expected outputs. In Figure 7.8, the framework is in the core and it binds all the components, thus is a key to the entire proposed process.

Phases: these are used to divide the process into four key parts and can help to set intermediate milestones. As explained earlier there are purposes behind every phase (see Section 7.3.1).

Stages: are parts of the phases and involve various actors, tools and support systems throughout the process.

Matrix: the most important part of the framework because it suggests which support system and tools should be used throughout the phases (see Appendix J). Also, there are three levels within the matrix. Level-1 (one check mark) means important, moderately important is Level-2 indicated by two check marks and Level-3 means highly important presented by three check marks. An empty box in the matrix means the selection of tools, support system is optional and its implementation will dependent on the project team.

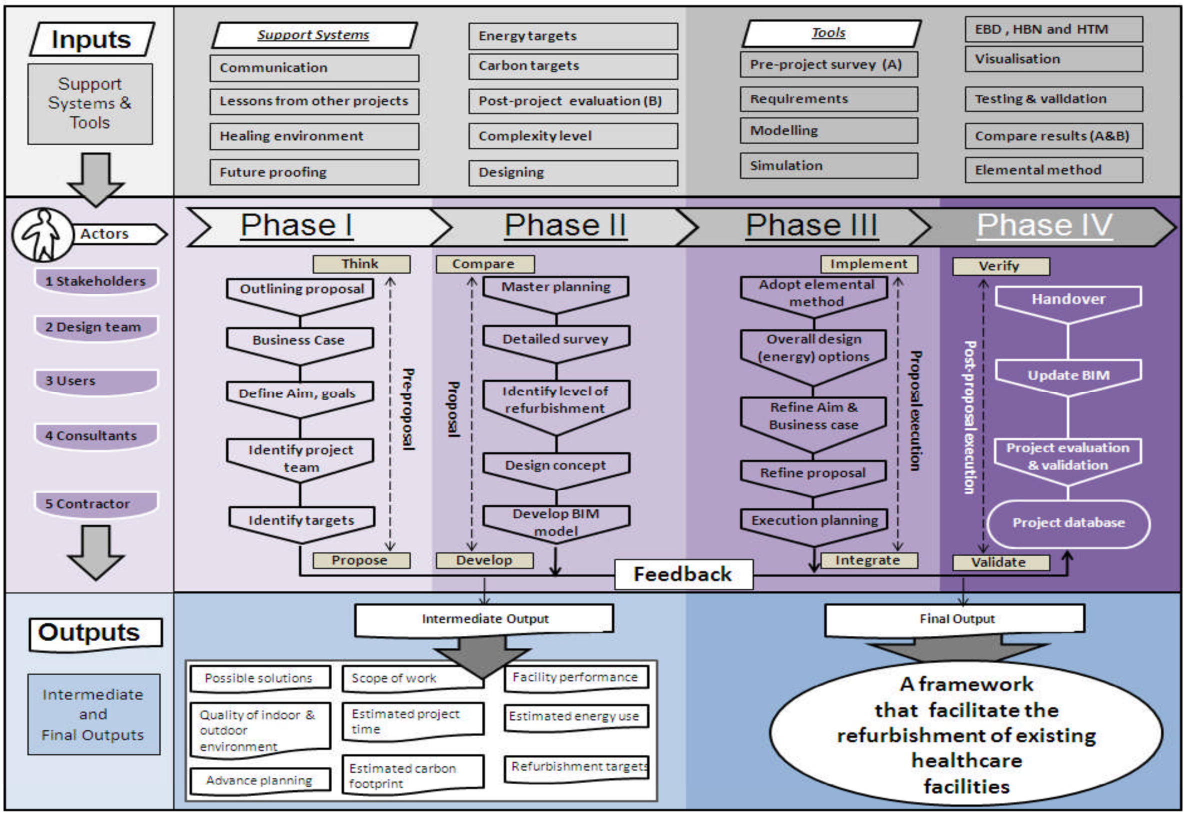

Figure 7.9. The final HEaR framework

Support systems: provide information required during the individual stages. Also, there can be several support systems involved on the project. For examples, energy or carbon targets will not assist the refurbishment process, but will help the process by providing targets.

Tools: play very important role on every project and are necessary depending on project needs. For example, knowing which tool to be adopted at various stages on project will help to identify require tool and to predict type of output to be expected. Tools will help also to obtain various outputs in terms of a brief throughout a project.

Modelling and simulation: is similar to stages but the process combines several stages, and is mostly part of Phases Three and Four. This informs the user how to use modelling and simulation during refurbishment. It is important to state that the aim of energy simulations is not to obtain the absolute prediction of energy performance in a modelled building, but to arrive at results to be used with a certain degree of accuracy and validity. Simulation and modelling is proposed to develop an existing building's virtual model and to validate how the design will influence future operations. The proposed modelling and simulation is presented in Figure 7.10.

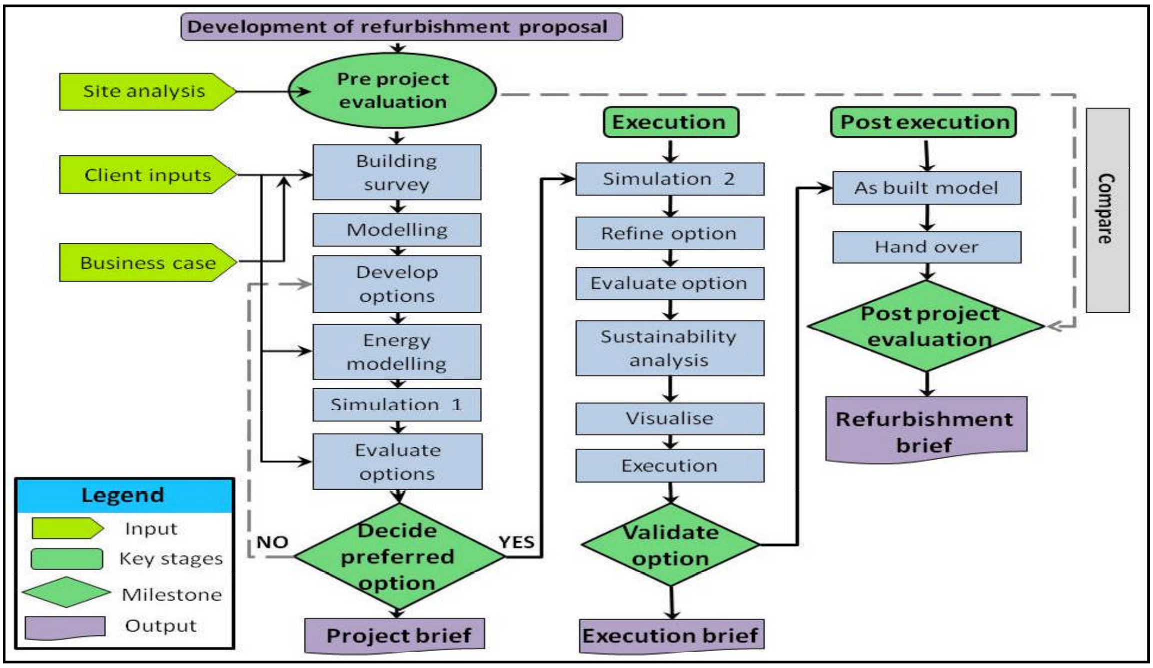

Figure 7.10 The proposed modelling and simulation process

Modelling specified as part of the proposed process will involve creating virtual building (information) model to be used throughout the process. The generated model can be used to share with different entities within the process, including clients. Also, at the end of the process this model can be stored and used in the future with subsequent refurbishment. However, simulation as part of the proposed process will be mostly considered from energy point of view. The key reason behind integrating simulation within the process is to make inform decisions and to compare and validate energy saving features, design options, etc.

Before selecting or proposing any modelling and simulation tools in the process, a pilot study was conducted. The details about the pilot study were presented in Sheth *et al.,* (2010b). This helped with the partial validation of the framework. To save time and efforts required for validation of proposed modelling and simulation tools, widely accepted tools by the experts and industry revealed from primary and secondary data collection were integrated into the framework. By giving an option to user decides which simulation package to be used, provides level of flexibility thus making this framework available for more people, a range of projects.

Final complexity level: is similar to initial complexity level, but is not based on assumptions. This is based on actual information with respect to the completed project and performs a comparative study with initial complexity level to identify the difference between the predicted and actual complexity experienced.

Project summary: this provides general project information. However, it is up to a project team and leader to decide what to include here.

The final framework was compiled using spreadsheets along with provision of user manual, which are presented in Appendices I and J respectively.

7.4.2 User manual

To make the framework self-explanatory, an in-built user manual within the spreadsheet was provided. The user manual provides information about the components and additional information on pre project survey, elemental method, and various actors to be involved during the project. The user manual was developed using a Word processing package (see Appendix J).

7.5 Validation of the framework

This section focuses on the verification of the framework presented above. Interviews were conducted for justification and validation of the framework. Early in the process, some modelling and simulation (M & S) was performed (see Sheth *et al.*, 2010b) to justify their use as part of this framework. The tools were validated with the help of review of literature to avoid unnecessary computational efforts during the application of the framework. The key reason behind demonstrating and verifying HEaR through interviews with professional from the industry were to:

1. test the applicability and verify the proposed framework, and to find if further development is required;
2. verify the efficiency and applicability of the framework components described in the preceding chapter; and
3. verify the overall theory presented in this research.

7.5.1 Evaluation of the framework

Four colleagues from the researcher's department were selected for piloting and four experts from the industry evaluated the framework. The selection of participants was solely based on their willingness to participate in the process and because the researcher knew they could make significant contributions. The participants were contacted through e-mails explaining the objectives of the evaluation. Ahead, Table 7.5 provides advantages and barriers of the framework as revealed from the evaluation process.

7.5.2 Objectives and basis for evaluating framework

The validation of the proposed framework was achieved by means of responses of healthcare construction professionals that were in a position to provide an overview of the whole refurbishment process for healthcare facilities. The objectives behind evaluation of the framework were as follows.

- To assess the effectiveness of the complexity level.
- The extent to which it presents pre-refurbishment complexity level and its ability to facilitate project objectives.
- To assess the effectiveness of the decision making process.
- To verify HEaR.

To achieve the above stated objectives, it was decided to demonstrate the framework to participants and provide them with an evaluation questionnaire (see Appendix K) to submit their response on the various aspects of the framework. It was decided that some (previous) participants from interviews could be used for evaluation, as they were familiar with the research. However, given the possibility of participants being biased, because they were involved in the early phases of the research, three new participants were also involved during the evaluation.

7.5.3 Validation participants' background

The framework has been developed based on the data collected and presented in Chapter Six, and it was felt important to validate the approach within the context of a real project; thus, professionals from the industry were contacted. Table 7.4 presents detail of the respondents, who participated during validation stage. Despite the constraints of the limited number of the framework evaluators, they were very experienced and fairly represent the potential organisations who will be involved with refurbishment projects. At the beginning of the questionnaire (see Appendix H), the objectives behind the validation process, components and general guidance were provided. In the questionnaire, information relating to background of the participants was also gathered (as presented in Table 7.4).

Table 7.4. List of participants for framework evaluation

Respondents	Experience in years	Background	Type of projects
Pilot evaluation			
PE1	12	Architect and Researcher	Architectural, research related to energy in housing sector
PE2	13	Architect and Researcher	Architectural, researching into energy & heat wave into existing healthcare facilities
PE3	11	Degree in Design, Research associate	Managing Value Delivery in Design
PE4	35	An NHS Trust employee	Development of tools and policies for healthcare design and construction
Final evaluation			
FE1	8	Researcher, Senior Consultant (ARUP)	Senior Design Consultant
FE2	12	A PCT Facility Manager	Contract Manager, and Ex-Site Manager
FE3	25	Estate Head	Involved with development of healthcare estate
FE4	5	Architect, Design Manager	PFI projects, Architectural design projects

7.5.4 Discussion of the validation results

During an interview, two experts applied the framework to an upcoming project and it was found to be useful (apart from the fact that it lacks direct consideration to cost related issues).

Questions Two and Three

Question Two provided the participants with an option to comment on the overview of framework with areas for improvement. Six participants reported the framework and its components were easy to understand whereas two experts said there was too much information at two stages (support systems and tools, and phases). This comment was analysed and the framework was further refined, which provided two levels within the framework. The first level is an overview level for stakeholders, clients and the second is a detailed level for designer and planners. These levels were introduced to make HEaR more user specific. With the former, some information presented in the framework, less relevant to the stakeholder will be hidden (e.g. characteristics of support systems) within MS Excel. Whereas, for the later, all the information presented in the framework will be displayed. One participant suggested a further improvement in the User manual: to add some more information about the framework to create a strong link between both levels. A response from one of the experts was:

"Yes, the framework allows a clear assessment of pre-project complexity; a framework to execute, plan project, and a post-project evaluation. It links complexity with tools plus process, i.e. level of importance."

Question Three provided the participants with option to comment on: 1) presentation of framework, and user manual; and 2) relevance with the research context. All the participants received the presentation very well and few comments were made. The pilot evaluation of the framework helped significantly to improve the framework before final evaluation. One of the participants reported the following comment, which was addressed by further development of the framework.

"A well thought-out presentation but needs fine tuning to avoid loose ends such as logical link to phases and matrix, depending on complexity."

The participants agreed that the framework had good relevance with the research context and with further developments it can be used for any type of healthcare facilities or for other sector in the construction industry. Also, this will help to gain commercial value to the framework.

Questions Four to Eight

With Questions Four to Eight, the participants were asked to give score on the scale of 1-10, where one being worst and 10 is very good.

Question Four was "*the extent to which the proposed developed framework assesses the relative possibility of refurbishment.*" The average score during pilot stage was seven, whereas the final evaluation indicates an average of 6.5. The major comments through pilot evaluation were a need to validate the framework with ongoing projects, and there was no major comment during final evaluation.

Question Five was related to whether the framework provides realistic scenarios and enables a potential user in making informed decisions to implement the framework. The respondents thought clear scenarios that account for various types of healthcare facilities during early stages were lacking; this is discussed later in Section 8.5 as a limitation of the framework. The average score during pilot stage was five, whereas, final evaluation indicates average of six.

Question Six gathered information related to degree of usability and user friendly interface. The average score was 8.2 and 6.75 during pilot stage and final evaluation respectively. The only comment for this part of the questionnaire was that it was difficult to understand the impact of the framework on the project timescale, but one of the participants said: *"I thought this was excellent – very intuitive and easy to follow"*.

Question Seven asked about the application (relevance and desirability) of framework within the industry. The average score during pilot stage was 6.5 whereas during final evaluation a mean of 6.4 was achieved. Two participants said that with further development of the framework, it would be very relevant to use within consultancy (property) and PFI/development planning stages.

Question Eight asked if the framework would improve overall refurbishment practices. The average score was 6.25 and 6.75 during pilot stage and final evaluation respectively. There was no major criticism and it was found that the framework would be very helpful to improve refurbishment practices.

Discussion of Questions Nine and Ten

Question Nine enquired whether the aim and objectives stated early in the questionnaire are satisfied. All the participants agreed that they were satisfied; however, further development of the framework would be required in accordance with various types of healthcare facilities. The participants reported (various) advantages and disadvantages of the framework, which are summarised and presented in Table 7.5.

Table 7.5. Advantages and disadvantages of HEaR

Advantages	**Disadvantages**
Could be useful to assess benefits of refurbishment, and with further development to assess cost	Could be overly simplistic, not mapped to existing generic and custom processes
All the stakeholder could input the information	Lacks quantitative information to some extend
Very good qualitative information	Non-evidence in reality
It works on the commonly used software/programme	Some difficult in navigation
Can help in feasibility studies, brief developments and good user manual	One size fits all
Detailed guidance could be very useful at all stages of the refurbishment process	Market testing with real organisations and real projects
Users could use the framework as the basis for discussion with teams internally and externally	Link to current energy/sustainability models
Could be adapted to work for other construction industry sectors	Need to link tools and process inputs with level of project complexity
Clear method to execute projects for healthcare refurbishment	
Consideration is given to energy models i.e. sustainability	
Level of risk highlighted and have prompts for risk managements	
Post-project analysis	

During the interviews, two participants invited the researcher to implement HEaR on upcoming refurbishment projects. This opportunity will be considered in subsequent research, which will help in the further development of HEaR.

7.6 Summary of research benefits

The research has contributed to the industry in the following seven ways as explained in Sections 7.6.1 to 7.6.7.

7.6.1 Overall decision making process

All refurbishment projects have similar features however, before now there was a lack of standardised approach with a structured process. This research has adopted ideas from construction processes (Sarshar *et al.*, 1998) into refurbishment. This approach benefited actors involved whilst undertaking refurbishment projects because using the overall decision making process saves time and eliminates other inefficiencies, and contribute towards success of the project. Furthermore, knowing the process helps to understand involvement of participants, and thus better coordination, and it clearly highlights the stages at which decisions should be made thus participants are aware about the critical stages. Finally, using the decision making process ensures that the project progresses according to the defined path. The decision making process helps to integrate a number of areas throughout the refurbishment process, as discussed below.

7.6.2 Complexity level

Until now, there was a lack of efforts to identify the level of complexity associated with existing buildings and refurbishment. Thus, this is a unique approach, which informs all the participants about complex areas with additional considerations to improve the overall success of a refurbishment project and helps in the following ways.

- To illustrate and understand when an expected process could face difficulties during the projects.
- By assessing the complexity level, participants can plan in advance for difficulties which may arise in the future.

- The complexity level highlights the types of data inputs require during the process in advance.
- It allows a clear assessment of pre-project complexity.
- It promotes advance thinking, thus possibility of improving overall success of the project.

7.6.3 Refurbishment scale

This is one of the original contributions of this research, which categorises refurbishment projects on the scale of 01-to-10. This provides an overview of the scope of work associated with the proposed projects. The further development of this scale can help the industry during refurbishment in various ways, such as suggesting a degree of refurbishment, scope and type of a project to be executed. The key aim behind the development of the scale is to provide a sensible way in which refurbishment can be considered during the design stages of a project.

The proposed scale is based on the characteristics of a project and not the size or quantity of the work. The investigation revealed that often, in the healthcare sector complexities of the project significantly depends on the characteristics of the facility considered for refurbishment compared to size of the facility. For example, at any given time, refurbishment of Accident and Emergency (A&E) will be challenging irrespective of the quantity/size of work, because the facility serves emergency purposes and needs to be operational round the clock.

7.6.4 The HEaR Framework

This is a key output of this research and the proposed framework helps to divide the refurbishment process into four phases and further into a number of stages. The framework will influence the development and outputs to ensure a '*best refurbishment*' solution for a project. More specifically, it focuses on the following areas; existing occupancy, hidden/unseen conditions, dependencies of and/or on adjacent areas, site restrictions, new regulations, existing building conditions, reduced or more floor-to-floor height, and structure/envelope performance.

Thus, the framework can help to improve building performance in the above possible areas. Every refurbishment project passes through various phases, each of which has a purpose and these phases can effectively be implemented using the proposed tools and support systems. Risk and uncertainty are inherent in all the phases of the process, which are addressed by this framework.

7.6.5 Matrix

The proposed matrix as part of this research helps to understand the types of tools and support systems to integrate during various stages of refurbishment. It will help to prioritise the decisions related to integration of tools and participants that will be part of the project. This can play a vital role at the outset of the project, if used effectively. The approach helps to understand whether any available tool is not at all important, important, moderately important, or highly important during the various phases of refurbishment. The matrix is developed with consideration to flexibility, which is very important for the success of any refurbishment projects.

7.6.6 Elemental method

As explained earlier, refurbishment is a bottom-up approach, and it is important that while developing a proposal, the same approach is followed. The elemental method proposed by Waters (2003) was found to be very useful to integrate within the refurbishment process because of its characteristics. The elemental method helps to access individual elements associated with the facilities, and it is important because performance of the elements in existing buildings varies significantly, unlike with new facilities. The consideration to the elemental method during refurbishment can help in improving performance of the individual elements, thus overall facility. To assess individual elements, it will provide boundary conditions of the every element to define detail scope of the work with areas needing immediate attention, and it will allow separation of components. Also, as explained earlier refurbishment is bottom-up approach, elemental method suits well in this framework because this is also based on the same principles.

7.6.7 Modelling and simulation

In recent years, an increasing use of modelling and simulation has been observed during the development of new projects. However, the investigation revealed that consideration of modelling and simulation could contribute to refurbishment project because:

- it promotes early involvement of engineers and consultants on projects, which can minimise design conflicts between architects, designers, contractors, consultants, etc., during later phases;
- a performance based design and simulation approach can offer an improved, comfortable indoor built environment, lower carbon emissions, and additional value to the client;
- provides comprehensive set of building knowledge related to form, materials, context, and technical systems of buildings;
- enables comparison of a range of design variants, leading to more optimal design;
- provides appropriate data for users from different disciplines for various analysis purposes; and
- it can optimise construction time by highlighting bottlenecks and site constraints in advance before construction.

This approach was found to be important because a pre-project survey can provide building related information to perform energy simulation of a building. Rich data and inputs needed for the simulation purposes are easy to gather from existing buildings as compared to proposed or buildings under construction in some cases, for example, occupancy patterns. A similar approach to the above mentioned work can be found in Azhar *et al.* (2008) work, however, the focus was on new construction and very limited consideration was given to refurbishment, renovation, etc.

7.7 Implementation strategy

To lay the groundwork for implementation of the proposed framework into the NHS and to improve the existing practices related to refurbishment, the DoH would need to take a step to make this mandatory. Below Figure 7.11 presents the diagrammatic representation of the potential implementation process for the framework. However, considering the fact that HEaR highlights a level of complexity in advance, may simulate its integration in the industry; noted by one of the participants during validation stage.

The proposed approach offers a crucial method for the client to achieve a better existing built environment and a good chance to improve existing facilities through the defined construction process; refurbishment. This would demand a shift in thinking from clients, operators and managers in the construction industry during implementation of the proposed framework in a project from short term to long term.

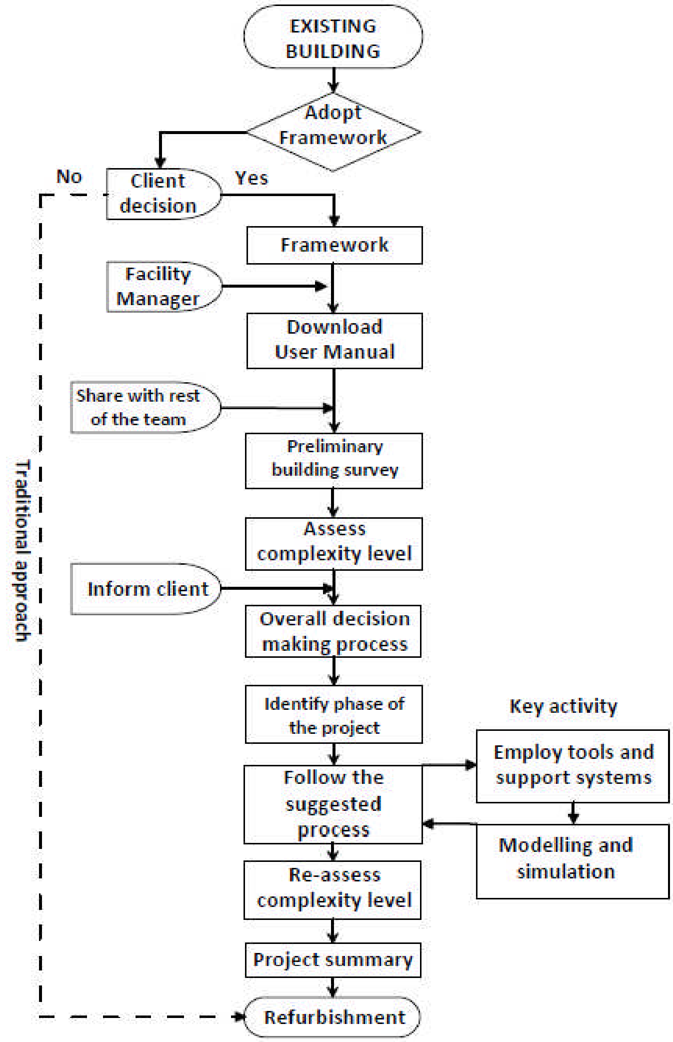

Figure 7.11. Diagrammatic representation of the implementation of HEaR

7.8 Barriers to the implementation of the framework

Barriers to the success of the proposed implementation framework were noted during informal discussions with colleagues and experts, whenever possible. Participants from the construction industry were asked whether they felt the initiative was potentially effective, and capable of being implemented. Generally, the participants were supportive and appreciated the approach as part of this research. However, further developments of the proposed framework in some areas were suggested to improve and gain more commercial value for the proposed framework.

During validation interviews, one facility manager was concerned that clients or stakeholders may not be enthusiastic about changing existing systems, which they perceived to have been effective for many years. Thus, a potential barrier for implementation can be the reluctance of organisations to change and adopt the initiative. It was reported that current practices are slow in nature to adopt any changes. However, during piloting and final evaluation the participants agreed that there could be a barrier to implementing the entire framework, but few components (e.g. the refurbishment scale, M&S) could be integrated within the process, without a significant change in the existing processes or components. By demanding early inputs on the project the HEaR framework may impose several challenges thus preventing its integration.

Making this framework mandatory is not a solution to improve refurbishment practices, but the proposed tools and support systems as part of this framework to be integrated should also be mandatory.

7.9 Chapter summary

The research focused on development of a framework (Hear) for improving refurbishment practices. This chapter has presented HEaR for improving the refurbishment planning and decision-making process, which organisations involved on a refurbishment project, can use. Considering the fact that any refurbishment project is a process, the proposed framework offers a process as an alternative approach.

The various components and complexity levels have been outlined. The framework has a potential to help organisations involved with refurbishment of existing healthcare facilities in a number of ways, during pre-refurbishment stages, for example, by identifying challenges associated with existing buildings and refurbishment; and highlighting factors and areas for improvement. Equally important, the framework provides a proactive measure during refurbishment as it evaluates the capabilities that drive improvement and effectiveness of the pre-refurbishment process. The framework has overwhelming benefits for successfully completing projects and programmes within the healthcare sector.

The chapter has also discussed results obtained from the validation of the framework with eight experts. The results generally show that the framework is an effective tool that could enhance refurbishment, particularly for large-scale projects with a more complex issues and great deal of dynamic change; however its integration is reported as a key challenge.

It is not clear how much time this framework would save but it has been developed with intention to improve refurbishment practices by identifying the complexities early in the process and by providing a database. Certainly, integration of modern methods and tools as part of the framework will reduce time and cost. In the next chapter, the overall research is summarised, discussed and areas for further research are proposed.

CHAPTER EIGHT. CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH

8.1 Introduction

This chapter presents conclusions from the research in terms of contribution to the theory and practice. The limitations of the research are also presented. The chapter ends with recommendations for further research followed by closing remarks. The main aim of the research was to develop a framework to assist and perform development of a refurbishment proposal in an existing healthcare facility to overcome the problem encounter during the project. In order to achieve the research aim, the research has focused on the objectives identified in Section 1.5.

It may generally be concluded that the primary goal of this research has been accomplished because the framework (HEaR) is developed (and validated) enabling a systematic approach towards refurbishment for healthcare projects. The implementation of HEaR in construction practices, especially refurbishment would enable changes and improvements in the industry. In addition, modelling and simulation based process has been developed as a quantitative approach supporting the proposed framework.

