Economic Considerations for Adaptability in Buildings

by

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Doctoral Thesis

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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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…………………………………………….. (Date)

Dedicated to my beloved **Dad** and two **sisters…**

for their unconditional **love** & **kindness**

Abstract

The existing buildings in the UK are not designed to be functionally adaptive to fit a spectrum of purposes. Alternatively, scrapping these buildings and building anew does not appear to be an economically viable and environmentally sustainable solution either. Proactive solutions to respond to future potential changes of use are rare in previous and current building designs, which ultimately make these buildings functionally redundant. At present, curiosity about adaptable buildings is spreading among owners, developers and policy makers; however, no detailed investigation has been undertaken to identify the economic costs and benefits of adaptability in new buildings. Thus, the present endeavour was designed to bridge this gap.

The research exploited both case studies and survey designs to explore the answers to the above problem. Two case studies were undertaken to establish that building changes occur over time, as well as to assess their economic implications in the current built environment at both macro and micro levels. Three web-based surveys (WBS) were designed and circulated among quantity surveyors and architects of the 100 leading consultancy practices in the UK to identify both the design and economic aspects of adaptability in buildings. The total numbers of respondents to WBS1, WBS2 and WBS3 were 13, 32 and 42, respectively. In addition, data was collected from semi-structured interviews with two policy makers, two structural engineers, a quantity surveyor and a facilities manager. Unstructured interviews with a senior planner, a project manager, two architects and a services engineer were used to clarify the issues of design and planning for adaptability in buildings. The findings were interwoven to develop a conceptual framework to identify the economic considerations for adaptability in new buildings. Two workshops were undertaken with the industry partners for the Adaptable Futures research project to verify the results obtained from the case studies and to test the usability of the developed conceptual framework. The group members had multi-disciplinary backgrounds of architecture, quantity surveying and structural engineering, allowing a robust grounding for verification.

The results contribute to the body of knowledge in two ways. Firstly, the developed conceptual framework identifies the economic considerations (costs and benefits) for change of use in buildings within the wider context of adaptability over the lifecycle aspects. This will assist owners/clients and developers in their economic decisions for designing new buildings for potential adaptations. Secondly, the research findings strengthen the reliability of the existing body of knowledge whilst confirming the urgent need for designing new buildings towards potential adaptations. In addition, the findings strongly emphasise plan depth and floor to ceiling height as the most influential design parameters for building change of use, the details of which are not highlighted in the previous literature.

Keywords: Building change of use, adaptable buildings, design parameters, economic considerations, conceptual framework

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Abbreviations

AB	Adaptable Buildings
AF	Adaptable Futures
ARP	Adaptive Reuse Potential
BCIS	Building Cost Information Service
BMCIS	Building Maintenance Cost Information Service
BREEAM	Building Research Establishment Environment Assessment Method
BSRIA	Building Services Research and Information Association
CAD	Computer Aided Design
CDM	Construction Design Management
CDP	Critical Decision Point
DFA	Design for Adaptation
EE	Economic Evaluation
EU	European Union
FFFH	Finished Floor to Floor Height
FM	Facilities Management
HMSO	Her Majesty's Stationary Office
HSBC	Hong Kong and Shanghai Banking Corporation
HVAC	Heating Ventilating and Air Conditioning
I3CON	Industrialised, Integrated, Intelligent Construction
IMCRC	Innovative Manufacturing and Construction Research Centre
IRR	Internal Rate of Return
ISO	International Standards Organisation

IT	Information Technology
LCC	Life Cycle Cost
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
RIBA	Royal Institute of British Architect
ROA	Real Option Analysis
SFCA	Standard Form of Cost Analysis
SWOT	Strengths, Weaknesses, Opportunities, Threats
TPI	Tender Price Index
UFCSH	Usable Floor to Ceiling Soffit Height
UK	United Kingdom
USA	United States of America
WBDG	Whole Building Design Guide
WBS	Web Based Survey
WLA	Whole Life Analysis
WLC	Whole Life Cost
WLCC	Whole Life Cycle Cost
WW	World War

Chapter One

1. INTRODUCTION

The purpose of this introductory chapter is to provide a summary of the research on 'economic considerations for adaptability in buildings'. The background explains the rationale and the literature on the adaptable potential needed in new buildings in order to present the current state of knowledge and the existing gaps in the literature. Subsequently, the chapter provides the study's aim and objectives and explains how the research was designed and its scope and delimitations. The last part of this chapter highlights the contribution to the body of knowledge and the value of undertaking this study.

1.1 Background and rationale

Recent consideration has been given to identify how the new building stock could be adapted for 21st century challenges (Henehan and Woodson 2003, Sheffer and Levitt 2010). This requires an understanding of the extent of changes required to the existing building stock and the lessons learned for designing new buildings to survive future markets. In general, buildings may change during their lifespans in terms of the *'function'* they house, the *'capacity'* to achieve the performance required for the population they hold, and the *'flow'* of reacting to internal and external environmental forces (Slaughter 2000). The need for such change is now being understood (Douglas 2006, Adaptable Futures 2008). Building '*change of function/use'* has emerged as a principal issue in the UK property market, as too many buildings perform inefficiently in terms of flexibility of use, operating and maintenance costs and sustainability (Egan 1998, Sev 2009). The main reason is that the existing building stock is not functionally adaptive to fit a reasonable spectrum of purposes, while, alternatively, scrapping and building anew does not appear as an economically viable and environmentally sustainable solution. However, proactive solutions for potential change of use are rare within current building design. This leads to *'dead building syndrome'* (Roaf *et al.* 2009), which has become another critical problem in the UK, such as in the aftermath of the 2008 economic crisis. Furthermore, recent government legislation (e.g. landfill tax) and policies (e.g. Strategy for Sustainable Construction 2008) encourage building owners/clients to rethink the possibilities and potential avenues for reusing space (adaptive reuse) while extending the functional lifespan of their buildings. In addition, the UK government is seeking alternative strategies to minimise functional redundancy while promoting optimum use of the existing building stock in urban centres; it encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than demolition and renewal (Davison *et al.* 2006). Nevertheless, the conversion processes might be neither economical nor practical in many circumstances; therefore, there is a real need to design new buildings for potential adaptations.

As an innovative solution to many of the above problems, consideration is now being given to exploring the possibilities of integrating adaptable potential in new buildings. The term 'adaptation' often appears in the manufacturing industry, although recently it has also emerged in the building industry as an innovative strategy for minimising the premature retirement/redundancy of buildings. Many of the manufacturing products are industrialised, produced on a mass scale, short in lifespan and highly focused on customer flexibility compared to construction products (Hashemian 2005). These adaptable techniques from the manufacturing industry could perhaps be exploited to a certain extent in construction practices when products need to show similar characteristics, like flexibility, customisation and adaptation. The importance of 'adaptable buildings' in construction businesses has been recently discussed by many authors, particularly with regard to various facets of building adaptations, like *'technical and functional performance of adaptable buildings'* (Gann and Barlow 1996, Slaughter 2001, Kendall 2003, Larssen and Bjorbery 2004), '*stakeholders' motivation and benefits'* (Arge 2005, Kalita 2006), *'regulations and policies'* (Kincaid 2002, Adeyeye *et al*. 2010), '*sustainability'* (Kincaid 2000, Thomsen and Flier 2009) and '*risk'* (Remoy and Voordt 2007). Assuming a potential growth in the need for adaptable buildings in the UK property market, such endeavours were taken to make buildings more adaptable for future changes. However, existing planning policies, building regulations, industry guidelines and government strategies appear to be key limitations for designing buildings towards potential adaptations; thus these standards urgently require revitalisation if such adaptation is to be enabled in the future.

This study assumes ‘adaptable building’ as an innovative strategy for designing new buildings towards future adaptations, not least because it extends the economic and functional lifespans of buildings (Douglas 2006). Specifically, adaptable buildings can be defined as ‘dynamic systems that carry the capacity to accommodate a set of evolving demands regarding space, function, and components’ (Adaptable Futures 2008). A maladaptive building is one that cannot match the new demand placed upon it, whether it is technically unviable or cost-inefficient. The line between the two can often become blurred and depends on a set of exogenous and endogenous demands that can be determined through careful evaluation. Correspondingly, open building design (Habraken 1980, Kendall 1999) provides a similar conceptual philosophy but falls short of providing clear criteria for evaluation, focusing primarily on the separation of long and short-term components.

In short, building change of use is recognised as a central issue for undertaking this study as many buildings have changed their use in the past and subsequently created predicaments (e.g. economic difficulty, social and environmental strains, and redundancy). Hence, many research studies have been concerned with the change of use (conversion) in existing buildings, emphasising it as a costly endeavour. However, no economic considerations for change of use in buildings at their design stage were envisaged, as it is difficult to foresee a building’s future. Many researchers see it as a worthless attempt because one cannot predict the extra costs for unforeseeable changes, unpredictable timings of actual occurrences in specific changes and the immeasurability of volumes of change, and the present costs may be higher than the future costs for the same changes. Hence, the recurrent trend was to design buildings for specific use only, without allowing any design/cost provisions for potential change of use. This leads the building to be functionally obsolete, requiring major refurbishments or demolition if an intolerable change of use is needed.

Interest in adaptable buildings is spreading among clients/owners, developers and policy makers (Kalita 2006); however, no-one has hitherto studied the economic considerations for adaptability in new buildings from the owners’ point of view. Of course, financial concerns are becoming increasingly difficult to ignore in client’s economic agendas. This appeared as a significant gap in the current literature, so this study was designed to bridge this gap.

1.2 Research aim and objectives

The aim of this research was '*to identify the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects'*.

The study followed five objectives:

1. to establish that building change occurs over time and to identify its economic implications;

2. to identify the principal design parameters for designing new buildings towards future potential change of use;

3. to explain the lifecycle extendibility of adaptable buildings to react to this change of use;

4. to investigate the economic considerations of extended functionality; and

5. to develop and validate a conceptual framework for evaluating the economic considerations for adaptability in buildings.

The research flow diagram (illustrated in Figure 1-1) encapsulates the work undertaken, methods used and the results obtained from this research investigation. Step 1 explains how the research question, aim and objectives were defined. Step 2 was designed to provide answers for objectives 1 and 2. Step 3 was used to explore the answers for objectives 3 and 4. Finally, step 4 was used to accomplish objective 5 of this research investigation and to provide overall conclusions regarding this endeavour.

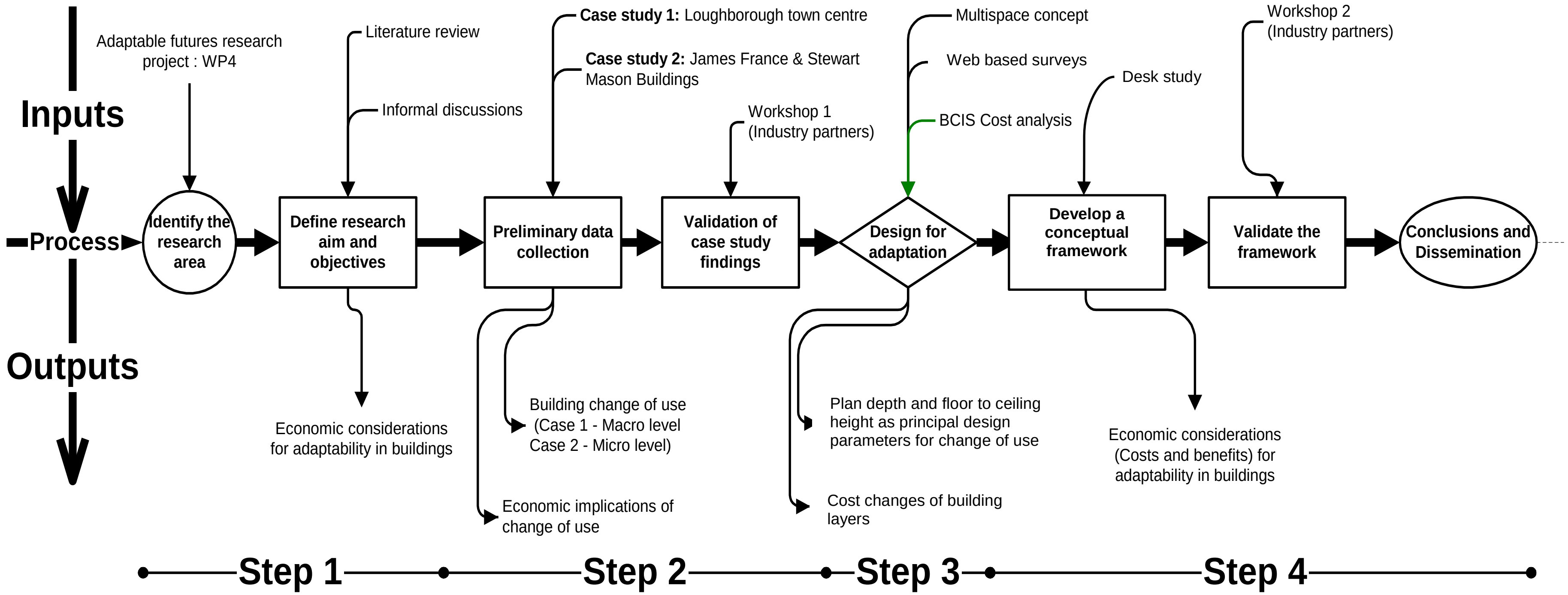

Figure 1-1: Research flow diagram

1.3 An overview of the work

The overview of the work is reflected through two research designs. Case study design was exploited to investigate building change of use over the last 100 years and to understand the real need to design new buildings towards potential adaptations. In a sense, two single case studies were undertaken to establish the building change of use at the macro and micro levels of the built environment. A survey design was used to identify the design and economic criteria for building adaptations. Three web-based surveys (WBS1, WBS2 and WBS3) were carried out by architects and quantity surveyors to clarify the design and economic issues of adaptability in buildings. The findings of the case studies and surveys were connected through a desk study and a conceptual framework was developed for identifying the economic considerations for change of use in buildings.

First, a case study of Loughborough town centre was used to study the chronological pattern of change of use in buildings over the last century. The case aimed to identify how functional uses have been changed in a typical borough through a morphological analysis. The second case study was used to explain the micro level change of use of a typical building and further discusses the design concerns behind that change of use. The justification for selecting the single case study method is discussed in chapter three and the reasons for selecting these specific cases are discussed in chapter seven. These case studies were analysed together to investigate the economic implications of building change of use, which ultimately helps to propose how new buildings could be designed to adapt for potential future changes of use. The findings of case studies have been presented in a workshop (Industrialised Integrated and Intelligent Construction - I3CON). Secondary data analysis and semi-structured interviews were used to generalise the findings of the case studies.

Secondly, three web-based questionnaire surveys were circulated among professional experts in the disciplines of architecture and quantity surveying to identify the design and economic issues in building change of use. In addition, an extensive analysis of secondary data (BCIS cost data) was carried out to identify the most cost-consuming building component/layer (in terms of initial capital cost) and its influence on potential adaptations. Secondary data from the interviews conducted by the Adaptable Futures project was used to understand the policy issues and design considerations for adaptability in buildings. In addition, eleven interviews (semi-structured and unstructured) were undertaken with quantity surveyors, structural engineers, facilities managers, academics, planners and policy makers to strengthen the above studies. The results of the second study were used to advise the design team in decisions on potential adaptations and their economic considerations. The findings of each study were assembled through a desk study and a conceptual framework was developed and tested for its usability through a workshop and two informal discussions with project partners for Adaptable Futures research project.

1.4 An overview of the methodology

To address the problems that the construction industry faces, researchers need to adopt a robust methodological approach that takes account of both ontological and epistemological viewpoints (Love *et al.* 2002). The study identifies *'building change of use'* as a driver for functional redundancy in buildings and seeks to identify the possibilities of using adaptable building strategies to react to this change while investigating the economic considerations.

The study was guided by the 'pragmatism knowledge claim' and categorised under the applied research category. The dominant purpose was in the tradition of explorative research. However, some aspects of descriptive and explanatory research traditions were exploited by objectives 3 and 4. The study requires such understanding of the cost and benefit aspects of change of use. Thus, empirical, evidence-based, practical investigation (applied) was undertaken. A multi-method approach was adopted and the methodology, literature review, case study, archival analysis, semi-structured and unstructured interviews, web-based questionnaire surveys and secondary data analysis were used to gather the data and a desk study was used to develop the conceptual framework for identifying the economic considerations for adaptability in buildings. These methods can be exploited to generate new knowledge specifically in the field of adaptable buildings by bringing the theoretical insights into a real-life context with empirical verifications. A summary of the research methods adopted (data collection, analysis and validation) for completing each objective is illustrated in Table 1-1.

Table 1-1: Summary of the adopted research methods

Research objectives	Adopted Research Methods								
	Literature review	Informal discussions	Archival analysis	Semi-structured interviews	Web-based surveys	Secondary data analysis	Case study	Focus group workshop	Desk study
1. to establish that building change occurs over time and to identify its economic implications;	●	●	●	●			●	●	
2. to identify the principal design parameters for designing new buildings towards future potential change of use;	●	●		●	●	●	●		
3. to explain the lifecycle extendibility of adaptable buildings to react to this change of use;	●	●		●	●	●			
4. to investigate the economic considerations of extended functionality;	●			●	●	●			
5. to develop and validate a conceptual framework for evaluating the economic considerations for adaptability in buildings.	●	●						●	●

The collected data was mainly qualitative; however, a small amount of quantitative data was also collected. The results were analysed through descriptive statistical methods and ‘triangulation’ was used to establish the quality and rigour of this scientific investigation.

1.5 Scope and delimitations

The scope and boundaries (theoretical and practical) of a particular research inquiry is one of the most significant concerns of research design. The main purpose of this study was to identify the economic considerations for adaptability in new buildings, while learning lessons from adaptive reuse. Building change of use is a general occurrence/process that is frequently endured by many buildings worldwide. In fact, the UK government is encouraging stakeholders in the construction industry to make their buildings more adaptable for potential change of use to minimise the rate of building redundancy. The literature reveals different design strategies for improving adaptability in buildings. However, restrictions on time and the availability of funds narrowed down the study to a single but most influential adaptable strategy: '*change of use*'. The rationale for selecting this specific strategy is explained in chapter two.

The research aimed to identify the potential lifecycle extendibility of a building in its 'use' phase and sought to identify such precautions at the 'design' phase. The intermediate phase, 'construction' (method statement and resources), is not detailed. The study exploited four use typologies: residential, hotel, office and retail. The main reason for this categorisation was the similarity in their use, design, procurement and economic considerations (cost per gross floor area). The building sample considered in this study was limited to 4 – 12 storeys (middle range) because the design loads on foundations are unlikely to deviate in this range. No attention was paid to high-rise structures or buildings with three or less storeys. However, the importance of undertaking economic evaluation for adaptable healthcare and social facilities is acknowledged, which is not reflected in the developed conceptual framework because of the specific design and procurement considerations. In a way, the flexibility/adaptability of hospital buildings is achieved by fragmenting the design into three systems based on service life (a primary system, a secondary system and a tertiary system). However, in retail and office buildings the separation of the systems ensures independence of the lower level system/s from the higher level system/s, affording flexibility to changes while minimising construction (Harvey *et al*. 2008). In addition, healthcare buildings are frequently procured through PFI (private finance initiatives) and they are also typically designed to have separate service floors (i.e. interstitial space). Therefore, special attention would need to be given to the design and procurement of healthcare facilities, which is outside the scope of this thesis.

1.6 An overview of the research findings

The results of the case study depicted:

- that building 'change of use' is a generic occurrence that many buildings usually undergo; and

- growth of population, developments in industrial, manufacturing and higher education businesses, and changes in planning policies are highly influential to the change of use in buildings.

The web-based surveys with architects and quantity surveyors, the semi and unstructured interviews of policy makers, planners, quantity surveyors and facilities managers and the inputs of the Adaptable Futures research project helped to confirm the following findings:

- 'plan depth' and 'floor to ceiling height' are the most influential design parameters for building change of use. However, they are dependent on other design and physical parameters;

- the 'cost of building services' has a significant influence on the total cost of building change of use; and

- in addition to the standard cost categories of ISO 15686 – Part V (2008), the cost of adaptation is introduced within the specific subcategories of:

    - **Non-construction costs:**

        - Cost of finance, market research, design and development.

    - **Lifecycle costs:**

        - Initial capital cost of potential adaptations (structure, skin, services and space plan);

        - cost provisions for future adaptation (extra space and load allowances);

        - maintenance costs (extra space);

        - operation costs (energy cost, cosmetic repairs and refurbishments); and

        - end of life costs (adaptive reuse potentials).

The structure, skin, service systems and space plan (internal finishes and partitions) are the key layers/components that are highly influenced by the potential change of use to a building. Generally, these elements demand higher initial capital costs of construction. Design for adaptation (DFA) requires extra cost, space and load provisions than maladaptive buildings.

This leads to an increase in the maintenance and operation costs of adaptable buildings. The possibilities for converting the building to potential new functions are appreciated within the economic lifecycles of adaptable buildings. However, the financial risk (spending more for an unforeseeable challenge) seems to be a dis-benefit of adaptable buildings. Potential income, economic, social and environmental sustainability and tax concessions were identified as the key benefits of DFA.

1.7 Contribution to the body of knowledge

The contribution to the body of knowledge from this investigation is twofold:

First, the developed conceptual framework identifies the economic considerations (costs and benefits) for change of use in buildings within the wider context of adaptability over the lifecycle aspects. This will assist owners/clients and developers in their economic decisions on designing new buildings towards potential adaptations.

Secondly, the research findings strengthen the reliability of the existing body of knowledge while confirming the rapid trend for building change of use. In addition, the findings strongly emphasise that plan depth and floor to ceiling height are the most influential design parameters for building change of use, which were only vaguely identified in previous literature.

1.8 Guide to the thesis

After the introductory chapter, this thesis comprises ten more chapters:

Chapter Two

This short chapter is used to discuss the worst impacts of ‘change of use’ on built environment facilities and to emphasise the real need for exploiting innovative tools and techniques to respond to these built environment changes.

Chapter Three

This chapter elaborates on the research methodology used in this study. A comprehensive overview of the research philosophy, design and adopted research methods are discussed while providing pertinent justifications on method selection and sampling.

Chapter Four

The historical context of adaptable buildings is discussed in chapter four. Moreover, the chapter explains how other industry sectors exploit the concept of DFA in current practice.

Chapter Five

Chapter five explains adaptable buildings as nascent but strong and practical solutions to defeating the previously explained (chapter two) built environment challenges. A comprehensive literature review was undertaken to identify the capacity of adaptable buildings, their strategies and the principles for enabling potential built environment changes. The chapter concludes by emphasising the value of identifying the economic considerations for adaptability in buildings.

Chapter Six

Chapter six provides the theoretical underpinning of the literature related to the economic evaluation (EE) of built environment facilities. The chapter consists of three main sections. The first section elucidates the EE process and proposes whole life analysis (WLA) as a robust method for identifying the economic costs and benefits of adaptable buildings. The second section explains the WLA for adaptable buildings and the last section identifies the appropriate EE tools and techniques for undertaking WLA for adaptable buildings.

Chapter Seven

This chapter reviews the historical change of use in buildings over the last 100 years and the economic implications through two detailed case studies. The first case study (Loughborough town centre) focuses on the macro level change of use in a selected cluster and the second case study (industrial to classroom conversion) explains the micro level changes of a building to adapt to a new use. The findings of both cases were used to identify the economic implications of building change of use and establish the real need for designing new buildings towards potential adaptations.

Chapter Eight

This chapter identifies the economic considerations for adaptability in buildings through a series of empirical investigations. The chapter follows two different studies. In the first study, BCIS (Building Cost Information Service) cost analysis was used to identify the cost of significant building layers. The second study exploited three web-based questionnaire surveys with architects and quantity surveyors to identify the design and economic considerations for adaptability in buildings.

Chapter Nine

This chapter assembles the results of the work undertaken and develops a conceptual framework for evaluating the economic costs and benefits of adaptability in buildings. The whole chapter explains the development and validation process of this conceptual framework. The process follows the need analysis, development and validation processes of a conceptual framework for evaluating the economic considerations for adaptability in buildings.

Chapter Ten

Chapter ten provides an overall discussion of this research endeavour. The priority of this chapter is to explain how the research objectives were achieved within the specified research boundaries and the credibility of the results. Moreover, the chapter compares the similarities and differences of the research findings with the current state of knowledge.

Chapter Eleven

Chapter eleven covers three sections. The first section explains the conclusions of this research endeavour. In the second section, the contributions to the body of knowledge are envisaged. In the last section, recommendations for further research are provided.

Chapter Two

2. BUILT ENVIRONMENT CHALLENGES – A NEED FOR CHANGE

2.1 Introduction to chapter two

This preliminary literature review chapter explains the purpose and rationale of this study. The first section of this chapter discusses the different challenges that the existing built environment is confronted with in the 21st century. The next section reveals the capabilities and limitations of existing buildings to respond to these challenges. The last section underlines the real need for designing new buildings to respond to these challenges and the importance of identifying the economic considerations.

2.2 Built environment challenges

The built environment today faces myriad challenges. As a result, a significant change in quantitative and qualitative methods in the demand and supply of the built environment equation has been identified (Kincaid 2000). The challenges appear in the areas of *'environment considerations'* (Geraedts 2008), *'innovations in technology'* (Flanagan and Tate 1997, Nutt 2000), *'planning and policy issues', 'social requirements, 'political forces'* (Gann and Barlow 1996) and *'economic considerations'* (Arge 2005, Douglas 2006). To respond to these challenges positively, existing built environment facilities need to be upgraded or new facilities need to be incorporated in such adaptable potential.

Environment considerations have stimulated awareness among stakeholders in the construction industry. The built environment accounts for 44% of UK emissions, although new properties are increasingly more environmentally friendly (Craven 2011). Therefore, attention has been paid to improving energy efficiency practices, reducing carbon footprints and minimising construction and demolition waste in existing and new building stocks to fit the sustainability agenda. The strategies of *'adaptive reuse'* (Kincaid 2000) and *'brownfield developments'* (Silverthorne 2006) are discussed in the literature as better means for using existing buildings in a sustainable way. Building transformation, if structurally possible, is a much more environmentally efficient way to achieve the same results than demolition and new construction (Tard and Kunder 2007). In a way, reuse benefits are seen as not only a lower cost option for the typical end-user, but also in the value of retaining the style and character/heritage of buildings, the solid build qualities and the appropriateness of their location (Ball 1999). However, adaptive reuse is not always appreciated in the client's economic agenda, as this process is sometimes not practical to undertake and economically unjustifiable because the original design does not incorporate such adaptable potential. Therefore, there is a need to reduce the amount of materials consumed and waste produced from the production and demolition of buildings (Fernandez 2003).

The factors of innovations in information technology (IT), rapid change in both private and public organisations and new ways of working demand more innovative and flexible workplace designs (Nutt 2000, Kincaid 2002, Arge 2005). Today, 'home working' is becoming increasingly popular in worldwide businesses as one of the smarter practices for minimising social and environmental problems. Thus, it has been realised by designers that there is a need to upgrade existing buildings or design new buildings to respond to these modern technological challenges.