8.2 Conclusions

The size and nature of the NHS estate has resulted in significant energy consumption, a large carbon footprint and a considerable impact towards change in climate. Although there is a major ongoing new build programme, the existing estate comprises many former healthcare facilities and different solutions are required depending on the type of a facility. An integrated holistic approach towards compliance with legislation and regulation is needed to significantly reduce the NHS energy consumptions and carbon footprint. Also, considering the complexity and number of factors, no individual researcher possesses the complete knowledge and hence, a team approach is required. Therefore, integrated teamwork processes and modern approaches play an important role in every stage of planning, design and assessment. This research has considered energy consumption, however, this should not be considered in isolation, but in relation to sustainable healthcare infrastructure, such as consideration to broader environment impact; patient and public safety; waste management; broader social impacts; and economic impact on individuals and local communities.

There are multiple stakeholders involved in the design and operation phases of healthcare facilities, all of whom will have different opinions regarding the relative importance of the factors that contribute towards sustainability of healthcare facilities. Methods thus need to be developed to achieve a consensus around the definitions, factors and assessing the sustainability of healthcare facilities. There is also a need to take account of facility adaptability and resilience of healthcare facilities to the physical impacts of climate change and what effects could various climate change scenarios have on the performance of healthcare facilities in relation to patient safety, recovery and energy consumption.

Several sustainability assessment tools and guidelines exist but many need to be developed further to suit existing healthcare facilities and should be mandatory, for example, NHS Design Review Process, implementation of Health Building Notes (HBNs), etc. There is also a need to revisit existing planning, design and construction processes and applications of Environmental Management Systems (EMS). This research has raised a need to outline the case for the better integration of existing assessment tools when dealing with healthcare facilities.

To perform energy simulation of a building, rich data and inputs are needed which can be easy to gather (through detail survey) in existing buildings, compared to proposed or under construction buildings. A survey of existing facilities before refurbishment can produce various details related to operational hours, number of visitors, staffs and patient occupancy, existing IEQ, need for lighting, etc. However, in case of new construction most of the above factors are assumed or forecasted and can drastically change on completion; levels of accuracy of the assumptions made during design stages are based on the experience of team members and experts involved on a project. Investigation revealed that often, modelling and simulation based approaches are not commonly considered during refurbishment of existing buildings. Compared to traditional tools such as CAD; BIM can help to plan for future refurbishment, but various tools developed on the principles of BIM and simulation lack wide approval. Investigation revealed that there is a need to consider existing facilities from sustainability point of view and BIM based tools can be very useful for same. Also, though there is an increasing recognition of sustainability, refurbishment projects opt for traditional approach, such as consideration to initial cost and not life-cycle cost. This research has also defined a need for a framework or process to implement these kinds of modern tools into the construction of existing facilities.

In the healthcare construction industry it was observed that refurbishment is considered from a narrow perspective with emphasis on improved mechanical systems and work related to re-decoration. The trend in renovation of existing hospitals indicates that often, aesthetical (re-decoration) refurbishment is performed more frequently compared to refurbishment of fabric or building services. Many projects do not consider re-designing and re-planning during refurbishment resulting in no significant improvement in building performance post-refurbishment. Opportunities provided by refurbishment to reduce energy consumption and carbon emissions are often missed. Post-project Evaluation (PPE) can help to improve and speed up refurbishment processes in the future and to validate refurbishment proposals. Another aspect of PPE is to analyse the results and generate knowledge/database for refurbishment.

Though age is considered as an important factor in existing buildings, refurbishment cycle cannot be predicted only on the basis of age. There are several reasons for refurbishment and it is difficult to propose a single solution or a trend. Also, refurbishment is controlled by three major factors: budget, condition of the systems considered for refurbishment, and project/client's objectives.

The major objective of this study was to propose a framework for refurbishment including other key factors such as energy. Significant energy savings are possible with more sophisticated planning and mechanical systems by reducing air volumes and using appropriate energy features. In this research, various ideas and strategies from other projects are compiled together to propose a competent refurbishment framework to be used for existing hospitals refurbishments. Also, the main objective of the framework is to save energy and improve overall performance without compromising patient comfort and this should be one of the key objectives for every healthcare project.

8.3 Conclusions on the objectives

In this thesis, a proposal has been presented, which serves as a framework for refurbishment and to manage existing buildings with the aim of reducing their energy consumption and improving their conditions. With this framework, various functions are defined and the successful refurbishment is realised by performing a number of activities for each of the respective functions. There is an urgent need for buildings to decrease the total amount of energy consumed; within the EU, up to 40 per cent of the total final energy consumption and CO_2 emissions comes from buildings.

8.3.1 Objective One

'Explore healthcare sector and existing facilities in regard to sustainable development'

This objective was set to identify sustainable development trends in existing healthcare facilities and the relation between them. The review highlighted increasing adoption of sustainability in the healthcare sector, however, this tends to be limited to modern facilities and; existing facilities are excluded up to a certain extent. Also, the industry is still reluctant to adopt sustainability due to various reasons, such as stakeholders and design team think it increases cost and time respectively. Thus suitable policies and incentives to help dissemination of sustainability across the healthcare sector is required. The review highlighted several attempts to address sustainability over the years by various researchers and organisations. However, these attempts are not implemented in the industry, especially during refurbishment to a great extent. This gap has been increasing over the years and recently there is some increase in focus on studies related to existing facilities and integrating sustainability.

When reviewing the concept of sustainability, the literature findings revealed that there was no full agreement on the consideration of all sustainability concepts, i.e. environmental, economical and social. However, it is generally accepted that existing facilities have less impact on social factors, but significant impact on environmental and economical issues.

The review highlighted numerous critical factors related to existing facilities, healthcare sector and sustainability, such as design consideration, measuring sustainability, IEQ. These factors were classified as themes and discussed in the previous chapter.

Through this objective, the issues related to learning in terms of identifying the two common types (i) existing concepts related to sustainable development, and (ii) policies and frameworks for the same were discussed (see Chapter Two).

8.3.2 Objective Two

'Examine refurbishment trends in relation to healthcare facilities with the help of primary and secondary data collection'

Through this objective, trends in the healthcare sector in the UK and USA were examined. Many problems were addressed, which include theories related to refurbishment, building regulations, energy consumption in healthcare facilities, and carbon emissions from the healthcare sector. However, there are insufficient theories or information available for the same. Also, when searching for information related to re-designing of existing facilities during refurbishment, it has been investigated that a huge gap exists in the literature. Trends relevant to refurbishment as revealed from the investigation are listed below:

- a focus on mechanical aspects;
- if the physical building is considered, then it is only from an aesthetic point of view;
- limited considerations to daylight;
- lack of efforts to identify and rectify errors from the past;
- during planning stage, more importance is given towards economical considerations; and
- a limited consideration to architectural aspects.

There is a lack of post-project evaluation in refurbishment projects. The major findings from early phases of this research concluded that research in the area of refurbishment of existing hospitals has been neglected and a need to develop approaches for existing healthcare facilities to achieve overall sustainability and improve their performance.

8.3.3 Objective Three

'Review quantitative tools used for virtual building modelling and to facilitate simulation, such as BIM and, their integration during refurbishment'

The need for more information during the design stage has attracted the attention of researchers, experts, etc. As a result, the construction industry has started adopting 3D tools on construction projects over 2D CAD based tools. Also, the recent development of 3D models to include project information related to building (known as BIM), has been observed, but the process of designing buildings in BIM is complex compared to traditional CAD based approaches. Indeed much development has been observed related to quantitative tools in the construction industry. However, refurbishment is not part of these tools. One of the studies reported, "*BIM is a perfect fit for healthcare because of the complex nature of these buildings, the repetitiveness of the activity within the building and the need to really nail the process*" (Barista, 2007). The review of literature and the investigation revealed that integration of BIM and simulation offer particular benefits for refurbishment and construction projects.

It was found that fewer than 20 per cent of energy saving buildings components are selected with consideration to alternative options. Especially on a refurbishment project, very few alternative options or possibilities are considered. Quantitative tools (such as parametric modelling) are very important because they can help to test proposed options with the least disturbance to occupants. A lack of integration of quantitative tools is one of the reasons that opportunities to reduce energy consumption and carbon emissions on refurbishment projects are missed.

8.3.4 Objective Four

'Review qualitative tools such as LEED, BREEAM, etc., which are used in practice to analyse (energy) performance of buildings and their applicability to existing facilities'

This objective focuses on trends in the healthcare sector related to refurbishment. It was found that LEED and BREEAM are currently used extensively throughout the USA and UK respectively. Most of these tools have similar objectives: to raise awareness of sustainability by assessing design and construction processes mainly with consideration to the following key areas; energy use, water use, material use and waste management, pollution, environmental management, health and wellbeing, and land use and ecology.

In the industry, there are generally two barriers to these types of tools: cost and effectiveness, but a recent development indicates that tools are being developed for existing facilities. However, these tools are not widely accepted on refurbishment projects. The qualitative tools for existing facilities can be defined as a set of performance standards for the sustainable operation of buildings. Most tools offer credit for compliance with certain performance standards, and total credits are presented using a final scorecard. However, these qualitative as well as quantitative tools are yet to be at the core of the industry, especially for refurbishment; perhaps in a decade they will be developed and improved. However, the review of literature suggest that the development of these types of tools is slowing down, compared to the last decade.

8.3.5 Objective Five

'Establish drivers related to existing buildings, refurbishment and energy consumption in healthcare sector through investigation'

The investigation as part of this research highlighted various drivers and challenges for existing facilities refurbishment to reduce energy consumption. The key driver for the healthcare sector is that often occupants are present near to the refurbishment site, which may not be the case with refurbishment of other types of facilities. Also, occupants are physically ill and the most of the facilities perform medical related activities, which should be disruption free during refurbishment. Often, refurbishment is a time consuming and lengthy process, but can be very effective if executed in well-planned phases.

It was observed that in existing facilities much less importance is given to post-project evaluation, and lacks any formal comparison between two refurbishment projects, or pre and post refurbishment phases. Also, the overall existing building stock remains largely untouched, being replaced at a slow rate and many recent refurbishment projects have missed the opportunity to reduce GHG emissions and carbon footprint. While developing a proposal it is important to preserve the existing characters of the campus and buildings, especially if the (hospital) campus hold listed/heritage facilities. Some studies reported that a significant energy saving is possible in existing (hospital) buildings without spending much money; for example, by providing energy efficient lighting and shading devices.

8.3.6 Objective Six

'Develop a framework to support refurbishment of existing healthcare facilities and identify the components for management, design team to be included within the framework'

The achievement of Objective Six highlighted that improvement in refurbishment practices and existing facilities are influenced by the identified critical factors. The development of the framework was principally based on the three key components of the critical factors. Additionally, some guidelines derived from the preliminary study and literature review were used during the development of the framework.

The framework, presented in Chapter Seven and in Appendix I, presents a holistic picture of the connected components that would influence refurbishment practices and process. The framework as shown in Figure 7.9 is comprises four phases in the form of chronological sequences. These phases are Pre-proposal; Proposal; Proposal Execution; and Post-proposal execution. Each phase comprises 4-5 stages also known as sub-phases. The sharing of knowledge between the phases and components as part of the framework is necessary to ensure continuous improvement. This could be achieved by giving feedback across the framework to develop an integrated improvement practice for existing facilities' refurbishments. Also, current approaches lack a sharing of data within a project during various stages as well as from a project-to-project.

8.3.7 Objective Seven

'Evaluate, validate and enhance the framework through interviews and case studies'

This objective was achieved through testing the framework (developed to accomplish previous objectives). The aim of the validation process was to assess the appropriateness and workability of the refurbishment framework and ascertain whether it captures most factors affecting the improvement process of refurbishing existing buildings. The validation process presented in Chapter Seven was conducted by means of interviewing eight experts.

The validation process revealed that the framework adequately highlighted complexities affecting the existing facilities and refurbishment and identified a number of essential features, such as consideration of modern tools. The results showed that the relevance, usability, and desirability of the framework were more than adequate. The validation results also showed a high level of agreement on the framework components within the refurbishment practices. This also indicated a high level of approval for the complexity index and refurbishment scale.

The user manual for HEaR was also discussed during evaluation interviews and found to be self-explanatory and useful. It would, nevertheless, provide a significant step towards improving the refurbishment practices and existing facilities if, the client/stakeholder follow the manual carefully, in particular. Additionally, training workshops and support for staff involved in the refurbishment projects is needed to introduce the framework, but overall the process would help in the execution of refurbishment proposals.

8.4 Research findings

This section has discussed the findings identified from the preliminary studies, case studies and a questionnaire survey, from which 12 critical factors affecting the process of refurbishing existing healthcare facilities were revealed. These critical factors are classified under three main themes: sustainability with an emphasis on energy (8.4.1); refurbishment of existing facilities (8.4.2); and assessment and parametric tools for the same (8.4.3) and discussed in the context of the literature.

8.4.1 Sustainability with an emphasis on energy

The findings revealed that there are several factors related to sustainability that can affect existing healthcare facilities, refurbishment, or both. These factors are classified and discussed into the following five themes (in Sections 8.4.1.1-8.4.1.5).

8.4.1.1 Relation between sustainability and existing facilities

It was established that sustainability is not to be considered only with new facilities but also with existing facilities. In the context of sustainability, existing facilities need to reduce their impact on society and users. There are various possibilities to involve sustainability within the existing facilities as explained ahead. The investigation revealed that limited consideration has been given to existing facilities to achieve sustainability through refurbishment. All the participants reported negligence in the past towards integrating sustainability with works related to existing facilities and suggested improvements in accordance with existing facilities and/or refurbishment processes. Also, a combined focus towards sustainability and existing facilities is lacking.

The continuous considerations to existing facilities can help to achieve sustainability, which was not a major focus by the industry or the healthcare sector until recently (www.breeam.org). Accordingly, there is a need to bridge the gap between the two crucial areas through understanding and establishing a relation between sustainability and existing facilities. Nevertheless, considering the broad scope of sustainability and its multi-dimensionality, for one individual it is not possible to cover all the aspects or key dimensions, such as environmental, economical, and social. Thus, the focus of this research was narrowed down to energy, which is a critical part of environmental sustainability (also confirmed by Romm, 2008).

8.4.1.2 Measuring sustainability

The findings revealed that there are various ways to measure and assess sustainability. The possible directions in which sustainability could be measured are environmental, economical and social through qualitative, quantitative or mix approaches (Fricker, 1998). Sustainability can be achieved at a higher or lower cost, depending on the project context (Turrent, 2007). However, there is a lack of approaches to measure sustainability in existing facilities. Existing healthcare facilities differ in characteristics, thus they demand unique approaches to measure their sustainability. Often, complexities and challenges associated with existing facilities make it difficult to measure sustainability, and most current assessment schemes are not effective with existing facilities because they were developed to be used for new facilities.

Further issues highlighted through the interviews were a continual improvement in medical technologies and the presence of occupants throughout refurbishment in existing buildings, which are often not considered while measuring sustainability. All the participants as well as reviewed literature acknowledged the need for improved approaches to measure sustainability in existing facilities.

8.4.1.3 Designing process

In Section 2.4 and Chapter Six the design of existing facilities with respect to energy was explored, thus sustainability was considered. All the participants stated that a lack of collaboration between design phases and other phases, such as operational, maintenance has a significant influence on the performance of existing facilities. This is due to a lack of information, consideration and promotion of the importance of designing existing facilities by the industry and government. The investigation demonstrated that consideration of certain factors in existing facilities, such as envelope, design can improve their quality and performance in the future.

Two types of design impacts have emerged through the findings; first, relevant to value of the asset (building) and the other pertaining to social and environmental aspects of existing buildings. Vittori (2002) argued that a design error made by the designers, and physical built environment has a definitive impact on the users, especially patients. Vakili (2007) emphasised the importance of design during refurbishment when avoiding past mistakes to improve the performance of existing facilities.

8.4.1.4 Current practices

The findings revealed two distinct approaches in the healthcare sector and construction industry in accordance with existing facilities and their development. For existing facilities involving refurbishment, often capital expenses are considered (Battersby, 2008, Gann and Whyte, 2003), thus most current researches and approaches are based on the same (for e.g. Ali *et al.*, 2009, Doran *et al.*, 2009). Second, current researches and industry initiatives assume that new and existing buildings are similar in nature and they adopt the same approach to achieve sustainability with types of buildings. Current practices are applicable to the existing facilities, but need to be improved to align with existing facilities' context and requirements. In this regard, the improvements should be included within the scope of existing practices. Also, the findings revealed that there is a lack of post-refurbishment evaluation in existing refurbished buildings (Carbon Trust, 2008, Oseland, 2007). Hence, limited information related to the success of refurbished buildings is available.

Current practices can have a significant impact on existing facilities' performance as well as on the refurbishment through consideration of social, environmental and economical factors. The focus of the development of current practices towards refurbishments is crucial for achieving continuous improvement in the healthcare sector. Thus, improved current practices are required, rather than wasting efforts in resolving the errors from the past, which are often, discovered post-refurbishment.

8.4.1.5 Benefits to users

The findings of this research have various benefits to users via an improved built environment. The key benefits achieved in existing facilities because of improved performance are reduced patient stay, improved staff efficiency and attractive buildings. All the interviewees agreed that there is a need to re-consider existing facilities to satisfy users' expectations. Currently, this is lacking because existing facilities are often considered from a narrow point of view, for example, work related to just aesthetics and HVAC, provide limited benefits to the users through refurbishment. The broader point of view would be consideration to above issues as well as physical design, user comfort, sustainability.

8.4.2 Refurbishment of existing facilities

It was established that refurbishment of existing facilities is important to improve their performance (Burton and Kesidou, 2005). These include types of care and buildings; theories related to refurbishment; and building regulations. The investigation revealed increasing attention has been given to existing facilities and their refurbishments. However, with existing buildings consideration of such challenges is limited, which need to be changed.

8.4.2.1 Types of care and buildings

There are four key levels of care in the healthcare sector, which can be tackled using similar approaches, but have varying challenges. For example, consideration of round-the-clock operational hours of bigger facilities or five days a week in a GP surgery will demand different inputs or methods for refurbishment. However, the findings of the investigation revealed a lack of data related to refurbishment of existing healthcare facilities with consideration to the type of care provided within those facilities. In the future, efforts should be made to gather more information related to refurbishment based on the types of care.

Additionally, in this research although existing facilities typologies are not considered, efforts were made to segregate types of buildings based on operational hours, size of buildings, floor plate, etc. Also, the data collected as part of the framework will help in the future to identify approaches based on the type/level of cares observed in the healthcare sector.

8.4.2.2 Theories related to refurbishments

Throughout the research, efforts were made to understand existing theories related to refurbishments in healthcare facilities. The findings revealed that some attempts are being made in the construction sector, but most of them were focused on economical aspects. In the past, some studies related to energy consumption, such as Pan *et al.* (2008), Neto (2007), Chirarattananon and Taveekun (2004), Pedrini *et al.* (2002), etc., focused on general types of buildings and not existing healthcare facilities. Whereas, studies related to energy consumption by Jenkins and Newborough (2007), Yik *et al.* (2001) focused on commercial buildings, such as hotels, and Gieseler *et al.* (2004) explored housing. Also, the studies by Yoshida *et al.* (2007), Adderley (1988), etc., were related to energy consumption of hospitals, but lacked any focus on refurbishment of existing buildings. The study by Lonnberg (2007) focused on energy saving possibilities using variable frequency drivers (VFD) for hospitals, but does not consider design and built environment of facilities; this was a key focus in this research.

Nevertheless, the extant literature concerning refurbishment projects revealed two key theories or approaches; first, the role of mechanical systems, such as HVAC plants and second, re-designing existing space with consideration to existing errors. The former approach can have a significant impact on energy consumption and IEQ, and it is a tangible process because expected savings can be quantified. However, the later approach involves re-designing existing space, for example, re-orienting buildings with respect to outdoor view, accessibility, etc., and so difficult to quantify the benefits.

8.4.2.3 Building regulations

The case studies and the survey findings revealed that there are a limited number of building regulations specifically developed for existing facilities and refurbishment. However, some approaches exist, such as development of '*Part L2B'* for refurbishment, but during the primary data collection some experts reported that some of the current regulations are out dated and further development is needed.

8.4.3 Assessment and parametric tools for refurbishment or existing facilities

In this research, efforts were made to identify tools related to refurbishment or existing facilities as explained ahead. Often tools are employed on a project, for various purposes depending on the context. However, all the participants and literature concluded a lack of approaches related to guidance on integrating tools on projects. Also, it is not clear when and how to employ available tools on a project. The interviews and survey revealed a need for a framework to integrate BIM and simulation based tools on refurbishment projects.

8.4.3.1 Assessment tools

Assessment tools include LEED, BREEAM and Greenstar. These types of tools involve assessment of design or built environment and often their scope is extended to consider social aspects or impacts due to a proposal. These types of tools are classified as qualitative tools because of their nature and approach. The investigation revealed some application of assessment tools on refurbishment projects. However, still there are challenges while implementing them, as most of them are developed for new facilities and does not consider the characteristics of existing facilities.

As explained earlier discussions about the benefits of widely accepted tools for the new facilities and consequently for existing facilities can be found. Some private organisations are developing in-house tools to assess sustainability. More often, these tools are not part of a project because clients or stakeholders think it will add towards the project cost.

8.4.3.2 Parametric tools

Parametric tools include BIM and CAD; which involve parametric modelling. Often, these types of tools develop a virtual model, using software, such as Revit Architecture, Rhino, 3D CAD and Vectorworks. Parametric tools are classified as quantitative tools because of the nature and type of data they provide. The research revealed a limited application of parametric tools on refurbishment projects. Also, more often, industry uses these kinds of tools for new developments, whereas refurbishment uses traditional methods, such as 2D drawings and on-site coordination, which involve more manual work. These kinds of tools can provide information required for various building simulation purposes.

However, although industry understands the benefits of employing parametric tools on refurbishment projects, they are not an integral part of the refurbishment projects because of a lack of information related to facilities, or because of time needed to use those tools during the early phases of projects.

8.4.3.3 Simulation based tools

Recently, there has been an increase in development and application of simulation based tools in the construction industry. They are used for new facilities and during refurbishment when there are any technical difficulties. However, the overall impression of the status of these types of tools is that they lack a capability to support refurbishment processes. In general, designers involved with the refurbishment projects are aware of and in many cases make use of some packages on a project. These packages are usually associated with CAD or general BIM, but are not an integral part of the process. Also, there is a lack of framework to integrate these types of tools on refurbishment projects. Moreover, when simulation tools are used during the refurbishment, they are used to assess the proposed design option and not to compare and then to propose a design option, which needs to be changed.

There is a considerable interest within the refurbishment sector to employ more tools; technology is available, or under development. However, the government and healthcare bodies need to promote the same and there is a need to share good practices, exemplar projects and defined approaches.

8.5 Contribution to knowledge

By assisting effective management of refurbishment challenges faced by the construction, the framework makes several key contributions. One of the main problems that inhibits refurbishment of healthcare facilities is a lack of approaches to identify risk, challenges and complexities associated with existing buildings, especially healthcare facilities (also stated by Ali *et al.*, 2009). The research contributed to the body of knowledge by linking the improved refurbishment process to performance of refurbished buildings. The main aim of the research was to improve refurbishment practices. The framework provides a comprehensive approach that helps to solve problems associated with existing buildings and enables performance to be improved.

This research has developed a framework, for improving pre-refurbishment planning, that can be used by clients on refurbishment projects. The framework comprises three elements: (i) complexity level associated with the project, (ii) decision making process during refurbishment, and (iii) modelling and simulation during refurbishment. The framework was found useful and applicable by eight experienced experts from the construction industry during validation.

Considering the focus of academies, industry and government on the development of new facilities, this research has filled a gap by providing a new approach and process for existing facilities, especially healthcare facilities. Overall, the framework helps design teams to link refurbishment with a design. It has been established that a workforce, process, and consideration of tools and drivers during refurbishment are pivotal to success of refurbishment projects. The refurbishment framework, therefore, provides strategic guidance and a tool for commissioning the projects.

8.6 Limitations

There are, however, limitations to the research described in this thesis. Healthcare facilities are complex systems; very rarely a single methodology covers all significant aspects of a building. Therefore, it was important to include a qualitative assessment. The technical facet of the calculation methodology related to energy consumption was avoided by proposing validated tools and qualitative approach. This research, like any other, had limitations and shortcomings during its conduct and in its scope. These limitations provide the basis for recommendation, discussed ahead, for future research.

- The research suffered a setback in the planned numbers and diversity of interviewees and questionnaire survey that participated during the data collection stage, which would perhaps have provided more insights and perspectives.
- The number of participants in the interviews was relatively small, which calls for cautious interpretation of the qualitative analysis.
- The research was limited to a refurbishment perspective, only from design point view; it considered the built environment, but excluded clinical and financial aspects.

8.6.1 Limitation of the framework

The first three phases proposed in this framework are significant, thus, the emphasis of this thesis is largely on Phases 1-3; this is because Phase Four relates mostly to execution, actual construction.

Although several NHS facilities are being refurbished or considered for refurbishment, the respected authorities' have limited records and learning in regards to refurbishment and available data is not easily accessible for the research community. The NHS estate, which consists of a wide range of facilities, starting from the mid 19th century to date, lacks a centrally located database on its built environment, so it can be difficult to get performance related data and all the information needed about NHS facilities. Moreover, healthcare facilities being a service oriented industry, it is difficult to find a single cause for high energy consumption and carbon emissions and this research might have missed some critical factors due to lack of information. Also, there are various types of refurbishment depending on a type and function of the building and age. Looking at the scale/size of the healthcare industry, which includes buildings built in the late 19th century to date, a three-year research project related to existing healthcare facilities is relatively brief. Hence, only existing healthcare facilities, especially built in the late 20th century, which are expected to be scheduled for refurbishment in the coming decades, are considered here. However the framework does have general relevance to all ages of existing buildings.

8.6.2 Time and resource constraints

The collection of data was a learning process in that the techniques used and research methods evolved throughout the process. The range of complex issues emerging from the primary data collection meant that there were occasions when there was no time for the interviewer to go back to issues for discussion due to pressure on the informants, especially for group interviews. Furthermore, due to limited resources, the informants early in the research could not return to for further validation (except one participant) of the findings emerging from later interviews. These may have yielded deeper insights into the issues emerging later in the study. Any further studies could address this by returning to the original informants for follow-up interviews.

8.6.3 Informants' bias and interview techniques

The subject discussed in the interviews led some participants to discuss refurbishments and projects providing in-depth details and personal viewpoints. This may have resulted in over-emphasis in the data or it may not provide balanced information. In this case, informants had to be guided carefully to ensure that the discussion remained focused on the aspects of existing facilities relevant to the research. This sometime prevented the conversation from taking its natural course.

8.6.4 Limitations in sample size for primary data collection

The findings and recommendations of this study are based upon a sample of 54 subjects, 11 of which were face-to-face interviews and eight site visits. This sample allows only tentative conclusions to be drawn, as there is a large pool of experts involved in refurbishment, most of whom were not involved here. It by no means uncovers all of the contributing factors that affect refurbishment and existing facilities, nor does it necessarily reflect the views of every expert involved with refurbishment projects in the healthcare sector. However, such limitations do not undermine the significance of the findings of the research or the potential practical implications of the proposed framework.