In social considerations, the changing pattern of user requirements and expectations also demands built environment changes (Kincaid 2002). The thinking patterns of new generations and their dynamic lifestyles require buildings to adapt as quickly as possible. However, the maladaptive performances of existing buildings and their inability to respond rapidly to change makes it difficult for them to survive these volatile demands. This drives the building to be obsolete or demolished. Also, vacant spaces have macro level impacts on society and can lead to opportunities for theft and vandalism. Adaptable buildings have the ability to *'respond to different spatial layouts'* (OECD 1976) and to respond to *'quick transformations'* (Juneja and Roper 2007) in the built environment whenever required.

Government policies, planning and zoning considerations, and political forces also have dramatic impacts on built environment changes. New policies and guidelines were introduced with the transition of the new government to further respond to sustainable requirements. These policies and initiatives consider improvements in the urban agenda and inner city regeneration while seeking to shift existing buildings/functions completely and/or partially from their original locations. In this realm, adaptable strategies (‘movability’ and ‘convertibility’) are acknowledged when responding to planning and policy issues. Economic factors, which are inflation, economic growth, business cycles, tax levels and interest rates, are highly influential to changes in buildings (Douglas 2006). The growth of businesses influences existing buildings to adapt quickly to different markets, as business lifecycles are increasingly being designed with shorter lifespans.

In short, innovations in technology, growing global ecological awareness and changing economic and societal priorities drive building change (Fernandez 2003). Changes of use/function, volume/capacity or condition/status (Slaughter 2001) are considered to be the ‘demand’ issues of building change; availability, suitability, quality and distribution are considered to be the ‘supply’ issues (Douglas 2006). The imbalance between demand and supply creates social, environment and economic predicaments. Therefore, the characteristics of existing building stock need to be evaluated to respond to potential built environment challenges.

2.3 The existing building stock

The existing building stock is an important physical, economic, social and cultural capital to any nation (Kohler and Hassler 2002). However, it diminishes in value as it cannot respond to dramatic built environment changes because it is purposely designed to hold a single (mono) function during its whole lifecycle. Nutt (1997) argues that traditional buildings will provide an inadequate basis for the requirements of re-use, mixed use and change of use in the future as they no longer meet the present day user’s needs and are less likely to fit the sustainable agenda (Geraedts 2008). The existing building stock is showing different trends towards:

- the long lifecycles of buildings compared to the short lifecycles of their functions;
- the vacancy of buildings because they no longer meet present requirements;
- the rapid change of user demands compared to the slow-changing possibilities of buildings; and
- a trend towards sustainable buildings.

These trends describe the need to upgrade the existing building stock to adapt to different built environment challenges, which were discussed in the previous section. To respond to these challenges, the building and its associated components need to be altered in their function, capacity and/or flow. Table 2-1 explains the typical types of changes and discusses how buildings can practically respond to these changes.

Table 2-1: Types of change required in buildings to adapt to different demands

Type of change	Category	Response to
Function	• Upgrade existing functions • Incorporate new functions • Modify for different functions	• Higher performance levels that require different components/processes • New facility performance objectives that require new components/systems • Different objectives from change in usage class that require different components, systems and/or processes
Capacity	• Change in loads/conditions • Change in volume	• Higher expected performance under specific load conditions • Increased requirements for operable space per usage class
Flow	• Change in environmental flows • Change in flow of people/things	• Higher/different performance requirements for internal or surrounding environmental conditions • Different performance requirements for passage, movement or organisation of people/things within/into the facility

Source: Slaughter (2001 p.210)

However, the endeavour of upgrading older maladaptive buildings to meet present day user needs seems economically expensive and technically unjustifiable. In the developed world, there is an increasing need to adapt obsolete or redundant buildings to continue the same use or to modify them for new uses (Douglas 2006), which seems like an economically sound solution for minimising building redundancy. Sometimes these conversion processes are uneconomical and demolition seems unsustainable, thus making it more economical to maintain the original space as redundant until demand for a potential use reappears. On the other hand, the designing of new buildings to a single class of use needs to be re-examined in the business case scenario. The apparent built environment challenges and the limitations of existing buildings to respond to these changes were discussed. The next section elaborates on how the design for adaptation could be considered as a strong mechanism for responding to these built environment challenges.

2.4 A need to design new buildings for adaptations

Building change is a significant issue in built environment facilities that depends on internal pulls and external pushes (Douglas 2006). A failure to respond to such built environment changes results in obsolete buildings on physical, functional, economic, social, technological, legal and environmental grounds (Shenkel 1984, Wurtzebach and Miles 1994). However, the current building stock in the UK only vaguely fits the evolving needs of businesses and users. The likely reason for this is that the original design cannot adjust to the potential changes. This leads buildings to be demolished, renewed, refurbished or redundant (3DReid 2006, Arja *et al.* 2009). Mayr and Varvakis (2006) argue that a huge stock of buildings is becoming inadequate and insufficient as time goes by, as other needs arise and as performance levels soar with new requirements. Maintaining a redundant building stock is economically unviable and a socially unacceptable solution, as these buildings generate no income while the building owners are liable to pay taxes for the buildings. Also, scrapping and rebuilding relatively young buildings is neither economically nor socially desirable and does not correspond with the demand for durability and sustainability (Remoy and Voordts 2009).

'Sustainability' has been an important element of all real estate developers' agendas, regardless of time and market perspective (Arge 2005). If buildings were designed for potential adaptations, it would be possible to successfully respond to the aforementioned built environment changes. On the other hand, sustainability will be a major criterion in judging future buildings and their installations. Among the factors that play a role here are savings in base materials, minimising waste production, ease of dismantling, adaptability and deposit money arrangements. Flexible buildings and installations that are readily adaptable to changing conditions respond to this trend (Geraedts 2008). Buildings designed to maximise the potential for adaptation to accommodate different uses are required, together with appropriate transportation and communication infrastructures (Gann and Barlow 1996). 'The construction industry must respond by creating new buildings that are adaptable, allowing their operating facilities managers to readily respond to changing space use demands throughout their life' (Webb *et al.* 1997 p.318). A building that is 'unfit for purpose' leads to it being redundant in its functional tenures. In this light, either design for adaptations (DFA) or design for short lifespans can be considered. However, the latter is not yet appreciated in the sustainable agenda as many of the construction materials are economical in long structural lifespans, although reusable solutions have not been very well practised in the construction history recently. Hence, this study promotes the potential for extending the functional lifecycles of buildings through DFA. However, the future-proof endeavour seems complicated and risky because the decisions taken today need to be justifiable tomorrow, and perhaps these decisions may only vaguely fit tomorrow's requirements. In this regard, spending too much over budget for an unattainable target could also be considered a waste.

As a critical dilemma, building redundancy encourages stakeholders to rethink the adaptable possibilities of their new buildings and the potential for designing new buildings with shorter lifespans. The latter is not encouraged in the sustainable agenda as short lifespans reduce the value of the building without reducing costs – simply because there is no way of economically constructing a building for a short physical life (Slaughter 2001, Hughes *et al.* 2004). The literature reveals adaptable buildings as a nascent but strong and practical solution to defeating the problem of building redundancy (Douglas 2006, Kronenburg 2007, Adaptable Futures 2008). However, the critical challenge to building designers/owners/developers is the inability to prepare for unforeseeable futures, mainly because of the difficulty in predicting future uncertainties, risks and the costs of changes (Ellingham and Fawcett 2006). Property developers are more concerned with the returns on their investments in adaptable properties; however, economic evaluation for adaptable buildings needs to be conducted to provide the needed 'hard' evidence to show that these buildings provide a more economically sound answer than a typical fit-to-use solution. Thus, there is a need to respond to the increasing pressures of rapid changes in user needs, technological shifts, altered working and living patterns and other forces that render buildings obsolete before the depletion of their service lives (Fernandez 2003).

2.5 Summary

Challenges to the built environment emerge from the areas of environment, technology, planning and policy, society, and the economy. The imbalance between demand and supply creates social, economic and environment inequities in the built environment. Adaptable buildings are considered an innovative approach and are further proposed as a principal requirement for the UK construction market. These modern construction industry-led approaches need to consider how adaptable features can be included at the earliest possible phase of design. To respond to potential future challenges, it is far easier to realise the adaptable potential in new buildings rather than existing stock. Therefore, this preliminary literature review chapter is intended to explain the need for designing new buildings towards potential adaptations. Economic considerations play a vital role in the client's decision-making protocol; however, no-one has yet identified the cost and benefit aspects to encouraging adaptable potential in new buildings. Therefore, the identification of the cost and benefit considerations of adaptable facilities seems a critical milestone in long-term economic decisions.

Chapter Three

3. RESEARCH METHODOLOGY

3.1 Introduction to chapter three

A research methodology is the skeleton of a scientific study that mainly consists of the research philosophy and design. A robust methodology gathers rich data, makes logical assumptions and assures acceptable results while placing the research in the correct theoretical position. By contrast, the lack of a vigorous methodology in scientific research creates weak conclusions that could result in the research not seeing the light of the day. Thus, it is necessary to select the most appropriate methodology for undertaking a particular research investigation.

This chapter describes the theoretical and practical perspectives of the research methodology that was adopted to solve the previously explained problem. In general, the theoretical position is reflected through the ‘research philosophy’, which primarily focuses on the ontological and epistemological stances of the study. The practical taxonomy of a research study is determined by the ‘research design’, which reflects the purpose of the research, time dimensions, method(s) of data collection, data sampling, analysis, interpretations, validity and reliability aspects.

3.2 Philosophical position of the research

The theoretical underpinning of scientific research is usually reflected through the ontological and epistemological paradigms of philosophy. In social research, the ontology involves *‘the philosophy of reality’* and epistemology explains *‘how we come to know that reality’* (Krauss 2005). In other words, ontology means *‘what are we studying’* and epistemology explains *‘how we can have warranted knowledge about our chosen domains’* (Gill *et al.* 2010). In this regard, ‘the researcher needs to be meticulous and articulate his/her research, especially the interrelationship between ontological, epistemological and methodological levels of inquiry' (Proctor 1998 p.76). Easterby-Smith *et al.* (2002) discuss the importance of research philosophy in scientific investigations and point out the relationship between research design and philosophy. Research philosophy enables one:

1. to clarify the research design (refine research methods, identify the types of data gathered and their origins and the way the data can be analysed and interpreted);
2. to understand which research design might work or not (avoid unnecessary choices while identifying the limitations of the selected methods);
3. to identify and/or create new research designs outside his/her past experiences.

However, there is a consensus within the discipline that management research does not operate within a single agreed ontological or epistemological paradigm (Tranfield and Starkey 1998). The relationship between theory and empirical research is still controversial because 'certain social scientists assumed that the first need is to carry out intensive empirical work to prepare the ground for a decent social scientific theory, while others asserted that empirical research without prior, comprehensive theoretical reflection would at best yield meaningless and at worst erroneous results' (Joas and Knobl 2009). The relationship between theory and practice is notable in scientific investigation because many theories are underpinned by practice and many practices originate from theories. The different types of research philosophy/paradigm are explained in the literature; however, the appropriateness of these philosophies depends on the context of the research problem. Specific to this research inquiry, the following sections justify the relevance and/or rejection of different philosophical positions.

3.2.1 Positivism and interpretivism paradigms

The paradigms of positivism and interpretivism (social constructionism) are popular in management research. Dainty (2008) explains that the past trend in construction management was more towards positivistic paradigms and proposes methodological pluralism as a way forward to bring practical insights to the theory. The paradigm of positivism deals with a hypothetico-deductive approach and quantitative methods are usually adopted to collect and analyse data (Tashakkori and Teddlie 1998, Easterby-Smith *et al.* 2002, Silverman 2005). Blakstad (2001) explains that the positivistic approach might not be practical when there is a lack of theory from which the hypothesis can be deducted. On the other hand, the paradigm of interpretivism accepts no neutral grounds for knowledge, since all observation is value and theory-laden (Johnson and Duberley 2000). This philosophy is commonly exploited in theory building. The paradigm appreciates social engagement (ideas, beliefs and empirics). The general polarisation between positivism and interpretivism is illustrated in Table 3-1.

Table 3-1: Characteristics of positivism and social constructionism

	Positivism	**Social Constructionism (interpretivism)**
The observer	Must be independent	Is part of what is being observed
Human interests	Should be irrelevant	Are the main drivers of science
Explanations	Must demonstrate causality	Increase general understanding of the situation
Research progress through	Hypothesis and deductions	Gathering rich data from which ideas are induced
Concepts	Need to be operationalised so that they can be measured	Should incorporate stakeholder perspectives
Units of analysis	Should be reduced to simplest terms	May include the complexity of ‘whole’ situations
Generalisation through	Statistical probability	Theoretical abstractions
Sampling requires	Large numbers selected randomly	Small numbers of cases chosen for specific reasons

Source: Easterby-Smith *et al.* (2002)

This study endeavours to find a reasonable answer to the current problem of designing buildings towards potential change of use and further to identify the cost and benefit criteria of potential adaptations. Thus, the problem investigated in this study is neither testing an existing theory nor developing a new theory for adaptable buildings but searches for a reasonable answer to an evolved problem. Therefore, the paradigms of positivism and interpretivism do not work for this investigation.

3.2.2 Pragmatism paradigm

The paradigm of pragmatism considers *'whatever works, is likely true'* (Creswell 2003 cited Patton 1995). The paradigm is defined by 'usefulness; the ultimate test of a proposition is whether it 'works', particularly in helping individuals to solve practical problems' (Vogt 2005 p.243). The primacy of practice in explaining notions of truth and the possibility of knowledge are highly appreciated within the pragmatic paradigm (Tee 2010). Pragmatism provides reasonable flexibility for undertaking this research when compared to positivism and interpretivism. Creswell (2003) explains these flexibilities:

- The freedom to choose the research methods, techniques and procedures that best meet the research's needs and purposes.
- Pragmatists do not see the world as absolutely unified.
- 'Truth' is what works at the time. It is not based on a duality between reality independent of the mind or within the mind.
- Pragmatist researchers look at what and how to research based on the intended consequences.
- Pragmatists agree that research always occurs in social, historical, political and other contexts.
- Pragmatists believe in an external world independent of the mind, as well as that lodged in the mind.
- Thus, for the mixed methods researcher, pragmatism opens the door to multiple methods, different worldviews and different assumptions, as well as different forms of data collection and analysis.

The study aimed to identify the specific economic considerations for adaptability in buildings and the researcher exploited a multi-method approach to collect the data. The methods adopted to collect the data and the alternative approaches to addressing the research question are discussed in Table 3-5 by justifying the rationale for selecting specific methods and rejecting other methods within this inquiry. In short, the research philosophy explained before has helped to place the research in the correct philosophical position. The research design, which will be explained in the next section, encapsulates the practical attempts made towards achieving the research objectives. More importantly, researchers' instincts and experiences play a vital role in their research.

3.3 Research process and traditions

Research is a '*voyage of discovery'* (Fellows and Liu 2008) that *'begins with a curiosity'* (Stebbins 2001) and continues with a *'systematic process'* to discover a solution to a contemporary problem. This systematic process guides the researcher to undertake the study in a logical sequence, from identifying the problem through to reporting and publishing the results (Punch 1998, Sekaran 2003). In its broader sense, the research process concerns the '*conceptual organisation'* of the overall research, ideas to express *'needed understanding'*, '*conceptual bridges*' from what is already known, *'cognitive structures'* to guide data gathering and *'interpretations'* to present the data (Stake 1995, Robson 2002, Sekaran 2003, Lanksher and Knobel 2004, Neuman 2011). A typical research process is illustrated in Figure 3-1 and the key elements are discussed in this section.

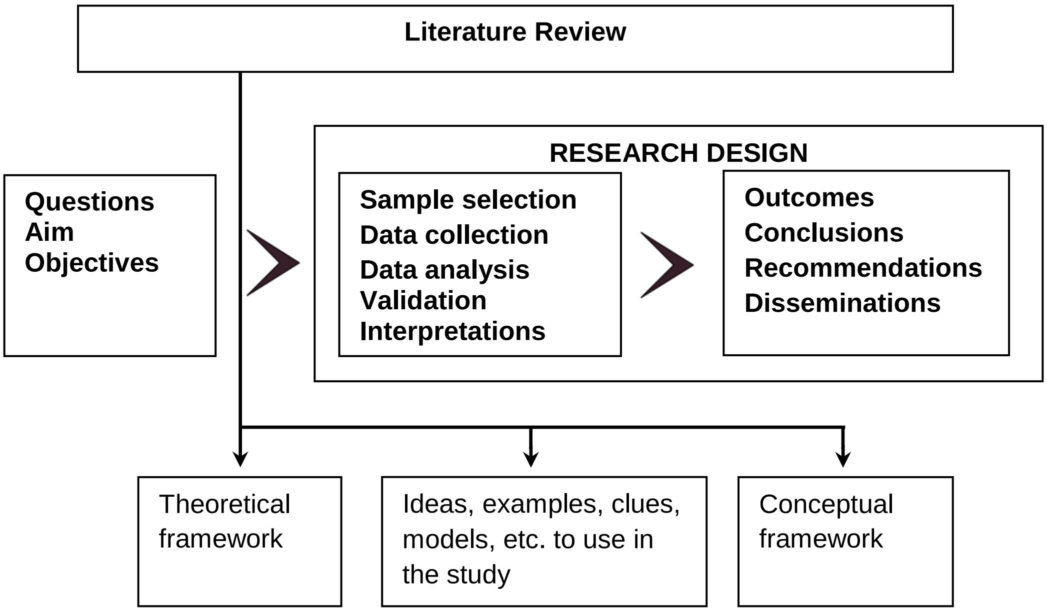

Figure 3-1: Research process

Source: Adapted from Robson (2002), Flick (2006)

The fundamental issues for designing a research endeavour, and therefore underpinning the selection of suitable methods (qualitative, quantitative, mixed and multi), concern the research question and the problem contexts. The research question lays the foundation for any scientific research while encouraging the researcher to undertake it within the boundaries of time, cost and quality. A preliminary literature review is often used to identify the research problem and further to determine the research objectives. Generally, much research begins with a specific purpose/s that is surrounded by broader contextual phenomena. From these broader contexts, a workable research question needs to be identified and well defined to provide an achievable target within the given boundaries. Corbin and Strauss (2008 p.12) critically argue that 'the research question should dictate the methodological approach that is used to conduct the research'. Well-defined research questions are able to identify what is to be measured or explored, while ensuring the rigour (the reliability and validity) of the research. The key characteristics of a workable research question are noted in Table 3-2.

Table 3-2: Characteristics of workable research questions

Clear	Easily understood and unambiguous.
Specific	Concepts are at a specific enough level to connect to data indicators.
Answerability	Can see what data is required to answer them and how the data will be obtained.
Interconnectedness	The questions are related to each other in some meaningful way, rather than being unconnected.
Substantively relevant	The questions are interesting and worthwhile, justifying the investment of the research effort.

Source: Punch (1998 p.254)

The research problem discussed in this investigation emanated from the Adaptable Futures[1] (AF) research project. The project acknowledges the importance of undertaking economic evaluations for different adaptable strategies encapsulated in their framework (Figure 5-5). However, this study was able to focus on a single but most influential strategy, i.e. change of use, and investigate the economic considerations. An extensive literature review and informal discussions were exploited to refine the research question and to establish the

[1] Integrated research project, funded by the Research Council (EPSRC) through Loughborough's Innovative Manufacturing & Construction Research Centre (IMCRC), and industrial partners. (www.adaptablefutures.com)

research objectives. There is a variety of research traditions (turning points) discussed in the literature. Therefore, it is worthwhile to explain these research traditions and discuss the appropriate traditions for this investigation.

- **Applied - pure tradition**

Research can be categorised into traditions of applied - pure by analysing the 'use' of it. Applied research is considered a practical problem-solving method that attempts to solve known problems while pure research is undertaken in order to expand knowledge and probe into the unknown (Encyclopaedia of Business 2010). The main difference between these dichotomies is that the researcher in pure research does not define the research problem (Vogt 2005). However, applied research is rarely undertaken to build, test or make a connection to theory, but it offers practical solutions for a particular problem within a short period of time (Neuman 2011). This study is placed under the category of applied research as it seeks reasonable solutions to a contemporary problem.

- **Explorative – explanatory – descriptive – predictive traditions**

A research project can be placed into exploratory, explanatory, descriptive or predictive categories by identifying the 'purpose' of it. 'Exploratory' studies look for patterns, ideas or hypotheses, rather than try to test or confirm a hypothesis. Exploratory studies are well suited if the area/subject is new and little information is available to undertake the study (Neuman 2011). They are qualitative in nature and provide answers for 'what' questions. By contrast, explanatory research seeks to understand variables by discovering and measuring causal relationships among them. Explanatory studies are mostly quantitative by nature and address the 'why' questions. In fact, descriptive research describes phenomena as they exist (Vogt 2005), while identifying and maintaining records of all the elements of a phenomenon, process or system (Fellows and Liu 2008). Descriptive research answers the 'how' and 'who' questions (Neuman 2011). Most often, predictive research is undertaken to envisage the outcomes of future occurrences and behaviours (Fellows and Liu 2008). In addition, Neuman (2011) proposes that some research studies have multiple purposes; however, in all cases the dominant purpose needs to be identified. Even though this study has some aspects of descriptive and explanatory traditions, its key purpose is explorative.

- **Within – across case tradition**

Within - across case studies are another popular form of research tradition. Within-case study research is undertaken to investigate certain phenomena in detail and across-case study research aims to gather surface information from a large number of cases (Neuman 2011). The sample size is comparatively smaller in within-case study than in across-case study research. This study follows within-case study traditions while exploiting two different case studies to understand the macro and micro level changes to buildings. The selected cases provide in-depth information about building change over the last 100 years while discussing the economic implications of change of use.

- **Cross-sectional – longitudinal tradition**

Neuman (2011) explains that research can be further differentiated into cross-sectional or longitudinal categories, which includes a time dimension. Cross-sectional research gathers data at a single point in time and longitudinal research gathers data over a period of time. The Loughborough town centre case study accessed the building maps of a selected cluster of buildings over the last 100 years (1886 – 2008 maps in 15-year intervals). Moreover, the available census and statistical data of England and Loughborough's populations were analysed (1821 – 2004 at 10 year intervals) to identify the growth of populations to understand the economic impacts. Thus, the Loughborough town centre case study is identified under the longitudinal tradition. The second case study (the Stewart Mason building) did not follow a time series analysis. However, it considered the changes to the building (physical and functional) in 1957 (as a foundry) and in 2004 (as a teaching learning unit). Hence, it provided cross-sectional data for this investigation.

- **Qualitative – quantitative – mixed tradition**

Qualitative research intends to *'explore issues'* (Hakim 1987) or *'understand phenomena'* (Flick 2006) that 'individuals or groups ascribe to a social or human problem' (Creswell 2009 p.3). Quantitative research is a 'means for testing objective theories by examining the relationships among variables' (Creswell 2009 p.3) and mixed method research considers both qualitative and quantitative approaches to answer a particular problem. Qualitative and quantitative data were used in this investigation to achieve the set objectives. Hence, the study has the characteristics of the mixed method category.

3.4 Research design

Research design is 'the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions' (Yin 2009 p.26). The design involves a series of rational decision-making choices, which ultimately lead to improving the scientific rigour (Sekaran 2003). Human cognition and empiricism seem the most important facets in research design as they interact with theory and practice. The literature reveals three types of research design: quantitative, qualitative and mixed method designs (Creswell 2009). Quantitative research design shows how the variables are seen and organised with respect to each other (Punch 1998), although they are explanatory in nature, predetermined and number-driven (Mason 2002). By contrast, qualitative design elicits the illumination, understanding and extrapolation of a particular phenomenon (Hoepfl 1997) and is exploratory in nature, fluid and flexible, data-driven and context-sensitive (Mason 2002). The demarcation between quantitative and qualitative design is mainly '*searching for causes versus searching for happenings'* (Stake 1995). A typical mixed method design considers aspects of both quantitative and qualitative designs together. Having considered the ultimate research aim and the underpinning objectives of this investigation, both quantitative and qualitative approaches were exploited to collect the appropriate data. Thus, this study can be placed under mixed method design (case study and survey), which is explained in the hourglass model in Figure 3-2.

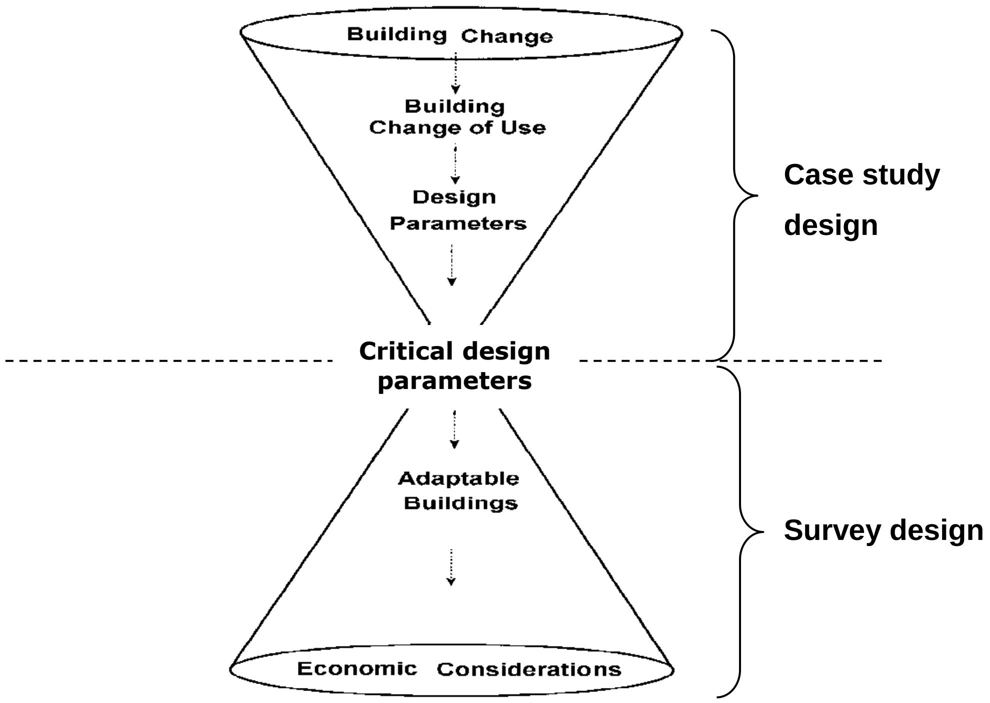

Figure 3-2: Adopted research designs

The overall study followed two phases. The first phase aimed to test the intuition that building change occurs over time and to understand the economic implications. Qualitative case study design was exploited to complete the first phase of this investigation, which provides an answer to the first objective of the overall research investigation. This hourglass model explains how the problem of building change (a big issue) has such influences on project economy. The second phase supported the second, third and fourth objectives of the study. Survey design was exploited in the second phase. Secondary data (the Building Cost Information Service's cost data and interview transcripts of the Adaptable Futures team) and both semi-structured and unstructured interviews were undertaken to gather relevant data for the second phase (see Figure 3-3). Most commonly, 'case studies are used to gain insight into causal processes, whereas surveys provide an indication of the prevalence of a phenomenon' (Yin 2009 p.175). The justifications for selecting the specific designs are explained in the following sections.

3.4.1 Case study design

The existing theories can be categorised into three groups: theories that are in accordance with the research findings, in contrast with the research findings or neutral (provide no framework or grounding) to the research findings (Eisenhardt 1989). Case studies can be exploited to build new theories and/or test and retest existing theories that are well developed in foundation (Yin 2003). Thus, theory plays an important role in case study research.

Case study design is appropriate where it is necessary to study a real-life situation in real time (in a limited space and time) with immediate impact and relevance (Johns 2008). Moreover, case study design can be used to gather and analyse data about one or a small number of samples as a way of studying a broader phenomenon. Generally, the case is bound by time and activity, and a variety of data collection methods (interviews, document and record analysis, and observations) are usually exploited to collect detailed information over a sustained period of time (Stake 1995). A distinctive feature of the case study is the use of multiple sources of evidence to examine the case holistically (Tan 2002). Hence, case studies inherit different strengths and weaknesses (Gillham 2000). Yin (2009) explains the logic of case study design in two different aspects. Point (a) below considers the scope of the case study and point (b) explains the technical characteristics and data collection and analysis strategies encompassed in case study design.

a) A case study is an empirical inquiry which:
   - investigates a contemporary phenomenon in depth and within its real-life contexts: especially when
   - the boundaries between the phenomenon and the context are not clearly evident.

b) The case study inquiry:
   - copes with technically distinctive situations in which there will be many more variables of interest than data points and, as one result:
   - relies on multiple sources of evidence, with data needing to converge in a triangulating fashion and, as another result:
   - benefits from the prior development of theoretical propositions to guide data collection and analysis.

Yin (2003) further states that many social scientists deeply believe that the best use of case studies can be obtained in exploratory research rather than descriptive or explanatory investigations. Walsham (1995) proposes that the most appropriate method for conducting empirical research in the interpretative tradition is the in-depth case study; however, such studies are not necessarily qualitative (Stake 1995). The case study's main strength is its ability to provide a real situation in which practice can be studied and contact can be made with real participants who can contribute to the research with their practical knowledge (Blakstad 2001, Simons 2009).

Case study design is an ideal method/design for particularisation (Stake 1995). Notably, the data gathered is more qualitative than quantitative (Sekaran 2003). Its poor ability with regards to generalisation seems to be the key limitation of case study research (Stake 1995). Eisenhardt (1989) argues that binding the emergent theory with existing literature strengthens the internal validity, generalisability (external validity) and theoretical level of theory building from case study research. The generic characteristics of case study research (Punch 1998), types of case studies (Yin 2003) and their central components (Yin 2009) are discussed in the literature.

Table 3-3: Characteristics of case study research

Each case has boundaries that must be identified at an early stage of the research.
Each case will be a case of something in which the researcher is interested. Hence, the unit of analysis must be defined at the outset in order to clarify the research strategy.
Case studies seek to preserve the wholeness and integrity of the case. However, in order to achieve some focus, a limited research problem must be established geared towards the specific features of the case.

Source: Punch (1998 p.153)

There are four types of case study design and Yin (2003) discusses the characteristics of each type and their rationales, as noted in Table 3-4.

Table 3-4: Types of case study design

	Characteristics	Rationale
Type 1	One case, holistic, one unit of analysis, case and unit of analysis are indistinguishable.	Critical case Unique case Typical case Revelatory case Longitudinal case
Type 2	One case, embedded units of analysis, not holistic but still context dependent, case and unit of analysis are distinguishable.	Extensive analysis More focused analysis
Type 3	More cases, holistic, case and unit of analysis are indistinguishable.	More robust findings Replication logic (literal/theoretical) External validity
Type 4	More cases, embedded unit of analysis, not holistic yet context dependent, case and unit of analysis are distinguishable.	More robust findings Replication logic (literal/theoretical) External validity Extensive analysis Focused analysis

Source: Yin (2003)

Within the boundaries of this investigation, a single Type 1 case study design was exploited to understand building change of use at macro and micro levels. The single case design provides more opportunities for in-depth investigations. The rationale of the Type 1 category suits situations where the selected case:

- represents a critical case in testing a well-formulated theory;
- represents an extreme case or a unique case;
- is a representative or typical case;
- is a revelatory case; or
- is a longitudinal case, studying the same single case at two or more different points in time (Yin 2003).

The Loughborough town centre case study was exploited to establish that building change occurs over time and to investigate the economic implications. Loughborough represents a typical English regional town and it is indeed a representative/typical case for this investigation. The rationale for limiting the study to a single case (Type 1) was because the first objective requires in-depth data on building change, its sequence/pattern and, most importantly, the economic implications of change. Having selected a case study design, these three factors could be studied clearly to a good depth. In addition, secondary data (interviews) from the Adaptable Futures project was used to justify the selected case as a typical representative case by revealing a similar pattern of building change of use in another English city (Leicester). This data is compiled in chapter 7. The unit of analysis is a significant factor in case studies, as it determines what or who is to be analysed. This study looks into patterns of building change, thus buildings are considered the unit of analysis. In a way, the study contributes to theories of building change and their economic impacts. The central components of case study design are discussed in the literature (Yin 2009). These components are explained in detail below to complete the first objective of this research investigation.

- Case study questions – ‘how’ and ‘why’

  Two case studies were undertaken to study how building change of use has happened over the last century at macro and micro levels. In other words, these cases were used to test the intuition that building change occurs over time by using empirical data to underpin the assumption. The first objective of this study deals with ‘how’ questions by understanding building change and ‘why’ questions in reasoning the facts behind this change. Thus, a case study method was exploited to accomplish the first objective of this study.

- Case study (theoretical) propositions – pointing attention, limiting scope and suggesting possible links between phenomena
  Instead of having a proposition, the purpose of the objective 1 is to explore the patterns of building change of use and to understand the economic implications. The scope was limited to selected building typologies of middle range (4 -12 storeys) buildings.

- Case study units of analysis – main units must be at the same level as the study questions and typically comparable to those previously studied
  The unit of analysis of the selected cases is 'buildings'. They were analysed to identify how change of use/function has happened in different decades over the last century. The buildings of the selected cluster were compared with their previous uses/functions to identify the 'pattern of change of use'. The passing years, which showed a remarkable change in building functions, were considered to explain the economic impact of building change of use. Thus, buildings were considered the primary unit of analysis in this research to understand the pattern of building change of use.

- Logic linking the data to the propositions – matching pieces of information to rival patterns that can be derived from the propositions
  First, the pattern of building change of use was identified from historic maps of the selected building cluster over the last century. Following this, four economic indicators were considered (growth rate of population, growth of higher and further education, growth in the industrial and manufacturing sectors, and policy changes) to study how they have changed over the different periods of time. The relationships between building change of use and these economic indicators are then explained.

- Criteria for interpreting the findings – iteration between propositions and data, matching sufficiently contrasting rival patterns to data; there is no precise way of setting the criteria

The pattern of building change of use was analysed through typo-morphological analysis. The changes (growth) in economic indicators during the selected time period were identified by analysing the collected data (census and statistics, facts and figures). The economic indicators were used to interpret the pattern of building change of use. In addition, secondary data (interviews by the Adaptable Futures research group) and semi-structured and unstructured interviews were exploited to understand the economic implications of building change of use and to generalise the findings.

The above points clearly discuss how case study design was exploited in this research inquiry to test the intuition of building change occurring over time and to understand the economic implications by identifying empirical data to underpin the assumption. In a way, the case study can be considered to be an 'all-encompassing method' that covers the logic of research design, data collection techniques and approaches to data analysis (Tan 2002, Yin 2009). It is important that it must use some empirical methods and present some empirical data. The adopted data collection methods within this investigation's case study design and what data was collected and how it was analysed are discussed in chapter 7. The next half of the hourglass model represents the survey design.

3.4.2 Survey design

A survey design was adopted to identify practitioners' views on economic and design considerations for adaptability in buildings. The web-based questionnaires developed for the survey consisted of both open and closed-ended questions. This method has several advantages over other methods. However, there were some methodological challenges as well. Simply, this method can be inexpensive, user friendly, less time-consuming and can be delivered to a particular person's address while providing opportunities for easy follow-ups. The limitations can mainly be seen in accessing the survey, as the whole population of the UK do not have the internet, although in a professional setting this can probably be assumed. Errors in survey research design can occur in the areas of respondent selection, survey questions and administration (Neuman 2011). Generalisation in survey findings is a critical issue in scientific research because many surveys end with low response rates. Therefore, proper attention must be paid throughout the survey.

Three web-based questionnaire surveys (WBS1, WBS2, and WBS3) were designed through www.surveymonkey.com (refer to appendix D). WBS1 was circulated among the top 100 design consultancy practices in the UK (based on staff numbers) to identify what adaptability means to industry practitioners and the economic costs and benefits to their stakeholders. The list of construction consultants was obtained from www.cnplus.co.uk and many of their email addresses were accessed through the individual company websites. The missing email addresses were obtained through a phone call to the company's general number picked up from British Telecom directory 2009. The questionnaire was piloted with ten academic and research staff members in selected disciplines (architecture, quantity surveying and structural engineering) at the School of Civil and Building Engineering, Loughborough University for feedback on clarity and readability. As a result, the wording of two questions was amended and a scenario was added to Question 5 of WBS1 to aid understanding about the cost variations of adaptable options. After all changes were made, the link (www.surveymonkey.com/s/XFWJZ9Q) was emailed to the general email address of the selected companies along with a request to forward the email to their authorised departments (architecture and quantity surveying). Four emails bounced back with a failure in delivery. Questionnaire return was requested within three weeks and a follow-up was issued after two weeks as a reminder. In addition to the thirteen respondents, another two respondents directly emailed their thoughts without undertaking WBS1.

Having identified the complexity of the questions and the low response rate to WBS1, the second and third survey questionnaires (WBS2 and WBS3) focused on the individual disciplines of architecture and quantity surveying, respectively. These two questionnaires were piloted by four architectural scholars and six quantity-surveying scholars at the School of Civil and Building Engineering, Loughborough University. The feedback was that the questions were well phrased and very clear. Minor changes to punctuation were made in the original templates. The same list of companies was used to circulate WBS2 and WBS3. First, a polite request was sent to the companies' general addresses asking for help from their architecture and quantity surveying divisions. However, many of the companies did not respond to this mail, thus the researcher subscribed to the LinkedIn professional networking website and accessed the individual email addresses of architects and quantity surveyors of 100 leading construction consultancy companies in the UK. This professional network guaranteed delivery of the survey requests to the individual email address of the selected professionals through the 'in-mail' facility. A reminder was given at the end of the first week and two follow-ups were made soon after the cut-off date. The respondents were given three weeks altogether to complete the survey. Miller and Smith (1983) explain that late respondents are often similar to non-respondents. To address the generalisation, the respondents were categorised into three groups: early respondents, late respondents and non-respondents. The late respondents are the people who responded after the follow-ups. The total responses received to surveys WBS2 (www.surveymonkey.com/s/GC7TKJV) and WBS3 (www.surveymonkey.com/s/TFGQ6PH) were 32 and 42, respectively (see appendix J).

3.4.3 Data collection methods

For data collection to be a part of a research design, it needs to fulfil two key objectives (Lankshear and Knobel 2004). First, it must be conducted by aiming towards a particular problem, and next it needs to support some kind of explanation or interpretation instead of simply providing information. Thus, proper tools/instruments need to be exploited for extracting the relevant data to provide robust information. Research can be espoused by undertaking either a mono-method or a multi-method approach for collecting data. Several authors (Tashakkori and Teddlie 1998, Creswell 2003, Saunders *et al.* 2003, Bryman 2008) point out the key strengths of the multi-method approach over the mono-method approach. The multi-method approach may provide more confidence in the research and it enables triangulation or the use of different data collection methods within one study, ensuring that the data is clear, valid and reliable (Saunders *et al.* 2003).

To complete the research objectives, the study exploited the different data collection methods noted in Figure 3-3. Some semi-structured and unstructured interviews were used to collect data for more than one objective of this research inquiry. The justifications for the selected methods, other alternative approaches to address the research objectives and the rationale for rejecting these alternative approaches are explained in Table 3-5.

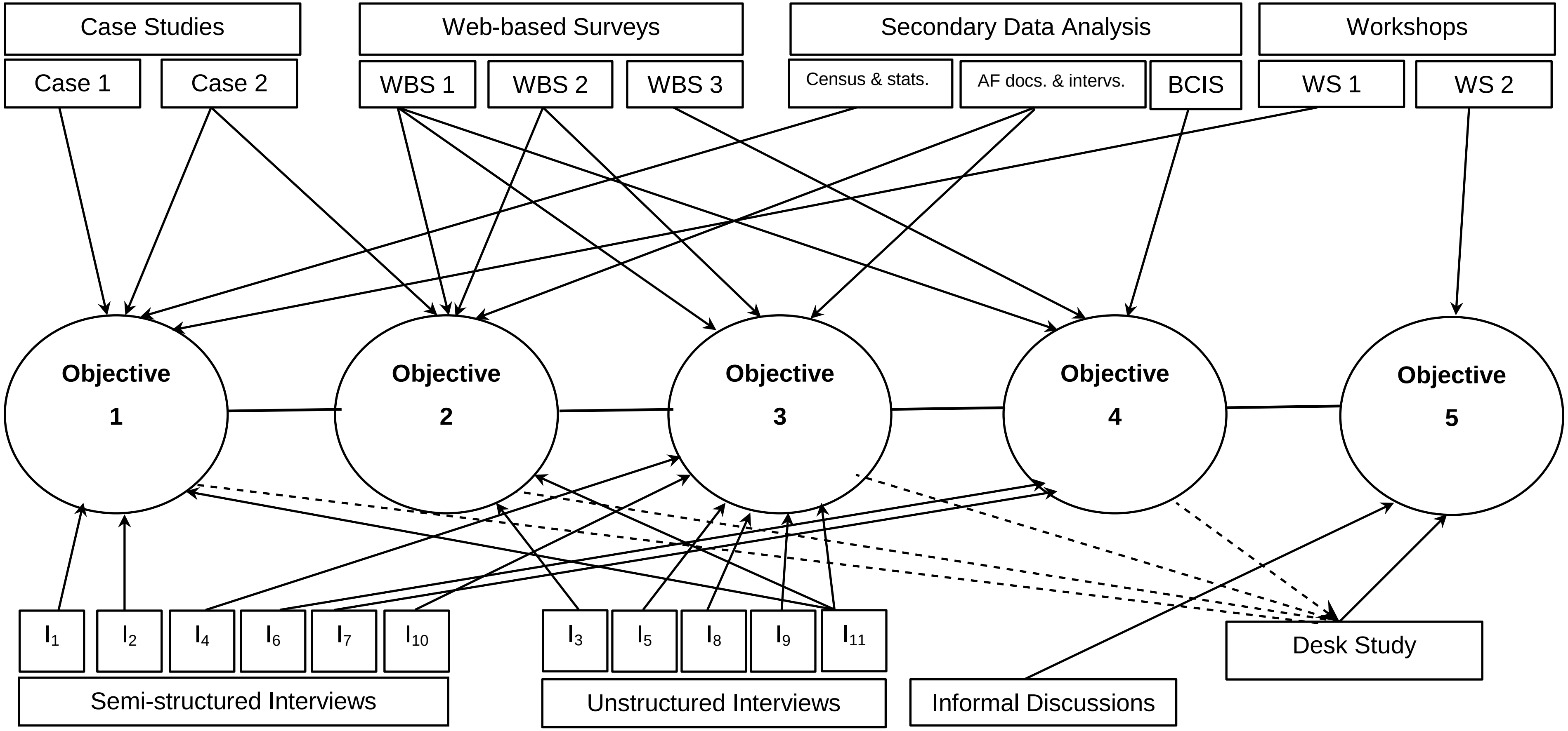

Figure 3-3: Adopted research methods

Table 3-5: Justifications for the adopted research methods

Research objectives	Data sources and methods used	Justification for selected methods and rejection of other alternative methods
1. To establish that building change occurs over time and to identify its economic implications;	• Two case studies (to explain building change of use at macro and micro levels) Case study 1: Loughborough town centre Case study 2: Stewart Mason redevelopment project	• Two case studies were undertaken to determine that built environment change occurs over time, at both macro and micro levels. The rationale for selecting the single case study method to complete this objective was mainly because this objective requires detailed investigations into building change (physical), building use changes and the economic implications of these changes. Thus, a case study method was adopted to answer 'how' building change of use has happened over time and then to study the likely reasons for 'why' this happened. The case study method is considered an all-encompassing method, as the data can be collected from multiple sources. However, difficulty in generalising the findings from a single case study seems to be a critical issue. Evidently, the findings of two case studies (even though they were categorised under different built environment levels) can be used to generalise the phenomenon of building change occurring over time. The two selected cases are located in two different locations in Loughborough, UK. In addition, the secondary data interviews were used to generalise the issue by

		giving evidence of building change of use in another English borough (Narborough Road area, Leicester). This is explained in chapter 7. This evidence helps to confirm that building change occurs over time and that there is a current need to design new buildings to adapt to future changes if they are economically acceptable.
	• Archival analysis (historic maps of buildings)	• Although future changes are not easily predictable, historical data of spatial behaviour can be useful for a better approximation of the aspects that either have a bearing on the specific flexibility and adaptability requirements of a building or, at least, indicate where decision making should be directed (Pietroforte 1990). The historical maps and the documentary data of buildings show clear evidence of building change over the last century. However, the functions of some buildings on the historic maps were not shown clearly, thus this was clarified by informal discussions with a development control officer of Charnwood Borough Council and officials of the Leicester Record Office.

	• Semi-structured Interviews	• Planners and architects are responsible for addressing the issues related to building policies and their design considerations. Two planners and the director of a change project were subsequently interviewed individually (see appendix B) to identify the generic factors for building change and specifically to identify the influence of policy changes on building change. Tan (2002) explains that personal interviews are advantageous if probing questions are involved, visual demonstrations are required or when instant feedback is desirable. In particular to this investigation, these interviews were used to probe the issues on building change of use, required adaptations, and design and economic considerations for adaptability in buildings.
	• Documentary data	• Documentary evidence (architectural and structural drawings) was used to study how the original plans of a foundry building had changed to adapt for new teaching facilities at Loughborough University's Stewart Mason (SM) building. The design queries were clarified from the design engineer for the SM redevelopment project. In fact, documentary data provided detailed information about the project, which was used to visualise how the building conversion occurred in the SM redevelopment project.

	• Secondary data analysis (census and statistics, interviews by the AF project)	• The up-to-date census and statistics of national and local populations were collected from the Office for National Statistics and Charnwood Borough Council, Loughborough, UK. This statistical information was used to analyse the economic implications of building change of use at the macro level. In addition, the data collected from the Adaptable Futures research project was used to generalise that building change occurs over time. Continuous informal discussions were undertaken with Adaptable Futures research members to discuss the importance of building change of use over other adaptable strategies.
	• Workshop (to validate the findings of the case studies)	• A validation workshop was conducted with 16 stakeholders from the Adaptable Futures project to test the validity of the main finding, which was to confirm and predict the potential trend for building change of use. This one-hour workshop was held on 15th May 2008 and was attended by seven senior architects, four experienced quantity surveyors, four structural engineers and a planner. The workshop method was used in this verification because it provided a good opportunity to collect ideas from a multi-disciplinary team.

Research objectives	Data sources and methods used	Justification for selected methods and rejection of other alternative methods
2. to identify the principal design parameters for designing new buildings towards future potential change of use;	• Literature review • Case study (semi-structured interviews/ project documents)	• The literature explains different design parameters for building adaptation (refer to Table 5-4). Thus, the second objective aims to identify the influential design parameters for building change of use. • Apart from the literature review, case study 2 noted above (Stewart Mason: a successful project - industrial to classroom conversion) was used to identify the design parameters for building change of use. This case study provided an opportunity to undertake a detailed investigation into the influential design parameters for change of use in buildings. Two unstructured interviews with the project engineer and the facilities manager for this project were undertaken to clarify the technical and maintenance issues of the redevelopment. In addition, project documents and photos were studied to understand this conversion.

	• Web-based surveys <u>WBS1:</u> Circulated to both architects and quantity surveyors (leading 100 consultancy organisations, UK) <u>WBS2</u> Circulated to 100 architects	• In parallel to the above case studies, two web-based questionnaire surveys (WBS1 and WBS2) were undertaken to identify the design considerations (parameters and methods of conversion) for adaptability in buildings. Web-based questionnaires provide greater geographic flexibility and a fast, cost-efficient response and respondents have more time to think about the questions before replying. The main intention of WBS1 (appendix D1) was to ascertain data within a short period of time to confirm the issues already noted from previous studies. However, the questionnaire combined both architectural and quantity surveying practices together, which may have led to the poor response rate and to the number of answers with missing values. The response rate was 13% and it was therefore hard to generalise the findings. Therefore, WBS2 (appendix D2) was designed and targeted at 100 practicing architects (top 100 consultancy organisations) in the UK to clarify the design issues related to building adaptation. Interviews with architects would have been another alternative method to collect data for this objective. However, the associated cost and time in the interview process was the reason for rejecting this option within objective 2.

Research objectives	Data sources and methods used	Justification for selected methods and rejection of other alternative methods
3. to explain the lifecycle extendibility of adaptable buildings to react to this change of use;	• Documentary data • Informal meetings (AF project team)	• The AF project documents (the Multispace Guide, internal reports and minutes of meetings) and informal discussions were used to clarify design strategies for the lifecycle extendibility of buildings.
	• Secondary data analysis	• The case studies and interviews undertaken by the AF project were analysed to support objective 3. The different case studies focused on different adaptable strategies. This data provided a strong platform for identifying how the lifecycle extendibility of buildings helps to respond to a new environment.
	• Web-based survey 2 (WBS2)	• WBS2 (appendix D2: questions 4 - 8) was used to collect the architects' experiences of different practical adaptations (adaptable options) of buildings to extend their functional lifecycles. Case studies and interviews were alternative methods for collecting data for this objective. They were rejected due to time and cost limitations but the AF data was used as required for this objective.

Research objectives	Data sources and methods used	Justification for selected methods and rejection of other alternative methods
4. to investigate the economic considerations of extended functionality;	• Literature review • Interviews	• The literature review was used to identify the generic cost considerations of typical buildings. Semi-structured interviews with quantity surveyors and a web-based survey (WBS3) were used to cluster cost and benefit considerations specific to adaptable buildings and their potential change of use.
	• Secondary data analysis	• The secondary analysis of BCIS (Building Cost Information Service) data was used to identify the cost-significant *'shearing layers'* (Brand 1994) of buildings. This analysis was used to model how the cost of building layers varies with their lifetime.
	• Web-based survey 3 (WBS3)	• WBS3 was circulated among 100 quantity surveyors (UK) to identify the economic costs and benefits of adaptability in buildings. A case study method would have been another alternative to identify the specific costs and benefits of adaptable buildings. However, this method was not chosen due to the difficulty in accessing the cost information of real cases. Thus, WBS3 was used to complete the fourth objective of this study.

Research objectives	Data sources and methods used	Justification for selected methods and rejection of other alternative methods
5. to develop and validate a conceptual framework for evaluating economic considerations for adaptability in buildings.	• Desk study	• The empirical evidence from the previous four objectives was logically assembled together in a desk study to develop a conceptual framework. In addition, the researcher's intuition, the literature review and the informal discussions with the AF project team were used to design a logical and readable format for the framework.
	• Workshop (to validate the framework)	• The strength of the workshop approach in assessing the usability of the conceptual framework is that it offers the possibility to look at many different facets of the system at the same time. The conceptual framework considers physical and economic criteria for adaptability at the front end and then looks at the evaluation method at the tail end. All these three elements (physical criteria, economic criteria and evaluation methods) require different expertise to conceptualise the framework in a logical sequence. A workshop was organised by the industry collaborators for the Adaptable Futures project. The main reasons for selecting the workshop method for validation were the multi-disciplinary behaviour of the team, their experience and their interest in building adaptation.

- Methods like group interviews could have been used to validate the framework; however, they fall short in group interaction as a method to generate data. Instead of asking questions of each person in turn, focus group workshops encourage participants to talk to one another (Kitzinger and Barbour 1999).

- Focus groups can be easily combined with qualitative and quantitative methods, for example to develop a questionnaire or refine the key issues. Having studied the qualities of focus group workshops/interviews, the study used workshops to fine-tune and validate the issues of economic considerations for adaptability in buildings.

It is appropriate to make note of the rejection of other alternative methods, including interviews, surveys and case studies. Indeed, this conceptual framework aims to address design and economic aspects of adaptable buildings in a single picture. If interviews or surveys were exploited by architects, quantity surveyors or structural engineers, then higher possibilities could be gained by improving the single aspects (either economic or design) individually. However, it is important to understand the design-cost relationship for adaptability

	in buildings while studying these aspects concurrently. Case studies were rejected because of the difficulties with generalisation. Thus, a focus group workshop and two informal discussions were undertaken by Adaptable Futures project partners (see Table 9-1 of chapter 9 for additional information) to validate the developed conceptual framework. The validation process is explained in chapter 9.

The justified data collection methods for this investigation are explained below.

3.4.3.1 Literature review

A comprehensive literature review was undertaken throughout the study. First, the literature review was used to identify the seminal studies previously undertaken and then to set the foundation for this investigation without *'reinventing the wheel'* (Sekaran 2003). Secondly, the literature review was exploited to narrow down the research problem, refine the objectives and explore suitable research methods for undertaking this study. The availability of published literature on adaptable buildings seemed sparse, thus a snowball[2] method was adopted to find the most relevant and reliable sources of literature. This was done by first selecting the most recent and relevant articles in the areas of adaptability and the economic considerations of buildings. From these papers, it was possible to find all the relevant articles cited and they were then collected from online databases and inter-library loans. The challenge was the unnecessary time and cost consumption of acquiring the specific literature from reliable sources (in many cases it was through an inter-library loan) for this investigation. Third, the literature review was used to compare the research findings with the existing body of knowledge, which provides robust conclusions at the end.

3.4.3.2 Informal discussions

Together with the literature review, several informal discussions were undertaken with the Adaptable Futures research team and their collaborative partners throughout this research endeavour. Their suggestions and criticisms reinforced and facilitated the robust grounding of this study. Notably, informal discussions were used to select turning points for this study in three specific instances. At the very first stage, it was used to fine-tune the research aim and objectives. Subsequently, their experiences were adopted to select the most influential adaptable strategy (i.e. convertibility: change of use). Finally, two informal discussions were undertaken with project partners to refine the clarity and usability of the developed conceptual framework for evaluating economic considerations for adaptability in buildings.

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[2] A technique for expanding the literature from the available source.