The author's position as an independent researcher allowed a degree of objectivity that would not be possible for an individual from the construction industry, the NHS or government. This led to deep and objective insights being gained into current refurbishment practices. However, it can be seen that there is a need to conduct a similar study across the construction sector, as the depth of the refurbishment process gained during this research has certain limitations as mentioned above. This would ensure that the theory of refurbishment practices will have wider relevance to all the possible types of refurbishment projects.

8.7 Recommendations for further research

It is important that research is continued into existing facilities and their refurbishment in the healthcare sector. A need for research related to daylight in hospitals and solar gain was reported because more daylight means maximum solar gain resulting in increasing requirements for cooling, whereas, less daylight minimises solar gains but then increases demand for heating. This research has led to many such potential areas, which require further investigation as explained below.

In the future, modelling during refurbishment will be easier with the help of laser/3D scanning of existing buildings. Also, these methodologies will help to achieve more accurate and trust worthy data related to buildings. With time, BIM will be integrated with e-construction, as most of the project information is stored in a single model and is easy to transfer from one party to another with the help of the internet, through data sharing, etc.; this needs to be explored. Also, there is a need to study how to incorporate "*open building concept/principles, adaptability*" during the refurbishment or in an existing building. Mostly, this is an untouched area and research needs to be initiated in this area.

The following recommendations, based on the limitations outlined in Section 8.6 and other related issues identified from the literature are proposed for future research. Given the huge investments in the UK healthcare sector that have an impact on current and future generations, assessing existing healthcare facilities has become imperative. Some of the key pertinent issues that need to be addressed by further research are mentioned below.

- Ascertaining the impact of existing buildings and appropriateness of current practices for these buildings; there is a definite need for a distinct approach to refurbishments.
- Exploring ways by which existing facilities can be used, measured (against performance) and enhanced in long-term through this framework.
- Exploring how to mitigate the barriers to effective learning and sharing of best practices from: a project-to-project; a scheme-to-scheme, a new development-to-development of an existing facility; and an existing facility redevelopment-to-new facilities development.
- Investigating the drivers and barriers in existing buildings during the implementation of the preferred refurbishment framework for the benefits of projects and participants, and identifying effective mitigating strategies.
- Assessing the extent to which these preferred refurbishment practices and the proposed framework facilitate meeting the sustainable healthcare construction agenda of the UK government and specific targets related to existing buildings.
- Follow-up qualitative research with the identified projects from industry, which can provide further in-depth insights.
- Technology-based solutions can be explored for capturing, processing and storing knowledge related to existing buildings and refurbishment process.

8.7.1 Recommendation for NHS

In-depth energy assessment in NHS facilities is needed and clearly development in benchmarks and targets specific to areas within NHS trusts is required. However, in the future particular studies related to existing facilities, for example, refurbishment of A&Es, PCTs, GPs, etc., should be considered. This will help to identify their characteristics, performance and to predict type of work to be conducted in the future with NHS facilities. Also, this will provide with future opportunities provided by NHS facilities. The current research in the healthcare sector needs to align with consideration to future requirements.

Throughout this research it has been highlighted that there is a lack of information related to existing hospitals, including the impact of refurbishment on healthcare facilities in the UK, which needs to be initiated. The improvements to NHS facilities are one of the key players in delivery of the health services and it has been established that built environment play a very important role in recovery of patients. The recommendations set out in this thesis are designed to support and deliver improved existing healthcare facilities.

8.7.2 Recommendations for designers

While working with existing facilities designers need to gather data related to facilities in such a way that it will be available in the future. There is a need to generate databases, which can provide information about NHS facilities and their characteristics. This will help to understand client needs, which is often difficult, because in most case client is not end user. Also, the approach towards existing facilities should be extended and not to keep limited to work related to HVAC. There are several possibilities, for example, improvement in existing layouts, re-designing of areas, better look and feel of facilities, and considerations to indoor environment quality during refurbishment. Often, designers are using 2D CAD based tools during refurbishment, however, in this research it has been established that BIM based and simulation tools can be used for refurbishment, but this should to be explored further. Designer needs to focus on improving user experience through refurbishment and to ensure errors from the past would not be repeated and are resolved. Also, while proposing any energy saving features for healthcare facilities, they should be assessed properly, especially with respect to the healthcare sector. For example, while planning the Dell Children's Hospital, in the USA, interior light shelves were not permitted because they can act as a dust collector thus spoiling internal environmental quality (Cassidy, 2010).

8.8 Closing remarks

This chapter provided a discussion and summary of the overall results, including the literature review, preliminary studies, and findings. It examines the research findings in the light of the literature review and collected data. The critical factors were discussed under their main themes; sustainability with an emphasis on energy; refurbishment of existing facilities; and assessment and parametric tools for refurbishment or existing facilities.

The selection of various design options still depend on the first cost, and not life-cycle cost and the selected options are not simulated to explore their impact on the design or contribution towards existing facilities through refurbishment. This was highlighted through primary as well as secondary studies. There have been some attempts to explore existing buildings with the help of parametric tools and simulation studies, but then those are very limited and could not provide an exemplar project or approach.

This thesis presents a framework for refurbishment of existing healthcare facilities with emphasis on improvement of their energy consumption. It addresses all the critical aspects required in performing successful refurbishment and may be used as a reference or tool in managing existing healthcare facilities and maintaining their performance.

Because these facilities are so energy intensive and varying in their characteristics, a relatively small change in energy and/or performance can lead to a significant improvement, including reduce energy consumption. Reduction in energy use shows effective management of existing buildings, lower operational cost, and indirect benefits such as reduced CO_2 emissions, better indoor environment, and improved user satisfaction.

From the above it can be seen that managing and maintaining existing buildings can help to achieve trusts/organisations' objectives and an effective answer to environmental concerns and increasing user demands in the healthcare sector. Finally, equal consideration and approaches should be given to new as well as existing facilities; resulting overall improved healthcare facilities.

REFERENCES

Adderley, A. E., O'Callaghan, P. W. & Probert, S. D. (1987) "Prospects for energy thrift in Welsh hospitals." *Applied Energy* 26: 83-96.

Adderley, A. E., O'Callaghan, P. W. & Probert, S. D. (1988) "Optimising the choice of energy-thrift measures for hospitals." *Applied Energy* 30: 153-160.

Adetunji, I. O. (2005) *Sustainable Construction: A Web-Based Performance Assessment Tool,* Leicestershire, Loughborough University.

AFUH Design (2006) *Unaccompanied Housing Design Guide*, United States Air Force.

Akhtar, J. (2010) "Research in the Discipline of General Surgery: Evidence Based Data." *Journal of Surgery Pakistan* 15: 1-2.

Alabama Hospital Association (2006) *Hospital Types*.

Ali, A. S., Kamaruzzaman, S. N. & Salleh, H. (2009) "The characteristics of refurbishment projects in Malaysia." *Facilities* 27: 56-65.

Ali, S. (1998) Research Methodology : Questionnaire Issues. Bilkent University.

American Institute of Architects (2008) *The architect's handbook of professional practice*, Wiley & Sons.

Appleby, J. (2005) "Economic Growth and NHS Spending." *Health Service Journal* 115: 23.

Aronson, J. (1994) "A Pragmatic View of Thematic Analysis." *The Qualitative Report* 2.

Atkinson, J. G. B., Jackson, T. & Mullings-Smith, E. (2009) "Market influence on the low carbon energy refurbishment of existing multi-residential buildings." *Energy Policy* 37: 2582-2593.

Augenbroe, G. (2002) "Trends in building simulation." *Building and Environment* 37: 891-902.

Azhar, S., Brown, J. & Farooqui, R. (2009) BIM-based Sustainability Analysis: An Evaluation of Building Performance Analysis Software. Alabama, Auburn University.

Azhar, S., Nadeem, A., Mok, J. Y. N. & Leung, B. H. Y. (2008) "Building Information Modeling: A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects", *First International Conference on Construction in Developing Countries*, 4-5/07/2008, Karachi, Pakistan.

Baccarini, D. (1996) "The concept of project complexity-a review." *International Journal of Project Management* 14: 201-204.

Bailey, P., Brodkin, D., Hainsworth, J., Morrow, E., Sedgwick, A., Simpson, M. & Simondetti, A. (2008) "The Virtual Building." *The Arup Journal* 2: 15-25.

Balaras, C. A., Dascalaki, E. & Gaglia, A. (2007) "HVAC and indoor thermal conditions in hospital operating rooms." *Energy and Buildings* 39: 454-470.

Balaras, C. A., Droutsa, K., Argiriou, A. A. & Asimakopoulos, D. N. (2000) "EPIQR surveys of apartment buildings in Europe." *Energy and Buildings* 31: 111-128.

Barista, D. (2007) *Early BIM adopters are receiving a windfall of healthcare work*, Building Design and Construction.

Barlow, S. & Fiala, D. (2007) "Occupant comfort in UK offices--How adaptive comfort theories might influence future low energy office refurbishment strategies." *Energy and Buildings* 39: 837-846.

Basit, T. N. (2003) "Manual or electronic? The role of coding in qualitative data analysis." *Educational Research* 45: 143-154.

Battersby, M. E. (2008) Is it a repair, or a capital expense? *DVM Newsmagazine.*

Baum, J. A. C. (Ed.) (2005) *Companion to Organizations*, The Blackwell.

BBC News (2007) NHS repairs 'backlog' hits £4bn. *BBC Health.*

Berger, G. (2007) *Sustainability Impact Assessment: Approaches and applications in Europe,* Vienna, Austria, European Sustainable Development Network.

Bizzarri, G. & Morini, G. L. (2006) "New technologies for an effective energy retrofit of hospitals." *Applied Thermal Engineering* 26: 161-169.

Bloor, M. & Wood, F. (2006) *Keywords in Qualitative Methods,* London, SAGE.

Bolboaca, S. D. (2009) Data Analysis with Microsoft Excel & Results presentation with Microsoft Powerpoint. Academicdirect.

Boswell, I. (2008) *Anticipating Change, Flexible Hospitals: Interlocking strategy and estate planning,* London, London South Bank University.

Bourke, K., Ramdas, V., Singh, S., Green, A., Crudgington, A. & Mootanah, D. (2005) *Achieving whole life value in infrastructure and buildings,* London, BRE.

Bovey, T. (2008) How BIM helped a hospital go green. Healthcare design and construction

Brewer, R. C. (2007) *Your PhD Thesis* London.

Brinkmann, S. & Kvale, S. (2009) *Interviews: An Introduction to Qualitative Research Interviewing,* Los Angeles, SAGE.

Bristol, N. (2007) "USA health-care providers go green." *The Lancet* 369: 453-454.

Bryman, A. (2004) *Social Research Methods,* Oxford, Oxford University Press.

Burgess, J. C., Barbier, E. B., Neil, J. S. & Paul, B. B. (2001) Sustainable Development. *International Encyclopaedia of the Social & Behavioral Sciences.* Oxford, Pergamon.

Burstein, F., Holsapple, C., Seref, M. & Ahuja, R. (2008) Spreadsheet-Based Decision Support Systems. In Bernus, P., Błażewics, J., Schmidt, G. & Shaw, M. (Eds.) *Handbook on Decision Support Systems 1.* Springer Berlin Heidelberg.

Burton, R., Ellis, J., Moss, R., Pollock, R., Prasad, S., Priestman, J., Senior, P. & Trant, K. (2002) *Advice,* Design Brief Working Group, NHS Estates, Department of Health, NHS Estates.

Burton, S. & Kesidou, S. (2005) "Refurbishment of old buildings for sustainable use", *Passive and Low Energy Cooling for the Built Environment*, 19-21/05/2005, Santorini, Greece.

Caccavelli, D. & Genre, J. L. (2000) "Diagnosis of the degradation state of building and cost evaluation of induced refurbishment works." *Energy and Buildings* 31: 159-165.

Caccavelli, D. & Gugerli, H. (2002) "TOBUS - a European diagnosis and decision-making tool for office building upgrading." *Energy and Buildings* 34: 113-119.

CADDET (2005) *Energy efficiency in hospitals,* Sittard, The Netherlands, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies.

Carbon Trust (2008) *Low Carbon Refurbishment for buildings* London, Carbon trust.

Carr, R. F. (2008) *Hospital*, Whole Building Design Guide

Carr, R. F. (2010) *Health Care Facilities*, WBDG.

Carvalho, L., Scott, L. & Jeffery, R. (2005) "An exploratory study into the use of qualitative research methods in descriptive process modelling." *Information and Software Technology* 47: 113-127.

Cassidy, R. (2010) America's Greenest Hospital. *Building Design and Construction.*

Centre for Healthcare Design (2002) *Better health buildings,* Leeds, UK, NHS Estate, Department of Health

Cheng, T. (2009) "Meta-modeling for model-based system design." *Design & Test of Computers, IEEE* 26: 2-2.

Chirarattananon, S. & Taveekun, J. (2004) "An OTTV-based energy estimation model for commercial buildings in Thailand." *Energy and Buildings* 36: 680-689.

Chlela, F., Husaunndee, A., Inard, C. & Riederer, P. (2009) "A new methodology for the design of low energy buildings." *Energy and Buildings* 41: 982-990.

Chwieduk, D. (2003) "Towards sustainable-energy buildings." *Applied Energy* 76: 211-217.

Cinquemani, V. (2009) *BREEAM Healthcare,* Watford, UK, BRE.

Clarke, J. A. & Maver, T. W. (1991) "Advanced design tools for energy conscious building design: Development and dissemination." *Building and Environment* 26: 25-34.

Cooper, J. (2008) Creating efficiencies with building information modelling. Healthcare Design

Corbin, J. & Strauss, A. (1990) *Basics of Qualitative Research: Grounded Theory Procedures and Techniques,* Newbury Park, CA, Sage.

Cyon (2003) *The Building Information Model: A Look at Graphisoft's Virtual Building Concept,* Ethesda, MD, A Cyon Research.

Dainty, A. R. J. (1998) *A Grounded Theory of the Determinants of Woman's Under-achievement in Large Construction Companies,* Loughborough, Loughborough University.

Dascalaki, E. G., Gaglia, A. G., Balaras, C. A. & Lagoudi, A. (2009) "Indoor environmental quality in Hellenic hospital operating rooms." *Energy and Buildings* 41: 551-560.

Dascalaki, E. G., Lagoudi, A., Balaras, C. A. & Gaglia, A. G. (2008) "Air quality in hospital operating rooms." *Building and Environment* 43: 1945-1952.

Davies, D. (2009) "Refurbishing buildings will play a vital part in meeting carbon targets " *Modern Building Services* 6: 18-19

Davis, M., Reibnitz, C. v. & Mankelow, G. (2008) *Sustainable Development Action Plan 2007-08,* London Department for Communities and Local Government.

Davis, R. (2009) *What makes a good process?*, BPTrends.

De Wilde, P., Augenbroe, G. & van der Voorden, M. (2002) "Design analysis integration: supporting the selection of energy saving building components." *Building and Environment* 37: 807-816.

DEFRA (2007) *Draft Strategy for Sustainable Construction*, DEFRA.

Department of Health (2000) *The NHS Plan: a Plan for Investment, a Plan for Reform,* London, The Stationary Office.

Dey, I. (1993) *Qualitative Data Analysis: A User Friendly Guide for Social Scientists,* London, Routledge.

Dickerman, K. N. & Barach, P. (2008) "Designing the Built Environment for A Culture and System of Patient Safety – A Conceptual, New Design Process." *Advances in Patient Safety* 2.

Directive Implementation Advisory Group (DIAG) (2006) *Part L Review / EPBD Implementation - Collation of Consultation Issues*.

Dix, T. (2009) Bird's Nest Stadium and Revit. *CIBSE National Conference.* London, CIBSE.

Doran, D., Douglas, J. & Pratley, R. (2009) *Refurbishment and Repair in Construction,* Scotland Whittles Publishing.

Dunsdon, A., Day, A. & Jones, P. (2006) "Towards a computer based framework to support the low carbon building design process." *International Journal of Low-Carbon Technologies* 1: 355-371.

Easterby-Smith, M. & Lyles, M. A. (2003) *The Blackwell Handbook of Organizational Learning and Knowledge Management*, Blackwell.

Ecclest, P. (2007) "NHS needs to tackle energy consumption", *Telegraph*, 22/06/2007, Available online at http://www.telegraph.co.uk/earth/earthnews/3298222/NHS-needs-to-tackle-energy-consumption.html [accessed on 06/08/2009].

Ellis, M. W. & Mathews, E. H. (2001) "A new simplified thermal design tool for architects." *Building and Environment* 36: 1009-1021.

Fangting, S., Yi Jiang, Anne Le Mouel, Jean-Jacques Roux (2007) "Development of a data model for energy consumption analysis and prediction of large scale commercial buildings." *Building Simulation 2007*.

Fayad, M. E., Johnson, R. E. & Schmidt, D. C. (1999) *Building Application Frameworks,* New York, Wiley.

Fellows, R. F. & Liu, A. M. M. (2008) *Research Methods for Construction*, Wiley-Blackwell.

Fenwick, S. (2008) Seizing the moment. *Coal.* Tradeship Publication Ltd.

Fitzgerald, B. & Howcroft, D. (1998) "Towards Dissolution of the IS Research Debate: From Polarisation to Polarity." *Journal of Information Technology* 13: 313-326.

Forsberg, A. & Von Malmborg, F. (2004) "Tools for environmental assessment of the built environment." *Building and Environment* 39: 223-228.

Forza, C. (2002) "Survey research in operations management: a process-based perspective." *International Journal of Operations & Production Management* 22: 152-194.

Fricker, A. (1998) "Measuring up to Sustainability." *Futures* 30: 367-375.

Frumkin, H., Coussens, C., (2007) Green Healthcare Institutions: Health, Environment, and Economics, Workshop Summary. National Academies Press.

Gallaher, M. P., O'Connor, A. C., Dettbarn, J. L. & Gilday, L. T. (2004) *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry,* Gaithersburg, MD, National Institute of Standards and Technology.

Gangemi, V., Malanga, R. & Ranzo, P. (2000) "Environmental management of the design process." *Renewable Energy* 19: 277-284.

Gann, D., Salter, A. & Whyte, J. (2003) "Design Quality Indicator as a tool for thinking." *Building Research and Information* 31: 318-333.

Gann, D. & Whyte, J. (2003) "Design quality, its measurement and management in the built environment." *Building Research & Information* 31: 314 - 317.

Genre, J. L., Flourentzos, F. & Stockli, T. (2000) "Building refurbishment: habitat upgrading." *Energy and Buildings* 31: 155-157.

Gesler, W., Bell, M., Curtis, S., Hubbard, P. & Francis, S. (2004) "Therapy by design: evaluating the UK hospital building program." *Health & Place* 10: 117-128.

Gieseler, U. D. J., Heidt, F. D. & Bier, W. (2004) "Evaluation of the cost efficiency of an energy efficient building." *Renewable Energy* 29: 369-376.

Gill, J. & Johnson, P. (1991) *Research methods for managers,* London, Paul Chapman.

Glaser, B. G. & Strauss, A. L. (1967) *The Discovery of Grounded Theory: strategies for qualitative research,* New Jersey, Transaction.

HaCIRIC (2010) *What is HaCIRIC?*, Available online at http://haciric.org/about-us [accessed on 12/05/2010].

Han, L. B. (2005) *Building Smart - A Strategy for Implementing BIM Solution in Singapore,* Singapore.

Hancock, T. (1999) "Creating health and health promoting hospitals: a worthy challenge for the twenty-first century." *Health Care Quality Assurance incorporating Leadership in Health Services* 12: viii–xix.

Harputlugil, G. U., Hopfe, C. J., Struck, C. & Hensen, J. (2006) "Relation between design requirements and building performance simulation", *1st Internation CIB Student Chapters Postgraduate Conference "Built Environment and Information Technologies"*, 16-18/03/2006, Ankara.

Harriss, C. (1998) "Why research without theory is not research A reply to Seymour, Crook and Rooke." *Construction Management and Economics* 16: 113 - 116.

Hecht, L. (2008) A Sustainable Building Industry Requires Service-Based BIM. Vector 1.

Heng, K. (2003) *Energy Performance, Energy Efficiency & Commercial Buildings: How do they all link up?,* Lund, Sweden, The International Institute for Industrial Environmental Economics.

Henk, I., Zeel, H. V. & Bnsp, B. B. (2009) "The architecture of quality performance based quality checking of virtual' design and as build' prototype in BIM", *Changing Roles, new roles, new challenges* 2-5/10/2009, The Netherlands.

Higgs, S. C. & Stokes, D. Z. (2008) *BIM: It's not all just hype*, Healthcare design.

Hill, M. (2007) *Interoperability in the Construction Industry,* New York, McGrow Hill Construction

Holtz, M. J. (2005) *Sustainable Rating Systems and Healthcare Facilities*, Available online at http://www.archenergy.com/library/publications//white%20paper%20-%20healthcare%20facilities.pdf [accessed on 08/03/ 2008].

Hong, S. H., Oreszczyn, T. & Ridley, I. (2006) "The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings." *Energy and Buildings* 38: 1171-1181.

Hoover, S. & Schubert, N. (2007) "BIM Changes the Culture of Design and Construction." *FMI Corporation* 1: 104-115.

Howell, I. & Batcheler, B. (2004) *Building Information Modelling Two Years Later*, Newforma.

Huang, Y. C., Lam, K. P. & Dobbs, G. (2008) "A Scalable Lighting Simulation Tool for Integrated Building Design", *Third National Conference of IBPSA-USA*, 01/08/2008, Berkeley, California.

Huberman, M. A. & Miles, M. B. (2002) *The Qualitative Researcher's Companion,* London, Sage Publications.

Ibrahim, A. D. (2007) *Development of a Continuous Improvement Framework for the Procurement of Primary Health Care Facilities,* Loughborough, Loughborough University.

Islam, A. & Panda, K. C. (2007) "Web-based information retrieval trends of researchers." *The Electronic Library* 25: 757-765.

Jaggs, M. & Palmer, J. (2000) "Energy performance indoor environmental quality retrofit -- a European diagnosis and decision making method for building refurbishment." *Energy and Buildings* 31: 97-101.

Jeffreys, B. (2009) *NHS 'faces huge budget shortfall'*, *BBC News health correspondent*, Available online at http://news.bbc.co.uk/1/hi/health/8091427.stm [accessed on 15/07/ 2010].

Jenkins, D. & Newborough, M. (2007) "An approach for estimating the carbon emissions associated with office lighting with a daylight contribution." *Applied Energy* 84: 608-622.

Jochelson, K. (2003) *Building a sustainable and healthy NHS?*, Kings Fund

Joseph, A. (2006) "The impact of the environment on infections in healthcare facilities." *The Center for Health Design* 2006: 2-18.

Juan, Y. K., Kim, J. H., Roper, K. & Castro-Lacouture, D. (2009) "GA-based decision support system for housing condition assessment and refurbishment strategies." *Automation in Construction* 18: 394-401.

Kagioglou, M., Cooper, R., Aouad, G. & Sexton, M. (2000) "Rethinking construction : the generic design and construction process protocol." *Engineering, Construction and Architectural Management* 7: 141-153.

Kaklauskas, A., Zavadskas, E. K. & Raslanas, S. (2005) "Multivariant design and multiple criteria analysis of building refurbishments." *Energy and Buildings* 37: 361-372.

Kapoor, P., Harrington, C., Church, C., Gale, T., Tan, P., Abou-Zaki, A. & McCarthy, B. (2006) "Guide to Sustaining Existing Tower Blocks in the UK", *Comfort and Energy use in Buildings*, 30/04/2006, London.

Karolides, A. (2005) *Design for Health,* Snowmass, Rocky Mountain Institute.

Kibert, C. (2007) "The next generation of sustainable construction." *Building Research and Information* 35: 595-601.

Kirst, P. (2008) *Supplier switching management*, Cuvillier Verlag Gottingen.

Knight, A. & Ruddock, L. (2008) *Advanced Research Methods in The Built Environment*, Wiley-Blackwell.

Lai, E., Lundie, S. & Ashbolt, N. J. (2008) "Review of multi-criteria decision aid for integrated sustainability assessment of urban water systems." *Urban Water Journal* 5: 315-327.

Lain, M., Hensen, J. & Zmrhal, V. (2009) "Computer simulation for better design and operation of large office building air-conditioning", *Eleventh International IBPSA Conference* 27-30/07/2009, Glasgow, Scotland.

LANL (2008) *Chapter Two. Whole Building Design*, EERE.

Leahy, J. (2004) Using Excel for Analyzing Survey Questionnaires. University of Wisconsin-Extension.

Lee, Y. C. & Gilleard, J. D. (2002) "Collaborative design: a process model for refurbishment." *Automation in Construction* 11: 535-544.

Levy, Y. & Ellis, T. J. (2006) "A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research." *Informing Science* 9: 181-212.

Lister, S. (2004) NHS is world's biggest employer after Indian rail and Chinese Army. The Timesonline.

Lonnberg, M. (2007) "Variable Speed Drives for energy savings in hospitals." *World Pumps* 2007: 20-24.

Love, P. E. D., Holt, G. D. & Li, H. (2002) "Triangulation in construction management research." *Engineering Construction and Architectural Management* 9: 294-303.

Macpherson, S. J., Kelly, J. R. & Webb, R. S. (1993) "How designs develop: Insights from case studies in building engineering services." *Construction Management and Economics,* 11: 475-485.

Maile, T., Fischer, M. & Bazjanac, V. (2007) *Building Energy Performance Simulation Tools,* Stanford, Center for Integrated Facility Engineering.

Manning, R. & Messner, J. (2008) "Case studies in BIM implementation for programming of healthcare facilities." *ITcon* 13: 246-257.

Manor College (2006) What is Empirical Research?

Martinaitis, V., Rogoza, A. & Bikmaniene, I. (2004) "Criterion to evaluate the "twofold benefit" of the renovation of buildings and their elements." *Energy and Buildings* 36: 3-8.

Mason, M. (2010) "Sample Size and Saturation in PhD Studies Using Qualitative Interviews." *Forum: Qualitative Social Research* 11.

Matthiessen, L., F., Peter Morris (2004) Costing Green: A comprehensive cost data Base and Budgeting methodology. Davis Langdon.

Mazzarella, L. & Pasini, M. (2009) "Building Energy Simulation and Object-Oriented Modelling: Review and Reflections Upon Achieved Results and Further Developments", *Building Simulation*, 27-30/07/2009, Glasgow, Scotland.

McKahan, D. (1999) Healthcare facilities: Current trends and future forecasts. CNY Business Journal

McKahan, D. (2006) *Emerging Trends & Successful Strategies for the Planning and Design of Healthcare Facilities*, The American College of Healthcare Architects.

Michael, J. H. (2005) *Sustainable Rating Systems and Healthcare Facilities*, Available online at http://www.archenergy.com/library/publications//white%20paper%20-%20healthcare%20facilities.pdf [accessed on 08/03/ 2008].

Mickaityte, A., Zavadskas, E. K., Kaklauskas, A. & Tupenaite, L. (2008) "The Concept Model of Sustainable Buildings Refurbishment." *International Journal of Strategic Property Management* 12: 53-68.

Milburn, A. (2004) Building a Better Patient Environment. In CABE (Ed.) *Good design is a commitment to a better quality of life for all.* Leeds, Centre for Healthcare Design.

Morel, N. & Faist, A. (1993) "Design tools for building thermal analysis: The significance of integration." *Building and Environment* 28: 465-473.

Neto, A., Hernandez., Flávio Augusto Sanzovo Fiorelli (2007) "Use of simulation tools for mamaging buildings energy demand", *Building Simulation 2007*, Sao Paulo, Brazil.

New Economics Foundation (2007) NHS must act to tackle climate change. New Economics Foundation

NHS (2009) About the NHS. NHS Choices.

NHS (2010a) Community Hospitals (Local Hospitals). NHS Evidence - health management

NHS (2010b) Resources for carbon reduction - Energy, Travel and Procurement. Sustainable Development Unit.

NHS Cambridgeshire (2010) *A Sustainability Strategy for NHS Cambridgeshire 2010 to 2015,* Cambridge, NHS.

NHS Scotland (2007) Architecture + Design Scotland Healthcare Design Assessment.

NHS SDU (2010) *NHS England Carbon Footprint: GHG emissions,* Stockholm, NHS.

Oberlin, J. (2008) BIM use in healthcare. Healthcare design.

Oliver, P. (2004) *Writing Your Thesis*, Sage.

Olofsson, T., Meier, A. & Lamberts, R. (2004) "Rating the Energy Performance of Buildings." *The International Journal of Low Energy and Sustainable Buildings* 3.

Omer, A. M. (2008) "Renewable building energy systems and passive human comfort solutions." *Renewable and Sustainable Energy Reviews* 12: 1562-1587.

Oseland, N. (2007) *Post-Occupancy Evaluation,* London, British Council for Offices.

PAHO (2000) *Principles of Disaster Mitigation in Health Facilities,* Washington, D.C., Pan American Health Organization, World Health Organization.

Pan, Y., Yin, R. & Huang, Z. (2008) "Energy modeling of two office buildings with data center for green building design." *Energy and Buildings* 40: 1145-1152.

Payne, H. & May, D. (2009) "Evaluation of a refurbishment scheme incorporating the King's Fund "Enhancing the Healing Environment" design principles." *Journal of Facility Management* 7: 74-89.

Pearce, D., Markandya, A. & Barbier, E. (1990) "Blueprint for a green economy." *Long Range Planning* 23: 127-127.

Pedrini, A., Westphal, F. S. & Lamberts, R. (2002) "A methodology for building energy modelling and calibration in warm climates." *Building and Environment* 37: 903-912.

Pelikan, J. M. (2007) "Making the hospital a more effective agent for individual and public health by implementing the comprehensive vision of HPH", *15th HPH IC* 12/04/2007, Vienna.

Pelikan, J. M., Krajic, K. & Dietscher, C. (2001) "The Health Promoting Hospital (HPH): Concept and development." *Patient Education and Counselling* 45: 239-246.

Pendry, M. (2009) *BREEAM Healthcare* London, Gleeds.

Penoyre, G. & Prasad, S. (2006) *Refurbishment Feasibility Report,* Dulwich, London, Southwark PCT.

Perry, M. (2007) *NHS overview: Energy*, NHS.

Popov, V., Juocevicius, V., Migilinskas, D., Ustinovichius, L. & Mikalauskas, S. (2009) "The use of a virtual building design and construction model for developing an effective project concept in 5D environment." *Automation in Construction* 19: 357-367.

Pushkar, S., Becker, R. & Katz, A. (2005) "A methodology for design of environmentally optimal buildings by variable grouping." *Building and Environment* 40: 1126-1139.

Randolph, J. J. (2009) "A Guide to Writing the Dissertation Literature Review." *Practical Assessment Research and Evaluation* 14: 1-12.

Rao, S. K. M. (2004) "Designing Hospital for better Infection Control : an Experience." *MJAFI* 60.

Reiling, J. (2006) "Safe design of healthcare facilities." *Quality and Safety Health Care* 15: 34-40.

Ren, M. J., Cotton, M., Brown, K. & Palme, G. (2007) "Meeting the current and future UK challenges for sustainable building designs", *Building Simulation 2007*, 03-06/09/2007, Beijing, China.

Revit (2007) *BIM and Facilities Management* Autodesk.

Roderick, Y., McEwan, D., Wheatley, C. & Alonso, C. (2009) "Comparison of energy performance assessment between LEED, BREEAM and Green Star", *Eleventh International IBPSA Conference*, 27-30/07/2009, Glasgow, Scotland.

Romm, J. (2008) *The Green Building Imperative: Understanding the Impact of Workplaces on the Environments*, Center for Energy and Climate Solutions.

Rorarius, J. (2007) *Existing Assessment Tools and Indicators,* Finland, Finland's Ministry of the Environment.

Roulet, C. A. (2001) "Indoor environment quality in buildings and its impact on outdoor environment." *Energy and Buildings* 33: 183-191.

Ruikar, K. D. (2004) *Business Process Implications of E-commerce in Construction Organisations,* Loughborough, Loughborough University.

Rutter, B. G. (1996) "Environmental design technologies: designing the ergonomically correct medical environment", *the Eighth Symposium on Healthcare Design*, 16-19/11/1996, San Diego, California.

Sanguinetti, P., Eastman, C. & Augenbroe, G. (2009) "Courthouse energy evaluation", *11th International IBPSA Conference*, 27-30/07/2009, Glasgow.

Santamouris, M., Dascalaki E., Balaras C., Argiriou A., Gaglia A. (1994) "Energy performance and energy conservation in health care buildings in Hellas." *Energy Conversion and Management* 35: 293-305.

Sapsford, R. & Jupp, V. (1996) *Data Collection and Analysis,* London, Sage Publications.

Sarshar, M., Hutchinson, A., Aouad, G., Barrett, P., Minnikin, J. & Shelley, C. (1998) Standardised Process Improvement for Construction Enterprises (SPICE). *SPICE.* Salford, University of Salford.

Schenkel, C. (2009) LEED for health care: Worth it? , Cleantech.

Schoenleber, B. (2003) *Manatee County Florida Green building strategies: Hospital Construction project* Florida Manatee county.

Scholte, N. & Rich, P. (2010) *Sustainable Development Action Plan including Carbon Reduction Strategy*, Building Services Authority

Seidel, J. V. (1998) Qualitative Data Analysis. *The Ethnograph v4.* Salt Lake, Qualis Research.

Seppanen, O. (2009) *Empirical research on the success of production control in building construction projects,* Helsinki, Helsinki University of Technology.

Seymour, D., Crook, D. & Rooke, J. (1997) "The role of theory in construction management: a call for debate." *Construction Management and Economics* 15: 117 - 119.

Sheely, B. (2008) The Future Is Now: 2005 Planning Design and Construction Conference AIA.

Sheth, A. Z., Price, A. D. F. & Glass, J. (2010a) "BIM and refurbishment of existing healthcare facilities", *26th Annual ARCOM Conference*, 6-8/09/2010, Leeds.

Sheth, A. Z., Price, A. D. F. & Glass, J. (2010b) "Existing Healthcare Facilities, Refurbishment, and Energy Simulation", *The Constructed Environment*, 17-19/11/2010, Venice, Italy.

Sheth, A. Z., Price, A. D. F. & Glass, J. (2010c) "A framework for refurbishment of healthcare facilities", *HaCIRIC 2010 International Conference Better healthcare through better infrastructure*, 23-24/09/2010, Edinburgh.

Sheth, A. Z., Price, A. D. F., Glass, J. & Achour, N. (2008) "Reviewing the sustainability of existing healthcare facilities", *24th Annual ARCOM Conference*, 01-03/09/2008, Cardiff, Wales.

Shi, Q. (2008) "Strategies of Implementing a Green Building Assessment System in Mainland China." *Journal of Sustainable Development* 1: 13-17.

SHINE (2008) What are Sustainable Healthcare Buildings.

Short, A. (2005) "Healthcare Design for the Future." *Business Briefing: Hospital Engineering and Facilities Management* 2005 1-4.

Siller, T., Kost, M. & Imboden, D. (2007) "Long-term energy savings and greenhouse gas emission reductions in the Swiss residential sector." *Energy Policy* 35: 529-539.

Sitar, M. & Krajnc, K. (2006) "The Existing Housing Stock - New Renovation Possibilities; A Case of Apartment building Renewal in Maribor", *Housing in an expanding Europe: theory, policy, participation and implementation (ENHR)*, Slovenia.

Smith, J. (1984) "Idea and designs II: harness and nucleus." *British Medical Journal* 289: 1513-1516.

Smith, R. F. (2003) "Emory's LEED-EB Pilot Project at Goizueta Business School", *National Conference on Building Commissioning*, 20-22/05/2003, USA.

Stanger, C. (2003) *Construction Best Practices,* Watford, Department of Trade and Industry.

Succar, B. (2009) "Building information modelling framework: A research and delivery foundation for industry stakeholders." *Automation in Construction* 18: 357-375.

Susman, G. I. & Evered, R. D. (1978) "An Assessment of the Scientific Merits of Action Research " *Administrative Science Quarterly* 23: 582-603.

Sustainable Building (2007) Sustainable refurbishment versus demolition. Newzeye Ltd.

Sustainable Development Unit (2008) *NHS Carbon Reduction Strategy for England,* Cambridge, NHS SDU.

Swetnam, D. & Swetnam, R. (2007) *Writing Your Dissertation,* Oxford Spring Hill House.

Tesch, R. (1990) *Qualitative Research: Analysis Types and Software Tools,* London, Routledge.

The Carbon Account (n.d.) *What are carbon emissions?*, Available online at http://www.thecarbonaccount.com/carbonexplained/ [accessed on 28/11/ 2009].

Thomas, D. R. (2006) "A General Inductive Approach for Analyzing Qualitative Evaluation Data." *American Journal of Evaluation* 27: 237-246.

Tuan-Fang, F., Churn-Jung, L. & Tsau-Young, L. (2007) "Positional Analysis in Fuzzy Social Networks", *Granular Computing*, 2-4/11/2007, San Jose, California.

Turrent, D. (2007) *Sustainable Architecture* London, RIBA.

Vakili, A., Ardebili, Abdel Halim Boussabaine (2007) "Creating Value through Sustainable Building Design." *Architectural Engineering and Design Management* 03: 83-92.

Van der Flier, K. & Thomsen, A. (2005) "Sustainable housing transformation Best practice evaluation of the 10th National renovation award", *XXXIII IAHS World Congress on Housing*, 27-30/09/2005, Pretoria, South Africa.

Van, H. H. (2009) "The architecture of quality performance based quality checking of virtual' design and as build' prototype in BIM", *Changing Roles, new roles, new challenges* 2-5/10/2009, The Netherlands.

Vittori, G. (2002) Green and Healthy Buildings for the Health Care Industry. *CleanMed 2002.* Austin, Texas, Centre for Maximum Potential Building Systems.

Vivian, L., Hartkopf, V., Poh, L. K., Snyder, M., Hua, Y., Gu, Y., Choi, J. & Yang, X. (2006) "Sustainability and Health are Integral Goals for the Built Environment", *Healthy Buildings*, 4-8/06/2006, Lisbon, Portugal.

Wagenaar, C., Swaan, A. d., Verderber, S., Jencks, C. & Betsky, A. (2006) The Architecture of Hospitals. NAi.

Waters, J. R. (2003) *Energy Conservation in Buildings: A Guide to Part L of the Building Regulations* London, Wiley-Blackwell.

Webb, T. (2010) "Heavy industry claims carbon emission targets are 'death by a thousand cuts'", *Guardian*, Available online at http://www.guardian.co.uk/business/2010/apr/11/manufacturing-carbon-emmissions-pollution [accessed on 28/09/2010].

Wendt, A. (2008) Healthcare May Take LEED in New Directions. *The Magazine of Sustainable Design.* Green Source.

Wilkinson, S. J. & Reed, R. G. (2006) "Office building characteristics and the links with carbon emissions." *Emerald* 24: 240-251.

Wilson, A. (2009) "Existing Buildings are the Key to Meeting Carbon targets." *Modern Building Services* 6: 14-16.

Wittchen, K. B. & Brandt, E. (2002) "Development of a methodology for selecting office building upgrading solutions based on a test survey in European buildings." *Energy and Buildings* 34: 163-169.

Yan-chuen, L., Phil, M. & Gilleard, J. D. (2000) "Refurbishment of building services engineering systems under a collaborative design environment." *Automation in Construction* 9: 185-196.

Yang, J., Shen, G. Q., Ho, M., Drew, D. S. & Xue, X. (2010) "Stakeholder management in construction: An empirical study to address research gaps in previous studies." *International Journal of Project Management* In Press, Corrected Proof: 1-11.

Yik, F. W. H., Burnett, J. & Prescott, I. (2001) "Predicting air-conditioning energy consumption of a group of buildings using different heat rejection methods." *Energy and Buildings* 33: 151-166.

Yin, R. K. (2009) *Case Study Research Design and Methods,* London, SAGE.

Yoshida, S., Ito, K. & Yokoyama, R. (2007) "Sensitivity analysis in structure optimization of energy supply systems for a hospital." *Energy Conversion and Management* 48: 2836-2843.

Young, N. W., Jones, S. A. & Bernstein, H. M. (2007) *Interoperability in the Construction Industry,* New York, McGram Hill Construction.

APPENDIX A LIST OF PUBLICATIONS AS PART OF THIS RESEARCH

Table A.1. List of publications

Title	Key output	Reference
Journal papers		
A Framework and Parametric Tools to Facilitate Refurbishment Healthcare Facilities (in press)	A conceptual framework for refurbishment is presented. A pilot study based on BIM and energy simulation is also presented.	The international journal of Constructed Environment
Healthcare Refurbishments Aim, Objectives and Process through Case studies (under review)	Aims and objectives for healthcare facilities refurbishment.	Emerald_ Facilities Management Journal
Conference papers		
Reviewing the Sustainability of Existing Healthcare Facilities	Sustainability drivers and various strategies for the healthcare	Sheth *et al.* (2008)
BIM and Refurbishment of Existing Healthcare Facilities	Consideration to BIM, simulation for existing facilities & refurbishment process from industry	Sheth *et al.* (2010a)
Existing Healthcare Facilities, Refurbishment, and Energy Simulation	Pilot study implementing BIM and simulation for existing facilities	Sheth *et al.* (2010b)
A framework for Refurbishment of Healthcare Facilities	Conceptual framework and key components	Sheth *et al.* (2010c)
Targeted papers		
The Barriers for Refurbishment of Healthcare Facilities	Challenges to existing facilities and possible solutions	Summer 2011
Adaptability of Existing Healthcare Facilities through Refurbishment, Reconfiguration and Modernisation	The level of adaptability of existing healthcare facilities and possibilities through refurbishment are discussed	Summer 2011
Types of Refurbishments and Drivers in Existing Healthcare Facilities	Drivers and typologies related refurbishments are presented	Summer 2011

APPENDIX B SUSTAINABILITY INITIATIVES TAKEN BY THE GOVERNMENT

Table B.1. Initiative taken by the government towards sustainability

(Source: Davies **et al.** ***2008)***

Design	Innovation
60 per cent of PFI project exceeding £1 million to use DQI or equivalent by end of 2008	Increase the current 55% '*innovation active*' enterprises in the sector by 5%, to match and then track the benchmark for all UK enterprises
20% of all project exceeding £1 million should use DQI and BREEAM or equivalent and achieve an excellent rating, by end of 2008	A 10% increase in the number of enterprises in the sector taking up UK and European innovation support products and schemes by 2012
100% of construction new build projects on Government estate will meet BREEAM excellent standard (or equivalent).	Government updated list in Quick Wins (environmental product standards) in 2007

Table B.2. Initiative taken by the government towards sustainability

	Environment Protection	
Health & Safety	**Climate Change**	**Water**
Reduce the incidence rate of fatal and major injury accidents by 10% from 2000 levels by 2010	All new homes to be zero carbon by 2016, with building regulations locking in improvements in 2010 and 2013	All new homes meet Level 3 of the Code for Sustainable Homes (105 litres per person per day) from April 2008
Reduce the incidence rate of cases of work-related ill health by 20% from 2000 levels by 2010	By 2010 the general level of energy efficiency of residential accommodation in England to be increased by at least 20 per cent compared with the general level of such energy efficiency in 2000	Amendments to be made in 2008 to the Building Regulations considering whole building performance standard for new homes, to be set at a target level of 125 litres/head/day
Reduce the number of working days lost per 100,000 workers from work related injury and ill health by 30% by 2010	All new homes to achieve a 25% improvement in terms of carbon emissions from 2008 as per the Code for Sustainable Homes	DEFRA to review the Water Supply (Water Fittings) Regulations 1999 in 2008

	Introduction of EPC Energy Performance Certificates for all homes (on construction, sale or rent) to be phased in from August 2007 for 4 bedroom houses	A reduction in water consumption to an average of 3 cubic metres per person per year for all new office builds or major office refurbishments on the Government Estate
	Reduce carbon emissions on the central Government office estate by 12.5% and 30% by 2010 and 2020 respectively	Reduce water consumption by 25% on the office and non-office estate by 2020 relative to 2004/5 levels
	Central Government's office estate to be carbon neutral by 2012	Public consultation on options for ownership and adoption of Sustainable Drainage Systems
	Departments to increase their energy efficiency per square metre by 15% by 2010 and 30% by 2020	
	Action plan to reduce carbon emissions from new commercial buildings within the next 10 years	
	Mandatory rating against the Code for Sustainable Homes for every new home from 2008	

Table B.3. Initiative taken by the government towards sustainability

People	**Sustainable Consumption**		**DoH SD Action plan for 2007-08**
Skills	**Waste**	**Materials**	
Increase the number of Construction Skills Certification Scheme card holders to 1.6 million by 2010, and to 2.0m by 2015	By 2012 a 50% reduction of construction, demolition and excavation waste to landfill compared to 2005	Proposed 50% of products with type III Environmental Product Declarations by 2010	Highlight the profile of sustainable development in DOH

Ensure the content of all qualifications are reviewed, and where appropriate include sustainability components and provide skills necessary to apply the latest technologies, by 2010	By 2015, zero net waste, at construction site level	Proposed 50% of buildings and construction schemes over £1 million in value using stewardship and responsible sourcing principles by 2010	Set out the SD principals for DoH
Provision of work experience places to increase to 16,000 by 2010 and to 20,500 by 2015	By 2020, zero waste to landfill		Action to contribute to defined goals
All domestically trained and competent construction workers to be still involved in the industry after 5 years - target achievement by 2010, and for 10 years - target achievement date 2015			Define SMART (specific, measurable, agreed, realistic, and time-based) targets for DOH
			Outline benefits realisation plan
			Development of Good corporate citizen assessment tool
			Produce an outline delivery plan addressing potential activity
			Achieve a target of 35-55 GJ/ 100cu.m energy efficiency performance for the healthcare estates

APPENDIX C A LIST OF WEB-BASED CASE STUDIES

Table C.1. A list of web-based case studies

Project	Description	Remarks
1. Beth Israel medical Centre. New York. Guenther 5 Architects	Continuum Centre for Health & Healing	1. Recycle carpet tile and organic wood. 2. No PVC, cork, linoleum, reclaim wood, minimal carpet. 3. Paint; Durable, fast-curing and stains with low VOC content and no ammonia, formaldehyde, etc. 4. 100% recovered wood from old pallets, construction waste and manufacturers' outfall made Green medium Density fibreboard (MDF) used for cabinet. Adhesive for binding was urea formaldehyde resin less. 5. Formaldehyde free fibreglass for insulation. 6. Recycled glass tiles for toilets walls. 7. Formaldehydes, CFCs and VOC's were eliminated while selecting furniture. 8. PVC was excluded from construction and furniture spec. 9. Follow up IAQ monitoring every 6 months
2. Birmingham Children´s Hospital Refurbishment Scheme. Birmingham. Powell Moya Architect.	Refurbishment of children's hospital. Victorian Building	1. The project involves refurbishment of Victorian building and maintaining Victorian features. 2. The work involves enhancing the original entrance. 3. During refurbishment interior and art work was also considered. 4. A new envelope was added effectively internally as well as externally
3. Bradford Royal Infirmary A&E Dept. Bradford, UK. RBS	Refurbishment of 2 ward blocks & a new 3 storey block	Construction of triage, reception, a main waiting area, a children's waiting area, major resuscitation, trauma clinic and x-ray unit
4. Claypath Medical Centre. Durham. Howarth Litchfield Partnership	Conservation	1. Terrace, Front façade, access for disable
5. Clevedon Hospital at Somerset. Strid Treglown.	Redevelopment	1. Redevelopment of patient areas, painting 2. Installation of roof and addition of main entrance area and lift tower

6. Hillingdon Hospital A&E unit, Hillingdon. Nightinangle Associates	Refurbishment and Expansion of 1960s facilities	1. Restoration of roof, envelope, main entrance area and waiting area
7. Lynfield Mount Hospital at Bradford. Estate Service Executive	Refurbishment	1. Remodelling and re-planning of existing in patient services. 2. Increase patients privacy and dignity. 3. New security system installation 4. Landscaping, sites for the day facilities and concealing car park
8. Montpelier Health Centre in Bristol. Vic Love Architects.	Up-gradation	1. Addition of first floor to serve the present need and solve the lack of space problems. 2. Re-planning of reception and waiting area
9. Newham General Hospital in Newham. Architects Design Partnerships.	Re-roofing to 1983 building	1. A work related to re-roofing in order to capture maximum day light 2. Installation of sun-pipes
10. Orchard Medical Practice at Ipswich. Design Solutions	Complete redevelopment	1. Restoration of envelope and painting work of 1970s facilities
11. East Yorkshire Primary Care NHS Trust in Hull. Gelder and Kitchen	Refurbishment and Extension	1. A multi-location project with either a refurbishment or extension of exiting six facilities. 2. Common equipments specification and layout plans were used for all the six. 3. All projects involve providing areas for patients and play areas for children's
12. South Western Hospital Development, PCT at Lewisham. Greenhill Jenner Architects	Redevelopment	Master planning; to rationalise circulation and articulation of soft landscapes and zones
13. West Dorset General Hospital at Dorchester	Expansion by Percy Thomas Partnership	Re-planning internal layouts, addition of separate dedicated entrances for departments (Phase II)
14. The Laureates project in Guiseley Leeds. Jenneson Ass.	Timber frame erection	1. Erection of timber frame three storey building 2. Demolition of existing vacant care home

APPENDIX D AVAILABLE BIM GUIDES, REPORTS AND VISIONS

Table D.1. Publicly available guides, reports and visions relating to BIM

(Source: Succar, 2009).

Organisation	Project	Type and date	Description
CRC-CI, Australia	National Guidelines & Case Studies	Guidelines and six case studies — 2008.	"The guidelines will highlight open and consistent processes and test selected software compatibility"
BIPS, Denmark	Digital Construction	Guidelines 2007, in 4 parts (251+ pages)	A guide made of 4 components: 3D CAD Manual, 3D Working Method, Project Agreement and Layer — and Object Structures
Senate Properties, Finland	BIM Requirements 2007	2007 Guidelines in 9 volumes 200 pages break into discipline	General operational procedures in BIM projects and detailed general requirements of BIModels — focuses on the design phase
TNO, Netherlands	E-BOUW	Framework —2008 presented through a wiki	"a BIM Framework consisting of seventeen orthogonal Dimensions that describe in general the Building Information Modelling world constituting a "Way of Thinking" about BIM
STATSBYGG, Norway	HITOS	Documented Pilot (52 pages). Sections based on modelling roles	A 'full-scale IFC test' documenting experiences gained on a collaborative project
AGC, USA	Contractor's Guide to BIM	Guidelines — version 1, September 2006 (48 pages)	"This guide is intended to help contractors understand how to get started (with BIM or VDC)
AIA, USA	Integrated project Delivery (IPD)	Guide — 2007 (62 pages)	"A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication & construction"

GSA, USA	3D–4D-BIM Program	Guidelines —2006 in 7 series	A guide “intended for GSA associates and consultants engaging in BIM practices for the design of new construction and major modernization projects for GSA”
NIST, USA	NBIMS	Guidelines — 2007 (183 pages)	“NBIMS establishes standard definitions for building information exchanges to support critical business contexts using standard semantics and ontologies… (to be)... implemented in software”
USACE, USA	USA Army Corps of Engineers	BIM — A roadmap for Implementing BIM to solve the Time and Cost Challenges of MILCON Transformation (96 pages)	“The scope of this plan is to focus on the implementation of BIM in the USA Army Corps of Engineer's civil works and military construction business processes, including the process for working with the USACE Architectural Engineering Construction (AEC) industry partners and software vendors”
USCG, USA	USA Coast Guard	BIM User Guides and Standards	“The aim is to develop and maintain a BIM standard”
Consortium of organisations, European Union	InPro	Report — 2006 till 2010 (131 pages in 4 or more parts so far)	“The Open Information Environment is a set of results due to the junction of two approaches: on one hand business processes and the required organisation and on the other hand the underlying technologies supporting the business processes.”
Consortium of organisations, EU	Concurrent Engineering in Building and Civil Engineering	Demonstration Project — 2002	“CONCUR has demonstrated concurrent working in construction engineering and design between project partners using advanced web based ICT”
Consortium of organisations, EU	ERABUID	Report — 2008	Review of the development and implementation of BIM: technology, standards and necessary future steps
Consortium of organisations, EU	STAND-INN	Development Process — Quick Guide 2007	“Integration of performance based building standards into business processes (and manufacturing processes) using IFC standards to enhance innovation and sustainable development”

APPENDIX E COVERING LETTER USED FOR THE INTERVIEWS, QUESTIONNAIRE SURVEY

Dear Sir/Madam,

Hi, this is Amey Sheth, a research student from Civil and Building Engineering Department, Loughborough University, UK. My area of research is development, modernisation (refurbishment/reconfiguration) of existing healthcare estates in the UK from designing point of view with key focus on energy consumption of existing buildings. The project is a part of HaCIRIC (www.HaCIRIC.org).

For this study, as part of my field research I need to collect first hand information about refurbishment process. Considering your experience and presence in healthcare sector, we feel that your feedback is very much important for our project. Is it possible for you to give me 45-60 minutes out of your busy schedule to conduct an interview to have your feedback? If you are ok with the interview, then I will mail you brief agenda and to confirm the date, etc. Also, it is acceptable if you are working on new constructions and not doing any complete refurbishment project, presently.

To know more about Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) please visit HaCIRIC web site www.haciric.org. In short, the HaCIRIC is multi-university project and a collaboration between existing research centres at Imperial College London and the Universities of Loughborough, Reading and Salford.

I would be very happy to answer any questions you may have and can be contacted on the telephone number or e-mail address below.

I look forward to hear from you in due course. Thanking you in anticipation.

Regards,

Amey Z. Sheth

HaCIRIC

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APPENDIX F INTERVIEWS AND QUESTIONNAIRE SURVEY PROTOCOL

Sustainable Refurbishment/Redevelopment of an Existing Healthcare Facility

Aim

The interview is part of a 3 year research (PhD) project aims to develop a framework that facilitates the sustainable refurbishment of existing healthcare facilities. The project is a part of Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) www.haciric.org.

The objectives of this interview are to:

- Explore the methodologies adopted during the various stages of refurbishment.
- Explore the different methods used to develop and execute refurbishment (redevelopment) proposals related to healthcare facilities.
- Understand project team involvement/contribution (architect, Department of Health (DH), client, stakeholders, consultants, etc.) and range of software, tools (BIM, simulation, 3D visualisation) modern methods, and frameworks used, applicable for the same.
- The interviews are being conducted to gather information from experts (researchers, professionals) to identify current trends related to refurbishment (redevelopment/extension).