3.4.3.3 Interviews

This technique provides great access to understanding human cognition while accessing the perceptions, meanings and definitions of situations and constructions of reality (Punch 1998). In other words, the main aim of an interview is to see the research topic from the perspective of the interviewee and to understand how and why they have this particular perspective. The literature suggests many forms of interviews, mainly based on the type of questions, mode of conduct and the number of participants involved. The categories of quantitative and qualitative interviews focus on highly structured to unstructured typologies, which focus on the type of question. The main differences can be seen in the pattern of questions being asked. Many of the questions in this study were closed-ended and respondents are given limited flexibility in structured interviews. Unstructured interviews use open-ended questions and semi-structured interviews consider both open and closed questions. The interviews can be undertaken either face-to-face or over the phone. Depending on the situation and the convenience for the interviewee, the most suitable method can be selected. On the other hand, group interviews are highly likely to be conducted among respondents with different disciplines to get their perspectives on a single phenomenon. This will improve group dynamics and synergy, meaning the interviewer might be able to gather rich data. All the above-mentioned types are very popular in construction management disciplines.

This research applied six semi-structured interviews and five unstructured interviews to gather data at different points of time over the study, while keeping records. Many of the open-ended questions were placed at the beginning of the interview to understand the broader context of adaptability and policy issues. The scope was then narrowed down to a certain extent in the middle part of the interview and closed-ended questions were used at the end. Keeping records of an interview is part of the artistry (Stake 1995). A digital voice recorder was used to record the interviews while taking notes at the same time. Later, the voice recorder and notes were reviewed together with direct quotes that were deemed especially relevant. The recordings were kept as a record but were not transcribed word for word.

3.4.3.4 Archival analysis

Analysing historic data to accomplish the research goal is another way to gather the required information. Gillham (2000) underlines that *'ethical permission to access', 'technical* *difficulties', 'data format'* and *'data quality'* are expected difficulties of archival analysis. This information can be used as a base for predictive research to envisage the future. Similarly, this study used the historic maps of buildings over the last 100 years to forecast the potential pattern of building change of use in the future. The permission to access and use that information was initially obtained from Charnwood Borough Council, Loughborough and Leicester Record Office. However, the available data was originally not in a compatible format to use for this study. Therefore, Auto CAD software was used to map the consequent change of use in buildings over the last 100 years.

3.4.3.5 Documentary data

Documentary data is a source of rich data in any research undertaking. The key sources of documentary data for this study, which were building regulations, building plans and cross-sections and design guides (London Housing Design Guide, British Council for Offices and the Multispace Design Guide developed by 3DReid Architecture), were accessed at different stages of this study. These documents were used to understand the policy issues related to adaptable buildings.

3.4.3.6 Secondary data collection

Secondary data collection is undertaken prior to the primary data collection process. The application of this method can be used for a single or a multi-dataset. The latter is collated from a variety of sources (Hakim 2000). Boslaugh (2007) suggests the importance of asking the following questions before collecting secondary data:

- What was the original purpose for which the data was collected?
- What kind of data is it, and when and how was the data collected?
- What cleaning and/or recoding procedures have been applied to the data?

In this study, the census and statistics of England and Loughborough's populations were obtained as the secondary data, which was used to explain the economic impact of change of use. The primary purpose of collecting this data was to make such inferences for the results derived from the case study that was previously undertaken. In addition, the published cost information of buildings (residential, hotel, office and mixed use) was extracted from the Building Cost Information Service (BCIS) to identify the most cost-consuming building elements as explained by the Pareto principle (the 20:80 rule). The cost data was adjusted for the time and location to make reliable conclusions. In addition to these two forms of quantitative data, qualitative data (interview transcripts) from the Adaptable Futures research project was used to generalise that change does happen in buildings and the pattern/sequence of building change is likely to be different in every case. These patterns are explained in chapter 7.

3.4.3.7 Desk study

A 'desk study' means *'an investigation of relevant available facts and figures, often before starting a practical study of a problem'* (www.science-dictionary.com 2011). By contrast, a desk study was used in this research at the end to assemble the findings of each objective and then to develop a conceptual framework for evaluating the economic considerations for change of use in buildings. In addition to the findings of each objective, the researcher's instinct and the previous literature on framework development provided a pertinent platform for undertaking the desk study.

3.4.3.8 Workshop/focus group

Focus groups are ideal for exploring people's experiences, opinions, perspectives, wishes and concerns (Kitzinger and Barbour 1999). A frequent application of the workshop method can be seen in the process of data collection. The main purpose of organising workshops within this study was to verify the results obtained from the case studies and to validate the conceptual framework. Two workshops were arranged with the industry partners for the Adaptable Futures research project as they were more familiar with the subject. The first workshop was arranged to obtain empirical data to underpin the assumption that building change occurs over time and to identify the economic implications that were established from the case studies. The second workshop was undertaken with the same project partners to verify the usability of the developed conceptual framework. The selected group members had multi-disciplinary backgrounds of architecture, quantity surveying, structural engineering and research and development, allowing for a robust ground for verification. The second workshop generated a large amount of data (group members from different disciplines). This data was recorded using a tape recorder and transcribed immediately after the workshop. However, the transcription process consumed a lot of time due to attempting to recognise individual voices. Thus, a summary of the transcription was emailed to the participants' individual email addresses to re-clarify their ideas. The verification protocols of both situations are discussed in chapter 7 and chapter 9.

3.4.4 Data sampling strategies

Data sampling plays a vital role in the credibility of the overall results of research. However, it is not practical to gather data from the whole population; thus an ‘accessible population’ is used in many studies to represent the whole population (Tashakkori and Teddlie 1998). Sampling involves deciding which technique to adopt to capture a representative group (Wilkinson *et al.* 2010). The literature reveals two main forms of sampling method: probability sampling and non-probability sampling. The literature suggests that probability sampling allows for statistical methods, eliminates population parameters and bias and must have random selection of units and that non-probability sampling is used in exploratory research, so the population parameters are not of interest and can be used when the adequacy of a sample is unknown (Germain 1997). The difference between these two methods depends on the form of sample selection. In random sampling, the sample is selected randomly; in non-probability sampling, the sample is not selected objectively (Fink 2006). However, this study exploited a purposive sampling method, meaning the data was collected purposely to achieve specific objectives. However, the method has bias and can create errors (Teddlie and Tashakkori 2009).

3.4.4.1 Case study sampling

As previously noted, a purposive sampling method was adopted in this study for sampling the case study. Silverman (2005) explains that purposive sampling allows one to choose a case because it illustrates the features or processes in which we are interested. In contrast, Vogt (2005) argues that it is an unwise procedure because the researcher knows in advance what the relevant characteristics are and therefore runs the risk of introducing unknown bias. The purpose of the case studies within this research investigation was to establish that building change occurs over time and to identify the economic implications; thus it was necessary to select a suitable building cluster for detailed study. Assistance was obtained from a development control officer who was responsible for undertaking building developments at Charnwood Borough Council. The selected case represented a typical case and the selected cluster represented the maximum number of use typologies compared to other clusters. Thus, it was selected for further analysis, improving the validity and reliability of building change of use.

3.4.4.2 Survey sampling

The web-based questionnaire surveys aimed to achieve three main goals. First, to identify the design parameters for change of use in buildings, then to recognise the most practical options (in terms of adaptability) for achieving the change of use, and finally to understand the costs and benefits of adaptability in buildings. These issues are more technical and empirical evidence was needed to improve the validity and reliability. By assuming the high possibilities in undertaking innovative practices like adaptable strategies, these surveys targeted experienced professionals in the top ranked construction consultant organisations in the UK. The simple cluster sampling method was adopted to design the sample frame, which considers that 'the clusters are randomly selected and then all of the units of interest are sampled within the clusters' (Teddlie and Tashakkori 2009 p.173). The selected cluster consisted of the top 100 construction consultancy practices in the UK and the unit of interest was based on their profession, limited to quantity surveyors and architects.

3.4.4.3 Interview sampling

The purposive sampling method was used in the interviews. Altogether, six semi-structured and five face-to-face interviews were conducted (interview templates can be found in appendices B, C and E) with the selected professionals. The sample consisted of industry and academic practitioners (see appendix I) in construction management disciplines. The data gathered related to their perspectives on building adaptations, planning and policy issues, and economic considerations.

3.4.4.4 Focus group sampling

As previously noted, the convenience sampling method was used to select the focus group. Statistical 'representativeness' is not the aim of most focus group research (Kitzinger and Barbour 1999). The selected samples consisted of the project partners for Adaptable Futures, which consisted of leading industry practitioners, clients and researchers. Two workshops were undertaken during the period of research to verify the results of this investigation. The first workshop (sample size: 16) was undertaken with delegates of the

I3CON (Industrialised, Integrated and Intelligent Construction) conference organised by Loughborough University in 2008; they had backgrounds in architecture, quantity surveying and engineering. The second workshop was intended to verify the developed conceptual framework (sample size: 12). Dominant bias was minimised to a greater extent while providing random opportunities for everyone to speak about the issues of adaptable designs, costs and benefit considerations for adaptability in new buildings.

3.4.5 Data analysis methods

The collected data can be placed in the categories of quantitative and qualitative data. Hence, the most appropriate data analysis methods were used in both cases to create a vivid narrative. Quantitative data analysis is about how the measurements of variables are analysed (Punch 1998) and qualitative data analysis is a process of resolving data into its constituent components, in order to reveal its characteristic elements and structure (Dey 1993).

The qualitative analysis referred to in this study was mainly based on the interview transcripts, secondary data and analysis of archival data exploited in the case study design. Miles and Huberman (1994) introduced data reduction, data display and drawing conclusions as the basic steps of qualitative data analysis. This study also followed the same sequence for analysing the qualitative data. The collected data was filtered through the reduction process. First, the data was grouped into big ideas/themes and then it was narrowed down to specific codes. The data was represented through diagrams and graphs, which were based on AutoCAD and MS Excel. However, Yin (2009) identifies the difficulty in analysing case study evidence as one of the limitations in case study design. A morphological analysis is a 'method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes' (Richey 1998 cited Zwicky 1969). Consequently, it is considered to be a 'classification system made up of categories that divide some aspects of the world into parts' (Ariga 2005). In this sense, the same method is used in this research to investigate the space use pattern in buildings (either mixed or sole use) and their surrounding structures.

The data generated from the three web-based surveys includes both qualitative and quantitative data. Quantitative data can be further sub-grouped into the typologies of nominal, ordinal, interval and ratio data. Both nominal and ordinal data are categorical.

Ordinal data is most often used to compare the available categories/attributes. Many of the closed questions in the web-based questionnaire surveys (WBS2 and WBS3) aimed to identify the respondents' perceptions on design and economic considerations for building change of use. The respondents were given a 0-5 scale of answers (for example, 0 = Not sure, 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly agree). In other words, a Likert index was used to get an attitude scale of the ordinal data. The collected cost data of building elements was supported by quantitative analysis; their central tendency (mode, median and mean) and the statistical dispersion was considered while analysing the data. The t-test was used to evaluate the differences in means between the two groups (i.e. architects and quantity surveyors). MS Excel 2007 was used to represent the processed data. Lastly, the conclusions were articulated with verifications. Punch (1998) explains that conclusions should be in the form of propositions and they need to be verified.

3.4.6 Validity and reliability

Validity and reliability (rigour) are emerging as salient measures for evaluating the quality of research. Neuman (2011) cites reliability and validity as ideas that help to establish the 'credibility' of findings. Reliability aims towards the consistency or replication of research findings in similar conditions, while validity evaluates the truthfulness of findings. The latter can be demonstrated in three ways: the validity of selected measures or 'construct validity', 'internal validity' and 'external validity'. Most often, validity is associated with the 'operationalisation' of concepts, which is commonly used in quantitative research (Mason 2002). Although reliability and validity are treated separately in quantitative studies, these terms are not viewed separately in qualitative research. Instead, terminology that encompasses both, such as credibility, transferability, trustworthiness or dependability, and confirmability are used (Hoepfl 1997, Riege 2003). Internal validity is used for establishing causal relationships and external validity deals with the generalisation of findings (Neuman 2011). Generalisability aims towards making general conclusions/claims based on the research findings, rather than them being particular to the research context. However, chance, bias and confounding are the three main threats to validity. Miles and Huberman (1994) identify the essential questions that need to be asked in the domains of reliability, internal validity and external validity (see Table 3-6). Yin (2003) explains two types of generalisation: statistical generalisations and analytic generalisations. He further differentiates that the statistical generalisation is established by an inference made about a population on the basis of empirical data collected about a sample and that the analytic generalisation is employed as a framework with which to collate the empirical results of the case study. This study exploited analytical generalisation in the case studies and statistical generalisation in the web-based surveys. However, generalisability is a particular concern for a single case study design (Saunders *et al.* 2007). Attention was paid to explain the validity and reliability issues particular to case study research, as this investigation was fundamentally supported by two main cases. Excluding external validity, the other three case study design tests (construct validity, internal validity and reliability) were undertaken to check the confirmability, credibility and dependability/trustworthiness of the findings. Table 3-7 discusses the techniques for evaluating validity and reliability in case study research.

Table 3-6: Key considerations of validity and reliability

Component	Reliability	Internal validity	External validity
Research question	Clear? Matches with the research design?	Meaningful?	Defines the scope and delimitations?
Role of the researcher	Described explicitly?		
Data	Across the suggested full range?	Rich? Well linked to the emerging theory? Any negative evidence? Rival explanations?	True representative sample? Any threats to generalisability?
Research paradigms	Clearly specified?		
Participants	Any comparable data collection protocol?		
Checks	Coding? Quality/bias?	Uncertainty?	
Research findings and conclusions	Meaningful parallelism across the data sources?	Did triangulation provide converging conclusions? Internally coherent? Replicated in other parts of the research? Considered accurate by original informants?	Consistent? Connected to prior theory? Applicable? Narrative sequence? Could fruitfully be tested further?

Source: Miles and Huberman (1994)

In this study, each component is discussed in particular sections of this chapter.

Table 3-7: Techniques for evaluating validity and reliability in case study research

Case study design tests	Corresponding design tests	Case study techniques	Qualitative techniques	Phase of research in which techniques occur
Construct validity		• Use multiple sources of evidence • Establish chain of evidence • Have key informants review draft case study report		• Data collection • Data collection • Researcher’s diary and report writing
	• Confirmability (corresponding to objectivity and neutrality of positivism)		• Confirmability audit (examine the data, findings, interpretations and recommendations)	• Data collection and analysis
Internal validity	• Credibility	• Do within-case analysis, then cross-case pattern matching • Do explanation building • Assure internal coherence of findings and concepts are systematically related		• Data analysis • Data analysis • Data analysis
			• Triangulation (sources, investigators and methods) • Peer debriefing • Member checks • Researcher’s assumptions, worldview and theoretical orientation • Researcher self-monitoring	• Data collection and analysis • Data analysis • Researcher’s diary and report writing • Research design • Data collection and analysis

Case study design tests	Corresponding design tests	Case study techniques	Qualitative techniques	Phase of research in which techniques occur
External validity	• Transferability	• Use replication logic in multiple case studies		• Research design
		• Define scope and boundaries of reasonable analytical generalisation for the research		• Research design
		• Compare evidence with extant literature		• Data analysis
			• Predetermined questions	• Research design
			• Thick description (develop case study database)	• Data collection
			• Cross-case analysis	• Data analysis
			• Specific procedure for coding and analysis	• Data analysis
Reliability	• Dependability	• Give full account of theories and ideas • Assure congruence between research issues and features of study design • Develop and refine case study protocol • Use multiple researchers • Record observations and actions as concretely as possible • Use case study protocol • Record data, mechanically develop case study database • Assure meaningful parallelism of findings across multiple data sources • Use peer review/examination		
			• Dependability audit (examine and document the process of inquiry)	• Research design
			• Clarify researcher’s theoretical position and biases	• Research design

Source: Riege (2003 p.78)

3.4.6.1 Triangulation

As illustrated in Table 3-7, 'triangulation' is a popular technique for testing the credibility of findings in qualitative research. On the other hand, it is identified as a very powerful technique to gain insights and results, assisting in making inferences and drawing conclusions. Simply, triangulation is a 'means of cross-checking the relevance and significance of issues or testing out arguments and perspectives from different angles to generate and strengthen evidence in support of key claims' (Simons 2009 p.129). In a way, it is a 'validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study' (Creswell and Miller 2000 p.126). The literature reveals four types of triangulation (Love *et al.* 2002 cited Denzin 1978):

- Data triangulation, where data is collected at different times or from different sources;
- Investigator triangulation, where different researchers independently collect and analyse data on the same phenomenon and ultimately compare results;
- Methodological triangulation, where multiple methods of data collection and analysis are used; and
- Interdisciplinary triangulation, where the research process is informed not only for example by psychology, but also by other disciplines such as economics, law and sociology.

This study exploited the method of triangulation to find the credibility (the internal validity) of the results. This method can be used to approach the research question from different angles (Mason 2002). In one way, it is a strong method; however, the whole process takes considerably much more time than a single method. The literature suggests that the rationale of multi-method research is underpinned by the principle of triangulation, which implies that researchers should seek to ensure that they are not over reliant on a single research method and should instead employ more than one measurement procedure when investigating a research problem (Bryman 2008). More specifically, this study used multiple methods to cross-check the internal validity of the findings. Initially, interviews were undertaken and then a case study method was exploited for in-depth evaluation. In addition, web-based questionnaire surveys were undertaken to clarify issues on design parameters and economic considerations for adaptability in buildings.

The data exploited in this study was obtained from different sources. For example, the building maps of Loughborough over the last century were collected from the Leicester Records Office and Charnwood Borough Council. The information was reassessed by a professional at Charnwood Borough Council and the Leicester Planning Authority to improve reliability and generalisability. The cost data for this analysis was obtained from the Building Cost Information Service. This study also exploited the cost information to identify cost-significant building elements. No major deviations (outliers) could be seen in the unit costs of the selected buildings.

3.4.6.2 Analytical generalisation

The theory for case studies is characterised as analytical generalisation and it is frequently adopted in qualitative research. It aims to test the validity of a research outcome against the theoretical network that surrounds the phenomenon and the research outcome (Yin 1994). This study used analytical generalisation to generalise the outcome of the case studies, which is that building change occurs over time. Yin (2009) explains that the previously developed theory is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed. The existing theories on building change patterns and their adaptations were used with some empirical evidence (interviews and secondary data analysis) to generalise the phenomenon.

3.4.6.3 Statistical generalisation

Statistical generalisation is making an inference about a population on the basis of empirical data collected about a sample from that universe (Yin 2009). This research used statistical generalisation to generalise the findings of WBS2 and WBS3. As noted previously, the respondents for each survey sample (architects and quantity surveyors) were grouped into three categories (early respondents, late respondents and non-respondents) and then early and late respondents were compared.

3.5 Summary

This chapter has outlined the research methodology that was adopted to gain well-informed insights into this scientific investigation. The research aim was to identify the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects. The adopted research design was a multi-method approach, which was further explained in terms of purpose, type of investigation and temporal aspects. The dominant purpose of this study was explorative in nature; however, some aspects of descriptive and explanatory traditions were adopted in the research objectives. The ultimate aim was to explore the economic considerations for change of use in buildings. This required understanding of design, cost and benefit aspects of change of use. Thus, empirical evidence-based practical investigation (applied) was undertaken. Holistically, the study exploited a multi-method approach and a literature review, case studies, interviews, web-based questionnaire surveys, archival analysis, secondary data analysis and workshops were used to gather the data for the research development and validation stages. The method of 'triangulation' was used to evaluate the quality and rigour (reliability and validity) of the research.

Chapter Four

4. ADAPTATION – A HISTORICAL PERSPECTIVE

4.1 Introduction to chapter four

The following literature review chapters (4, 5 and 6) are designed to explore the previous knowledge on the subject, bring a new dimension to the existing problem, bridge different types of existing knowledge and develop ideas on how new knowledge may be discovered. Generally, this PhD literature study has been restricted to the past twenty years. However, because the development of floor to ceiling heights dates back to at least the middle of the 20th century, some key publications in this area have been included.

This chapter reveals the historical perspective of ‘adaptation’, as this approach has been the primary consideration of this research endeavour. The chapter follows three main sections. The first section discusses the historical review of ‘adaptation’ in built environment facilities. The second section describes how other industries exploit this approach in their product and process development protocols. The last section explains two different traditions for building adaptation, pre-configuration (initial design choices) and re-configuration (subsequent changes in use), with two practical case studies.

4.2 Historical review of building adaptation

The term ‘adapt’ originates from the French word *‘adaptare’* (ad= to, aptare= fit), meaning to make something suitable for a new use/purpose or to modify it (Oxford Dictionary 2011).

Building change can be seen in many ways, such as change of size, change of use and change of location. Seemingly, these changes are a big challenge to the existing building stock because many current buildings are not intentionally designed to respond to changes in the market. Buildings that are unable to cope with the aforementioned changes or with the information technology that they use would become prematurely obsolete or require substantial refurbishment or demolition. Over the centuries, buildings have continued to be primarily constructed for a specific use; they have then been modified, replaced or simply demolished due to the natural processes of weathering and decay or to respond to cultural, social, religious or political changes (Madden and Gibb 2008). Thus, adaptation is becoming an important issue in built environment facilities and the process of adapting buildings for new uses has been happening for centuries (Gregory 2008). The primary purpose of a building is to provide shelter and safety for its occupants. Caves were used to meet these requirements in the very earliest days. A continuous improvement in buildings can be identified throughout history and today buildings are becoming branded; they are aesthetically pleasing and flexible to serve multiple types of users. Jacobs (1961) explains the historical changes in great American cities and the macro level changes in the built environment in her book *'The Death and Life of Great American Cities'.* This elaborates how cities work in real life and describes their change over time, identifying the principles of planning and practices in rebuilding that can promote social and economic vitality and what deadens these attributes. Thus, the challenge is to understand these changes and to design buildings to respond to future changes.

In the product environment, the concepts of *'specific'* adaptability and *'generic'* adaptability are well-established terms. With regards to the built environment, intentionally designing for foreseeable changes is considered specific adaptation and generic adaptation means designing for unforeseeable changes. However, generic adaptation is difficult in built environment facilities because they involve a large amount of interdependent elements. Thus, specific adaptation is proposed as a cost-effective option for built environment facilities.

Having observed the building morphology over the past 100 years, the changes in floor to ceiling height are remarked upon. First, the reasons for these variations in floor to ceiling heights in buildings are identified and then the relationship between floor to ceiling height and building costs is explained, as this is a major concern within this study. The following section is taken largely from Rybczynski's (2009) explanations of the change in floor to ceiling height in buildings over the years, combined with additional information provided by experienced researchers in architectural history, Alistair Fair[3] and Peter Madden[4]. In fact, changes in the floor to ceiling height of a typical building are affected by design as well as social, environmental and economic factors. Compared to older buildings, modern buildings, from the middle of the last century, have low floor to ceiling heights. The literature explains the main reasons for this trend in the different domains of aesthetics/prestige (Ashworth 2010), environment, social and economic (Rybczynski 2009).

Throughout the 19th century and the early part of the 20th century, the typical floor to ceiling height in middle-class homes, offices, and institutional buildings was 10-12 feet (3.05m – 3.66m). At first, taller ceilings were offered as extras, but soon 9 feet (2.75m) became standard. Rybczynski (2009) identifies that these buildings followed the architectural rule of thumb: "The larger the room, the taller the ceiling”. Moreover, Fair (2012) explains that the key reason for a high floor to ceiling height in aged buildings was mainly related to aesthetic considerations (for example, for the followers of Palladio in the 18th century, the first floor of a building was the grandest because it was raised above the damp of the ground, and so it had the tallest ceilings). Sometimes the builders of custom homes went to 10 feet (3.05m), and during the post-war era, when buildings started being mass-produced, builders and architects considered higher floor to ceiling heights to be wasteful and inefficient, and saw no reason to make them taller than the legal minimum, which could be as little as 7 feet or 2.14m.

A similar pattern was followed by the office buildings over the last century. Rybczynski (2009) states that the office buildings were designed to be 8¾ feet (2.67m) high in 1965, slightly taller than the norm at that time. By the late 1970s, office ceilings were routinely 9 feet (2.75m), and 25 years later, the ceilings were 11 feet (3.36m), which is quickly becoming the standard for Class A office buildings. Sometimes the ceilings of executive floors were designed for 13 foot (3.97m). Thirty years later, office ceilings have continued to grow taller. Taller ceilings in office buildings have been driven not only by the prestige associated with taller rooms but also by the growing popularity of open planning and office cubicles. These

[3] *Email exchange with Dr. Alistair Fair, University of Cambridge, UK (Research Associate) 1/03/2012*

[4] *Email exchange with Professor Peter Madden, Coventry University, UK (Retired architect and founder member of the Adaptable Futures research team) 1/03/2012*

allow for large expanses of space to be visible, and taller ceilings make these work places more pleasant.

In the 1990s, the motivation of homebuilders was extended towards the taller ceilings. Rybczynski (2009 p.4) further states that 'the historic preservation movement can take some of the credit for this evolution'. Previously, when old buildings were "modernised", tall ceilings were usually covered over with a lower suspended ceiling. When the public started becoming interested in older buildings, there was a heightened appreciation for "interesting" details such as ceiling mouldings, coves, and plastered ornaments. Suspended ceilings were removed and the old tall ceilings were restored to view. Moreover, Madden (2012) explains that the floor to ceiling heights of Georgian, Regency and Victorian houses were higher than today's normal height in the UK and not only were these heights related to the proportion and elegant appearance of the rooms, they were also more adaptable for future change of use. Historical preservation of aged buildings to facilitate new uses has been popular in the UK. Part of the historic preservation movement was the adaptive reuse of old buildings, especially old industrial buildings, which usually had tall ceilings (Rybczynski 2009). Living and working in older buildings, people discovered that taller rooms simply felt and looked better. On the other hand, the high floor to ceiling heights helps to create a comfortable indoor environment for its users.

Before the advent of air-conditioning, taller ceilings made for cooler rooms, as hot air gathers at the top of a tall room. With air conditioning, this was no longer true. Lower rooms were more convenient and cheaper to cool. 'Since conditioned air is fed from the floor, rather than from the ceiling, the taller height is not a disadvantage to cooling' (Rybczynski 2009 p.3). On the other hand, taller ceilings allow light to penetrate deeper into the building, which is important in optimising day lighting. This point is particularly important in office buildings seeking BREEAM certification. However, tall ceilings in pre-modern non-domestic buildings can also be related to an interest in natural ventilation and to improve day lighting (by allowing bigger windows) (Fair 2012). There is evidence that, as mechanical ventilation and electric lighting became more prevalent, ceilings became lower. In essence, 'the improvement of central air conditioning encouraged the development of increased floor sizes and lower ceilings' (Hysom and Crawford 1997 p.147).

Social/human considerations also affected the selection of appropriate floor to ceiling heights for a building. For example, the minimum ceiling height in the Netherlands was raised from 8 feet (2.44m) to about 8 1/2 feet (2.59m) in 2003, and the reason given was that people were taller, which may be another reason for higher ceilings. Although the general trend in commercial construction has been higher ceilings, there are situations where lower ceilings persist. In accordance with planning and statutory concerns, when developers want to maximise the carrying capacity of a site, there is pressure to minimise floor to floor heights. This is done by keeping ceiling heights relatively low and minimising structural depth by using thin post-tensioned or pre-stressed flat concrete slabs. The aforementioned facts highlight the continuous change (high to low) in the floor to ceiling height of buildings over the past 100 years. The innovations in technology, new materials, and the changes in building acts and regulations (Barritt 1996) were in favour of achieving this change effectively. The literature explains the adaptable potential of buildings with high floor to ceiling heights (Ratcliffe and Stubbs 1996, Heath 2001, Arge 2005, Rawlinson and Harrison 2009). However, the cost implications attached to floor to ceiling height need to be discussed within this study. It is important to identify the optimum limits of floor to ceiling heights which are more economical to facilitate different use typologies. The following paragraphs provide details about the influence of floor to ceiling height in building costs, which ultimately gives a clear picture to the designer when designing the building to a specific budget and with potential adaptations.