Section 1: Background information

The aim of this section is to *identify individuals and institutional background information* related to the (healthcare) construction industry.

1.1. What is your **background** (architect, project manager, etc.) and how many years have you been working in the (healthcare) construction industry?

1.2. What **types** of current construction (healthcare refurbishment and/or research, etc.) projects you involved in?

Section 2: Current trends in refurbishment; with special focus on energy and carbon emission.

The aim of this section is to identify *current trends while developing and executing refurbishment projects*.

2.1. How **often** healthcare facilities are refurbished (after how many years)? Why it is **important**?

2.2. What are the reasons, **driving factors** for refurbishment? (For e.g. increasing demand, age of the building, energy consumption, future extension, scheduled activities, etc.)

2.3. What are the **risks, challenges** involved in refurbishment and to reduce energy consumption in existing healthcare facilities? Why?

2.4. In your experience, what is general **level (type) of refurbishment** in the context of healthcare facilities? (Energy, interior re-planning, built environment, mechanical, up-gradation, extension, schedule activity, etc).

2.5 Is there any difference in the **occupancy pattern** and number of **visitors** before refurbishment and after refurbishment? Why?

2.6 Are you using **any tool** (BIM, simulation, etc.), **guidance notes** and **framework** during refurbishment of healthcare facilities? If yes, why and how (for visualisation, for energy analysis, to predict performance, client demand, etc?)

2.7 Is **energy** consumption and **carbon** emission **considered** and **assessed** during any stages of refurbishment? How (if yes)?

2.8 During the planning of a refurbishment project, what are the driving factors and issues (related to energy consumption and carbon emissions) **considered**?

2.9 What is your **opinion** on current refurbishment procedure? How satisfy are you? What could be done better to **reduce energy** consumption of existing healthcare facilities?

2.10 Based on your experience/knowledge can you **suggest** any tools, frameworks, methodologies dedicated to (refurbishment of) healthcare facilities? (LEED, BREEAM, ASPECT, AEDET, etc.)

Section 3: The National Health Services (NHS), Department of Health (DH) role.

The aim of this section is to *identify and understand concern authorities and governmental organisations*, their roles and contribution during refurbishment projects.

3.1 Is the NHS/DH, **client**, stakeholder involved during the various stages of the refurbishment projects? Do they provide, impose any guidance notes, targets, etc.?

3.2 What are the **current standards**, legislations, regulations, guidance notes need to be followed during refurbishment? Please mention mandatory as well as non-mandatory.

Section 4: Comments, suggestions and further thoughts.

Please provide any other information, which might be useful to our project. (For e.g. software, case study, reference, contact, comment, suggestion, etc.)

Thank you very much for participating in this interview.

No information provided by you will be shared with anyone and the information is for research purposes only.

APPENDIX G INTERVIEW AND SURVEY PARTICIPANTS

Table G.1. Research participants for face-to-face interviews

Sr. No.	Code	Background	Years of experience	Country
1	INT.1A	Project Manager	20	UK
2	INT.1B	Project Engineer	15	UK
3	INT.1C	Chartered Builder	12	UK
4	INT.1D	Project Architect	20	UK, USA
5	INT.2	Project Manager	25	UK
6	INT.3	Principle Architect	18	UK, USA
7	INT.4	Architect + Consultant	30	UK, USA, India
8	INT.4	Architect	15	UK
9	INT.5	Community Hospital's Manager	10	UK
10	INT.5	Site Manager	12	UK
11	INT.6	Site Manager	6	UK

Table G.2. A list of questionnaire participants

Sr. No.	Version no.	Code	Background	Years of experience	Country
1	V3	A1	Healthcare Architect	35	USA
2	V3	A2	Healthcare Architect	25	USA
3	V3	A3	Healthcare Architect	35	USA
4	V3	A4	Healthcare Architect	30	USA
5	V3	A5	Healthcare Architect	32	USA
6	V3	A6	Healthcare Architect	15	USA
7	V3	A7	Healthcare Architect	30	USA
8	V3	A8	Healthcare Architect	23	USA
9	V3	A9	Healthcare Architect	33	USA
10	V3	A10	Healthcare Architect	31	USA
11	V3	A11	Healthcare Architect	50	USA
12	V3	A12	Architect + MBA	13	UK

13	V3	A13	Healthcare Architect	33	USA
14	V3	A14	Architect + Consultancy	20	UK
15	V3	A15	Healthcare Architect	20	UK
16	V3	A16	Healthcare Architect	30	USA
17	V3	A17	Architect, Medical Planner	22	UK
18	V3	A18	Healthcare Architect	22	USA
19	V3	A19	Healthcare Architect	18	USA
20	V3	A20	Healthcare Architect	35	UK, USA
21	V3	A21	Healthcare Architect	40	UK
22	V3	A22	Healthcare Architect	15	USA
23	V3	A23	Architectural Technologist and LEED Consultant	20	UK
24	V3	A24	Healthcare Architect	21	USA
25	V3	A25	Healthcare Architect	28	UK, USA
26	V3	A26	Healthcare Architect	14	USA
27	V2	B1	Healthcare Architect	35	USA
28	V2	B2	Healthcare Architect	18	USA
29	V2	B3	Healthcare Architect	21	UK
30	V2	B4	Healthcare Architect	35	USA
31	V2	B5	Healthcare Architect	40	UK
32	V2	B6	Healthcare Architect	30	USA
33	V2	B7	NHS manager	15	USA
34	V2	B8	Healthcare Architect	25	UK, USA
35	V2	B9	Healthcare Planner	35	USA
36	V2	B10	Healthcare Architect	20	USA
37	V1	C1	Hospital Planner	30	USA
38	V1	C2	Healthcare Architect	22	USA
39	V1	C3	Healthcare Architect	15	USA
40	V1	C4	Healthcare Architect	31	UK
41	V1	C5	Healthcare Architect	39	UK
42	V1	C6	Healthcare Architect	26	UK
43	V1	C7	Healthcare Interior Designer	10	UK

APPENDIX H RIBA PLAN OF WORK STAGES

RIBA Outline Plan of Work 2007

	RIBA Work Stages			Description of key tasks	OGC Gateways
Preparation	A	Appraisal		Identification of client's needs and objectives, business case and possible constraints on development. Preparation of feasibility studies and assessment of options to enable the client to decide whether to proceed.	1 Business
Preparation	B	Design Brief		Development of initial statement of requirements into the Design Brief by or on behalf of the client confirming key requirements and constraints. Identification of	2 Procurment Strategy
Design	C	Concept		Implementation of Design Brief and preparation of additional data. Preparation of Concept Design including outline proposals for structural and building services systems, outline specifications and preliminary cost plan. Review of procurement route.	3A Design Brief and Concept Approval
Design	D	Design Development		Development of concept design to include structural and building services systems, updated outline specifications and cost plan. Completion of Project Brief. Application for detailed planning permission.	
Design	E	Technical Design		Preparation of technical design(s) and specifications, sufficient to co-ordinate components and elements of the project and information for statutory standards and construction safety.	3B Detailed Design Approval
Pre-construction	F	Production Information	F1	Preparation of production information in sufficient detail to enable a tender or tenders to be obtained. Application for statutory approvals.	
			F2	Preparation of further information for construction required under the building contract.	
Pre-construction	G	Tender Documentation		Preparation and/or collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project.	
Pre-construction	H	Tender Action		Identification and evaluation of potential contractors and/or specialists for the project. Obtaining and appraising tenders; submission of recommendations to the client.	3C Investment decision
Construction	J	Mobilisation		Letting the building contract, appointing the contractor. Issuing of information to the contractor. Arranging site hand over to the contractor.	
Construction	K	Construction to Practical Completion		Administration of the building contract to Practical Completion. Provision to the contractor of further Information as and when reasonably required. Review of information provided by contractors and specialists.	4 Readiness for Service
Use	L	Post Practical Completion	L1	Administration of the building contract after Practical Completion and making final inspections.	
			L2	Assisting building user during initial occupation period.	
			L3	Review of project performance in use.	5 Benefits evaluation

The activities in italics may be moved to suit project requirements, ie

D Application for detailed planning approval;
E Statutory standards and construction safety;
F1 Application for statutory approvals; and
F2 Further information for construction.
G+H Invitation and appraisal of tenders

APPENDIX I THE REFURBISHMENT FRAMEWORK

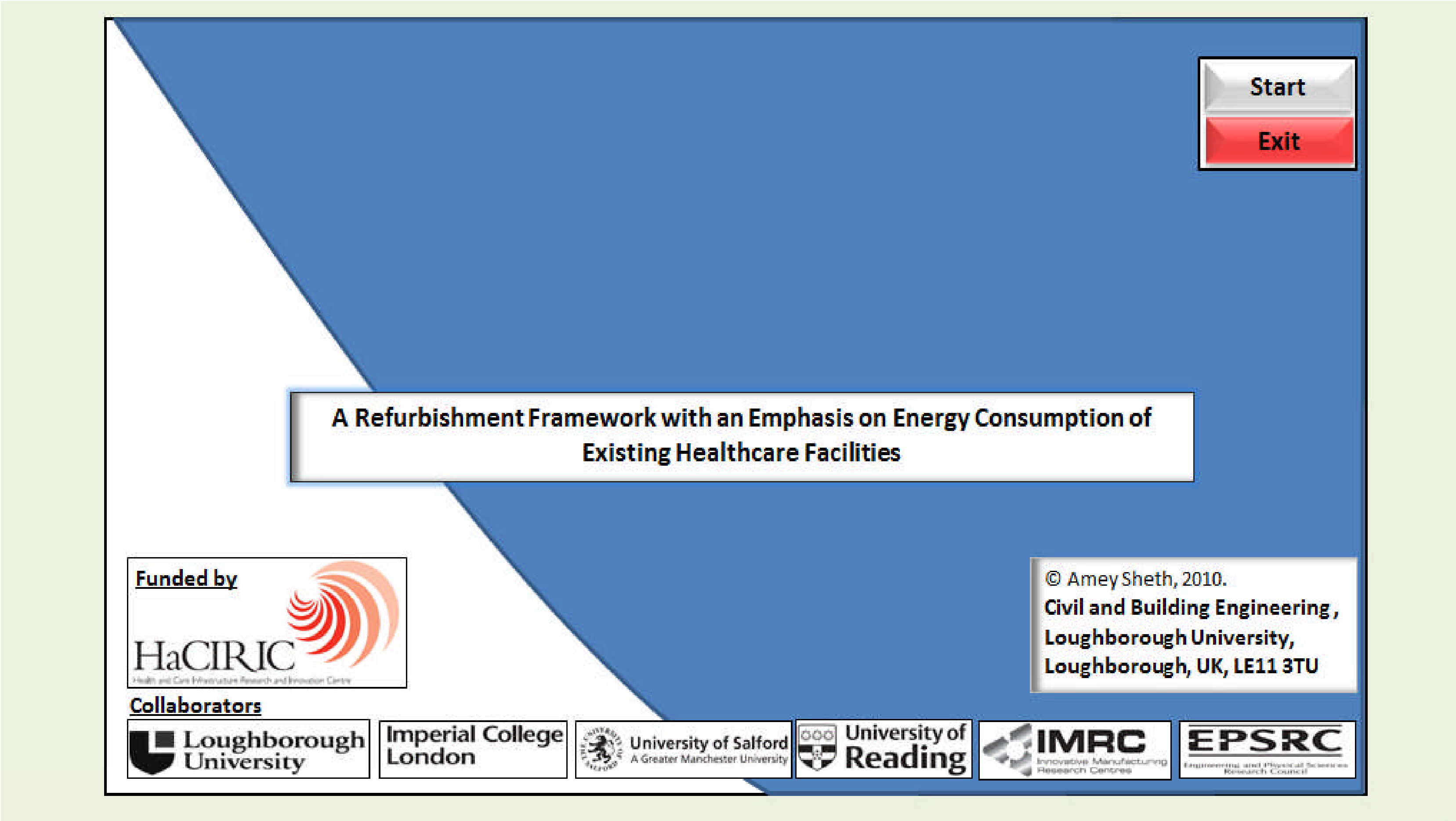


Figure I.1. Cover page

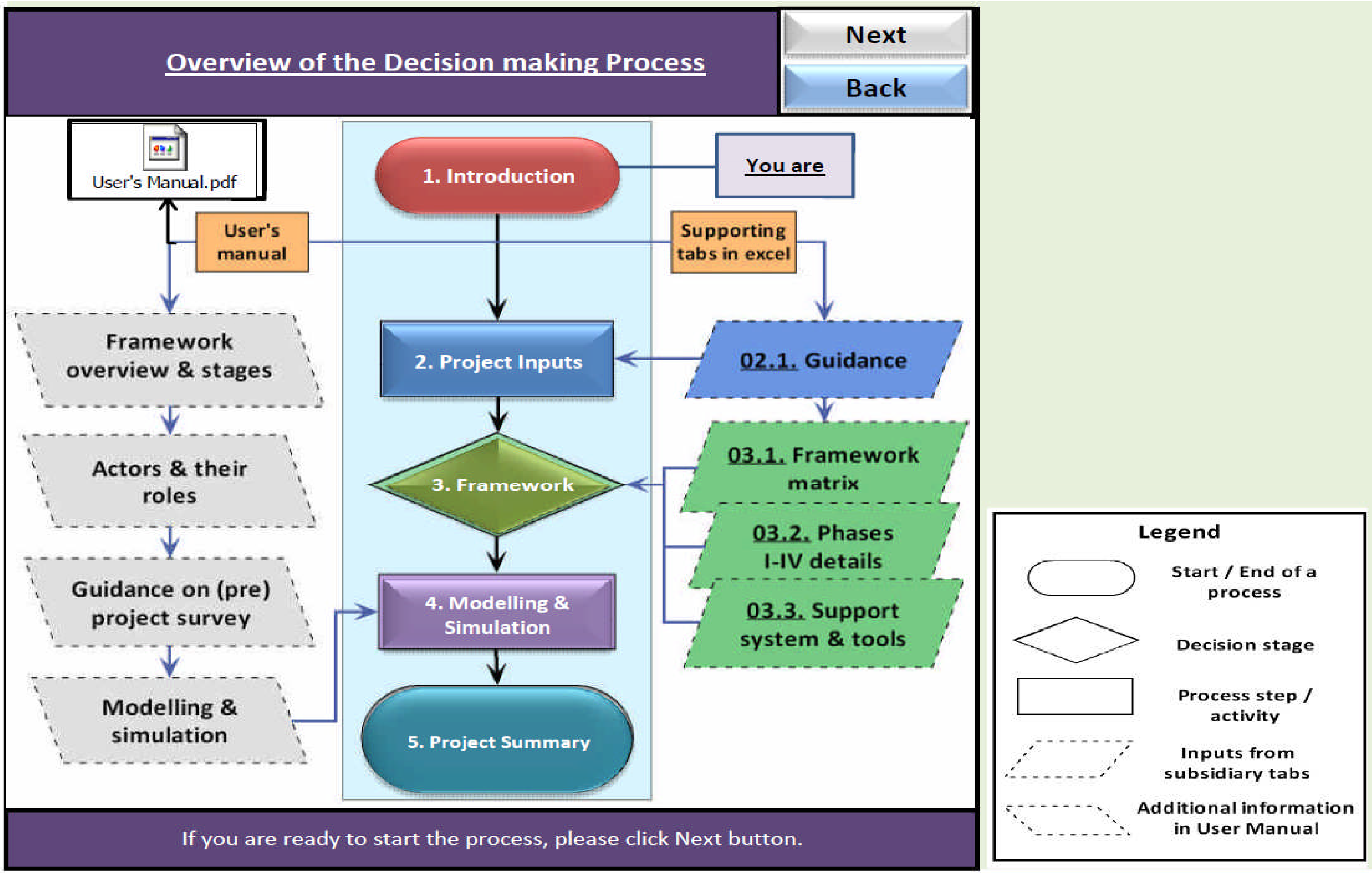
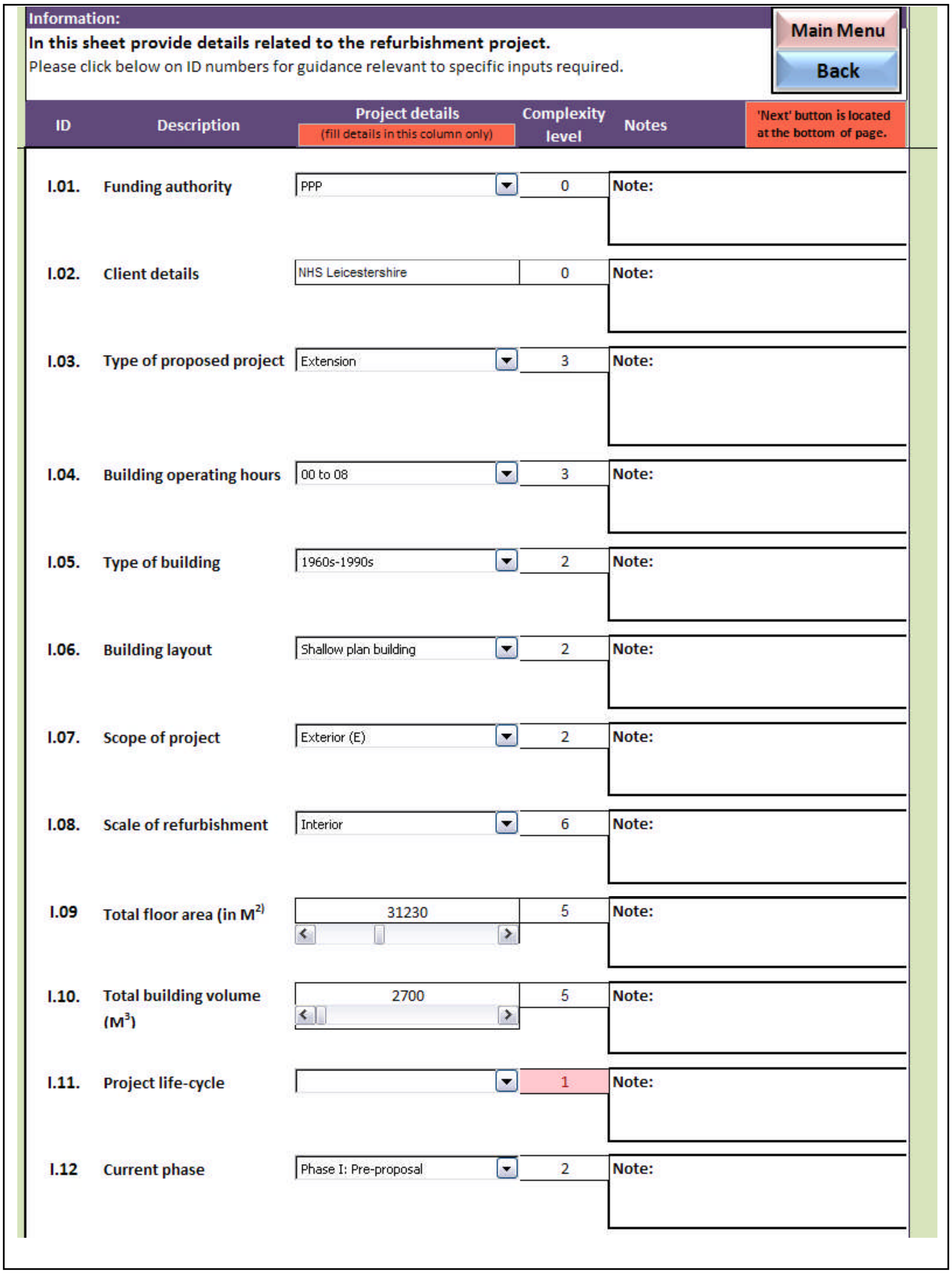


Figure I.2. Overview of decision making process



Information:
In this sheet provide details related to the refurbishment project.
Please click below on ID numbers for guidance relevant to specific inputs required.

Main Menu
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'Next' button is located at the bottom of page.

ID	Description	Project details (fill details in this column only)	Complexity level	Notes
I.01.	Funding authority	PPP	0	Note:
I.02.	Client details	NHS Leicestershire	0	Note:
I.03.	Type of proposed project	Extension	3	Note:
I.04.	Building operating hours	00 to 08	3	Note:
I.05.	Type of building	1960s-1990s	2	Note:
I.06.	Building layout	Shallow plan building	2	Note:
I.07.	Scope of project	Exterior (E)	2	Note:
I.08.	Scale of refurbishment	Interior	6	Note:
I.09	Total floor area (in M^2)	31230	5	Note:
I.10.	Total building volume (M^3)	2700	5	Note:
I.11.	Project life-cycle		1	Note:
I.12	Current phase	Phase I: Pre-proposal	2	Note:

Figure I.3.1. Input sheet

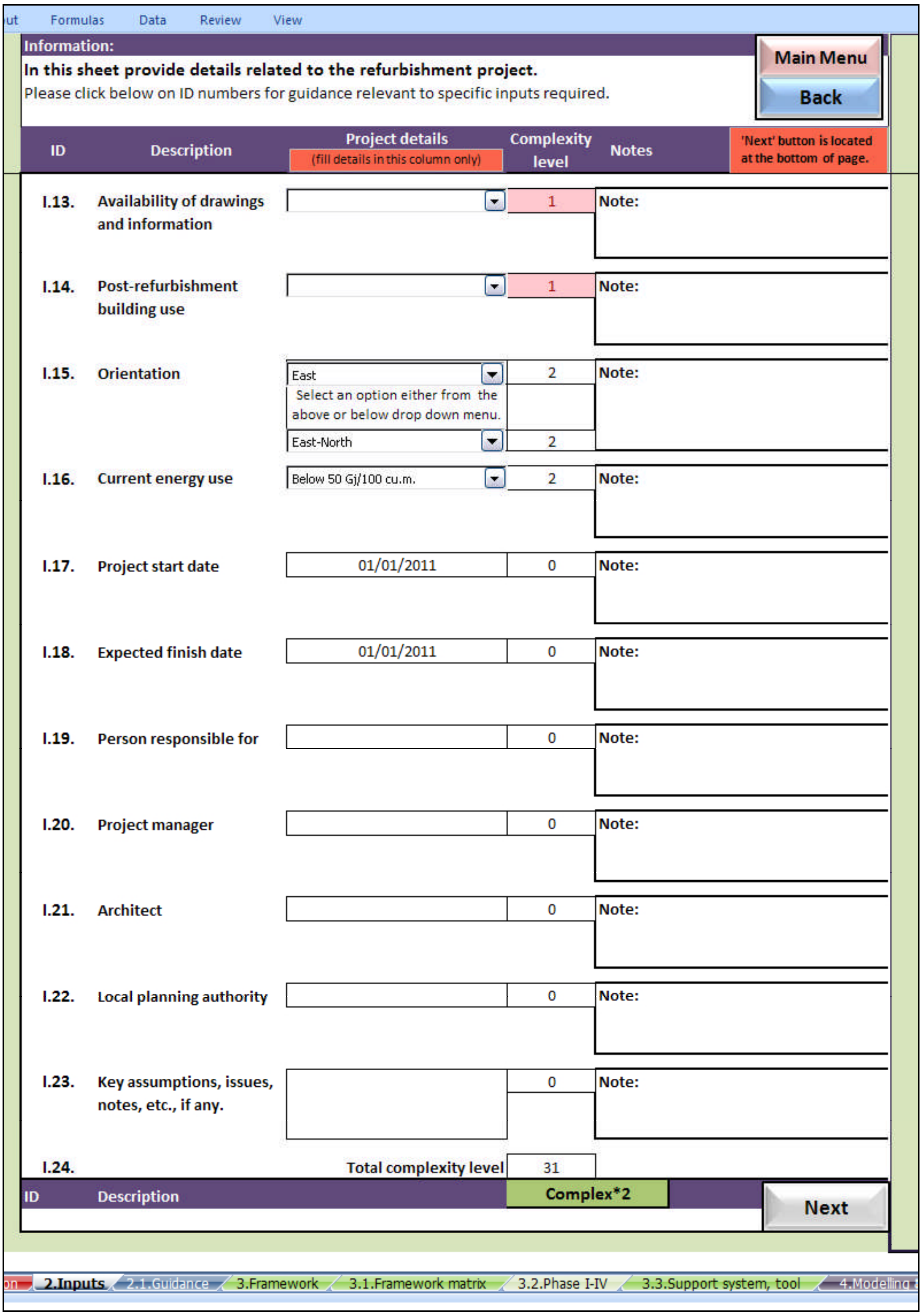


Figure I.3.2. Input sheet

Guidance ID (click below)	Description	Details
I.01.	Funding authority	Mention about funding authority, or from which source funds are secure for this refurbishment.
I.02.	Client details	Provide name of the client, if different from funding authority.
I.03.	Type of proposed project	New project: a building which is being constructed or less than three year old.
		Extension: a new part being added to existing building.
		Refurbishment: a building which is more than three year old and considered for redevelopment, modernisation, improvement, retrofit, etc.
		Extension (new) + Refurbishment: with this kind of a project, an extension part should be treated as a new building and refurbishment should be considered on the guidelines related to existing buildings and this framework.
		Demolish: guidance about how and when to carry on usage of existing building, refurbishment or demolish and construct new should be made based on assessment of above options enabling the client to decide whether to proceed or not.
I.04.	Building operating hours	Because buildings considered for refurbishment is a healthcare facility, it is very important to know their operating hours. There is a possibility that most areas in the facility are operational round the clock.
I.05.	Type of building	Modern buildings: post 1990s to till date buildings.
		1960s to 1990s buildings: are built from 1960s onwards and before 1990s. This is a separate category because post 1990s, significant development in buildings regulations was observed.
		Victorian buildings: are built before 1960s, especially have large volumes, rigid layouts and were designed to be naturally ventilated, etc.
I.06.	Building layout	The layout of buildings will depend on wall to floor ratio. In shallow plan buildings core is 7-8 meter away from external facade, whereas, deep plan buildings are the buildings constructed especially in 1960s, when electricity was cheaper thus they rely on artificial lighting and their core is more than 8-10 meter away from external facade.
I.07.	Scope of project	Depending on scope of the project, project type can be decided. Most minor projects will be interior project where as major refurbishment project involves interior as well exterior work.