The general relationships between construction costs and design variables are discussed in the literature. These relationships are very important in establishing accurate cost estimates for buildings, which are always acknowledged in building economics. The literature also covers the relationship between construction cost and the different design variables. These are mainly plan shape (Wing 1999), building height (Flanagan and Norman 1978, Tan 1999, Kunze 2005), storey height (Wilderness Group 1964, Lowe *et al.* 2006, Ashworth 2010), floor loadings, column spacing and number of storeys (Wilderness Group 1964, Seeley 1972, Ashworth 2004). This study is limited to explaining the adaptable potential of buildings with different floor to ceiling heights. Storey height appears as a key variable in building cost estimating (Skitmore *et al.* 1990, Lowe *et al.* 2006) and cost modelling (Cheung and Skitmore 2006). Thus, the cost implications with different floor to ceiling heights are noted as an important area to address within this study to advise building owners about the total cost of adaptable buildings.

The Wilderness report (1964) provides an easy reference to design teams on the cost changes of buildings with an increase in storey height (see Figure 4-1). The greater the floor to floor height, the greater the cost (Ashworth 2010). The American Institute of Architects (2008) explains that the vertical elements in a building account for 25% to 35% of the total cost; thus, a 10% reduction in a storey height saves 2.5% to 3.5% overall. Moreover, according to Rybczynski (2009, cited in Stern 2006), 'making ceilings taller doesn't add that much to the overall cost of a building'. As Figure 4-1 illustrates, the unit cost continuously rises as the storey height of the buildings increases. Even though a high floor to ceiling height is appreciated in the adaptable building agenda, the most economic floor to ceiling height needs to be identified to facilitate required use typologies.

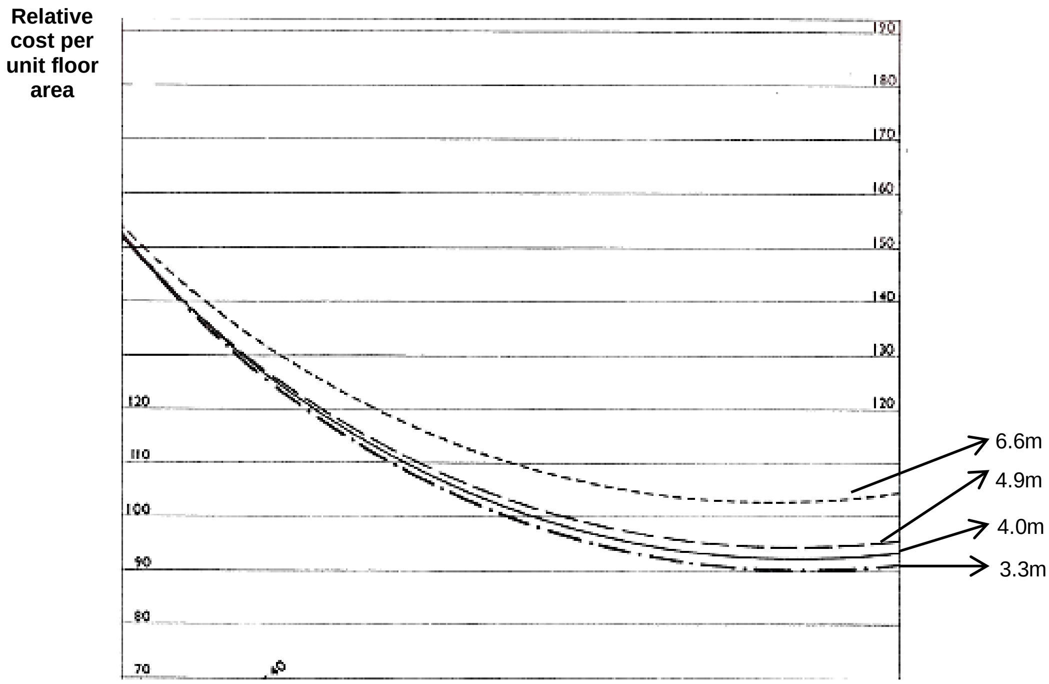


Figure 4-1: Cost changes with the storey height of a single storey building

Source: Wilderness Group (1964)

The chart clearly depicts the cost increments with different storey heights. This information can be used as a tool for quantity surveyors to advise on cost changes with different storey heights, which is becoming an easy reference for designing new buildings for potential adaptations. However, maintenance and operational costs were not taken into account in the above chart, even though these costs are important within the lifecycle cost considerations.

In conclusion, changes in floor to ceiling height appeared in buildings over the last century and various factors were behind those changes. A high floor to ceiling height is considered as a good potential for future adaptation; however, cost increases can be seen with the increases of storey height. Apparently, these increments are not proportional to the height difference. Therefore, an economical floor to ceiling height to facilitate potential uses needs to be identified when designing new buildings for future adaptations.

The following table (Table 4-1) summarises the work undertaken by Madden and Gibb (2008) as part of the Adaptable Futures project about the history of adaptable architecture.

Table 4-1: History of adaptable architecture

Building/Space	**Adaptable characteristics**
18th and 19th centuries	
Society of Preservation of Ancient Buildings (SPAB) headquarters, Whitechapel Street, London 	Conversion of an 18th century terraced house to offices for SPAB (in 1990). This conversion included a re-configuration of the internal layout and installation of new mechanical and electrical services to respond to the new office environment. The generous, well-proportioned and elegant architecture responded well to future internal changes of use and the re-configured layouts of the original building helped this conversion to succeed.
Bertie Terrace, Royal Leamington Spa, Warwickshire, 1826 	Conversion of Grade II listed Regency terraced houses to apartments (in 1970). The structural stability of the old structure and the high floor to ceiling height of the original building are the key measures that helped to complete this conversion.

<table>
<tr><td colspan="2">Early 20th century: Development of industrialised building techniques and prefabrication</td></tr>
<tr><td>Nissen hut, Gloucestershire (1916)
</td><td>Lightweight steel structure.
Minimum material for maximum enclosed volume.
Mass production.</td></tr>
<tr><td>Bauhaus, Dessau, Germany (1926)
</td><td>Prefabrication and mass production.
Flexibility in change of use.
‘Flexible’ accommodation in the form of areas that could be sub-divided by moving partitions.</td></tr>
<tr><td colspan="2">Mid-20th century</td></tr>
<tr><td>Illinois Institute of Technology (IIT), Chicago
</td><td>Flexible design (for example, the envelopes can be easily adapted to the various requirements of the IIT without any alterations whatsoever to their structure, services or fabric).</td></tr>
</table>

Farnsworth House, Plano, Illinois  The Glass House, New Canaan 	Framed construction. Non-load-bearing external and internal walls. Facilitate internal changes to the plan if required at a later date.
Ford House, Illinois 	Re-use of redundant components.
St Martin's House, Bull Ring, Birmingham 	Vertical flexibility in design (designed to increase height by a further ten storeys in the future).

Lecture theatres and electrical engineering/engineering production buildings, Birmingham 	Sliding, demountable and re-locatable partitions to allow the plans to be re-configured. The provision of mechanical, electrical, ventilation and other services was designed to allow them to continue to serve the buildings even in the event of future internal alterations.
Extension to civil and building engineering building, Loughborough University 	Over-designed to be flexible and 'loose fit'. Tartan grid with wide spans capable of carrying very heavy loads. Open plan. Can readily accommodate a variety of new functions. High ceilings and deep ceiling voids are capable of containing a 'blanket' provision of services.
21st century buildings	
Eden Project, Cornwall (2000) 	Exploited the space-frame principle (space frames are economical and aesthetically pleasing in appearance). Provides a unique solution to covering large column-free areas. Offsite fabrication, pre-assembly and modularisation.

Source: Adapted from Madden and Gibb (2008)

The case studies noted above explain how the buildings were adapted to respond to planned and unplanned changes. Many buildings designed in the mid-20th century and in the 21st century used factory-built products (modular, precast, panelised and prefabrication). Their related techniques, such as loose fit, plug and play, over-designed, demountable, recycle-able and re-locatable, helped to make buildings more adaptive for future changes (market demand and sustainable considerations). The future trend of modern buildings can be seen in the application of modern systematised methods of design, production planning and control, as well as mechanised and automated manufacturing processes. Having summarised different examples of building adaptations in Table 4-1, the use of the open building concept, the development of open building manufacturing techniques in the mid-20th century and the demand for intelligent buildings in the modern era are noted.

4.2.1 Open building approach

The ‘open building’ approach also provides a similar conceptual philosophy to the design of buildings that identifies both stability and change in the built environment. This concept separates the building into two levels: the base building level and the fit-out level. The base building level considers the static, more permanent part of the whole building and the fit-out level considers the more changeable part of the whole building. In other words, base building is concerned with what is shared by everyone and the fit-out is concerned with what is decided by each user independently (see Figure 4-2).

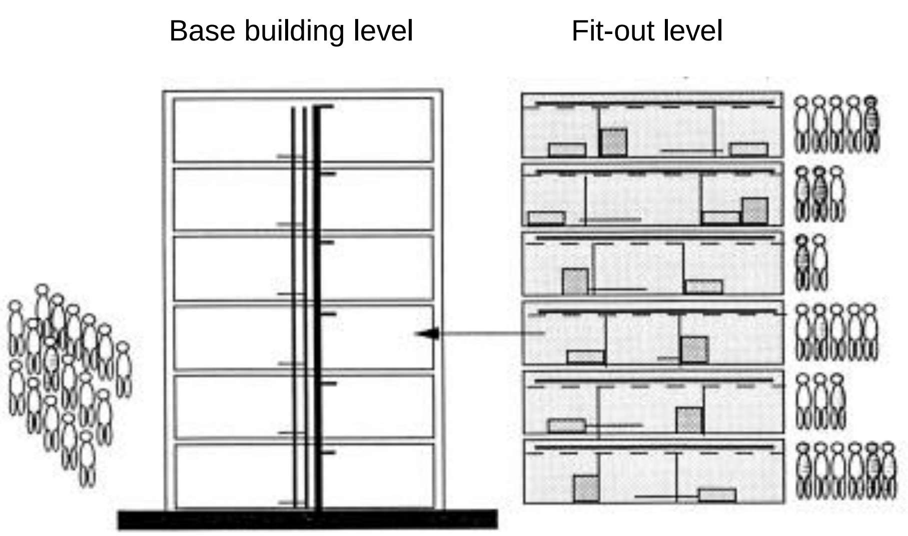


Figure 4-2: Open building

Source: Kendall (2003)

The literature (Habraken 1980, Kendall 1999, Edmonds and Gorgolewski 2000) explains the concepts of open building as:

- The built environment is in constant transformation.
- Change must be recognised and understood.
- The built environment is the product of an ongoing and never ending design process.
- Users/inhabitants may make design decisions, as well as professionals.
- Designing is a process with multiple participants.
- There are distinct levels of intervention in the built environment (base building and fit-out; urban design and architecture).
- Interfaces between technical systems allow easy replacement of one system with another performing the same function.

The mainstreaming of open building is a response to PESTLE (political, economic, sociological, technological, legal and environmental) changes. In its broader sense, the open building concept considers urban level changes. These concepts (base and fit-out) can be adopted in buildings designed to respond to potential changes. The integration of manufacturing techniques with the open building concept brings much flexibility to users.

4.2.2 Open building manufacturing

The 'open building manufacturing' approach attempts to bring some of the salient features of efficient manufacturing to the construction sector. ManuBuild (2008) identifies open building manufacturing as '*highly efficient industrialised production'*, combining '*ultra-efficient manufacturing'* in factories and on sites with an open system for products and components, offering diversity of supply in the market. Figure 4-3 explains the state of the art of open building manufacturing.

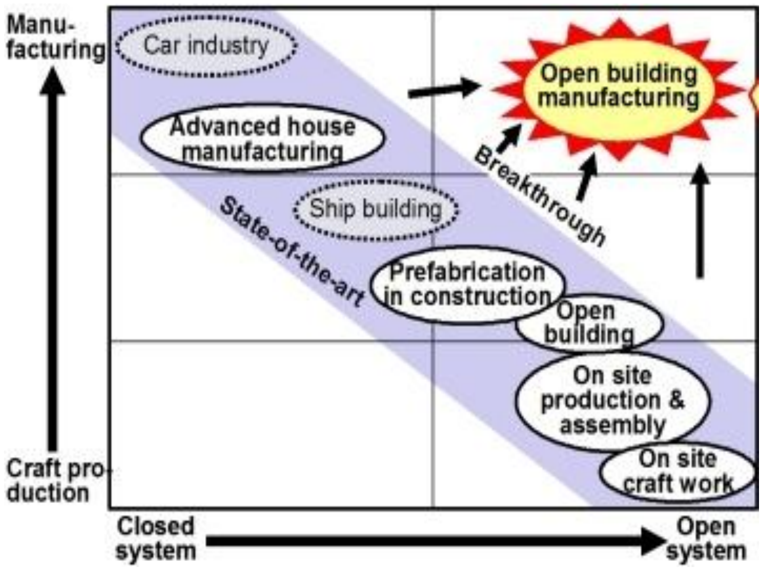


Figure 4-3: Open building manufacturing

Source: Manubuild 2008

This concept considers building construction as a knowledge-based industry, and products, processes and information communication technology are the key components of an open system. This approach acknowledges both craft and mass technologies within buildings. As a result, significant savings in construction and maintenance costs, fewer errors and less reworking, more choices and value for the customer, and new products and services that can be configured and assembled in mobile factories at construction sites can be expected as benefits over contemporary buildings (ManuBuild 2008). Section 4.2.3 explains the ability of intelligent buildings to respond to built environment changes.

4.2.3 Intelligent buildings

Innovations in technology (new tools and techniques) and building information modelling (BIM) facilitate the design of intelligent buildings that are the most advanced adaptable buildings. The intelligent building is 'one which integrates various systems to effectively manage resources in a coordinated mode to maximise: technical performance, investment and operating cost savings, and flexibility' (IBE 1992). It is dynamic and responsive architecture that provides every occupant with productive, cost-effective and environmentally approved conditions through continuous interaction among the basic elements of places (fabric, structure and facilities), processes (automation, control and systems), people (services and users), management (maintenance and performance) and the interrelation between them (CIB W98 1997). It responds to user requirements (fully or partially) without manual adjustment. The intelligent software and associated infrastructure (sensors) help to run the adaptable performance of buildings. Constructing an effective system for frequent changes is very challenging because it involves a large number of different and sensitive data to be used in the building systems. These buildings and their internal environments respond to change very frequently. The process of adaptation has been exploited in different industries with different protocols to make their products and processes fit for purpose. The next section explains the application of adaptable techniques in different industries.

4.3 Application of adaptable techniques in other industries

The ability to implement adaptive systems in the manufacturing, production and service industries stems from a series of technological advances, globalisation of the economy, imbalances between supply and demand and the fragmentation of markets over the last century. On the other hand, the production costs of motorised systems have dropped significantly and standardisation within the automation industry has helped to improve system reliability. Microprocessor technology continues to move in the direction of low cost, low power, small form factor design implementations, allowing for a greater distribution of embedded network intelligence. Combining these advances with diverse computational tools, sensors and environmental modelling allows truly dynamic and responsive environments to be created (Adaptive Building Initiative 2011). Changing market conditions and new technologies pose a fundamental challenge to manufacturing, production and services industries. Thus, the products and processes of these industries need to be designed to respond to immediate changes in the market and their potential customers.

Flexible manufacturing techniques are usually exploited in the automotive industry, as they combine the flexibility and high quality standards of craft production with the low cost of mass production techniques. They use less inputs, including time, labour, capital and inventories, than either of the other techniques (www.oup.com 2011). ‘Design for X’ is the generic approach that is frequently used in the product and manufacturing industries to respond to the market changes (Hashemian 2005). The specific variables for ‘X’ are upgrade, variety, versatility and customisation. The adaptable approaches often used in these industries are summarised in the following sub-sections.

4.3.1 Modularity

'Modular architecture' is a system in which it is easy to replace or add a component/module without affecting the rest of the system. Modularity involves partitioning product functions and allowing for flexible application (Marshall 1998). The unit 'module' is a self-contained component of a system that has a well-defined interface to the other components. The frequent applications of this technique in the electronics industry for computer manufacture, the automotive industry for car manufacture (Renault) and in the aerospace and service industries are well established (Marshall 1998). The basic idea underlying modular design is to organise a complex system as a set of distinct components that can be developed independently and then plugged together (plug and play). This will provide opportunities to upgrade the facility to the required condition by adding or replacing the standard modules. In architecture, this method is frequently used to form buildings by combining standardised units.

4.3.2 Mass production

Mass production refers to the production of standardised components on a mass scale. These methods use skilled personnel to design products and production methods and then the employment of relatively unskilled labour to produce standardised parts and assemble them using highly specialised, single-purpose machines. The result is a standardised product made in a small number of variants and produced at low cost with moderate quality. The work is repetitive and workers are regarded as variable costs to be laid off or taken on as the desired rate of production varies. However, the variety of change (technology, user requirements, policy change and sustainability) required in products and processes has made it impossible for most manufacturing and production companies to adhere to strict mass production principles, and many now seek to differentiate themselves from competitors on the basis of customer choice and customisation capabilities.

4.3.3 Mass customisation and flexible manufacturing

The notion of mass customisation emerged in the late 1980s. Generally, it emphasises the need to provide outstanding service to customers by providing products that meet customers' individual needs through unique combinations of modular components (Pine 1993). Simply put, it is a method used to customise and personalise products and services at a mass production cost. Industries like manufacturing, production and service produce their products on a mass scale and mass customisation is usually exploited to brand their products. They use flexible manufacturing technologies to achieve flexibility/adaptability from their products.

Flexible manufacturing methods are very effective in the long run in developing successful new products. They are flexible because the costs of switching from one product line to another are minimised. Lipsey and Chrystal (2007 p.114) explain the characteristics of a flexible manufacturing system, where 'the workers are organised as teams. Each worker is able to do all the tasks assigned to the team, using equipment that is less highly specialised than that used in mass production techniques. For example, Japanese motor car manufacturers using these methods have been able to achieve unit costs of production below those of mass production based North American and European car factories, which have twice their volume of output. They have also been able to lead in international competition to design new products efficiently and rapidly'. These approaches are very popular in the manufacturing and production industries because they produce products on a mass scale. Comparatively, construction products are one-off in many cases and customisation is required to a certain extent to respond to potential markets and minimise obsolescence.

Saker (2009) explains the importance of learning lessons from the manufacturing industry about '*how is the manufacturing industry responding to the issue of external forces?'* and then to know *'how the building industry could create commonality within our products',* for example how common floor plans can be used to design different building models/configurations. Sections 4.2 and 4.3 explain planned - unplanned adaptations of existing buildings and adaptable methods used in other industries to respond to potential changes in the future. Obviously, open building manufacturing considers both craft and mass production approaches in construction. Having considered these methods (modularity, customisation, plug and play, and loose fit) in building design, the building is able to be configured for the initial design (pre-configured), as well as subsequent changes of use (re-configured). The next section explains these configurations with examples of each approach.

4.4 Approaches for building configurations

Building configuration determines the arrangement of building elements in a particular form, figure or combination (Oxford Online Dictionary 2011). In this regard, two distinctive approaches are considered: 'pre-configuration' and 're-configuration'.

4.4.1 Facility pre-configuration

Built environment facilities can be designed to be assembled from a series of sub-assemblies and systems such that there are a number of different layouts, configurations or finishes (Madden and Gibb 2008). The application of standardised components is highly acknowledged in the sustainability agenda because these components provide opportunities for recycling and reuse at the end of the product/building lifecycle. The pre-configuration approach often adopts standard components in design and follows three concurrent processes of manufacturing, assembly and erection to deliver the end product. These components are manufactured either offsite or onsite. The term 'offsite' is often used to describe the spectrum of applications where buildings, structures or parts thereof are manufactured and assembled remotely from the building site prior to installation in their final positions (Buildoffsite 2010). They are assembled onsite or in the factory (off the site) and erected on the site. Facility pre-configuration considers different configuration options at the design stage prior to building construction. The following case study examines the different pre-configuration options for the assembly of the same units/components to hold different building functions.

4.4.1.1 Newways - A case study of facility pre-configuration

This case study (Newways) deals with the reduction in time for the design and build of a product (a building) for a leading pharmaceutical company (GlaxoSmithKline, or GSK) through the application of standard components or a kit of parts. The expected time reduction is from 24 months to 13 weeks to enable the drugs that they produce to get to market earlier or to enable the delay of the design and construction of the buildings until the drug is approved, thus reducing the risk of producing sub-optimal buildings and facilities (Beadle *et* *al.* 2008). Figure 4-4 illustrates the process of assembling a pre-configured kit of parts to construct three different buildings/assets.

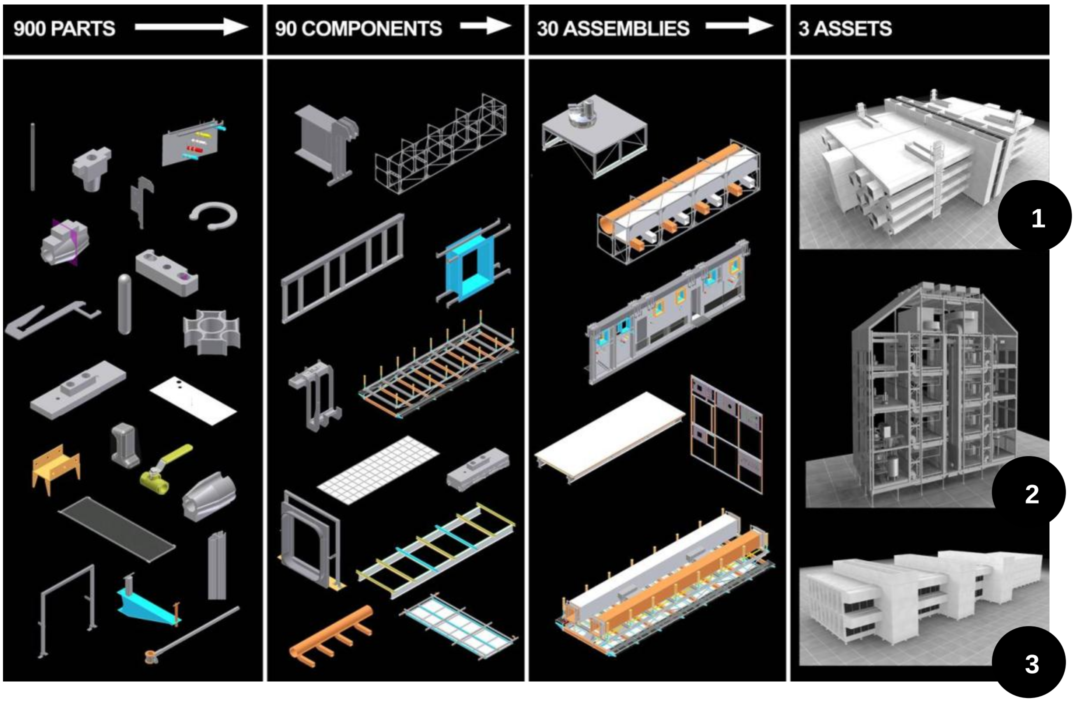


Figure 4-4: Facility pre-configuration (Newways)

Source: (Adaptable Futures 2008)

The first, second and third buildings serve the functions of research laboratory, primary production and secondary production for the requirements of GSK, respectively. The majority of the buildings are constructed from standard components and bespoke designs were allowed for site-related elements and finishes. Newways used the Flexilab system, which provides a relocatable furniture system and a plug and play services system for the laboratory environment (wemarson.co.uk 2011). The expected benefits from Newways can be summarised as reduced risk, reduced supply disruption, reduced capital project contingency, reduced cost due to less bespoke design and improved technology transfer (Beadle *et al.* 2008 cited Barnes 2007). However, when considering the business implications of Newways, there is a need to establish the market for the product, moving from a conventional project process to a lean capital programme, and to ensure the monitoring of the results, looking specifically at programme management, product development, supply chain management and the production of components and assemblies (Fuster *et al.* 2009).

4.4.2 Facility re-configuration

Facility re-configuration determines the re-arrangement of the units/components of a facility after its construction. This aims to extend the functional lifecycles of built environment facilities. This is the most obvious application of adaptability in the built environment (Gibb *et al.* 2007). Design contingencies for allowing new buildings to respond to future changes are an important consideration in facility re-configuration. The following case study explains the typical design considerations of a building to respond to future changes of use.

4.4.2.1 Multispace – A case study for facility re-configuration

The Multispace concept developed by 3DReid is driven by a desire to reduce the waste of resources and potential revenue that stem from un-let purpose-built accommodation. The concept offers potential solutions to the problems of creating multi-use buildings while identifying a set of design parameters. On one hand, the objective is to use design parameters that allow a change of use without any significant changes to the building shell. On the other hand, it is intended to design buildings that can accommodate a variety of uses without predetermining their location or extent (3DReid 2006). Having noted these objectives, a Multispace project is designed by considering the generic elemental specifications to facilitate potential changes of use (residential, hotel bedroom, office and retail) under one building. The features include:

- A target storey height in the order of 3.5m – 3.6m (lower storey heights are possible at the expense of servicing flexibility).
- Allowing for vertical and horizontal zoning around cores.
- Using a post-tensioned structural slab system to minimise slab depth and maximise economical span.
- Choosing structural grids to integrate with a suitable car park grid if necessary.
- The option to treat the ground floor as a double-storey zone, which can be in-filled with mezzanine space as required by use.
- Optimising site density by choice of building form.
- Designing core/main floor connections to allow for variations in floor depth – say 100mm to 350mm.
- Toilets and bathrooms being treated as fit-out items and kept separate from shear walls.

- Considering pre-fabricated pods or pre-plumbed panel systems for WC/bathroom fit-outs.
- Choosing cladding systems to maximise pre-fabrication, avoid scaffolding and allow the interchangeability of components.
- Setting the ceiling zone back from the perimeter to minimise interferences with cladding and maximise daylight penetration.
- Considering having a high percentage of glazing that can then be back-filled with insulation/privacy panels.
- Using cladding systems such as unitised/semi-unitised curtain walling that can allow opening casements to be added later.

Figure 4-5 illustrates the Multispace design concept. The concept identifies several design parameters for change of use and Table 4-2 determines the minimum requirements for each parameter.