	Scale of refurbishment	Description	Type of project
	Level on scale	Due to rapidly changing medical technologies there is a little probability that any medium or small scale healthcare facilities will fall into this category especially after three years since construction. Although refurbishment will not commence at this stage it can give an indication of when there will be a need for refurbishment.	**0.** Do nothing
	Minor	These types of projects are classified as redecoration and involve *'cosmetic refurbishment'*. They have very little impact on energy consumption, but can result in improved 'look and feel' of facilities thus overall enhanced environmental quality.	**1.** Re-decoration
		This work type involves partial interior work. Sometimes furniture/ergonomics is also considered. These projects are generally related to lighting fixtures, maintenance of detached furniture, plumbing works, curtains, louvers, etc.	**2.** Ceiling, furniture work

Figure I.4.1. Guidance for input sheet

Guidance ID (click below)	Description	Details	Back
I.08.		Mostly, these projects deal with the indoors of the buildings but can be minor or major work in terms of quantity. This kind of works can reduce energy consumption significantly compared to works Type 1 and Type 2.	**3.** Interior
	Average	This work involves partial improvement of the building's envelop. The work will reduce air leakage and heat transfer through windows and doors. Also, improvements to roof and signage within the hospitals are considered with these types of projects.	**4.** Doors, windows (Partial
		The building envelop has a major role to play in reducing energy consumption and to improving IEQ in existing facilities, for example, if the existing envelope is in a poor condition then another layer of envelop along with peripheral circulation pathway can be added to control air leakage through existing envelop. Also, this can involve work related to signage to improve the circulation with the facility.	**5.** Envelope
		Most of this work deals with Heating, Ventilating and Air Conditioning (HVAC) in buildings. Current trend shows that this kind of work accounts for most refurbishment proposals in the industry.	**6.** Electrical and mechanical
	Major	This involves improving building's layout usually due to a change in service delivery, an improvement in service delivery or efforts to minimise complexities within existing layouts. With these kind of projects, the building elements and features exposed to external weather should be treated with extra care.	**7.** Layouts
		This kind of work can significantly extend a building's life-cycle. Here, almost the entire building is new including work related to structural improvement and stabilisation, and the existing foundations remain mostly untouched. These projects will include almost all the above mentioned types (scope) of work.	**8.** Structural
		These types of projects mostly deal with outdoor areas. The scope of the projects generally includes onsite parking, landscaping, entry and exit roads, storm water drainage, etc. The projects are implemented in conjunction with all above mentioned projects types or sometimes executed individually.	**9.** Campus
		If buildings are in a dilapidated condition and difficult to maintain then it will be demolished. Sometimes, these types of building provide an opportunity for a change of usage (convert into warehouse or for archives) with some restoration work. This is end of building's life-cycle as a healthcare facility.	**10.** Demolish
I.09.	Total floor area (in M2)	From the drawings or through survey a part of a building considered for refurbishment can be measured in 2D (in metre square). It is important to know the area in M^2 as some of the targets are in M^2. Also, this will help with quantities and various other aspects of the projects.	
I.10.	Total building volume (M3)	From the drawings or through survey a part of a building considered for refurbishment can be measure in 3D (in metre cube). It is very important to know the area in M^3 as some of the targets are in M^3. Also, this will help with quantities and various other aspects of the projects. This calculation in 3D (volume) is important to calculate cooling and heating demand by calculating actual volume of the building.	

Figure I.4.2. Guidance for input sheet

Guidance ID (click below)	Description	Details	Back
I.11.	Project life-cycle	Project life-cycle will depend on how many times the facility considered for refurbishment has been refurbished in the past. If its first refurbishment, then there are possibility of having maximum building related information available. However, if its third refurbishment, then it will be difficult to gathered most of the information based on construction document and drawings thus a need for detailed project survey along with possibility of having more challenges associated with the projects.	
I.12.	Current phase	Phase I: Pre-proposal. This is early phase of the project. During this phase the information required for the development of refurbishment proposal will be gathered. Also, if implemented this framework at this stage, it will be very	
		Phase II: Proposal. Based on the information collected during the previous stage, a refurbishment proposal will be developed. This is a very crucial stage and most of the future decision will be taken in this stage.	
		Phase III: Proposal execution. During this stage the proposal will be executed and there will be minimum scope for a decision to be taken related to design or a building. During this phase most of the process will be taken over by a site/construction team.	
		Phase IV: Post-proposal execution. This stage will involve post project evaluation, verification and validation of the refurbishment proposal developed during the Phase II.	
I.13.	Availability of drawings and information	Facility manager or a trust should have at least some drawings and information available with them which can help during the preliminary investigation and conceptual planning. The availability of information will help the design team during initial phases of the proposal development.	
I.14.	Post-refurbishment building use	A facility manager or a client(s) can provide information about the same. This information is very important because the project brief, requirements and approach will be depend on this. Post-refurbishment, if the use of refurbished area is going to be different, then certainly, their might be some additional consideration or designing requirements.	
I.15.	Orientation	It is very important to study the orientation of a building considered for refurbishment as it will have impact on the energy consumption and other aspects, such as users comfort, etc. Also, during refurbishment, if possible, building can be re-orientated improving its energy consumption and accessibility.	
I.16.	Current energy use	Comparing energy consumption before and after refurbishment will help to validate refurbishment proposal. Also, there are certain targets imposed by government for new development and major refurbishment project, thus it is very important to know the energy consumption of the building.	
I.17.	Project start date	The date from which proposal development is started. This will help to know the actual time taken by the project for completion.	
I.18.	Expected finish date	Knowing expected date to finish the project will help to plan the activities.	

Figure I.4.3. Guidance for input sheet

I.19.	**Person responsible for**	A person responsible for Implementation of this framework and overall project.
I.20.	**Project manager**	If different than personal responsible for implementation of framework.
I.21.	**Architect**	At the beginning of the project, a name and contact details of the architect, or design team member should be provided here, this will help rest of the team to get in touch with a person responsible for development of the project.
I.22.	**Local planning authority**	It is very important to indentify the local authorities as there might be a possibility of having some local targets or consideration (for e.g. Environmental consideration, etc.). Also, local authority are responsible construction project approval.
I.23.	**Key assumptions, issues, notes, etc., if any.**	To provide any additional notes or information, which are not provided above. Also, this information can be used later in the project. For example information about occupancy and expected occupancy during refurbishment will help to plan refurbishment and construction related activities.
I.24.	**Total complexity level**	This will give total score of the project and level of complexity associated with the projects. It is very important to know score because the approach towards refurbishment will depend on it. The score will help to decide the level of design innovation required.
I.25.	**Highly Complex**	Highly Complex (Above 81): this will give total score of the project and complexity level associated with the projects. It is important to know the score because the approach towards refurbishment will depend on the total score. There is a possibility that most Victorian and the early 70s buildings will fall into this category.
	Complex*4	Complex*4 (61-80): with this projects, there is a possibility of having little information available about the existing building but efforts should be made to gather some more information about the existing building. Most healthcare facilities from the 60s-80s will fall into this category.
	Complex*3	Complex*3 (41-60): it will be better to refurbish buildings under this category compare to above two categories, however, careful planning and execution can insure successful refurbishment. Also, looking at current healthcare stock in the UK, most of the buildings will have similar level of complexities.
	Complex*2	Complex*2 (21-40): with these type of projects, either most of the information is available or the buildings considered for refurbishments are relatively new, thus there is a very low risk with refurbishment projects. Most modern buildings from the 21st century will fall into this category.
	Less Complex	Less Complex (00-20): with this kind of projects, the level of risk is very minimum compared to any other project category. Also, most likely there is a possibility that most of the information related to existing building will be available and this project can achieve great success. However, looking at the current refurbishment pattern in the industry, there are very less possibility that any building will fall into this category.

2.Inputs | 2.1.Guidance | 3.Framework | 3.1.Framework matrix | 3.2.Phase I-IV | 3.3.Support system, tool | 4.Mo

Figure I.4.4. Guidance for input sheet

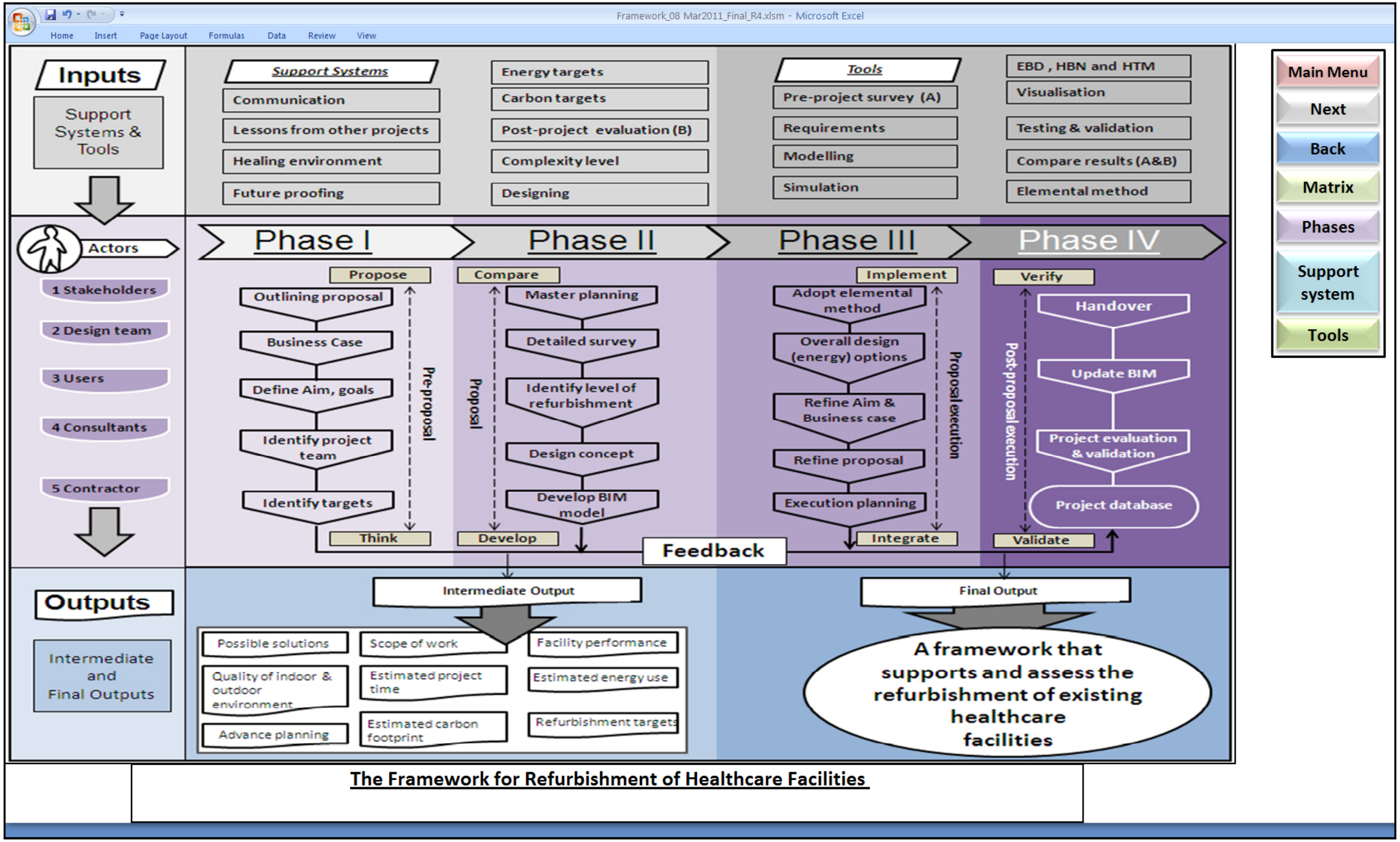


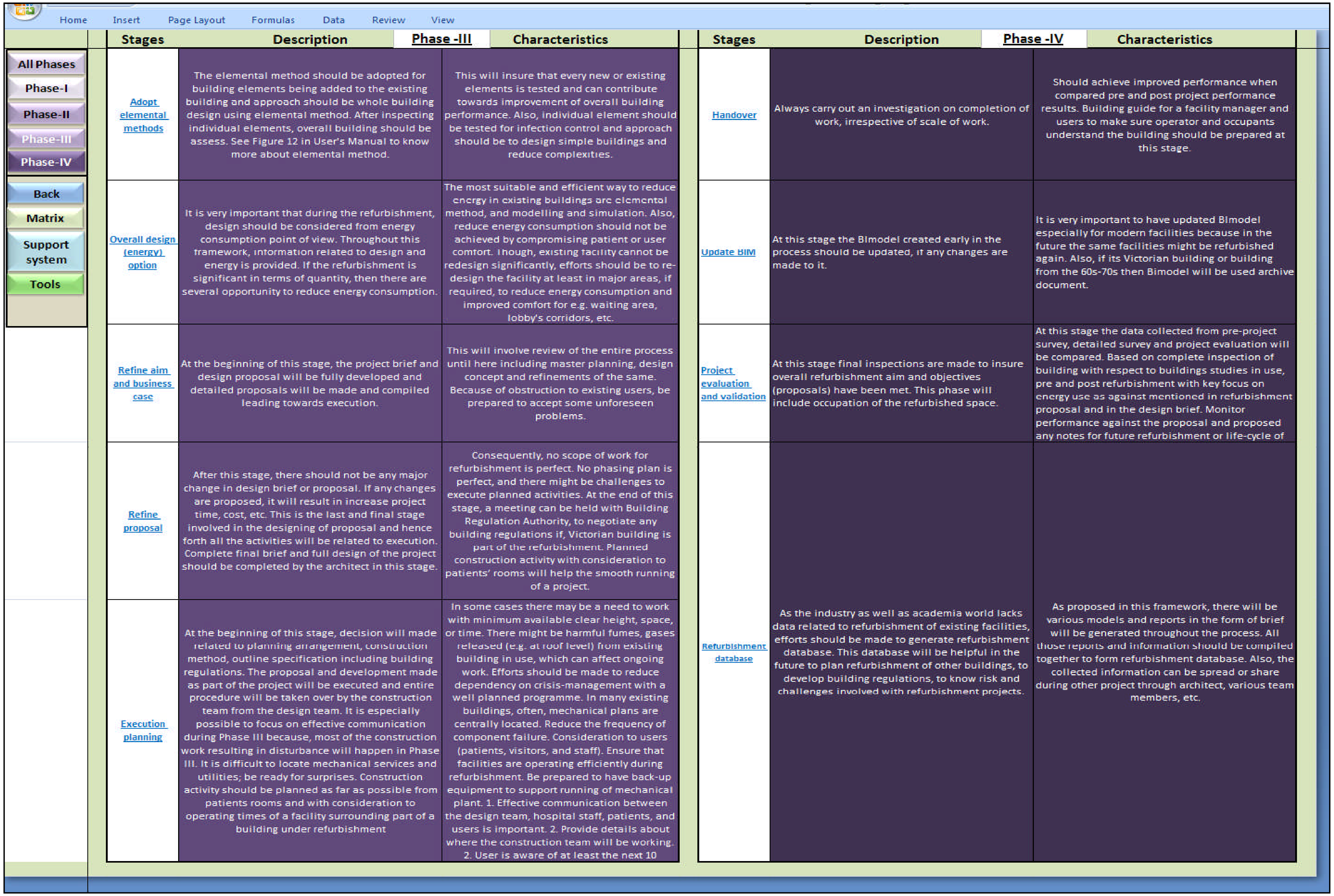
Figure I.5. Framework

Home Insert Page Layout Formulas Data Review View

All Phases | Phase-I | Phase-II | Phase-III | Phase-IV | Back | Matrix | Support system | Tools

Stage	Stages (Phase -I)	Description (Phase -I)	Characteristics (Phase -I)	Stages (Phase -II)	Description (Phase -II)	Characteristics (Phase -II)
Stage-I	Outlining proposal	At this stage experts should be involved to outline the type of a project, such as part/full refurbishment, demolishing, extension, etc. Determine post-refurbishment new function of the building and requirements for development of business case in the next stage.	Project leaders will take actions to indentify project needs and, how organisation is ready for refurbishment and type of projects. Experts should be involved as part of the project, to make decision related to existing buildings/facilities. The complexity level should be known to the team. The outline proposal will be develop with the help of basic information about the project and based on experienced of the team members.	Master planning	Based on studies of user requirements, technical aspects, planning, design, future requirements, etc., a master plan and overall conceptual plan related to facility should be developed.	The inclusion of master planning in refurbishment development is essential, especially in the case of large-scale project which takes significantly more time and lengthy process. Also, it should be developed with consideration to existing asset such as road layouts, electric grids, drainage, urban context. The proposed mater plan should be designed to cope with the future growth for new functions. The success of master planning depends on the client's understanding of
Stage-II	Business case	During this stage, based on the inputs from previous stage, feasibility studies, business case should be developed for the proposed project. Empower and choose an appropriate design team.	Consideration to existing condition of the building/facility. Gather data related to building operation schedule and backlog maintenance, if there is any. While developing business case, the support systems and tools mentioned in the matrix should be used.	Detailed survey	Collect information required for room-data sheets. and conduct '6 facet' survey. To assess condition of the building against their use, for example, work environment, nurses station and provide information to design team. Explore thermal bridging, air leakage. The data should be collected such that in the future with this information, building in use may be assessed against its performance and can be created using virtual building modelling.	This is one of the key stage in the development of the refurbishment proposal, as it will validate the proposal towards end of the project. Also, with this, a detailed building model can be developed, which can be used for testing and other planning related aspects. Also, in the user manual additional information on conducting detailed survey is provided.
Stage-III	Define aim, goals	Based on Business Case and other considerations such as infection control, users safety, modern regulations, quality of space, comfort, etc., the aim and goals for the refurbishment project should be develop and share with rest of the team, whenever possible.	While developing aim and setting goals for this project, BREEAM or equivalent should also be considered. Aim and goals are very important because this will decide the success of the project and entire team will know what to aim for and goals to be achieved.	Identify level of refurbishment	The level of refurbishment will be proposed at this stage with consideration to energy use, user comfort, complexity level and other collect data until now.	Based on information gathered level of refurbishment can be proposed. Also, this will help to indentify scope of work and other details related to project such as detail planning, estimation, etc. This will provide a design brief to design team to be used in the next stage. Also, use refurbishment scale proposed in User's Manual (see Figure 11).
Stage-IV	Identify project team	It is better to know the possible team which will be working on the project at the beginning of project. This will help to identify future needs as part of the project.	This will help to share project aim, goals, vision and refurbishment ideas with rest of the project team. Knowing project team will help to plan for any future needs, or process, which needs to define. This will help to select tools and methodologies to be used during the project as it depend on a project team. Also, with most refurbishment project, consultants and engineers are required from the beginning of project, thus knowing project team is very important and can contribute significantly towards success of refurbishment.	Design concept	Identify general approach to the layout, design and construction to provide basic inputs to generate BImodel with consideration to future requirements, adaptability, flexibility, envelope, etc. Design concept should be develop in accordance with current issues such as Healthcare Associated Infection (HAI), consideration to nature, etc.	Good integrated design and a clear plan with easy circulation spaces should be considered. Consideration to signage and if required, work to improve those. Provision of good public open spaces (waiting areas) and out of hours community use. Incorporating natural lighting (maximum use of day light), natural ventilation and consideration to energy efficiency. Refurbished hospital spaces for flexibility and modularity; for future. Exploration of a wide range of design options. Up-gradation of building fabric (insulation, windows) to improve thermal performance.
Stage-V	Identify targets	Decisions related to (virtual) mock-ups, evaluate outline proposal, consider air change per hour as this may result in increase or decrease energy consumption, maximise air and light through design and additional data related to same will be available from detailed survey.	This will involve implementation of output from Stages II & III and preparation of additional data. Based on identified target, the project team should be reviewed. Also targets should be set to achieve outdoor view for patient room and offices, if possible. To locate nightingale wards under use, if there is any, and, inform design team. Also, overall site specific, building specific, project specific drivers and challenges should be identified and consider throughout the project.	Develop Building Information Model (BIM)	Preparation of virtual building model sufficient to co-ordinate construction management and planning related activities. The aim is to develop a 3D model which will allow full co-ordination. Extract data from ADB into BIM model.	Based on observation made during pre-project survey. Certain areas, where there is no day light available but needed should be provided with windows, fins, etc. Consider re-designing of the existing building; part/full building. Model should be capable of supporting various simulation requirements. In this stage building elements, design features should be checked and assessed against their performance.

Figure I.6.1. Details of phases



Phase -III

Stages	Description	Characteristics
Adopt elemental methods	The elemental method should be adopted for building elements being added to the existing building and approach should be whole building design using elemental method. After inspecting individual elements, overall building should be assess. See Figure 12 in User's Manual to know more about elemental method.	This will insure that every new or existing elements is tested and can contribute towards improvement of overall building performance. Also, individual element should be tested for infection control and approach should be to design simple buildings and reduce complexities.
Overall design (energy) option	It is very important that during the refurbishment, design should be considered from energy consumption point of view. Throughout this framework, information related to design and energy is provided. If the refurbishment is significant in terms of quantity, then there are several opportunity to reduce energy consumption.	The most suitable and efficient way to reduce energy in existing buildings are elemental method, and modelling and simulation. Also, reduce energy consumption should not be achieved by compromising patient or user comfort. Though, existing facility cannot be redesign significantly, efforts should be to re-design the facility at least in major areas, if required, to reduce energy consumption and improved comfort for e.g. waiting area, lobby's corridors, etc.
Refine aim and business case	At the beginning of this stage, the project brief and design proposal will be fully developed and detailed proposals will be made and compiled leading towards execution.	This will involve review of the entire process until here including master planning, design concept and refinements of the same. Because of obstruction to existing users, be prepared to accept some unforeseen problems.
Refine proposal	After this stage, there should not be any major change in design brief or proposal. If any changes are proposed, it will result in increase project time, cost, etc. This is the last and final stage involved in the designing of proposal and hence forth all the activities will be related to execution. Complete final brief and full design of the project should be completed by the architect in this stage.	Consequently, no scope of work for refurbishment is perfect. No phasing plan is perfect, and there might be challenges to execute planned activities. At the end of this stage, a meeting can be held with Building Regulation Authority, to negotiate any building regulations if, Victorian building is part of the refurbishment. Planned construction activity with consideration to patients' rooms will help the smooth running of a project.
Execution planning	At the beginning of this stage, decision will made related to planning arrangement, construction method, outline specification including building regulations. The proposal and development made as part of the project will be executed and entire procedure will be taken over by the construction team from the design team. It is especially possible to focus on effective communication during Phase III because, most of the construction work resulting in disturbance will happen in Phase III. It is difficult to locate mechanical services and utilities; be ready for surprises. Construction activity should be planned as far as possible from patients rooms and with consideration to operating times of a facility surrounding part of a building under refurbishment	In some cases there may be a need to work with minimum available clear height, space, or time. There might be harmful fumes, gases released (e.g. at roof level) from existing building in use, which can affect ongoing work. Efforts should be made to reduce dependency on crisis-management with a well planned programme. In many existing buildings, often, mechanical plans are centrally located. Reduce the frequency of component failure. Consideration to users (patients, visitors, and staff). Ensure that facilities are operating efficiently during refurbishment. Be prepared to have back-up equipment to support running of mechanical plant. 1. Effective communication between the design team, hospital staff, patients, and users is important. 2. Provide details about where the construction team will be working. 2. User is aware of at least the next 10

Phase -IV

Stages	Description	Characteristics
Handover	Always carry out an investigation on completion of work, irrespective of scale of work.	Should achieve improved performance when compared pre and post project performance results. Building guide for a facility manager and users to make sure operator and occupants understand the building should be prepared at this stage.
Update BIM	At this stage the BImodel created early in the process should be updated, if any changes are made to it.	It is very important to have updated BImodel especially for modern facilities because in the future the same facilities might be refurbished again. Also, if its Victorian building or building from the 60s-70s then Bimodel will be used archive document.
Project evaluation and validation	At this stage final inspections are made to insure overall refurbishment aim and objectives (proposals) have been met. This phase will include occupation of the refurbished space.	At this stage the data collected from pre-project survey, detailed survey and project evaluation will be compared. Based on complete inspection of building with respect to buildings studies in use, pre and post refurbishment with key focus on energy use as against mentioned in refurbishment proposal and in the design brief. Monitor performance against the proposal and proposed any notes for future refurbishment or life-cycle of
Refurbishment database	As the industry as well as academia world lacks data related to refurbishment of existing facilities, efforts should be made to generate refurbishment database. This database will be helpful in the future to plan refurbishment of other buildings, to develop building regulations, to know risk and challenges involved with refurbishment projects.	As proposed in this framework, there will be various models and reports in the form of brief will be generated throughout the process. All those reports and information should be compiled together to form refurbishment database. Also, the collected information can be spread or share during other project through architect, various team members, etc.