Table 4-2: Summary of adaptable requirements

Design parameter	Ground floor condition	Upper floor condition
Proximity of blocks	Determined by spread of fire regulations	18 to 21m min. between habitable rooms
Plan depth	13.5m (preferably 15m) to 45m	15 to 21m
Internal ceiling height	3.5m single storey 5 to 7m double storey	Approx. 2.7m
Ceiling zone	0 to 500mm	0 to 500mm
Floor zone	Preferably 100 to 350mm	Preferably 100 to 350mm
Structural slab and spans	Min 7.5m span. 260mm slab @ 9x9m; 330mm slab @ 12x9m	Min 7.5m span; max. 12m span. 260mm slab @ 9x9m; 330mm slab @ 12x9m
Design occupancy for fire	1 person per 5sqm	1 person per 6sqm
Travel distance for fire	30m two way (12m one way)	30m two way (12m one way)
No. and size of lifts	N/A	Design for mixed use as the worst case and offices as worst case for single use
Cladding specifications	Maximum glazing within fire, noise and cost constraints	40 to 100% glazing, NR 20-30; 1.5m module and option for opening casements

Source: Multispace Design Guide (3DReid 2006)

The Multispace concept acknowledges typical mixed use schemes and mixed use buildings. The design allows flexibility for change of use between four use typologies.

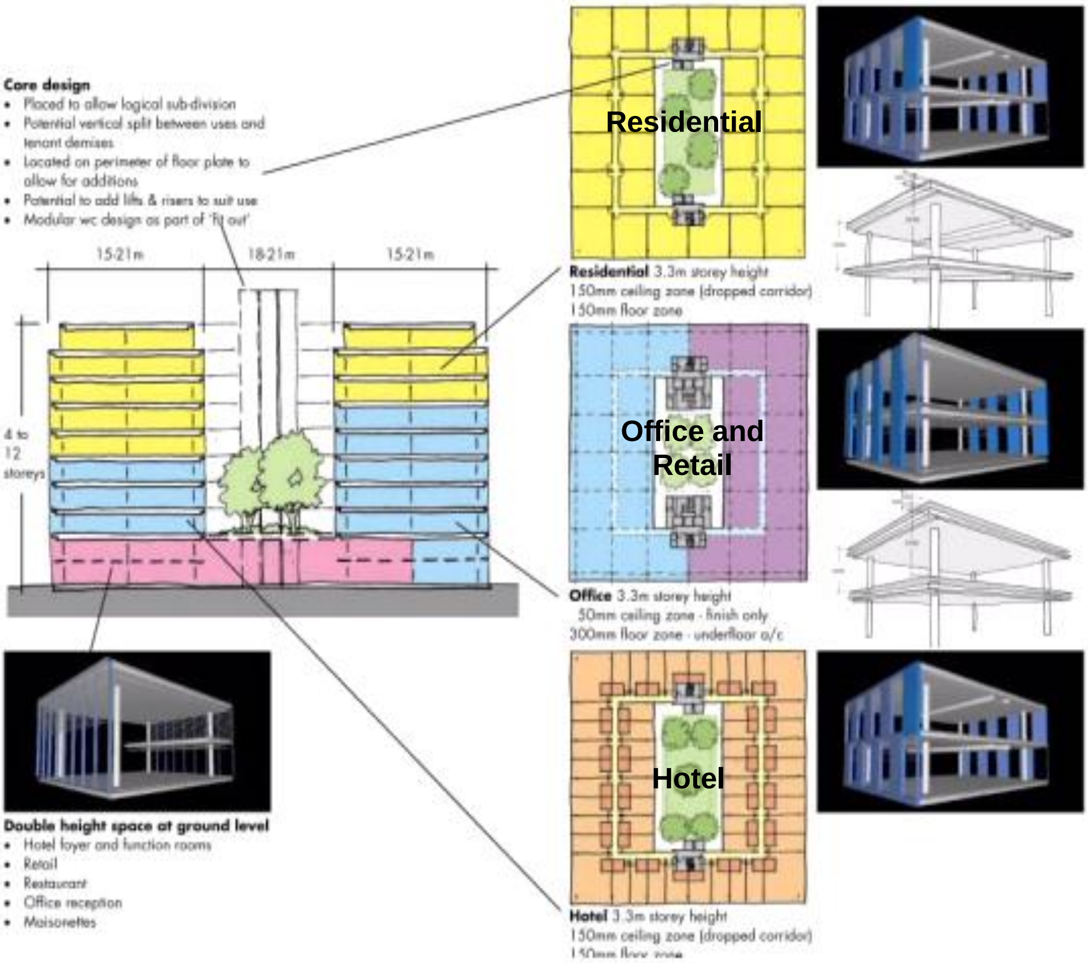


Figure 4-5: Facility re-configuration (Multispace)

Source: Multispace Design Guide (3DReid 2006)

As previously noted, the case studies considered in Table 4-1 explain post-construction re-configurations of built environment facilities. Apparently, some of them were easily adapted because of the planned adaptable architecture used in the initial design. Similarly, the Multispace concept aims to facilitate different uses while designing buildings to a common plan. This improves the flexibility, phasing, higher returns and reduced risk associated with mixed use schemes without having to predetermine which parts of the scheme perform a particular use (Davison *et al.* 2006).

4.5 Summary

This chapter encapsulated the historical review of adaptable buildings and the frequent approaches that other industries have exploited to make their products adaptable/flexible to respond to future changes. The historical evidence attests the apparent trend in building change over the last few centuries. Thus, the need to design new buildings to respond to these changes is highly acknowledged. In essence, two design configurations were considered (facility pre-configuration and re-configuration) to design new buildings to respond to future changes. The manufacturing and production industries use advanced technology, greater product diversity and more flexible methods of production to get their products to market and to attract customers. In addition, computer-aided design and manufacturing systems have reduced the lead time for the introduction of new models. The use of common components and sub-systems facilitates the generation of new variants, thus identifying the importance of exploiting these modern tools and techniques in built environment facilities to bridge the gap in adaptation.

Chapter Five

5. RESPONDING TO CHANGE – DESIGN FOR ADAPTATION

5.1 Introduction to chapter five

Chapter 5 reveals that design for adaptation (DFA) is an innovative approach for responding to potential built environment changes. The first section of this chapter explains the process of DFA, which takes into consideration design intelligence as well as different strategies, principles, rules, policies and products for potential built environment adaptations. The second section explains the adaptable potential of existing buildings and the tools and techniques available for evaluating the adaptability of buildings. The last section explains the benefits and limitations of DFA.

5.2 Design for adaptation

Buildings are designed for long lives: they are expensive to build and the cost of replacement is high and clearly unnecessary if they are physically robust and adaptable. They demand different changes (physical, structural and functional) and these demands are encouraging greater innovation in the design of new buildings to allow for potential adaptations during their lifecycles. To survive a more complex array of needs, modern buildings are required to be designed to improve space, environmental and safety standards and adapt for change of use situations (Godfaurd *et al.* 2011). DFA is the process of extending the lifecycle of a product, a process that is usually exploited in the manufacturing and production industries. However, it has a short history in the construction industry. Manufacturing products are often designed for mass customisation that considers a variety of flexibilities to fit different user needs. The strategies of *'flexibility of the product'*, *'flexibility of the tool', 'a multi-purpose framework'* and *'combinability'* are considered in the manufacturing industry to generate customisation (individualisation) within mass production (Richard 2006). Characteristically, traditional buildings are purpose-designed, single user centric and less adaptive to different built environment changes. Oostra (2006) discusses *'technology towards market pull', 'mass production towards mass customisation', 'in-situ construction towards prefabrication'* and *'project oriented towards the service centered'* as different strategies for improving adaptation/customisation within built environment facilities. The product, process, strategy and technology are considered to be the principal components for improving customisation/ adaptation possibilities in manufacturing and built environment products. 'Building adaptation' takes three principal forms: changes in function (e.g. conversion); changes in size (e.g. extension), and changes in performance (e.g. refurbishment) and is therefore concerned with adjusting, reusing or upgrading an existing building to suit new requirements. It is not therefore principally concerned with the adaptation of new methods of construction and products' (Douglas 2002 p.19). Langston *et al.* (2008 p.1711) propose that 'it is wise to design future buildings for change by making them more flexible yet with sufficient structural integrity to support alternative functional use'. These changes include the capability to extend or reduce the building either vertically or horizontally, the re-configuration of the internal spaces and the ability to respond either to new conditions or functions (Madden and Gibb 2008). In this light, DFA is identified as an innovative process for designing future-proof/adaptable buildings.

Adaptable buildings focus on potential bespoke solutions that (wherever possible) are flexible for varying customer needs. In reality, buildings with adaptable potential may survive in the near future; however, the traditional maladaptive buildings will remain as redundant stock unless they find a correct use. The literature reveals the multi-faceted values of 'adaptability': *'change the size or use of spaces'* (DCSF 2010), *'high capacity to respond to the change'* (Kronengburg 2007), *'quick transformations'* (Juneja and Roper 2007), *'change its capacity, function, or performance'* (Douglas 2006), *'maximizing its productive use'* (Graham 2005), *'less frequent, more dramatic changes'* (Leaman and Bordass 2004) and *'fit for purpose'* (Blakstad 2001). In its wider context, the 'adaptability' of buildings means the 'capability of altering its space, function, and/or components in order to respond to the evolved demands' (Larssen and Bjorberg 2004, Adaptable Futures 2008). Such buildings are capable of undergoing subsequent alterations to their physical fabric while responding to different spatial layouts to serve different functions (OECD 1976). However, Geraedts (2008 p.12) argues that 'the most interesting flexibility measures, obviously, are those involving no extra expenditure. Their implementation will meet with little opposition in the field. Things are different when additional expenditure is involved. It must be affordable in the first place. Unfortunately, the financial advantages to be expected are often not all that obvious. An important factor in this connection is the likelihood of the flexibility potential actually being utilized in the future. If its use is uncertain, the benefits are equally uncertain'.

DFA is a cyclical process of extending the life of built environment facilities (Adaptable Futures 2009). It considers a variety of aspects, such as 'design intelligence', 'policy and brief', 'rules, strategies and products' and 'technical solutions', together with 'built and un-built solutions' for potential adaptations. Figure 5-1 illustrates the principal components of the DFA process and each component is explained in the following sub-sections.

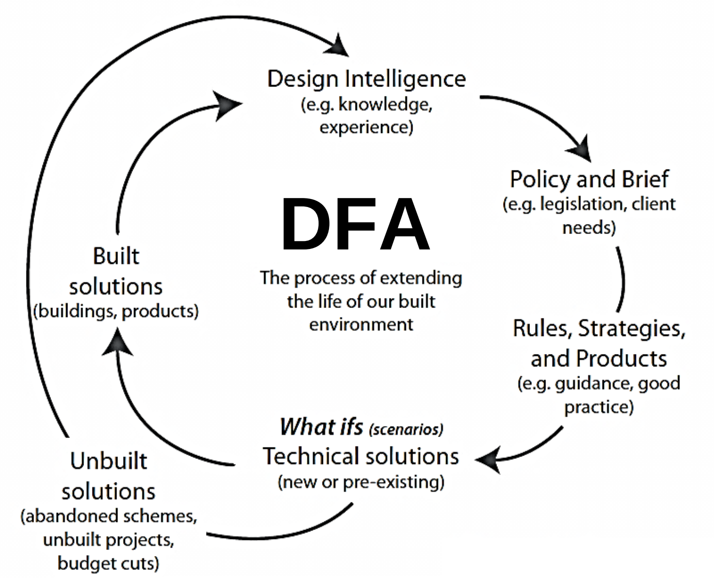


Figure 5-1: The process of design for adaptation

Source: Adaptable Futures (2009)

5.2.1 Design intelligence

Design intelligence considers the different sources for accumulating the knowledge and experiences for undertaking DFA. For example, proven and plausible concepts, components, methods and processes can be exploited to produce a variety of knowledge for the DFA process. The different sources for acquiring the knowledge within the process of DFA are considered in Figure 5-2.

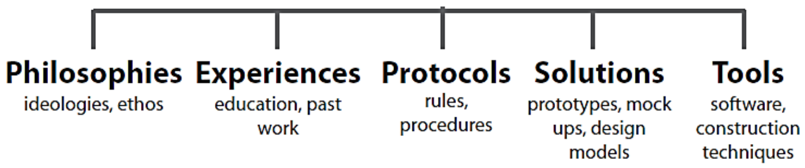


Figure 5-2: Sources for design intelligence

Source: Schmidt-III *et al.* (2009)

Design intelligence can be exploited to select suitable 'spatial' and 'design' approaches for adaptable buildings. The spatial approach discusses how the building space is designed for potential use. The 'big shed' approach allows a variety of uses within a single space and 'tight fit functionalism' (Rabeneck *et al.* 1974) focuses on the mono-functionality of buildings. Moreover, design intelligence shows that buildings with lots of adaptable potential are 'serviceable' to survive potential uses. In contrast, maladaptive buildings have poor serviceability but are rich in quality/character.

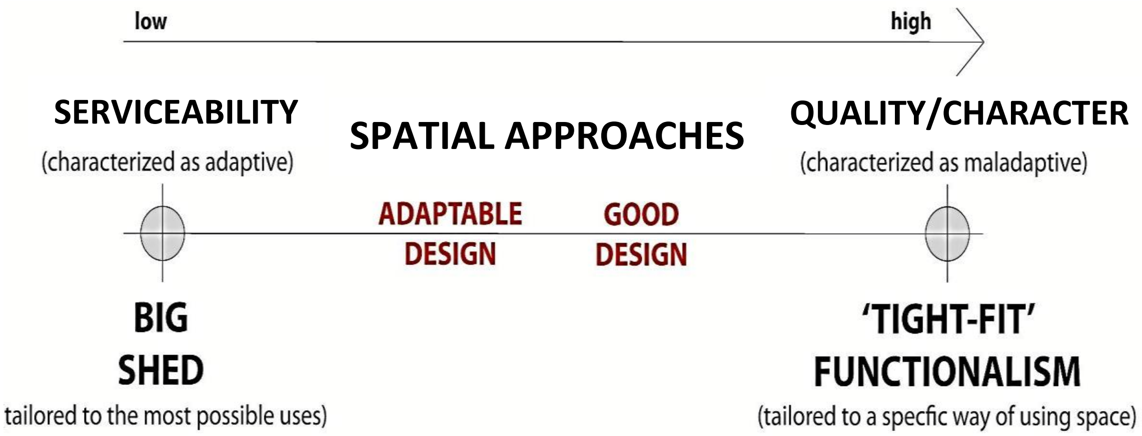


Figure 5-3: Spatial approaches for buildings

Source: Adaptable Futures (2008)

Characteristically, *'good design'* is able to deliver what the client has asked for, is fit for purpose, is sustainable, requires lower running and maintenance costs, provides a high return on investment, is completed on time and within budget, provides flexibility for future change of use, is cost-effective and delivers value over the whole life of the building (RIBA 2009). Economically cost-effective designs are likely to have one or more of the aforementioned attributes. Adaptable design also has the characteristics of good design and is tailored to the most possible uses. Design intelligence can be exploited to determine the appropriate design approaches for adaptable buildings. The generic design approaches can be placed within the boundaries of 'hard' and 'soft' while identifying the nature of their control, solution and system.

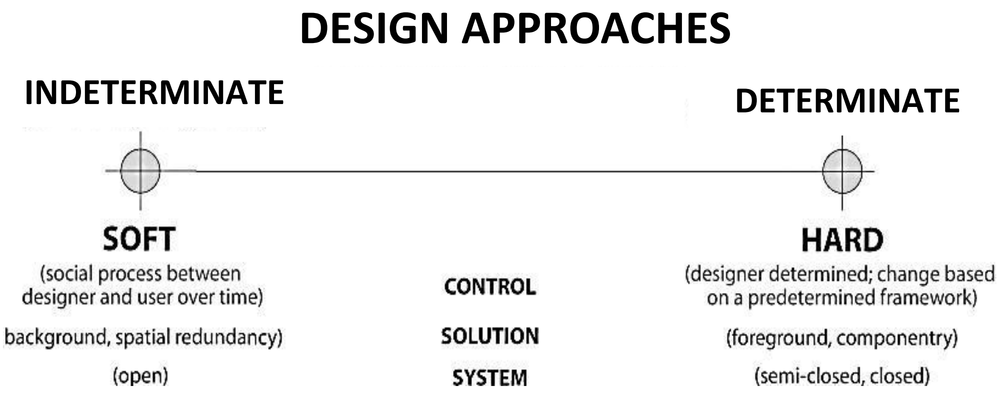


Figure 5-4: Design approaches for buildings

Source: Adaptable Futures (2008)

As elucidated in Figure 5-4, the 'hard' approach is given low flexibility (high control) for change, allows such changes limited to componentry (solution) and gives the opportunity for the designer to determine the required change (closed system). In contrast, 'soft' systems have much greater flexibility over changes throughout lifecycles and refer to tactics that 'allow a certain indeterminacy' (Till and Schneider 2005 p.289); thus they are considered open systems. Adaptable design can be placed nearer to the soft design approach. In short, design intelligence can be used to determine the spatial and design approaches for adaptable buildings. After identifying these approaches, the next step of the DFA process considers strategies for adaptability in buildings.

5.2.2 Policy and brief

The policy and brief consider the legal framework for the industry through taxes, regulations and incentives that either enable or impede the process of building adaptability (Schmidt-III *et al.* 2009). Planning and policy issues cover building regulations, government–led incentives, planning regulations, taxes on demolition (landfill tax), taxes on use of new resources, and design and industry guidelines. However, existing planning policies and regulations seem to be a major limitation for designing buildings towards potential adaptations. The change of use/class of a building will introduce new regulatory conditions and perhaps require zoning consent (Langston *et al.* 2008). Regarding the adaptive reuse potential of existing buildings, Adeyeye *et al.* (2010) identify spatial constraints, code compliance and disruptions to building use as difficulties in undertaking the adaptive reuse process effectively. Moreover, Jacobs (1961) explains how urban planning policies influenced the regeneration of American cities, whilst stating that primary mixed uses, small blocks, aged buildings and dense concentration are needed for urban diversity. Thus, consideration should be given when switching between different uses, as planning permission may need to be obtained from the relevant authorities to fit adaptable buildings into the urban landscape. In a way, design for potential adaptation provides opportunities to bring people back to cities whilst revitalising existing planning and building regulations (Langston *et al.* 2008). Thus, the need to revisit existing planning, zoning and policy issues regarding the initiation of adaptable potential in buildings is notable.

5.2.3 Rules, strategies and products

A concern of this research investigation was to identify how new buildings could be designed for potential adaptations. This does not imply that existing buildings are missing adaptable properties, but that older/existing building designs had not purposely considered adaptable performance in advance. Strategy determines how the building endures change over time (Adaptable Futures 2009). It is a plan of action designed to achieve a long-term or overall aim (Oxford Dictionary 2010), which can be usually reflected through the 5Ps (plan, ploy, pattern, position and perspective) (Mintzberg 1987). ‘Plan/ploy/pattern’ considers the macro level issues of adaptability, for example, the potential market for adaptable buildings. These plans/ploys/patterns are used to set goals and to develop them continuously and intentionally (Mintzberg 1987). The ‘position’ evaluates how adaptable buildings deal with external pulls and ‘perspective’ explains the internal pushes towards potential adaptations, which are client interests and profit margins. Apparently, 'adaptability' has meanings for different interest groups. Table 5-1 encapsulates the variety of strategies that were discussed in the literature to define adaptability in the built environment.

Table 5-1: Strategies for adaptability in buildings

	Design strategies for adaptability																	
Author/s	Generality	Flexibility/Versatility	Elasticity/Extendable/ Expandable/Scalable	Convertible	Dismantlable/ Separable/	Partitionable	Disaggregatable	Prefabrication/ Standardisation	Overcapacity	Movable	Rearrangeable	Reusable/Recyclable	Refitable	Multi-functional	Integratable	Universal	Modularity	Ejectable	Exchangeable
Gann and Barlow (1996)								●	●	●	●								
Blakstad (2001)		●	●		●									●					
Robertson and Sribar (2002)			●		●							●			●				
Arge (2005)	●	●	●														●		
Douglas (2006)		●	●	●	●		●												
Verweij and Poelman (2006)			●																
3DReid (2006)		●	●	●						●		●	●						
Geraedts (2008)		●	●		●					●	●					●		●	●
Pati *et al.* (2008)		●	●	●															
Gijsbers *et al.* (2009)		●			●			●		●									

These strategies ‘can effectively reduce life cycle costs by allowing a timelier and less costly response to a dynamic environment, which adds costs measured in terms of money, time, and complexity’ (Ford and Garvin 2010 p.54). Among these terms, ‘adaptability’ and ‘flexibility’ are often engaged to bring a similar kind of meaning. ‘Adaptability’ is used to explain macro level issues like *‘capability of social uses’* and *‘flexibility’* is used to address micro level issues like *‘capability of physical changes’* (Groak 1992). By contrast, Schneider and Till (2005) define ‘flexibility’ as a common term to represent the capability of buildings to accept both different social uses and physical arrangements. Beisi (1993) argues that providing adaptability is not a one-time strategy but should guarantee the long-term possibilities of use. The strategies of durability and design for disassembly are closely related to adaptability, which in different forms enhance long-term environmental performance (Russell and Moffatt 2001). Having considered all the adaptable strategies explained in the literature, the Adaptable Futures project has developed a theoretical framework.

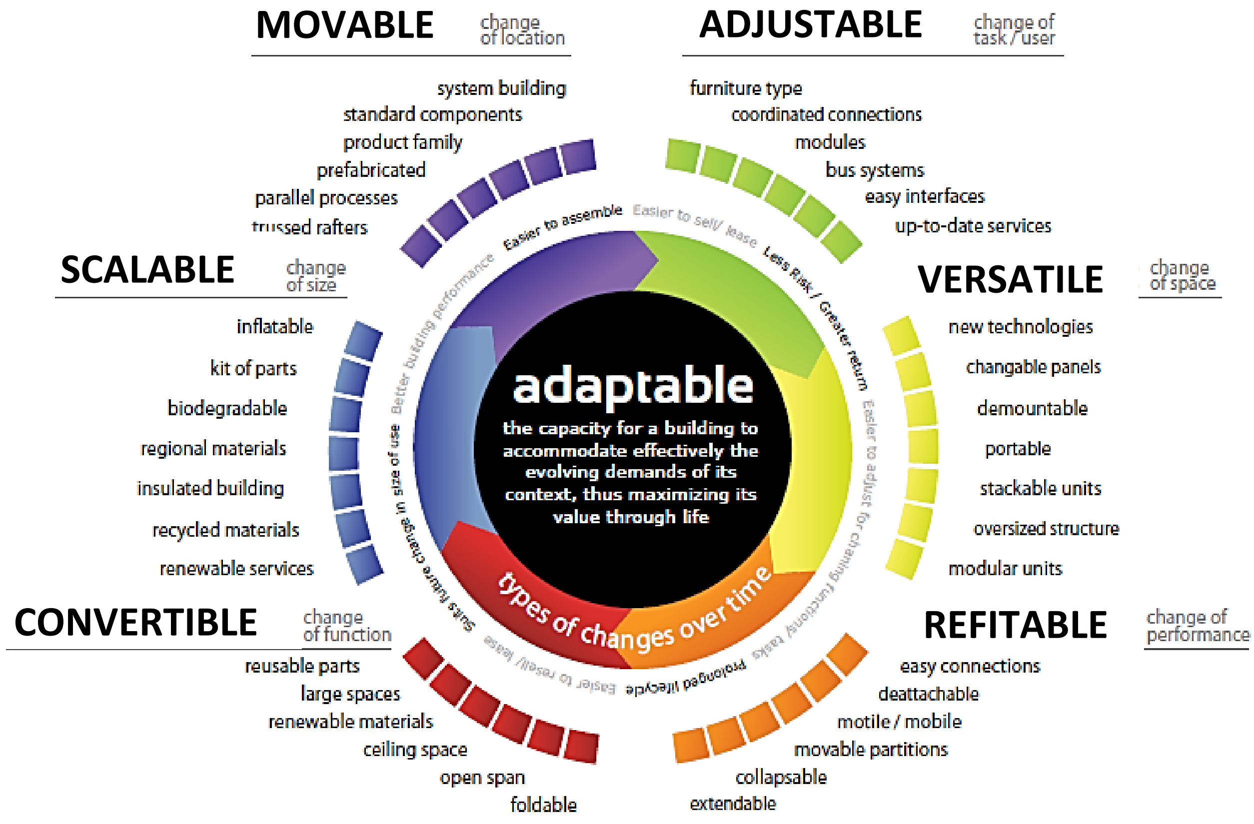


Figure 5-5: Adaptable framework

Source: Adaptable Futures (2009)

With regard to the above framework, the ‘adjustable’ strategy relates to the ability of buildings to change their tasks. This considers alterations of furniture type, coordinated connections and module systems. ‘Versatility’ explains the ability to change the internal space of a building. The strategy takes into account up-to-date service systems, changeable panels, demountable/portable and stackable units, oversized structures, modular units and easy connections. ‘Refitability’ elucidates the ability to change building components, which considers detachable, degradable, mobile, movable and collapsible components. The term ‘convertible’ determines the ability of buildings to shift between different uses/functions. This requires internal and external alterations to buildings. Considerations are given to managing large spaces, renewable materials, ceilings and open spaces to facilitate those uses. The ability to change the size of the building is reflected by ‘scalability’. ‘Extendible’, ‘elasticity’, and ‘expandable’ also have similar meanings to scalable. This considers such alterations as reusable components, renewable services, recycled materials, insulated buildings and kits of parts. The ability to change location is explained through ‘movability’. This encourages system buildings, standard components, product families, and prefabricated and parallel processes. However, semantic permutations/dependencies between some of the aforementioned strategies create difficulties in clustering them into specific individual categories. For example, design for potential change of use (convertible) connects with the scalable and refitable aspects of building components. Brand (1994) provides strong evidence that buildings are not just static objects but that they are dynamic. There is, for instance, a model (shearing layers of change) of the way a building tears itself over time. Hence, designing a building to adapt to a potential change of use means allowing its hierarchical layers to change; each in its own time scale. This is explained in the following section.

5.2.3.1 Shearing layers of change

Adaptable buildings have loosely coupled layers of constructional elements, and adaptability is a function of how easily layers can slip past each other (Edmonds and Gorgolewski 2000). The previously discussed adaptable strategies highly focus on improving adaptable potential in buildings and their components. In particular, when referring to the product environment, the difficulty of adapting to a new set of service conditions depends on the differences between the new service and the original service, as well as on certain attributes, which are: the way the product is divided into sub-systems, the way these sub-systems are connected and the possibility of altering the configurations and functions of various components

(Hashemian 2005). Building decomposition is highly appreciated in 'adaptable buildings' and a set of shearing layers was introduced by Duffy and Henney (1989) and Brand (1994) in particular for varying lifespans, speeds of change and functions of componentry. Having analysed the 'speed of change', the different sub-elements can be categorised under each shearing layer.

- **Site:** Defined as the geographical setting - the ground on which the building sits.
- **Structure:** The foundations and load-bearing components of the building - the parts that make the building stand up.
- **Skin:** The cladding and roofing system that excludes (or controls) natural elements from the interior is considered to be the skin.
- **Services:** These are the working guts of the building. Communications wiring, electrical wiring, plumbing, sprinkler systems, HVAC and moving parts like elevators and escalators can be categorised under services.
- **Space plan:** The interior layout – where walls, ceilings, floors and doors go.
- **Stuff:** The furniture system (Brand 1994 p.12).

Figure 5-6 explains the rate of change of these shearing layers.

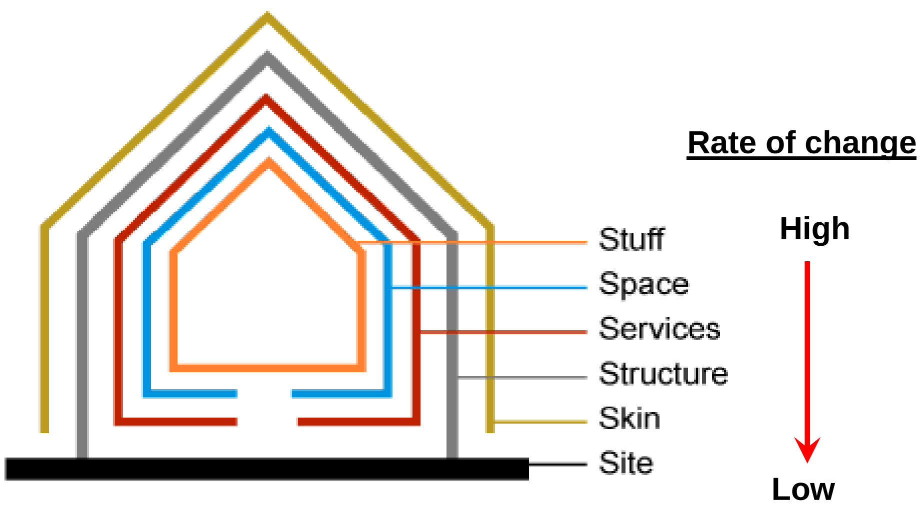


Figure 5-6: Shearing layers of a building

Source: Brand (1994)

The typical life expectancy of each shearing layer is illustrated in Table 5-2. Brand (1994) explains that since shearing layers have different life expectancies, changes/replacements need to be undertaken during the whole lifespan of a building. Thus, designing adaptable/flexible buildings is identified as a reasonable solution for responding quickly to these changes.

Table 5-2: Typical life expectancies of shearing layers

Shearing layer	Life expectancy
Site	Eternal
Structure	30 – 300 years
Skin	20+ years
Services	7 – 20 years
Space plan	3 years
Stuff	Under 3 years

Source: Brand (1994)

The 'theory of layers allows the components of the building to be broken down into packages of same or similar life expectance so that a whole package might be conveniently deconstructed from the building for replacement, recycling and/or reuse elsewhere' (Crowther 2001 p.12). A recent study from Adaptable Futures defines different built environment scales (B-E scales) and the most influential shearing layers for each adaptable strategy. Consequently, Figure 5-7 and Table 5-3 explain the B-E scales and the impact of shearing layers for each adaptable strategy.

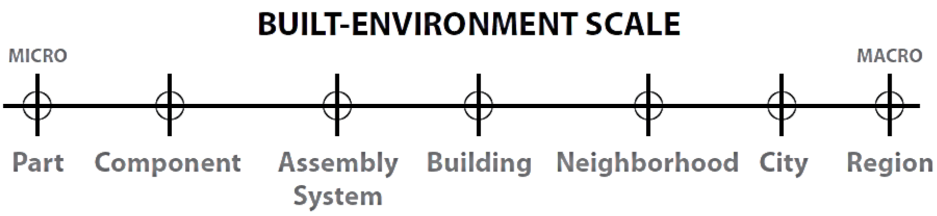


Figure 5-7: Built environment scales

Source: Schmidt-III *et al.* (2009)

The built environment scale was defined to understand the different changes to a building and its external environment. The micro level scale explains the indigenous (internal) changes to the building and the macro level scale reflects the exogenous (external) changes to the building. Table 5-3 explains how different adaptable strategies fit together with the B-E scale and the changes required for different shearing layers. This determines the influential shearing layers for each adaptable strategy and provides further understanding of the design parameters, which are discussed in the next section of this chapter.

Table 5-3: The influence of shearing layers in different adaptable strategies

Strategy	B-E Scale	Speed of change	Shearing layers					
			Stuff	Space	Services	Skin	Structure	Site
Adjustable	Components	Daily/monthly	●					
Versatile	Components	Daily/monthly	●	●				
Refitable	Components	7 years		●	●	●		
Convertible	Building	15 years		●	●	●		
Scalable	Building	15 years		●	●	●	●	
Moveable	Building	30 years					●	●

Source: Schmidt-III *et al.* (2009)

With regard to change of use (convertible), the structure is required to be designed to the optimum structural criteria (load, height and span) to adapt to potential change. However, the flexibility in use provided by overcapacity in the structure results in the excessive use of resources, whilst the extra capacity may remain unused during the lifespan of the building (Gijsbers 2009). The skin (the external façade), service systems and space plan (internal finishes and partitions) appear to be influential shearing layers for change of use potential. To respond to future potential conversions, the initial design should consider the influential design parameters (storey height and technical span) and these layers need to be designed for adaptable dimensions. The next section gives an overview of generic design parameters for adaptability in buildings whilst explaining the most influential design parameters for change of use potential in detail.

5.2.3.2 Design parameters

Design parameters determine cost, design and risk trade-offs in a facility development regarding the physical and functional characteristics of a component, device, product or system that contribute to the design process (Business Dictionary 2011). They 'allow the capacity for a range of appropriate uses beyond the specificity of its original use' (Adaptable Futures 2009). However, the inter-dependencies between these parameters are becoming a complicated issue in designing buildings for potential adaptation. In a principal component analysis, Wilkinson *et al* (2010) explain that the relationship between design parameters is a complex issue in identifying the adaptable attributes of buildings. Thus, the identification of appropriate design parameters is required at an early design stage. These design parameters can be placed under physical (service and structure) and spatial categories.

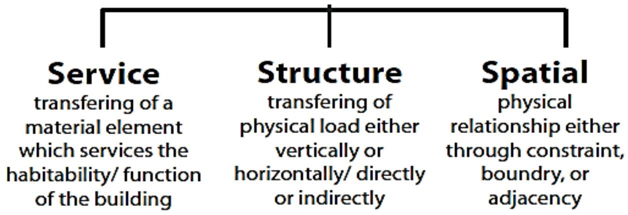


Figure 5-8: Types of design parameters

Source: Adaptable Futures (2008)

Table 5-4 summarises the key literature on different design parameters for adaptability in buildings. The original design needs to identify the correct measures for these parameters when the building is designed for potential adaptations. For example, if a residential building is expected to be converted to offices in the future, the lower storey height of the residential building seems to be the main difficulty in facilitating office use. Therefore, the design requirement is to identify a reasonable storey height for both functions. This will minimise physical damage to the building and also reduce the cost of conversion. The inter-connections between these parameters can be seen: for example, an increase in storey height (spatial) requires subsequent alterations in structural loads, building height, vertical circulations and external façade. The golden rule in providing an adaptable building is to reduce the dependency between elements/components as much as possible (Aylward 1979). Thus, it is important to identify the most influential design parameters for the previously discussed adaptable strategies, as possibilities for building changes are determined by technical parameters (Larssen and Bjorberg 2004).

Table 5-4: Design parameters for adaptability in buildings

Authors	Design parameters for adaptability in buildings																																
	Floor to ceiling height/ Storey height	Technical span	Structural load	Building orientation	Space/Area/Volume for system zone	Building height	Building width	Building size	Floor plan	Availability/Elevator/Vertical circulation	Location/Site condition	Floor systems/Raised floors	HVAC system & distribution	ICT service	Plug & play elements/ Interchangeable components	Ceiling zone/Soffit quality	Organisation of space	Separation of functions/ Decoupling	Fire sprinkling changes/ Fire safety design	Plan depth	Structural design/Slabs	External façade/Cladding design	Acoustic/Noise insulations	Physical access/System access flexibility/Proximity	Interior walls (movable)	Electricity supply	Central corridors	Inter-system interaction	Intra-system interaction	Internal layout/Layout predictability	Flow	Core design	Partial/Phased demolition
Gann and Barlow (1996)						●	●						●						●	●	●	●	●	●						●			
Ratcliffe and Stubbs (1996)	●																																
Keymer (2000)					●										●									●				●	●	●	●	●	●
Heath (2001)	●																			●	●						●						
Larssen and Bjorberg (2004)	●	●	●		●					●	●		●	●							●				●	●							
Arge (2005)	●	●					●					●	●	●	●	●	●	●	●														
Richter and Laubach (2005)												●	●						●		●	●		●									
Verweij and Poelman (2006)								●	●																								
3DReid (2006)	●									●		●				●			●	●	●	●		●									
Gijsbers (2009)	●				●						●			●				●						●	●			●					
Rawlinson and Harrison (2009)	●	●		●			●			●			●			●				●	●			●									
	7	**3**	**1**	**1**	**3**	**1**	**3**	**1**	**1**	**3**	**2**	**3**	**5**	**3**	**2**	**3**	**1**	**2**	**4**	**4**	**6**	**3**	**1**	**6**	**2**	**1**	**1**	**2**	**1**	**2**	**1**	**1**	**1**

The excess supply of built space will increase the rate at which redundant space needs to be converted to support new classes of use (Nutt 1997). A rising trend in building change of use and the macro level impacts are discussed in the literature (Nutt 2000, Kincaid 2002, Kronenburg 2007). In fact, the literature reveals that storey height, ceiling height, floor to ceiling height and floor to floor height are critical design parameters for building adaptations (Ratcliffe and Stubbs 1996, Heath 2001, Larssen and Bjorberg 2004, Arge 2005, Douglas 2005, 3DReid 2006, Gijsbers 2009, Rawlinson and Harrison 2009). Moreover, Douglas (2005) and 3DReid (2006) discuss the influence of storey height in building change of use scenarios whilst explaining the inter-dependencies between storey height and the other design parameters of technical span, design loads and total building height. In addition, Saari and Heikkila (2008 p.240) explain that the 'long-term adaptability of old industrial properties has been particularly good thanks to high floor heights and long spans and their conversion to office and residential use has been possible and relevant in several recent construction projects'. Thus, priority is given to identifying the principal design parameters for potential conversions in buildings.

The literature argues that there are buildings with adaptable features; however, it is uncertain whether they fully match the performance of their new purpose-built facilities because of their restrictions as regards to layout and height (Douglas 2006). Gregory (2006) states it is significant that the buildings best suited to adaptation are those with the most generous ceiling heights. For example, 'the inherent flexibility of many of the Georgian and Victorian domestic buildings has been very influential in the development of ideas of adaptability in new work, especially housing and industrial buildings' (Farrell 1979 p.59). Moreover, Kincaid (2000 p.158) explains that 'too much floor to floor clearance is wasteful in both the long term and short term; too little is always wasteful in the long term as use changes, and in the short term hostile to energy use and people'. These statements clearly explain the importance of floor to floor height/storey height in designing buildings for potential change of use.

In addition, Kaputsyan (1974 p.280) identifies storey height as a significant economic parameter whilst emphasising that the 'economic level of mass-scale housing construction for a specific period is stimulated by the standard requirements, thus formulating such economic parameters as the upper limits of the floor space of flats, the height of a storey, the number of lifts and the like'. Hence, storey height was considered in this study to be a significant design/economic parameter for change of use in buildings. Higher storey heights increase the flexibility of buildings. Having identified the influence of 'floor height/storey height' in building change of use, it is necessary to explain how this parameter could affect the economic considerations of buildings. Lau (2001) identifies 'floor height/storey height' as one of the marketable factors that clients/owners most often consider when buying or leasing a space. The next section explains the variety of policy issues that should be considered in the process of DFA.

5.2.4 Technical solutions

Technical solutions determine built and un-built solutions. Built solutions (buildings and products) explain how the building endures change over time (Adaptable Futures 2008). Having identified specific adaptable strategies, design parameters, influential shearing layers and planning and policy issues, the different technical solutions need to be identified prior to constructing the product/building. A practically doable solution is considered to be a built solution and abandoned schemes remain as un-built solutions. The lessons learned from both built and un-built solutions provide inputs to design intelligence in the DFA process.

The sections above explain the generic DFA process and its attributes. In a technical study, Edmonds and Gorgolewski (2000) discuss the specific technical solutions that would help to make buildings more adaptable. In summary, they are:

- Optimise structural grids to allow changing uses of space (use simple structural grids with clear support lines).
- Allow some redundancy so that additions and changes to the building can be accommodated (over-designed structural capacity may be appropriate to allow alternative uses and the option of extending the structure).
- Separate structure and cladding to allow independent alterations and replacements.
- Separate services into clearly accessible locations to allow easy changes and upgrades. Raised floors can also permit the easy upgrading of services.
- Loose fit to allow some redundancy to accommodate future additions/changes.
- Increase floor to ceiling heights.
- Integrate finishes to facilitate easy upgrades and replacement, without making access to other components difficult.
- Keep design simple to facilitate future change (independent systems allow changes where necessary. Strong inter-dependence reduces the scope for change).

- Provide sufficient space for the machinery needed for dismantling, renovation and addition.
- Avoid irreversible processes and complex composite materials that are difficult to separate.
- Incorporate each component so that it can be easily removed and recycled when obsolete.

Aged buildings are not purposely designed to respond to built environment challenges. Heritage building architecture has some possibilities to facilitate new use; however, services integration seems to be a difficult and cost-inefficient endeavour. To this end, a need for buildings to be designed for potential adaptations is identified. The process of ‘design for adaptation’ is considered as a way forward to invite potential uses to share the space during the whole lifecycles of buildings. The total DFA process considers design intelligence, underlining policies and regulations, strategies, design parameters, shearing layers and workable scenarios prior to the delivery of the adaptable product. Consideration should be extended to identifying practically possible, economically viable and environmentally sustainable adaptable design for buildings.

5.3 Adaptable potential of existing buildings

As the current building stock is rapidly becoming obsolete, increasing emphasis is beginning to be placed on it during the adaptive reuse process to ensure sustainable outcomes (Bullen and Love 2011). ‘Adaptive reuse’ (Kincaid 2000) and ‘brown-field developments’ (Silverthorne 2006) are strategies that the existing building stock could frequently adopt to respond to built environment changes. Adaptive reuse is considered to be a curative option for minimising building redundancy in existing built environment facilities (Kincaid 2002, Henehan and Woodson 2003). Langston *et al*. (2008) define adaptive reuse as an energy-efficient retrofit that breathes ‘new life’ into existing buildings whilst providing environmental and social benefits and retaining national heritage. In addition, ‘adaptive reuse will significantly reduce whole life costs, waste and lead to the improved building functionality’ (Bullen and Love 2011 p.42). It is also a lucrative business that provides potential for making profit through construction businesses. For example, Kalita (2006) explains developers’ interest in adaptive reuse, principally in business parks, whilst optimising the flexibility to adapt for future change of use and physical configuration. Blakstad (2001) further explains that if this motive arises from owner/users/developers, it can be assumed that the building has some sort of value that is believed to be greater than the cost of changing it.

There are alternative ways of converting constructed facilities to a potential new use; however, many of them are not practically viable, economically feasible or environmentally sustainable. Farrell (1979) explains that future expenditure can be saved whilst ‘keeping existing buildings by extending their lives and, when change is necessary, of finding new ways to use them’. Today, the UK government tends to promote the optimum use of existing building stock through mixed use in urban centres and encourages the conversion of redundant office and retail space into leisure, service and/or residential uses (Davison *et al*. 2006); it also had a target of 60% of new developments being on brownfield sites by 2008 (Watson 2009). This encourages greater vitality to meet changing needs over time, which aims to create more vertical mixed use within buildings – different uses on different levels within the same space (Rogers 2011).

The successful endeavours of adaptive reuse and brownfield developments explain the potential of existing buildings to adapt to a variety of pre-planned changes. Adaptive reuse is thus a special form of refurbishment that poses quite difficult challenges for designers. Changing the class (functional classification) of a building introduces new regulatory conditions and perhaps requires zoning consent. There are clear economic, environmental and social benefits that can make this option attractive to developers (Langston 2011). Many researchers realise the importance of developing a tool to evaluate the more productive possibilities for adaptive reuse in existing and new building stocks (Langston *et al.* 2008). The seminal studies explain three models: the *‘transformation meter’* (Geraedts and Vrij 2003), the *‘adaptive reuse potential model’* (Shen and Langston 2010) and the *‘adaptive reuse decision-making model’* (Bullen and Love 2011). These models are explained in the following sections.

5.3.1 Transformation meter

An initial attempt to evaluate the potential for transforming vacant office buildings into residential buildings was made by Geraedts and Vrij (2003) with their introduction of a ‘transformation meter’. The tool (Figure 5-9) evaluates a variety of performances of existing office facilities to adapt for residential requirements. The veto criterion explains the probable objections for undertaking the conversion process, which are the unsuitability of the location, the developer, policy issues, financial infeasibilities and sustainable considerations. If a positive balance can be expected from the issues concerned, the proposed conversion is undertaken. However, the usability of the transformation meter is designed and tested for evaluating the convertibility of office to residential buildings only.

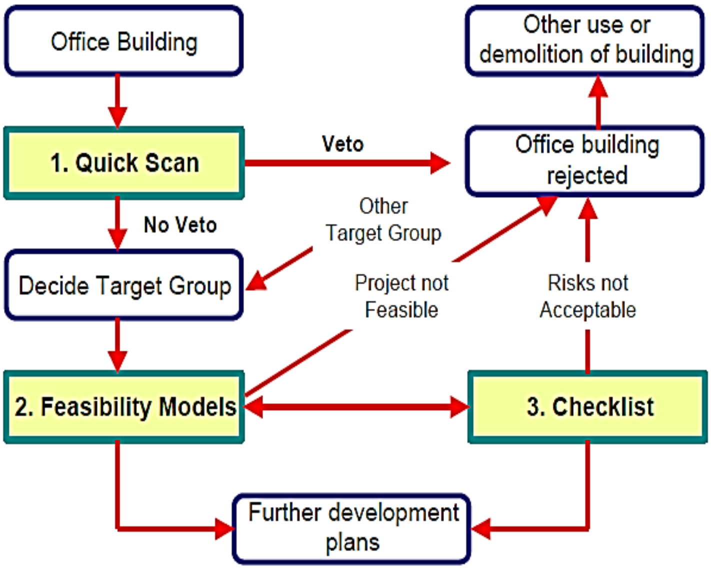


Figure 5-9: Transformation meter

Source: Geraedts and Vrij (2003)

Langston *et al.* (2008) highlight the importance of expanding this tool or developing a similar kind of tool for evaluating the transformation potential of other use typologies. As a result, an adaptive reuse potential (ARP) model (Figure 5-10) was developed to measure the possibilities of existing buildings to adapt for future potential change of use (Langston *et al.* 2008).

5.3.2 Adaptive reuse potential model

Langston (2011) explains the characteristics of the ARP model, which identifies and ranks adaptive reuse potential in existing buildings and therefore can be described as an intervention strategy to ensure that collective social value is optimised and future redundancy is planned. The model has generic application to all countries and all building typologies. It requires an estimate of the expected physical life of the building and the current age of the building, both reported in years. It also requires an assessment of physical, economic, functional, technological, social, legal and political obsolescence, which is undertaken using surrogate estimation techniques as no direct market evidence exists. This model is illustrated in Figure 5-10.

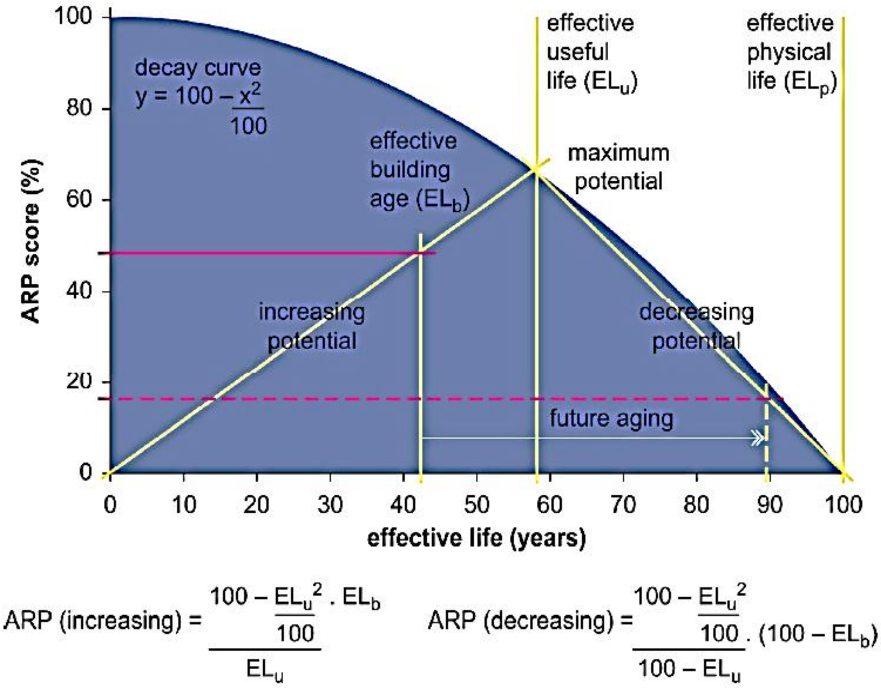


Figure 5-10: Adaptive reuse potential model

Source: Shen and Langston (2010)

The ARP model considers the building age, rate of obsolescence, predicted useful life, ARP scores (current, trend and maximum) and the risk. ARP scores in excess of 50% have high adaptive reuse potential, scores between 20% - 50% have moderate potential and scores below 20% have low potential for adaptations (Shen and Langston 2010). Having applied this model in different facilities, Langston (2011) developed an archetype to visualise the impact of implications of adaptive reuse potential for each facility classification. Archetypes are patterns that have generic applications. The derived archetypes are provided in Figure 5-11.

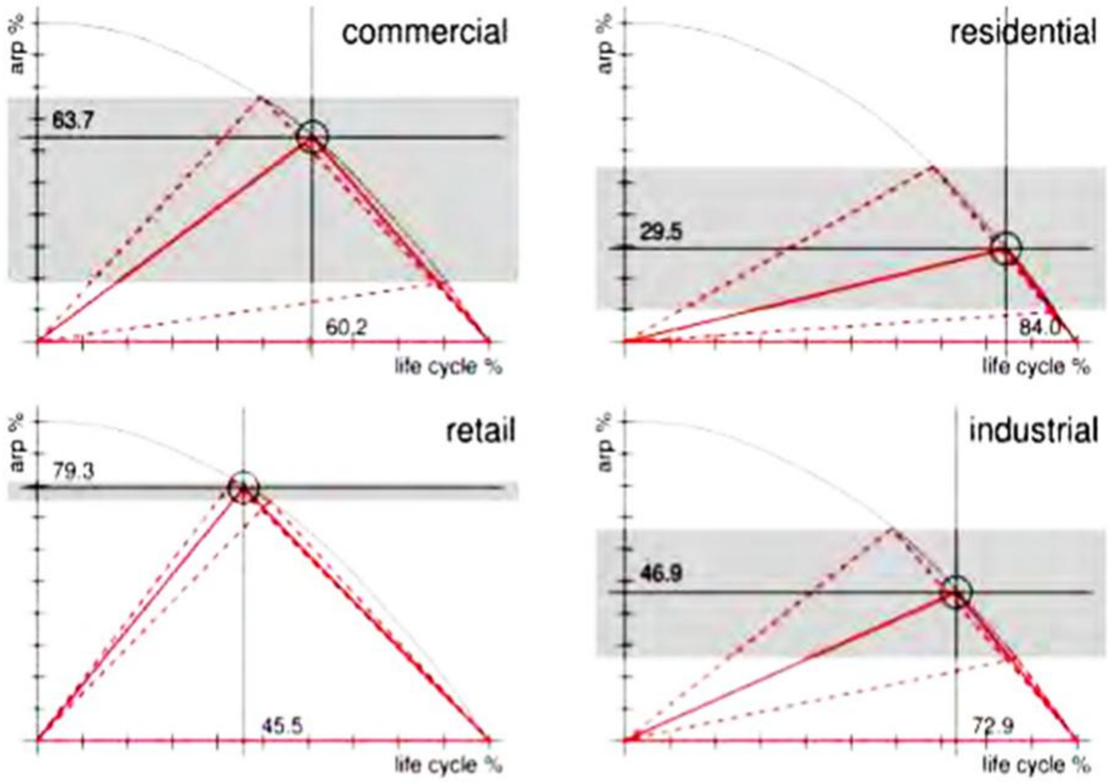


Figure 5-11: Archetypes of adaptive reuse

Source: Langston (2011)

The higher the ARP score, the better the potential for success. The shaded area indicates the likely range of ARP scores (large ranges are more uncertain). The solid triangle indicates the ARP profile, whilst the two dotted triangles indicate the range boundaries for best and worst ARP outcomes. A low skew value (i.e. <50%) indicates a more favourable ARP profile than a high skew value (i.e. >50%). The results depict that functions like retail (ARP score 79.3) and commercial (63.7) are more attractive as potential adaptive reuse projects, whilst industrial and residential showed moderate levels of attractiveness for potential reuse. Having stated the potential of existing buildings to survive in another 100 years, Bullen and Love (2011) introduce a new model (Figure 5-12) for making decisions on adaptive reuse.

5.3.3 Adaptive reuse decision-making model

This model captures economic, social and environmental issues when deciding to either reuse or demolish an existing building. The proposed adaptive reuse decision-making model is grounded in practice and therefore encompasses the real-life dilemmas and issues facing practitioners (Bullen and Love 2011). The model identifies that capital investment, asset conditions and regulation are the primary concerns for decision making on adaptive reuse and the whole life costing method was exploited to evaluate the economic considerations for adaptive reuse. The authors further explain that financial criteria, such as development and construction costs, are the primary determinants influencing the decision to reuse or demolish, the physical condition of the asset juxtaposed with regulations.

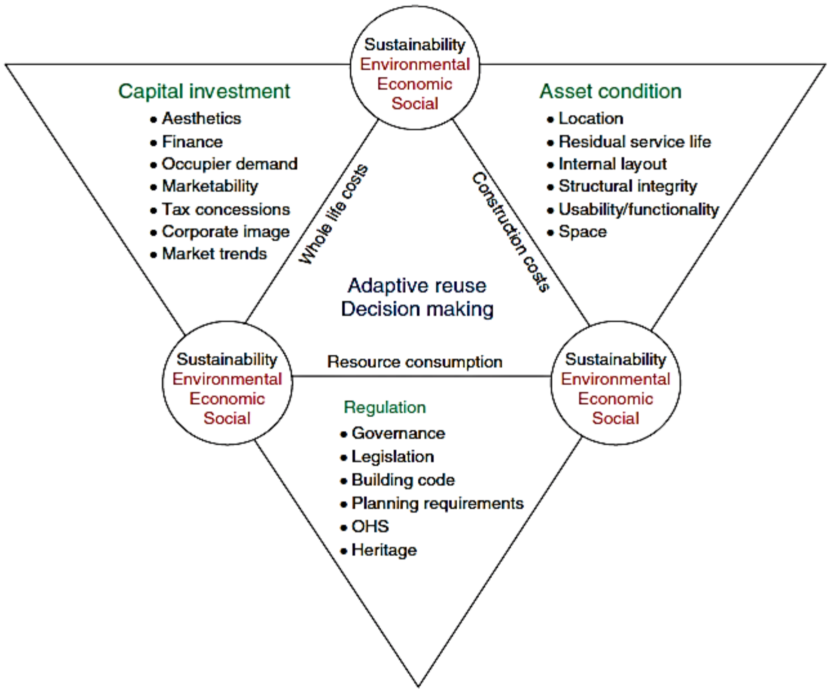


Figure 5-12: Adaptive reuse decision-making model

Source: Bullen and Love (2011)

These models/frameworks attempt to give new life to existing buildings while identifying their adaptive reuse potential. In a way, these findings encourage the design of new buildings with potential adaptations, which seems a more important consideration for future building stock. The development of these tools provides a strong platform for adaptable buildings to identify the good timing for profitable adaptations. The next section discusses the capabilities and the limitations of adaptable buildings to respond to the previously discussed built environment challenges.