Figure I.6.2. Details of phases

Home Insert Page Layout Formulas Data Review View

Show all
Support system
Tools
Back
All Phases
Matrix

Support system	Description	Characteristics	Tools	Description	Characteristics
Communication	Communication will happen mainly at two levels. 1. Direct communication, which means communication between two or more actors. It can be face-to-face, over a phone, internet, during project meetings, etc., and paper based or non-paper based. And 2. Communication through drawings, construction documents, agreement, notes, etc. During the communication every project participant should be in the loop. Depending on a scale of the project, advance technologies should be use for communication and recordings. Throughout the project, during every key stage, communication should happen between entire team, and everybody should be informed.	Improvements in communication should result in an increase refurbishment project quality and an overall reduction in the level of revisions or revision works. The main aim behind having communication at every stage, is to share information related to project between all the possible actors. On a refurbishment or construction project, it is recommended that the form of the communication should be such that, every possible exchange of information will be recorded and available in the future, thus, communication should be paper based, through email, through construction documents, etc.	Pre-project survey	This type of survey is used to locate and describe, as far as reasonably practicable, all the area where the refurbishment work will take place. More information on pre-project survey and how to conduct the pre-project survey is available in User's Manual.	Pre-project survey in refurbishment project is very important as success of this project depends on availability of information. During the survey, all the possible information related to existing building should be reported and share with the design team. Also, the information will help with validation of the project at the end, where, pre-and post project information will be compared.
Lessons from other projects	The availability of lessons learnt on other construction (refurbishment) projects will depend on the level of communication on that specific project. It is very important that experts involved on the project should share their experiences thus the ongoing refurbishment will be benefited from this.	This can prove to be one of the very powerful support system if, used effectively. Also, lessons learn during the initial stages of same project can help in later phases of the construction projects. It is used to build the knowledge base especially for existing building refurbishment projects and can establish a history of best and worst practices in the refurbishment industry.	Requirements	The basic requirements can be available from clients or clients representative and design team (architect) or project manager will help to propose a detail requirements. Also, the provision should be made to adopt any requirements in the future as with refurbishment project there are more possibility of additional requirements. During refurbishment, if there is any part being added or redesign, it should be concentrated and evenly distributed with respect to the foyer, central key areas, and overall design.	The requirements of the project will decide the length of the project, resources required, any special needs and other aspects. It is very important that entire project team is aware about the same and from time to time, everybody is updated. Requirements can be in the form of project brief. Also, the requirements should not be only related to refurbishment but various tools and process required during the project should also be included. To check proposed design against: 1. non-institutional look 2. open bays VS private bays 3. small VS large units 4. decentralised versus centralised units. Refer to Figure X in User's Manual.
Healing environment	Refurbishment project should focus on healing environment to minimise threats to health and safety user especially from built environment, to deliver improve health related outcome including faster recovery of patient leading towards overall health and wellbeing of occupant and the communities in which facilities sit. Also, project should focus on achieving healing environment during refurbishment and post-refurbishment as well.	Very important to give consideration to principles of healing environment throughout the projects as this is one of the key emerging issues in healthcare sector and can ensure success of the project. It is important because decisions made during refurbishment can critically influence health outcomes and the overall quality of care within the existing facility.	Modelling	Modelling will benefits to the planning role, resulting in a much more thoroughly planned project which in turn can improve health and safety, shorten contract periods, improve quality and reduce costs. Can be used to develop virtual mock-ups of any part, if required.	Modelling facilitates a better way of consistent working that involves the creation and use of co-ordinated information enabling faster decision making and better documentation by increasing efficiency and co-ordination to reduce errors and omissions. Also can be used to inform construction processes and facilities management that allows users to better communicate their ideas to Client and within the design team.
Future proofing	This will insure the design to facilitate expansion in the future and, also, of individual departments with no or least disruption to other core clinical facilities. While designing, future technology and needs should be considers. A design should be such that, the building will cope with current as well as future social and medical challenges.	Re-designing buildings during refurbishment for future will help the buildings to cope with the future challenges and needs such as multi-functional departments and varying occupancy with consideration to well designed internal environment. A future-proof hospital will adapt new demands concerning functionality. The best way to make facility future proof is by incorporating flexibility in the design.	Simulation	Simulation can be used for various purposes however, it is suggested mainly to be used for energy analysis and to justify building features such as shading devices, fins, glazing, etc. It can provide various types of data and information such as solar studies, etc., which can be used during designing stage. Modelling and simulation can be used to study daylighting performance of the building and to give data related to same to the architect.	Together modelling and simulation can provide built-in (virtual) validation of the development. Computer simulations can be carried out to predict the influence on thermal performance (overheating risk) and energy consumption of propose design options. The details about M & S are given in the next stage of the process.
Energy targets	There are several targets imposed by the government and concern authorities. The key objectives for existing buildings are to achieve a performance target of 55-65 GJ/m^3 energy consumption for existing buildings and 35-55 GJ/m^3 for new and major developments.	Achieving energy targets is very important as it will justify the refurbishment proposal. Also, this will minimise the impact of the existing building on the patient and surrounding community. The project should be developed against national and local targets. Upgrading existing healthcare building can ensure they meet modern guidelines.	Evidence-based design	The integration of EBD while designing a hospital provides a specific physical spaces and environment to patients, staff and visitors. There are range of ergonomic methods such as task analysis and user-needs analysis to provide a detailed knowledge of work processes within a defined space/area to produce a research-based or user-centred design.	It is a process of basing credible decisions and research in order to achieve the best possible outcomes for the development of effective built healthcare environments. Solutions on the principles of EBD have become a key aspect of mock-up simulations. However, evidence-based tools and guidelines can aid decision makers during a briefing, designing and with the evaluation process.
Carbon targets	Often, existing buildings are responsible for bigger carbon footprint, thus during refurbishment every option to reduce the footprint should be tried. Refurbishment project should try to meet the Climate Change Act targets of 26 percent reduction in carbon footprint by 2020.	Like energy targets, it is very important to achieve carbon targets as well. Considering climate change, global warming, etc., all the targets should be achieved beyond minimum specified limit by governing authority. While working on this, the Carbon Trust and other available guidance from the government and concern authority should be obtained.	Health Technical Memorandum (HTM)	Sets healthcare specific standards for building components - such as, windows and sanitary ware - and the design and operation of engineering services, such as medical gas installations and fire safety requirements.	It is very important to follow HTM with healthcare project. Though, most of the HTM's are for new developments, they can help existing building significantly. HBN provides guidance on energy efficiency in healthcare facilities and review of policies related to HAI.
Post-project evaluation (A)	The post-project evaluation should be performed such that it can be comapre with pre-project survey. The areas which are refurbished should be assessed in order to check their performance.	It assesses how well buildings match users' needs, and identifies ways to improve building design, performance and fit for purpose.	Health Building Notes (HBN)	Provides DoH's best practise standards in the planning and design of healthcare facilities. HBN assist project teams about accommodating specific department or service requirements. These is recommended to use with development of business case.	It is very important to follow HBN on healthcare related project as they are more specifically developed for healthcare building. Though, most of the HBN are developed for new developments, they can help existing building significantly. Also, together consideration to HTM, HBN and ADB will help to deliver significantly improved existing facilities.
Complexity level	At the beginning of the project, based on building conditions and project requirements a complexity level of the project should be identified. Often, if the building is in existance for many years without any major refurbishment then there might be a possibility of having very complex level of refurbishment.	Knowing complexity level will help with planning for refurbishment and to decide the required level. Also, with higher complex projects there might be a need to integrate some advance technologies unlike with less complex projects. Efforts to reduce complexities in design should be made. Knowing complexity level of the project from the beginning will help to plan for required tools, experts, etc.	Visualisation	Visualisation techniques can use to analyse the entire sequence, any specific sequence or overall building.	Can help to understand complex refurbishment system. Even people from the non-construction background can be benefitted from this.
Designing	Design principles to ensure that health facilities contribute as much as possible to the quality of the wider built environment and enhance and enrich wider community development.	This is a key aspect in any project however, in existing building it depends on criteria, such as detail knowledge about the building conditions and flexibility as healthcare facilities are operational during refurbishment. Consideration to various design principles such as Health Promoting Hospitals, Nucleus hospitals, Green hospitals, should be given.	Testing & validation	If possible during pre and post refurbishment evaluation behavioural observations should be made. Though this is suggested at the end of the process, this can be considered even during the intermediate stages of the projects.	It is very important to test and validate the entire refurbishment procedure as it can contribute towards refurbishment database and to measure the success of the project. Consideration to elemental method can help to perform testing and validation of individual elements during the process.
			Compare results	During pre and post project studies, data related to good and bad design features should be collected. This will help to understand if there is any design features, which needs to preserved or if there is any thing, which we should be change during refurbishment.	Based on testing and validation and information available from pre and post survey, a comparative study will help to present project closure report.
			Elemental method	Elements method leading to whole building design option should be adopted.	As existing buildings demand bottom-up approach against new buildings where top-to-bottom approach is adopted, elemental approach is suggested.

Figure I.7. Details of 'Support Systems and Tools'

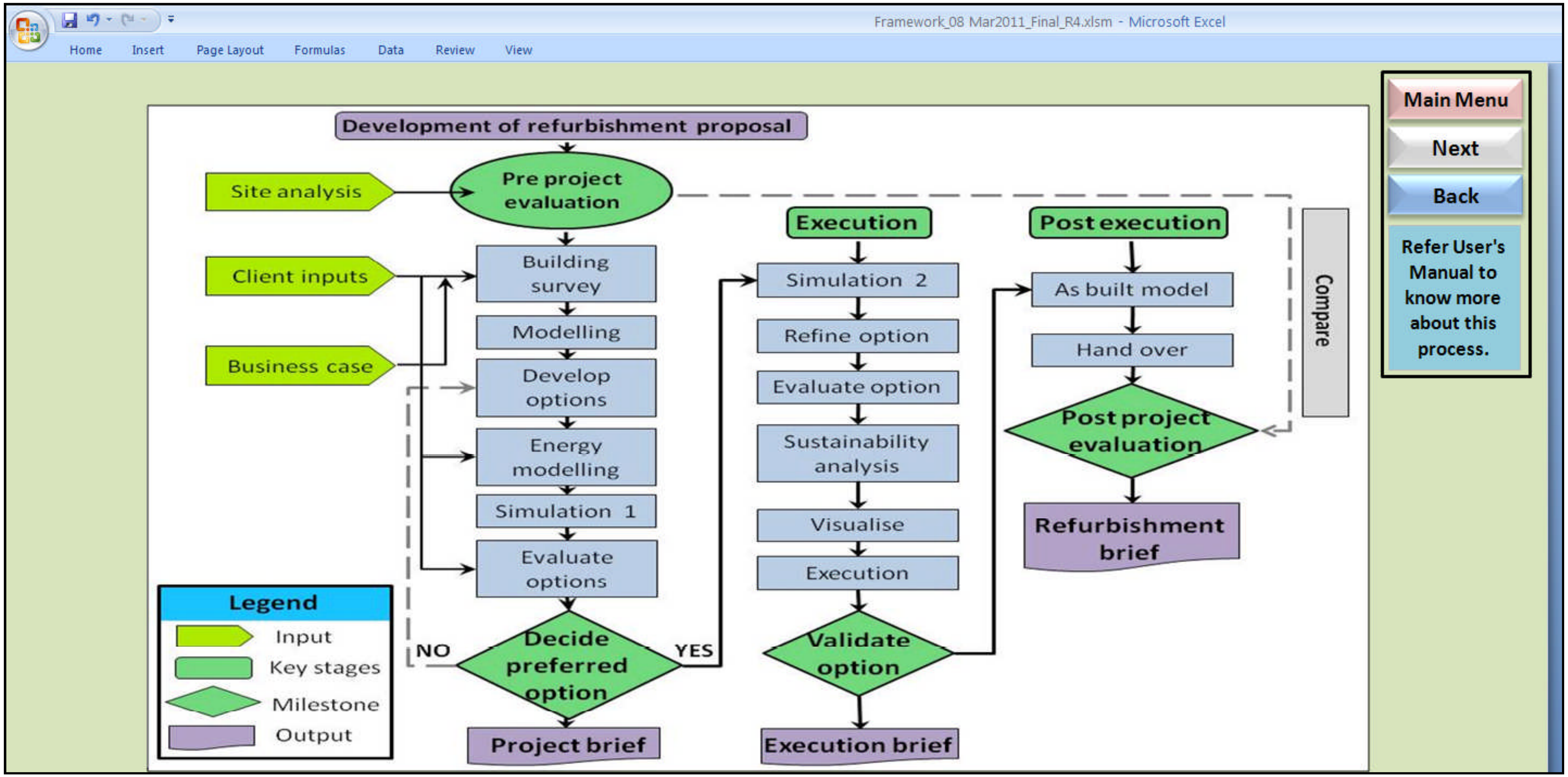
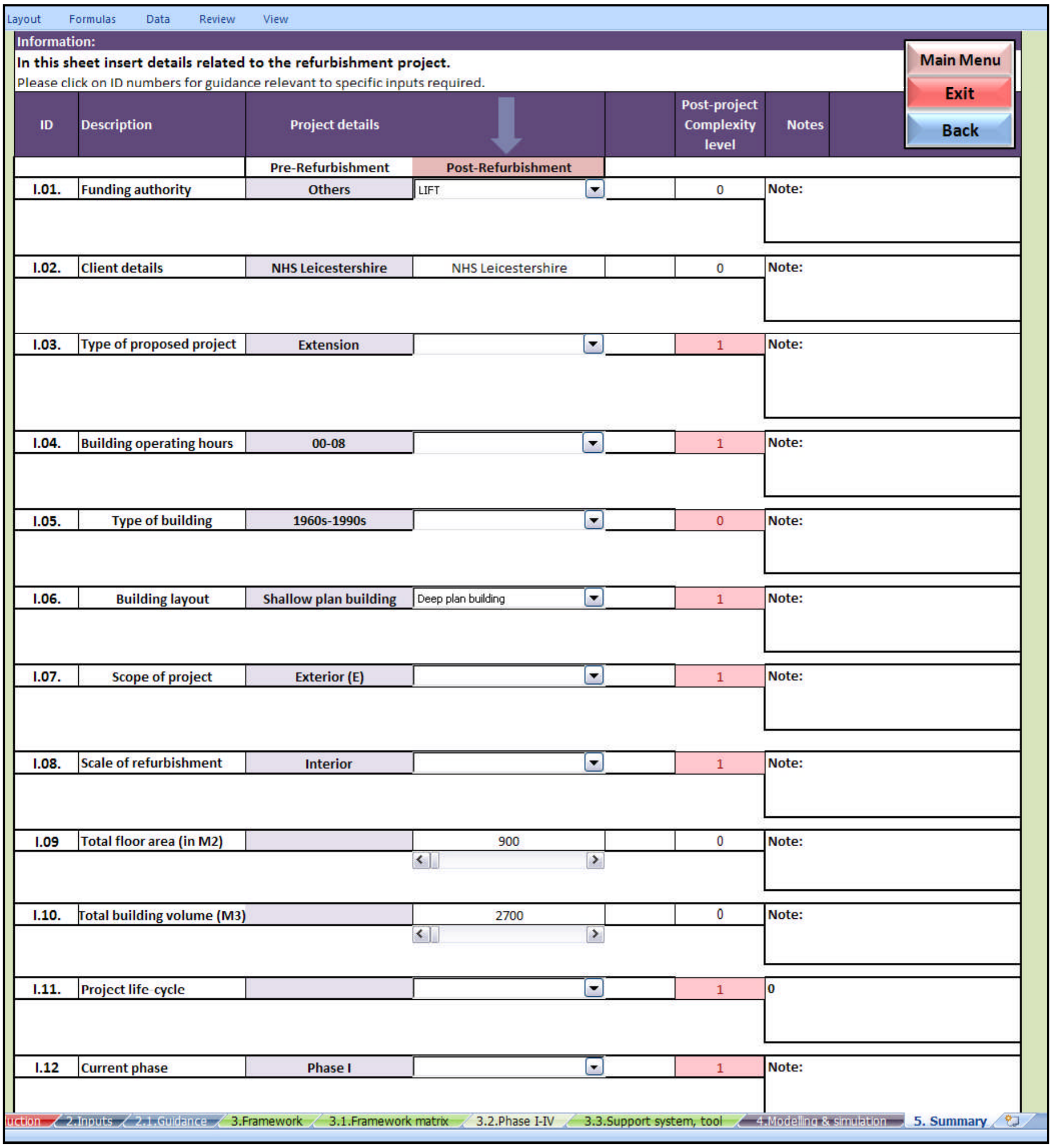


Figure I.8. Details of Modelling and Simulation



Layout Formulas Data Review View

Information:

In this sheet insert details related to the refurbishment project.

Please click on ID numbers for guidance relevant to specific inputs required.

Main Menu | Exit | Back

ID	Description	Project details: Pre-Refurbishment	Project details: Post-Refurbishment		Post-project Complexity level	Notes
I.01.	Funding authority	Others	LIFT		0	Note:
I.02.	Client details	NHS Leicestershire	NHS Leicestershire		0	Note:
I.03.	Type of proposed project	Extension			1	Note:
I.04.	Building operating hours	00-08			1	Note:
I.05.	Type of building	1960s-1990s			0	Note:
I.06.	Building layout	Shallow plan building	Deep plan building		1	Note:
I.07.	Scope of project	Exterior (E)			1	Note:
I.08.	Scale of refurbishment	Interior			1	Note:
I.09	Total floor area (in M2)		900		0	Note:
I.10.	Total building volume (M3)		2700		0	Note:
I.11.	Project life-cycle				1	0
I.12	Current phase	Phase I			1	Note:

uction / 2. Inputs / 2.1.Guidance / 3.Framework / 3.1.Framework matrix / 3.2.Phase I-IV / 3.3.Support system, tool / 4.Modelling & simulation / 5. Summary

Figure I.9.1. Project summary sheet

I.12	Current phase	Phase I			1	Note:
I.13.	Availability of drawings and information				1	Note:
I.14.	Post-refurbishment building use				1	0
I.15.	Orientation		Select an option either from the above or below drop down menu.		1	Note:
			South-East		5	
I.16.	Current energy use	Below 50 Gj/100 cu.m.	Above 71 Gj/100 cu.m.		5	Note:
I.17.	Project start date	01/01/2011			0	Note:
I.18.	Expected finish date	01/01/2011			0	Note:
I.19.	Person responsible for	0			0	Note:
I.20.	Project manager	0			0	Note:
I.21.	Architect	0			0	Note:
I.22.	Local planning authority	0			0	Note:
I.23.	Key assumptions, issues, notes, etc., if any.	0			0	Note:
I.24.	Total	Previous Total 31	Current Total = 13		17	
				Difference		
ID	Description		Complexity level	Less Complex		

uction / 2.Inputs / 2.1.Guidance / 3.Framework / 3.1.Framework matrix / 3.2.Phase I-IV / 3.3.Support system, tool / 4.Modelling & simulation / 5. Summary

Figure I.9.2. Project summary sheet

APPENDIX J USER'S MANUAL FOR THE FRAMEWORK

Introduction: In this appendix, the user manual provided with the framework (HEaR) is provided. The manual was provided to supply more information about the use of the framework. Many types of useful tables and notes are also provided, for example, guidance on pre-project survey. The manual was developed using Word Processor and provided within the framework (spreadsheet) to be downloaded by users. The key aim behind providing the manual was much faster and flexible usage of the framework.

A Refurbishment Framework with an Emphasis on Energy Consumption of Existing Healthcare Facilities

Healthcare Energy and Refurbishment (HEaR)

USER'S MANUAL

December 2010: V.01.

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1. Introduction to the Framework, Spreadsheet-based Tool, and User Manual

It is an Excel-based framework that guides development of a refurbishment proposal for existing healthcare facilities. The objective of the Healthcare Energy and Refurbishment (HEaR) framework (spreadsheet & user manual) is to assist in interactive discussions for developing decision support systems. The framework provides:

- an effective process for refurbishment;
- guidance for various stages involved during refurbishment; and
- effective management during development of existing facilities.

The framework is structured to encourage user to clearly identify the linkages between the refurbishment stages and phases. It is designed to help healthcare organisations and can be used by:

- planners and facility managers;
- contractors, client to implement sustainable construction and resource efficiency principles; and
- whoever seeking to demonstrate and execute successful refurbishment.

The framework asks users to input data through simple forms and illustrates a complexity level of the project at the beginning. It helps to identify the most sustainable and optimum choices available during refurbishment.

It is divided into two key parts, the workbook and a user's manual in PDF format (this document). The spreadsheet is illustrated in 5 key tabs along with several other supporting tabs located at the bottom. The framework will help to develop a '*fit for purpose*' refurbishment proposal. HEaR has got two levels; first, for clients, stakeholders and second, for designers. The first level provides overview level, whereas the second level is detailed level; provides significant information.

The matrix as part of this framework outlines the key activities identified for refurbishment especially considering energy consumption and overall performance. The Framework comes into two parts, process flow (presented in the spreadsheet), and guidance to some of the areas is available through this document and subsidiary tabs.

Note: Make sure that a person responsible for the implementation has prior basic knowledge about the building considered for refurbishment as time-to-time inputs will be required.

KEY POINTS TO REMEMBER

- Each workbook contains a set of simple step-by-step instructions.
- The only cells highlighted in pink or empty are require user to enter data either by selecting an option from the drop down list or manually.
- Both the documents (spreadsheet and manual) should be use simultaneously.
- The empty, hidden, cells/sheets contain formulas that are used to pull the information from another part of the workbook.

2. How to use this framework

Layout and methodology of the Framework is set out in a continuation manner, thus it is suggested that a same person should use this framework throughout the process. The refurbishment framework is laid out in a logical, systematic format, as mentioned below.

- Cover page
- Introduction
- Project inputs
- Framework
- Modelling and Simulation
- Project summary

3. Cover page (First tab in spreadsheet)

Figure 1. Screenshot of Cover page

Buttons: 'Client' is for clients, stakeholders, which provides overviews of the framework. With this certain activities required for designers will be hidden. 'Designer' button helps to see all the tabs presented in spreadsheet. This will present all the details, including some guidance and suggested procedures for designers.

Buttons: 'Next' to access the framework and 'Exit' to close the spreadsheet is located in the top-right corner.

Project collaborators': logos are located at the bottom of the spreadsheet and, click on logos to know more about individual collaborators. Make sure you are connected to the internet to access collaborator's website.

4. **Introduction** (1. Introduction tab in worksheet)

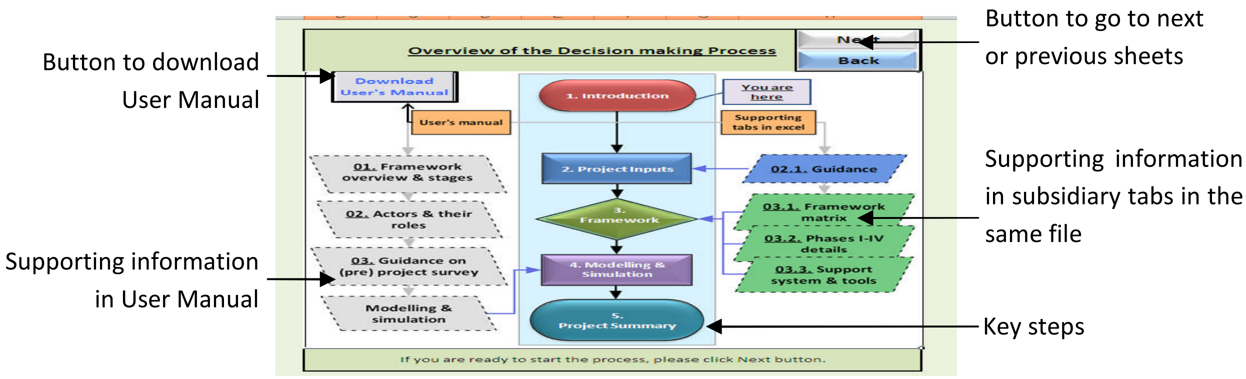

Figure 2. Screenshot of Introduction tab

Button to download User Manual: is located in the top-left corner of the sheet, will help throughout the application of the framework, and can be printed.

Supporting information in User manual: the column presented on your left hand side (LHS) indicates additional information available in this manual but not in the spreadsheet. The information will be required throughout the process and thus both the documents (spreadsheet and manual) should be use simultaneously.

Buttons to go to next or previous sheets: Back button will take you back to 'Introduction' sheet, from where process started. Next button will take you to the next stage of process however, before going to next step, make sure that you have completed all the information for this step.

Supporting information in subsidiary tabs in the same file: indicate supporting tabs available within the spreadsheet, to support key steps. The supporting information can be located in the tabs situated at the bottom of the sheet.

Key Steps: of this framework are presented in the middle column. Click on individual buttons located in the middle column to see more information about the specific key steps or click on 'Next' button in the top-right corner of the spreadsheet to start the implementation.

5. **Project Inputs** (2. Inputs tab in worksheet)

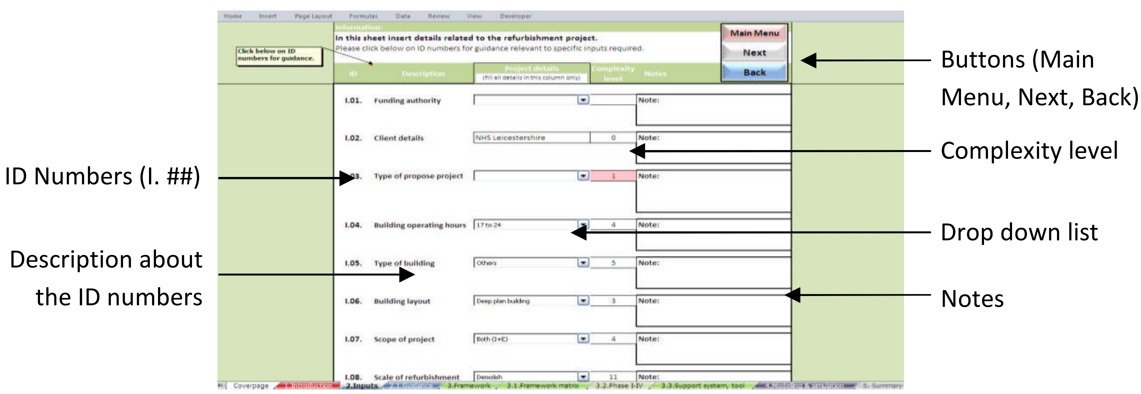

Figure 3. Screenshot of Project Inputs sheet

The section will be required you to enter some basic information about the proposed project.

ID numbers (I. ##): in regards to every input are located on left hand side. If you required help to complete any specific input please click on the ID number and this will provide additional information for that stage. This will take you to subsidiary sheets that will provide additional information.

Description about the ID numbers: is provided in the 2nd column. This is brief description and additional information (by clicking on ID number) can be found in the subsidiary sheets.

Buttons '*Main menu, Next, Back*': 1st button will take you back to 'Introduction' sheet, from where process started. Next button will take you to next stage of the process however, before going to next step, make sure that you have completed all the information for this step. Back button will take you to previous step.

Complexity level: is indicated in the box. Based on the selection from the drop down list, complexity level will change. Note that if the box is pink coloured means, no inputs have been given.

Drop down list: and combo boxes are located in the middle column of the sheets to give certain inputs. The value indicated next to boxes will be automatically adjusted depending on your inputs and choices. Make sure you have filled all the inputs, as the complexity level of the project will depend on the inputs given at this stage.

Notes: boxes are provided in the right column to add any specific information, which might be required later in the process as a reminder or for other experts involved on the project (especially client).

6. **Guidance** (2.1. Guidance tab in worksheet)

This is guidance to complete the Step Two (02. Project Inputs) indicated at the beginning of the process.

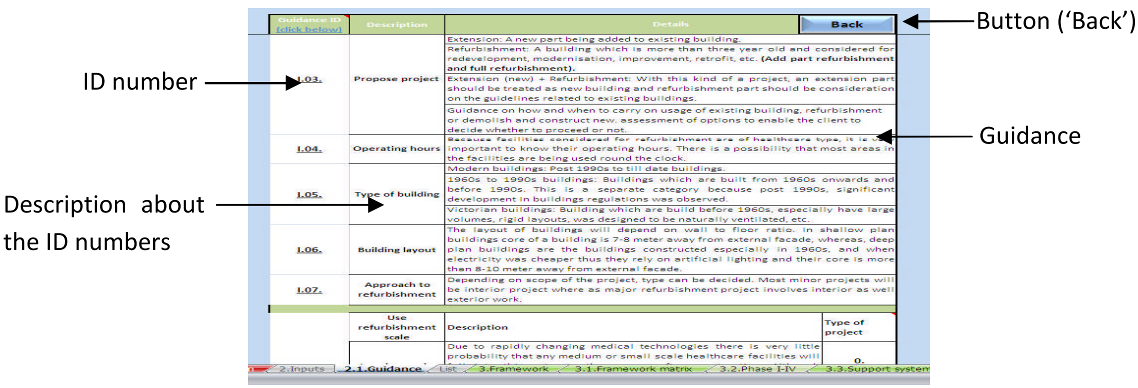

Figure 4. Screenshot of Guidance sheet

ID number: shown on this sheet and in the inputs sheet are same and must be cross checked before referring.

Description about the ID numbers: is provided in the 2nd column. This is brief description and additional information about the same is located in the next column.

Button: to go back to Project Input sheet.

Guidance: is provided to complete any input required in the previous sheet.

7. **Framework** (3. Framework tab in worksheet)

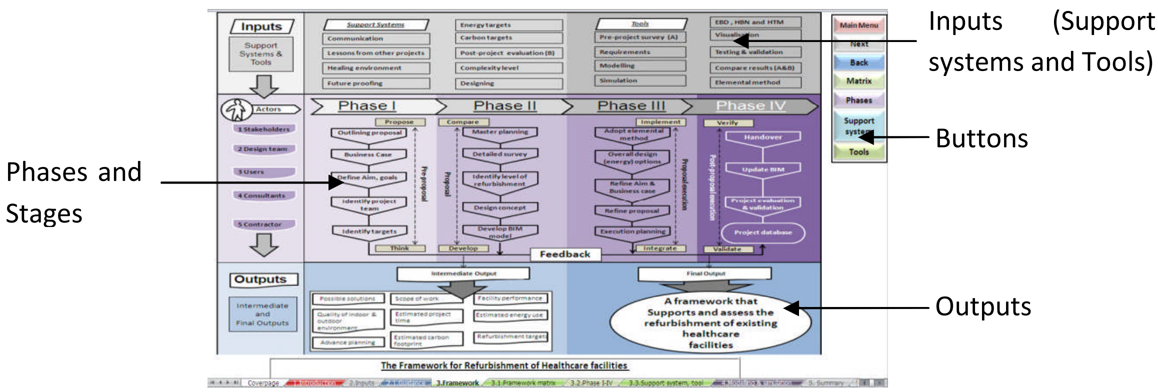

Figure 5. Screenshot of worksheet presenting framework

Phase and stages: as part of this framework are presented in this sheet in the middle row. The entire process is divided into four phases, and first three phases are divided into five and the last phase in divided into three stages. To know more about any of the phases or stages, click on that stage or phase and it will guide you to tab number 3.1 Phases I-IV details, which will provide you additional difference.