5.4 Capabilities and limitations of adaptable buildings

The literature reveals a growing need for designing new buildings that are adaptable and flexible over their lifespans whilst at the same time improving the benefits to stakeholders. The adaptable building strategies discussed in the previous sections explain the variety of capabilities that are incorporated to respond to built environment challenges. A building that continues to function effectively during its whole lifecycle whilst reducing waste and pollution, saving energy and increasing the use of recycled materials is considered sustainable (Douglas 2006). Long life, loose fit and low energy are identified as the key characteristics of sustainable buildings (Ellingham and Fawcett 2006). In addition, Mayr and Varvakis (2006) argue that *'technology'*, *'environment load'* and *'clean technologies'* are key factors that need to be considered alongside radical changes in production for optimising environmental sustainability. In essence, the benefits provided by adaptable buildings can be underlined in the triple streams of economic, social and environmental benefits.

The capability of adaptable buildings to respond to different uses improves occupancy levels, minimises redundancy and brings economic benefits to their owners. With regard to environmental concerns, the strategies for adaptability consider the reusable, refitable and recyclable practices within the design. This provides the opportunity to reuse building materials and components, which improves environment sustainability whilst defeating the problems of embodied energy and carbon footprints. Webb *et al*. (1997) and Thomson *et al*. (1998) explain that reusable building service components reduce alteration costs whilst increasing installation adaptability. From the owners' perspective, adaptable buildings exploit faster designs, less risk and greater returns on their investments. In a way, they are easy to sell or rent because the original space is designed for a variety of uses. Arge (2005) identifies that adaptability is one way to avoid early obsolescence and this makes the building sustainable. Kincaid (2000) proposes that sustainability can be achieved from adaptable buildings through addressing the issues of redundancy, ambiguity, flexibility, constraints and design in a proper way.

Adaptable building design encourages mixed and multi-use potential in buildings. Characteristically, these typologies share some socio–economic dysfunctions with adaptable buildings. Mixed-use buildings are identified as an efficient way of optimising the use of property that might otherwise remain empty or partially occupied, allowing financial risks to be spread across different types of occupancy (Douglas 2006). Economically, mixed-use developments have shown significantly better total investment returns than properties in conventional built environments (Barnes 2003). Socially, the promotion of mixed-use developments in the UK would reduce the need for travelling to work by private vehicle, make local facilities more viable and encourage community spirit, all of which would help to achieve sustainability goals (Pitts 2004) whilst adding to the vibrancy of a town (McClure 2005). Despite such obvious advantages of adapting products, adaptation is not always practically possible (Hashemian 2005). Gibb *et al.* (2007) explain the exploration of potential markets, designing for an unknown future, changing technology, process innovations, making adaptable buildings without creating unnecessary redundancy and significant increases in the first cost as key challenges for designing adaptable buildings. In addition, existing planning, zoning and building regulations seem to be a major constraint to the lifecycle adaptability of buildings.

5.5 Summary

Social, economic, political, environmental, technological, physical and legal factors demand built environment changes. However, the existing building stock lacks adaptable performance and vaguely responds to these challenges. As a result, the existing building stock has a tendency to remain redundant or is scrapped and rebuilt. In a way, adaptive reuse empowers a ‘new life’ into existing buildings; however, physical, economic, environmental and policy constraints appear to be the major difficulties in continuing such adaptations within existing buildings. Therefore, design for adaptation is considered as a means for empowering adaptable potential in new buildings to respond to built environment challenges. This process (DFA) considers the lifecycle extendibility of buildings, which takes into account different adaptable strategies, design intelligence and design parameters for improving adaptable potential in new buildings. These adaptable strategies are able to provide reasonable design solutions to micro and macro level changes.

However, there are limitations in adaptable buildings. Existing planning and policy issues appear to be major constraints to designing buildings for potential adaptations. Even though the exogenous demand arises for implementing adaptable strategies in built environments, a lack of owner/developer motivation tends to cause them to disregard these adaptable concerns in their brief. Existing design practices also need improvements to encourage adaptable potential in the new building stock. In short, this study considers adaptable buildings as a nascent but strong solution to respond to the variety of built environment changes. The next chapter discusses the economic evaluation of built environment facilities.

Chapter Six

6. ECONOMIC EVALUATION OF BUILT ENVIRONMENT FACILITIES

6.1 Introduction to chapter six

This chapter explains the theoretical underpinning of the literature related to the economic evaluation (EE) of built environment facilities. The first section elucidates the generic EE process usually undertaken for built environment assets. The second section describes the whole life analysis (WLA) process whilst recognising it as one of the strongest approaches to evaluating the economic costs and benefits of adaptable buildings. The same section looks at the appropriate EE tools and techniques required to perform WLA in adaptable building contexts. The last section conveys the benefits and hindrances of WLA in adaptable building considerations.

6.2 Economic evaluation (EE) of the built environment

The economic evaluation of built environment facilities is given a high priority in many investment decisions. In its wider contexts, EE is a method/process for determining the value of a policy, project or a programme (Litman 2006). It is also known as ‘an examination of the costs and benefits (monetary and non-monetary) expected to result from a particular course of action or from alternative courses of actions’ (Kirk and Dell’Isola 1995 p.35). The process determines the economic credibility of different alternatives whilst taking into account all costs, benefits and performances associated with a facility during its lifecycle (Department of the Army 1992). Presumably, EE can be proposed to identify the cost and benefit considerations of adaptations (a course of action) or to compare the total costs and benefits of adaptable and traditional (maladaptive) buildings (alternative courses of action). The EE process is usually exploited at the project feasibility or design stages in building lifecycles to compare alternatives and then to justify whether the selected option is economically viable and achievable. Kirk and Dell'Isola (1995) describe two types of EE for built environment facilities: one focuses on the 'principal purpose' of the analysis and the second looks at 'feasible alternatives'.

Table 6-1: Types of economic evaluation

Principal purpose		**Feasible alternative**	
Primary	**Secondary**	**Investment (Feasibility phase)**	**Design (Design phase)**
Save money or other economic benefits	Satisfy business or service requirement	Determines (1) whether an investment is justified and, if so, (2) the most economical strategic course of action	Seeks the most economical design solution that satisfies the 'required function'

Source: Adapted from Kirk and Dell'Isola (1995)

The particular course of action of adaptable buildings is to respond to potential built environment changes and the alternative courses of action are to explore different designs/plans to identify the best alternative. The difference between investment and design EE is based on whether 'one particular course of action – do nothing – is a feasible alternative' (Kirk and Dell'Isola 1995 p.37). Investment EE selects the best alternative within the framework of available funds/the budget and design EE considers different design solutions and selects the one that would better perform the required function(s) economically. The following factors provide a logical sequence for undertaking EEs in built environment facilities (Hendrickson 1989):

1. Basic concepts
2. Economic evaluation methods
3. Factors affecting cash flows
4. Effects of different methods of financing

Basic concepts considers the time preference for use, opportunity costs, minimum attractive rate of return, cash flows over the planning horizon and profit measures. There are a number of techniques available for undertaking an EE; however, its practical application in built environment facilities is seemingly less than many other techniques. The selection of a proper method depends on the context and availability of the project information. The literature reveals the techniques of simple/discounted payback, cash flow, discounted cash flows, net benefits – net savings, benefit to cost ratio/savings to investment ratio, internal rate of return, overall rate of return, net terminal value, net present value, real option analysis for evaluating economic costs and the benefits of a facility (Ruegg and Marshall 1990, Ashworth 2000, Boussabaine and Kirkham 2004, Ellingham and Fawcett 2006). Dale (1993) argues that simple payback, net present value and internal rate of return are the three most commonly exploited techniques for evaluating the economic considerations for buildings. However, these methods have some limitations, which are discussed in the forthcoming sections of this chapter. The third consideration of the EE process identifies factors affecting cash flows, which are depreciation and tax effects, price level changes and the treatment of risk and uncertainty. Therefore, these factors need to be studied in detail for an accurate EE. Moreover, attention needs to be paid to identifying the effects of different methods of financing, which includes types of financing and risk, public policies on regulation and subsidies, the effects of project financial planning and the interaction between operational and financial planning. These four steps explain the key considerations for undertaking a robust EE for built environment facilities. The EE process takes into account the present value of the future costs and benefits of the adaptable facility whilst exploiting the discounted techniques to evaluate these costs and benefits in monetary terms.

Developers do invest in a certain degree of adaptability; however, which means that the cost difference between what can be considered 'best practice' and 'worst practice' is somewhat less (Arge 2005). The design for adaptation (DFA) method aims to design new buildings to respond to potential future changes in built environments. The client/developer interest is in knowing that investments in these designs are cost-effective in the long term. The Whole Building Design Guide (2011) defines the characteristics of cost-effective designs as the lowest initial capital costs, lowest maintenance and operational costs, longest lifespan, most productive and the greatest return on investment. The same design guide further states that true cost-effectiveness requires a lifecycle perspective where all the costs and benefits of a given project are evaluated and compared over its economic life. In this regard, a number of alternative courses of actions (adaptable design options) could be generated and an EE would be required to identify the most economical design option. The building will be adapted if the value of adapting the building for new or future use is thought to be greater than the value of the alternatives and the cost of the adaptations (Blakstad 2001). Thus, the importance of undertaking EE for adaptable buildings is highly acknowledged in the built environment. The WLA approach is considered a cost-centred engineering economic analysis (Kirk and Dell'Isola 1995). Thus, the previously noted EE techniques could be successfully adopted to undertake WLA in built environment facilities.

6.3 Whole life analysis for buildings

The meaning associated with WLA has changed over time and the method has primarily been referred to as terotechnology, which is 'a combination of management, financial, engineering and other practices, applied to physical assets in pursuit of economic life cycle costs' (Taylor 1981 p.32). However, terotechnology has been largely ignored within construction practices because of shortfalls in the available data and the data collection mechanisms (Boussabaine and Kirkham 2004). The term 'cost-in-use' evolved in the services industry to evaluate the maintenance and operation costs of an asset. The approach was no longer exploited in construction facilities to evaluate the economic considerations because it focused on 'in-use' costs only. Thus, an urgent need emerged to introduce a reasonable approach to learn the total costs and benefits of constructed assets. As a result, the different terminologies of '*lifecycle costing'* (Kirk and Dell'Isola 1995), *'through life costing'* (Hodges 1996), *'total life costing', 'total cost of ownership'* (Whyte *et al*. 1999)*, 'ultimate life costing'* (Bakis *et al.* 2003 noted Edwards *et al.* 2000)*, 'total costing'* (Seeley 1996), *'whole life cycle costing'* (Boussabaine and Kirkham 2004) and *'whole life appraisal'* (Flanagan and Jewel 2005) were adopted to identify the whole life cost component of built environment facilities. Lifecycle costing is 'a tool/technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational and asset replacement costs, through to end of life' (ISO 15686-V 2008).

Even though many of the previously noted terminologies are used to explain the process of identifying the costs and benefits of products/facilities, the associated meanings reflect the idea of cost aspects only. Having noted this, Flanagan and Jewel (2005) introduce 'whole life appraisal/analysis' as a reasonable appellation, which systematically considers both cost and benefit aspects in the analysis. Thus, the WLA approach is a systematic economic consideration of all agreed significant costs and benefits associated with the acquisition and ownership of a constructed asset that are anticipated over a period of analysis expressed in monetary value (ISO 15686 – Part V 2008). WLA is one of the decision-making approaches for built environment facilities (Kishk *et al.* 2003). The frequent application of established EE techniques (discounted and real option methods) for undertaking WLA in built environment assets are discussed in the literature (Ellingham and Fawcett 2006, Ashworth 2008). The term ‘whole life analysis’ is used in this study to mean a systematic consideration of all costs (including the initial capital cost and cost of adaptations), benefits, risks and performances of a building for its total functional life expressed at present values. However, the performance of a facility is subjective in nature and difficult to measure in monetary value. Hence, weighted evaluation methods were proposed to make these non-quantifiable costs into quantifiable costs.

The application of WLA extends from the project level to the organisational (strategic) level; it is responsible as a ‘*decision support tool’* (Ashworth 2004, Flanagan and Jewel 2005), *‘management technique’* (Kishk *et al.* 2003) and *‘maintenance guide’* (Flanagan and Norman 1983), as well as a *‘forecasting tool/modelling technique’* (Taylor 1981, Ferry *et al.* 1999, Ashworth 2000). The literature discusses the flexibility of WLA in completing different purposes in built environment facilities. As a decision support tool, Flanagan and Jewell (2005 p.2) suggest that ‘WLA is not about spending more; it is about making the right decision at the outset or even during the operating phase’. Sherif (1982) states that WLA is becoming more important in all market areas, with reliability and maintainability being the most predominant factors in decision making. It is also a critical tool to assist strategic thinking with buildings (Brand 1994).

Taylor (1981) proposes that Lifecycle costing can be used as a forecasting tool to evaluate alternative planned capital expenditures with the aim of ensuring the optimum value from capital assets, considering all future costs and benefits at present day values. Moreover, as a form of modelling technique, WLA can be used to cope with the mixture of capital and running costs (Ferry *et al.* 1999). However, the ultimate answer depends on future assumptions; it involves high risk and uncertainty. A lot of research has been undertaken in the area of economic analysis, although the practical application of WLA in built environment facilities is still in its infancy. Difficulty in data collection (from a variety of sources) and the limited reliability of the collected data are the main reasons for the limited popularity of WLA for built environment facilities. The principles of WLA are strong in theory but poor in practical application (Kishk *et al.* 2003). The cost reduction potential from applying WLA in the different phases of a project lifecycle is illustrated in Figure 6-1.

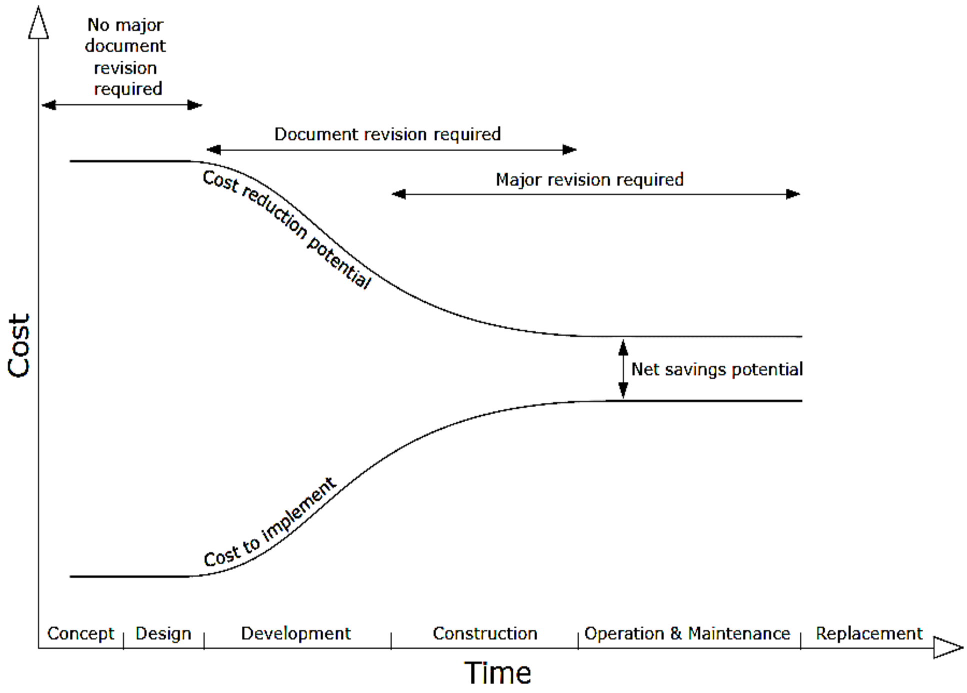


Figure 6-1: Cost reduction potential of WLA

Source: Flanagan *et al.* (1989)

The early exploitation of the technique in construction projects provides more cost savings than later applications. As illustrated in the above figure, most lifecycle issues can be determined in the design stage; hence WLA is particularly useful for estimating the total costs in the early stages of a project (Pulakka 1999, Bogenstatter 2000). Reassuringly, Constructing Excellence (2008) also explains that the benefits can be obtained if WLA is undertaken at the earliest stages of design and in setting initial budgets. The next section explains the typical process usually undertaken in WLA for built environment facilities.

6.3.1 The WLA process

The success of WLA depends on the accuracy of data collected from a variety of sources. The implementation logic of WLA (Figure 6-2) explains the total process and data required to complete this endeavour for built environment facilities. The project information, facility components and site data regarding potential projects/alternatives are considered as inputs to the WLA process. The potential alternatives are assessed under the project requirements and the best option will be implemented.

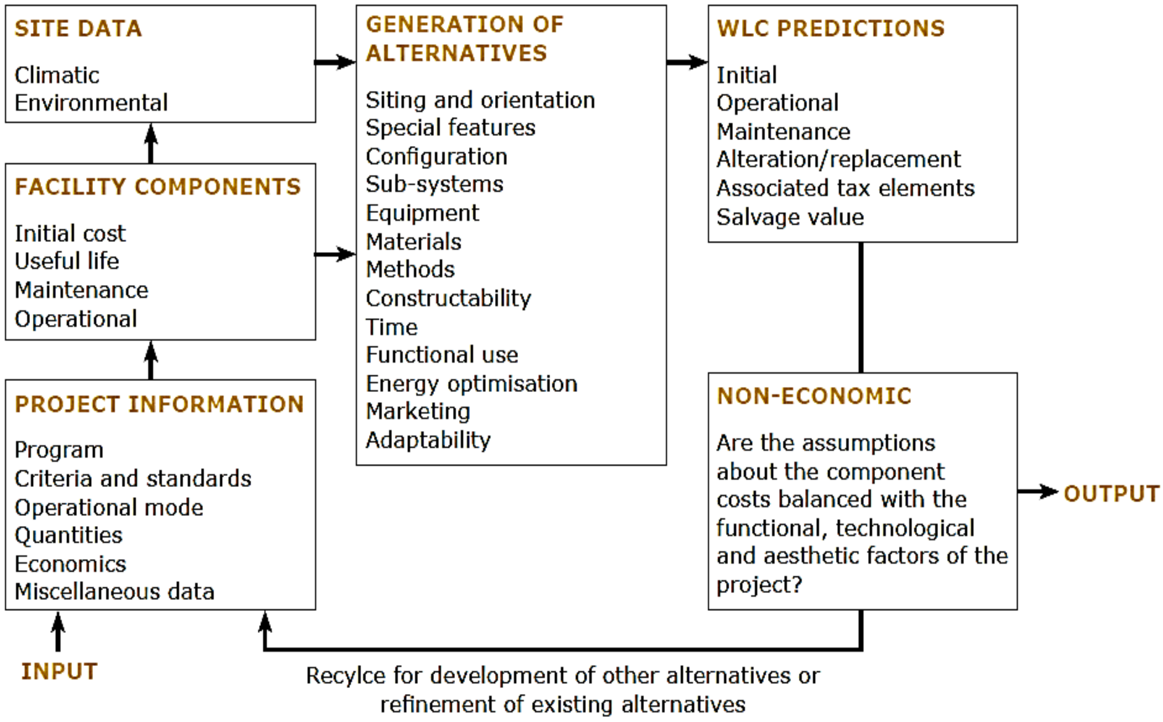


Figure 6-2: Lifecycle costing logic

Source: Kirk and Dell'Isola (1995 p.12)

Moreover, Constructing Excellency (2008) proposes different types of data requirements for undertaking WLA in built environment facilities. These are:

- the cost components (capital and operational costs and incomes) ----- (Facility components);
- the timings of them (when they are likely to occur) ----- (Facility components);
- the present costs of them (using the discounted cash flow method with real rate (excluding inflation)) ----- (WLC predictions); and
- sensitivity analysis of the variables (discount rate, study period, predicted design lives of components and assumptions about running costs) ------ (WLC predictions).

Therefore, it is necessary to understand these considerations before initiating WLA in built environment facilities. The following sub-sections explain these four categories and the different data requirements specific to adaptable buildings.

6.3.1.1 Cost components

The cost components are the major inputs to WLA. A well-structured cost breakdown was introduced in ISO 15686 – Part V (2008) to facilitate WLA in built environment projects.

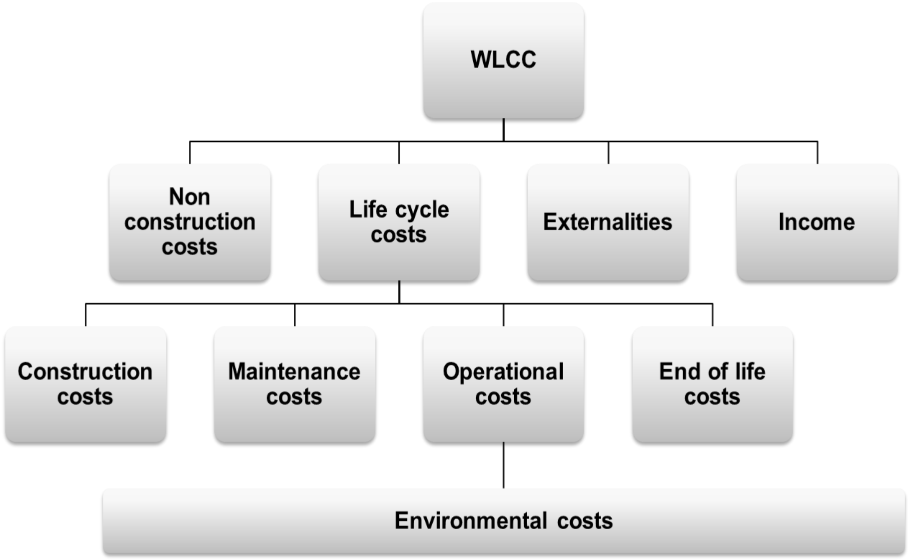


Figure 6-3: Elements of whole lifecycle costs

Source: ISO 15686 – Part V (2008 p.6)

As illustrated in Figure 6-3, the WLCC (whole lifecycle cost) is represented through four main cost categories: non-construction costs, lifecycle costs, externalities and expected income. These costs are entered into the process in different time frames. As a result, the time value of money needs to be considered in WLA.

1. Non-construction costs

Costs that are not associated with the practical construction work are categorised under non-construction costs. The preliminary costs for buying land, arranging a loan and other preparatory works are included in this category. The different cost categories that fall under the category of non-construction costs are illustrated in Figure 6-4.

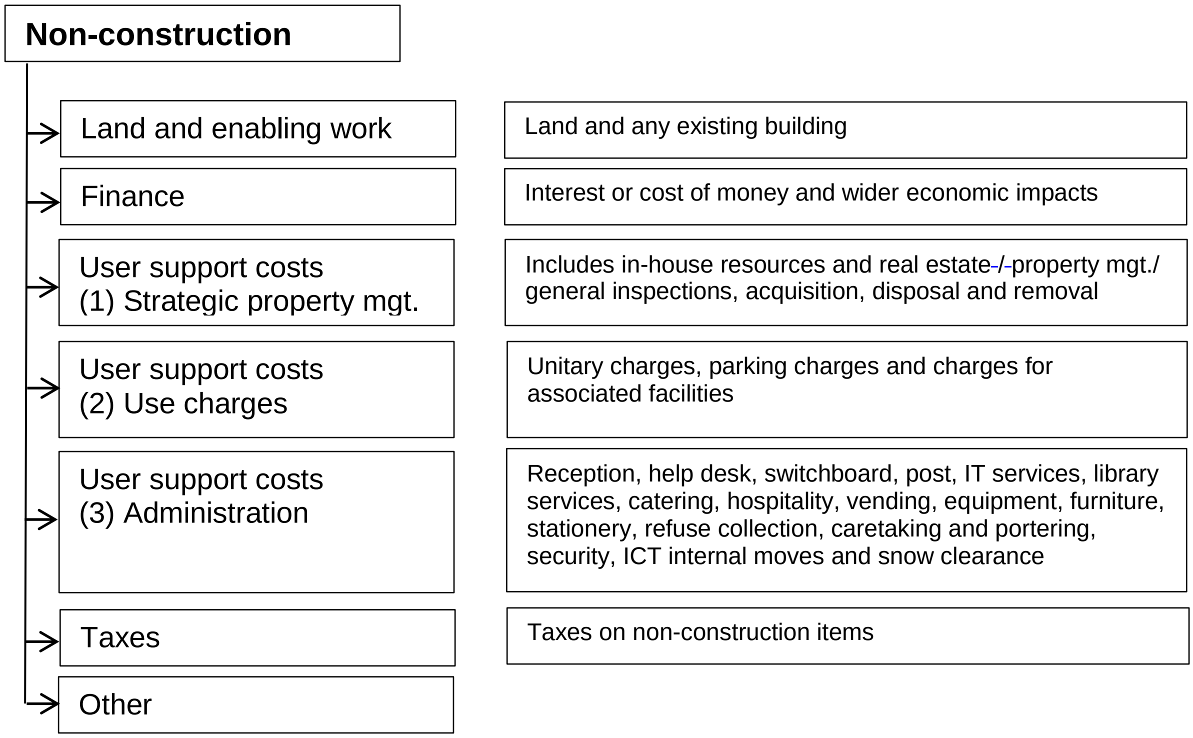


Figure 6-4: Non construction costs

Source: ISO 15686 – Part V (2008)

a) Land cost

The land cost is the total amount of money that the building owner pays for buying new land. This can be calculated by identifying the difference between the cost of the building to be built on the land and the market price of the total property. If the client owns a piece of land, then the land cost may not be included in the calculations (March 2009). The land cost depends on the factors of geographical location, topography and the proximity of infrastructure.

b) Cost of finance

The cost of finance means the total interest that needs to be paid to the lending organisation for providing the finance. The timing of finance is important and the discounted methods are used to bring future values into present consideration. Apart from these costs, other supportive costs are considered in the non-construction cost category.

c) Other

It is necessary to identify any associated extra costs to be categorised as ‘other’ because the building is designed for potential adaptations.

2. Lifecycle cost

The lifecycle cost is defined as a total cost of a facility during its whole life whilst fulfilling the performance requirements (Kirk and Dell’Isola 1995, ISO 15686 – V 2008). The cost categories of construction, maintenance, operations and end of life are taken into consideration.

a) Construction cost

The initial capital cost of the construction of a facility is the greatest outlay in WLCC. ISO 15686 – V (2008) considers the following cost categories under this section:

Professional fees	Project design and engineering, statutory contents
Temporary works