Inputs: will support the framework to complete the required tasks. Click on any of the *'Support Systems'* or *'Tools'* to know more about the same. Not all but few support systems and tools are to be used during each and every phases, stages of the framework and more details are provided in the matrix under tab *'3.1. Framework Matrix'*.

Buttons: Main Menu, Next, Back, Matrix, Phase I-IV, Support Systems, and Tools, are provided in the top right corner of the sheet. In this document function of the buttons, *'Main Menu'*, *'Back'* and *'Next'* is similar to that of previous sheet. The rest of the three buttons provides supporting information as indicated at the beginning of the process.

Outputs: throughout the process and at the end of the process, certain outputs are expected which can help to develop a refurbishment database. More details about expected outputs are provided ahead in this User manual.

8. **Framework Matrix** (3.1. Matrix tab in worksheet)

This provides supporting information for third step in the process; 3. Framework.

Figure 6. Screenshot of Framework Matrix

Support System and Tools (A): are presented in the top row of the sheet, support systems are mentioned in the green boxes, whereas, tools to be used during the process are under blue boxes. The number of tick marks in the boxes represents the degree of relationship between support system and tools with the phases and stages.

Buttons: Main Menu, Next, Back, Matrix, Phase I-IV, Support Systems, and Tools, are provided in the top right corner of the sheet. In this document function of the buttons, 'Main Menu', 'Back' and 'Next' is similar to that of previous sheet. The rest of the three buttons provides supporting information as indicated at the beginning of the process.

Phases and Stages (B): are presented in the columns on the left and right with phases and stages. Depending on the stage of the project, support system and tools should be selected.

Relation between (A & B): the boxes with tick marks suggest which supports system and tools to be used during which stage of the phase. However, these are just suggestion but if the design team wishes, they can use more tools than specified in the matrix. One tick means important, two tick means moderately important and three means highly important to use suggested tool or support system during specific stage of the phases.

9. **Phase I-IV details** (3.2. Phases tab is worksheet)

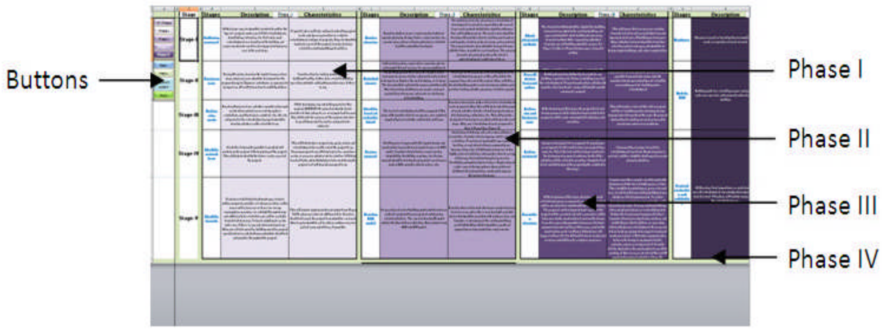

Figure 7. Screenshot of worksheet presenting Phases in details

Buttons: all phases' button to display information about all the phases is provided. Whereas, Phase I to Phase IV buttons are provided to see details about individual phases. Also, button, Back, Matrix, Support System and Tools are provided to see other subsidiary tabs provided in the sheet.

Phases I to IV: this sheets provides details about all four phases and stages during those phases. The sheet suggests what needs to be considered during each stage of the phases.

10. **Support Systems and Tools** (3.3 Support system, Tools in worksheet)

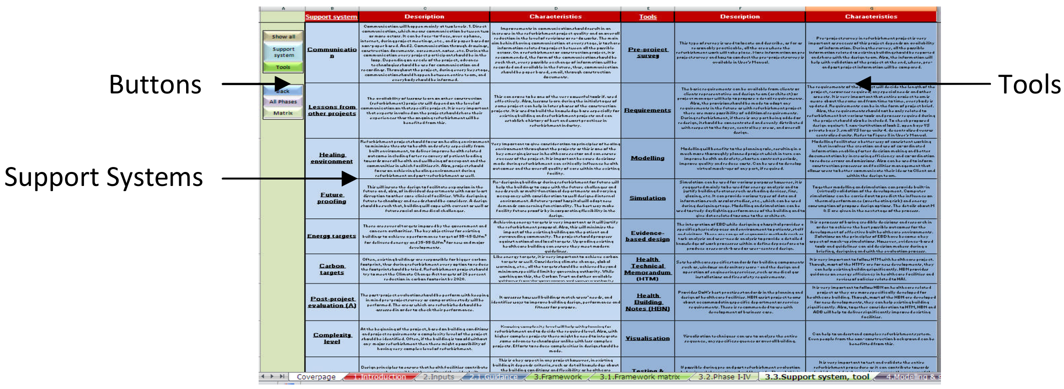

Figure 8. Screenshot of worksheet presenting Support System and Tools

Buttons: Back, Matrix, Phases are provided to see other subsidiary tabs provided in the sheet.

Support Systems: details are provided in this sheet. The will give details what individual support systems means, how and when to use with their benefits.

Tools: details are provided in this sheet. Details about which tools, and when to use those tools are mentioned earlier in the matrix and the framework. The will give details, characteristics of individual tool, how and when to use.

11. Modelling and Simulation (4. Modelling & Simulation tab in worksheet)

This will give additional details about from '*Stage 5 in Phase II*' to '*Stage 3 in Phase IV*'.

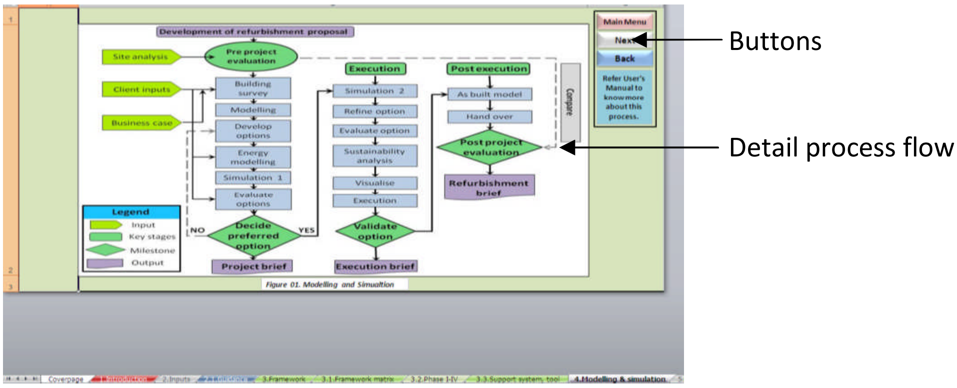

Figure 9. Screenshot of modelling and simulation

Buttons: three buttons (Main Menu, Back and Next) are located at the top. Button Main Menu will take to the beginning of the process, 'Back' will take you to the previous step and 'Next' to last step in the process; 'Project Summary'.

Detail Process Flow: the figure will give detail process about adopting modelling and simulation tools within the process.

The process indicated will generate various outputs throughout the process such as project brief, execution brief, refurbishment brief. The objective behind partial outputs during the project is to review projects to learn and avoid mistakes in the later stages as well as during development of similar projects in the future. The quality of the outputs will depend on the types of inputs received in the form of site analysis, client's inputs and business case. Figure 3 shows Phase II to IV in greater detail.

Inputs in the form of site analysis by the site team will be actual site data, physical conditions of buildings and surroundings. Inputs given by the client/stakeholder and end users may be related to their requirements and the type of end product they are expecting, whereas, the business case will include almost the entire project brief including financial and other issues. In any project, the business case plays a vital role, which can decide the refurbishment need, approach, type, and scale of construction. Also, all the briefs generated during the above process will validate the business case. Moreover, Project Brief and Execution Brief are important parts of Phases II and III.

Project Brief: will help to explore the early stages of projects. The brief will provide a ground on which a preferred refurbishment option can be selected or rejected. The brief should contain detail on the type of options considered, assessed and any learning during the process. The design team will be the major contributor to generate a Project Brief.

Execution Brief: will provide a brief about the execution of refurbishment proposal. This will contain most of the data related to site activities which can have influence on success of the projects and designing of future projects. An Execution Brief should provide a sound analysis of proposed operations in the context of the existing facilities. In this phase, a major contributor will be the site team and it will be useful for design team in the future.

Refurbishment Brief: will carry all the details from *'Project Brief'* and *'Execution Brief'*. The brief will be a part of Phase IV of the proposed framework (see Figure 2). This will help to validate the initial refurbishment proposal and refurbishment project and can prove to be very helpful with the future development of similar types of projects.

12. Project summary (5. Summary tab in worksheet)

This sheet will give you details about project summary, including what was the complexity level of the project, and summary of any notes if, provided at the beginning.

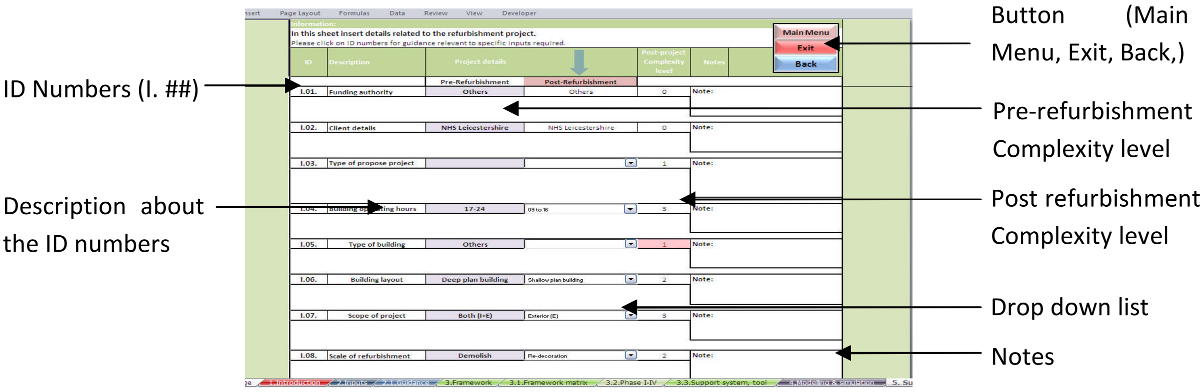

Figure 10. Screenshot of Project summary worksheet

In this tab all the inputs will be similar to *'Inputs tab'* and it will copy all the details automatically from input sheet. However, during the projects, some details might have changed thus, under column Post-refurbishment project details, all the inputs should be filled again which will help to compare pre and post refurbishment complexity level. Also, this will let help to know the actually complexity level involved in the project.

ID numbers (I. ##): are located on left hand side in regards to every input. If you required any help to complete any specific input please click on the ID number and this will provide additional information for that stage. This will take you to subsidiary sheets that will provide additional information.

Description about the ID numbers: is provided in the 2nd column. This is a brief description and additional information can be found in the subsidiary sheets.

Button '*Main menu, Exit, Back*': button back will take you back to 'Introduction' sheet, from where process started. Exit button will close this spreadsheet; however, before exiting make sure that you have completed all the information. Back button will take you to previous step.

Pre-refurbishment complexity level: is indicated in the box. Based on the selection from the drop down list, complexity level will change. Note that if the box is pink coloured means no inputs have been given.

Post-refurbishment complexity level: give you details about actual complexity level associated with the project.

Drop down list: and combo boxes are located in the middle column of the sheets to give certain inputs. The value indicated next to boxes will be automatically adjusted depending on your inputs and choices. Make sure you have filled all the inputs, as the actual complexity level of the project will depend on the inputs given at this stage.

Notes: boxes are provided in right column to add any specific information, which might be required in the future for experts involve on the project (especially client).

13. Guidance on pre-project survey

Table 1. Guidance on pre-project survey

Tasks	Description	Relevant issues
Room data sheet	Hygiene classification Air-conditioning Material to be used Operational facilities detail Room dependencies on or vice versa	All existing buildings.
Access	During pre-project survey, existing facility should be checked for whether it is possible to get access required for construction.	All existing buildings.
Users	Evaluation of behavioural observations should be made and, to check if entries and exit area for users will be obstructed by refurbishment work.	All existing buildings.
Investigation	Conduct a pre-investigation before starting any works. During investigation all the possible information should be recorded and shared with rest of the project team.	All existing buildings, pre 1990s buildings
Daylighting	Check window to wall ratio. If, there are areas which are not day lit, then provision of natural light and measures to avoid glare or extra sun light.	Especially buildings from 1970s-80s.
Envelope	With many existing buildings there is a problem of overheating because of excessive glazing area and/or single glazing area, and air leakages.	Especially buildings from 1960s-90s.
Check existing building elements and features against their efficiency	For e.g., check lamps for their efficiency; cleanliness. If there is any building feature or element which is not working properly, should be reported.	All existing buildings.
Nightingale ward	Check if there is any Nightingale ward. A Nightingale Ward is *"large open-plan space, which has not been subdivided into bays or cubicles and offers dormitory style accommodation for 12 or more patients"*.	Especially pre 1990s buildings
Hazardous material	With the help of experts a facility should be check for presence of any hazardous material such as asbestos, PVC, Polychlorinated Biphenyls (PCBs), Synthetic Mineral Fibres (SMFs) and lead-based paint.	Buildings from 1960s-80s

Six facet survey	*'Six facet survey'* should be considered which focuses on 1. Physical Condition Survey (Fabric, M&E). 2. Statutory Compliance Audit (including Fire). 3. Space Utilisation Audit. 4. Functional Suitability Review 5. Quality audit 6. Environmental management audit. The environmental characteristics that are known to contribute to stress or can have negative impact on health outcomes should be studied during pre-project survey or detailed survey.	All existing buildings.
Dependency of facilities	Refurbishments on large scale campus, before starting any work, buildings should be check if they day-to-day function are depend on adjacent buildings or vice versa.	For large scale campuses
Areas for construction works	Facility should be checked for if there is enough space available for refurbishment related work such as height, space.	Especially for Victorian buildings
Institutional features	Building should be check for what needs to remove to avoid institutional feature post-refurbishment.	Buildings from 1960s-80s

14. Actors and their roles in refurbishment projects

In any construction and refurbishment projects, several actors are involved and everybody must contribute to achieve successful refurbishment. Below Table 2 provides brief list of actors and their purpose and role in refurbishment project.

Table 2. Refurbishment actors and their roles

Actor	Definition	Project Planning Role
Owner	A private or public organisation (usually represented by a person or board of directors) ultimately responsible for the proper execution of the project	Defines the boundaries for performance (what they expect), budget, and time; provides much of the information that consultants utilise to determine feasibility and to develop the design program (transition into design phase)
Stakeholder	Specific people or organisations interested in the outcome of the project – can be internal (management, employees, etc.) or external (investors, community and environmental groups, government organisations, etc.)	Adds additional performance requirements and information to the process.

Consultant (s)	Are experts who provides advice and a variety of specialised services relevant to feasibility studies, master planning, functional and space programming, operational planning, geotechnical reports, environmental assessments, real estate acquisition, permitting consultants, etc.	Critical to the planning process – advise the owner and designers on various aspects (feasibility, cost expectations, future trends, operational effectiveness, constructability, design/contractor advertisement and selection, etc.)
Architect (designers)	Person or firm responsible for creating a building design that is constructible and meets the owners intent; delivers final drawings and specifications to be used by the Builder	Can be very beneficial in creating and finishing the design program (documents required at the start of design effort). Is part of the project throughout the life-cycle, depending on the type of contract.
Project Manager (PM)	Responsible for day to day management activities with regards to meeting project requirements and quality, schedule, and cost – usually considered the representative of the owner.	Can be utilized throughout the project construction life cycle – used to manage administrative functions, represent the owner in many cases, expedite decision making, etc.
General Contractor (GC)	Responsible for transforming the architect's drawings and specifications into reality – assumes overall responsibility for the construction, and holds the subcontractor trade agreements; therefore assumes the risk for the performance of work.	Can be utilized during planning (especially with a Design Build firm) where one contract is utilized. Can provide information on cost and timeline expectations early in the process.
Subcontractor(s)	Works for the GC and responsible for a particular trade or service as part of the construction effort.	Usually not involved in project planning – but can be used to obtain specific material or process costs and time expectations. Also, if possible should be involved during key stages of planning.
Facility manager (FM)	Is a manager from client/organisation side and will be responsible for day today running of facility.	One of the key actor involve with the project, who will be looking after the facility throughout its life and not during only refurbishment. The FM can provide good insight of the facility and will be key person during completion/handover stages.
User (1)	Patient, a type of users for whom the facility is being constructed or refurbished.	During critical stages of design, there group of users should be involved or consult.

User (2)	Staff, is type of user group who will be actual user of the facilities, all the time.	This user group should be considered during planning because they will be using this facility, more than any other user group. Also, involving this user for e.g. nurses can benefit significantly to design process especially in existing building as they have spent most of the time within the facilities.
User (3)	Visitor, generally they are relatives of user (1) and some of the areas such as lobbies, visitor toilets, waiting areas, etc., will be designed for them.	Though involvement of this type of users is optional, they should be consult during design as they are perspective user of the facilities

15. The proposed refurbishment scale

In below Figure 11 the refurbishment scale has been proposed with the help of data collected from the industry.

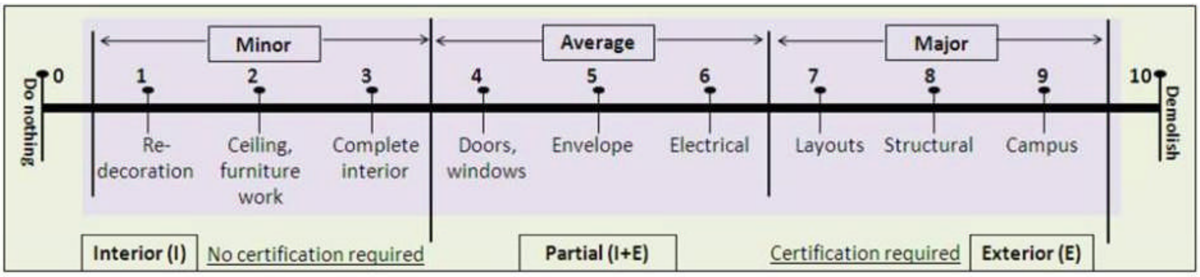

Figure 11. The proposed Refurbishment Scale

All refurbishment projects can be divided into one of three main categories: minor; average; and major. The key aim behind the development of the scale is to provide a sensible way in which refurbishment can be considered during the design stages of a project. In Figure 12, Type 0 means '*do nothing*', Type 5 being '*refurbishment of envelope*' including other activities for Type 1-4 on the scale, and Type 10 means '*demolish*' *or* to change the use of a facility considered for a refurbishment. The proposed scale is based on the characteristics of a project and not the size or quantity of the work, therefore, even though Figure 12 indicates that minor refurbishment works are usually interior and major works deal with exterior of facilities, sometimes minor works can be associated with exteriors and vice versa. Also, after a visit to a facility, the project team can decide on the type of the project, based on the above scale; this should help to establish overall project objectives and scope of work. Due to rapid changes in medical technology and service delivery, in more than three years old larger healthcare facilities there is little probability that the project will fall under '*do nothing*', (Type 0) on the scale. There are several certification schemes available that measure and assess the sustainability of new and existing healthcare facilities. However, due to a number of reasons it is not feasible or practical to consider such assessments for refurbishment projects under Type 1-3 (even though these projects are the most common and can be of large scale in terms of quantity). This kind of projects provide very limited opportunity to save energy, improve IEQ and have less impact on social and economical sustainability of facilities, which is the focus of most 'green' certification schemes. Whereas, in major refurbishment projects (Type 7 and above), almost the entire building is new apart from structural systems and foundations, where the project team and clients will choose to pursue certification, if projects goals and budget permit.

Sometimes existing buildings are refurbished to support the physical extension of existing facilities. In these types of projects, the scope of the buildings' refurbishment could be anywhere on the scale between Type 0-10, in addition to extension of facilities. The type of refurbishment project will depend on the approach towards refurbishment and the need for an extension project.

Considering the above types of projects, including Type 0 and Type 10 there are several factors which need to be emphasised during refurbishment. Before commencing any work, facilities should be checked for following conditions to decide type of refurbishment projects and scope of work.

Overall quality of the work: before commencing or finishing any work it is important to check overall quality of the work and space within the building. The quality of work has to be approved by experts or of approved standards. Even decisions related to '*do nothing*' or '*demolish*' will relate to existing work quality and space.

Energy consumption: except in Type 1 and Type 2, it is important to assess energy consumption and to have targets related to same. Also, targets related to energy will have a beneficial effect on IEQ and carbon foot-print of facilities.

Building conditions: in existing facilities this is important and must be considered during refurbishment of any type. Before adopting new technologies or new programs related to medical science it is important to check building height, strength, circulation spaces, etc. because insufficient floor to floor height, weak structure or lack of proper circulation spaces are common challenges associated with existing facilities.

Indoor environmental quality (IEQ): this should be assessed in all types of refurbishment projects and all proposals should demonstrate the ability to tackle IEQ in existing facilities. Indeed much of the healthcare industry's money is spent on staff salaries, and IEQ can have a significant impact on staff performance. Improved IEQ along with minimum energy consumption can reduce operational costs and improve performance of facilities by a significant amount.

Re-planning: is important to improve overall quality and to reduce complexities within existing hospitals, for example, improved ward layouts or circulation to reduce staff and nurse travel time within facility.

Sustainability: this should be considered because of an increasing demand from the industry to address environmental, social, and economical impacts. During refurbishment projects, sustainability should be considered irrespective of the scale of a project. Though there will be probably limited impact on social sustainability, refurbishment can improve economical and environmental sustainability significantly.

16. Elemental method

With this framework, an elemental method is proposed to be used with refurbishment projects. Below Figure 12, is an example of elemental method.

In most refurbishment project, individual building elements such as windows, lighting fixtures, floors, roof, envelop, etc., are treated. All such building elements should be treated or refurbished using above example to achieve overall success with the projects. The above method is suggestive and but overall approach should remain same for all the building elements. Even with this kind of approach, patient rooms, outpatient area, inpatient area should also be treated.

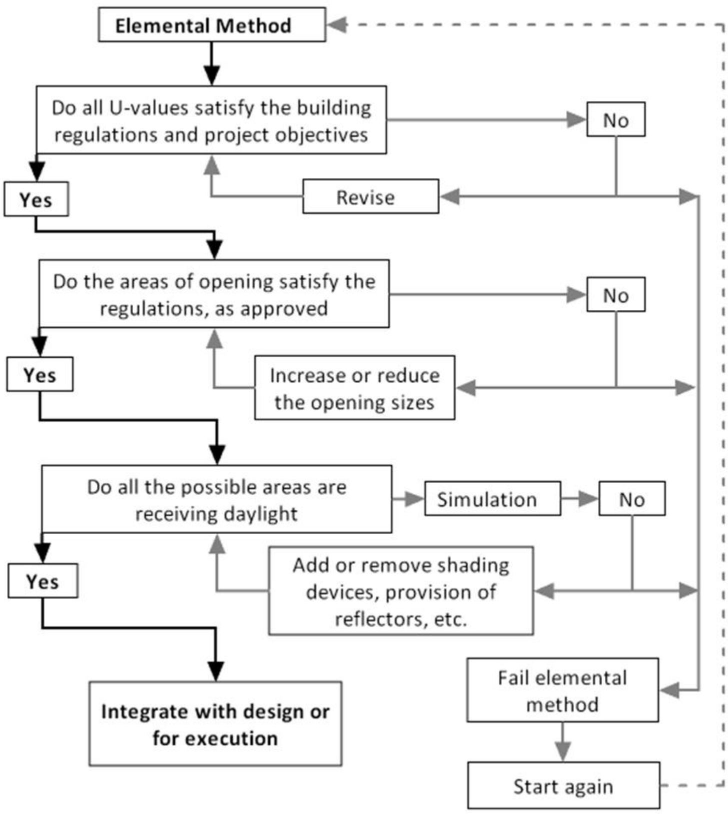

Figure 12. An example of elemental method

17. Expected outputs during the process

Through the process intermediate outputs and towards the end final outputs are expected. Outputs such as possible solutions, Scope of work, Facility performance, Advance planning should be generated throughout the process which will help in the later stages of the framework and with future refurbishment projects. Though these are the suggested possible output, a project team should decide the type of outputs to be generated throughout the process. This out will form as a database for this as well as future projects. Also, as part of the modelling and simulation process some additional outputs are expected, which should be also part of this task of the framework.

APPENDIX K FRAMEWORK EVALUATION QUESTIONNAIRE

Evaluation of the

"*Framework for Refurbishment of Healthcare Facilities*" with consideration to energy

General information and instructions:

- All the information provided will be retained, revised, and used exclusively by the researcher for academic and research purposes
- If you need additional space for comments, handwritten attachments may be added, or on request, copy of this evaluation questionnaire will be emailed. Please send your request to A.Sheth@lboro.ac.uk.

The framework aim and objectives are mentioned below.

Aim: to develop a framework that supports and facilitates the process of refurbishment of existing healthcare facilities with an emphasis on improving their energy and overall performance.

Objectives:

1. Develop a framework to support refurbishment of existing healthcare facilities and identify the components for management, design team to be included within the framework
2. To access the complexity associated with refurbishment projects
3. To generate refurbishment database to use throughout the process and with the future projects.

To accomplish above mentioned aim and objectives, the Framework includes following key components:

1. Complexity level
2. Decision making process
3. User's Manual

A.Sheth@lboro.ac.uk 1 The FM Evaluation Protocol_V2

1. **Personal details:**

   Full name:-

   Brief job description and background:-

2. **Do you think the framework and its components are clearly explained? If not, then please suggest which part and what should be improved?**

Response:

3. **What do you think about following aspects of the framework?**

   - Overall presentation of the framework including User's Manual:

   - Relevance with research context:

Note: *Responses to questions numbers 4 to 8 should be on the scale of 1 to 10, where 1 is worst and 10 is very good. Please put a circle or check mark around desirable option on the scale.*

4. **The extent to which the proposed developed framework assesses the relative possibility of refurbishment?**

Response:

1 2 3 4 5 6 7 8 9 10

5. **Whether the developed system provides realistic scenarios that enable a potential user in making informed decisions, so as to implement the framework?**

Response:

1 2 3 4 5 6 7 8 9 10

6. **The degree of usability in terms of provision for friendly and easy to understand interface?**

Response:

1 2 3 4 5 6 7 8 9 10

7. The relevance and desirability of the framework to the industrial community.

Response:

1 2 3 4 5 6 7 8 9 10

8. **Do you think this framework will help to improve current refurbishment processes?**

Response:

1 2 3 4 5 6 7 8 9 10

9. **Are the aim and objectives stated at the beginning fulfilled? If no, what can be done better?**

Response:

10. Advantages and barriers of the ***"Framework for Refurbishment of Existing Healthcare Facilities".***

- **Advantages**
  1.
  2.
  3.
  4.
  5.
- **Barriers**
  1.
  2.
  3.
  4.
  5.

Give feedback, recommendations and suggestions (websites, references, etc.,), if any. Please suggest any other framework, which can be compared with the proposed framework, if you know.

Response: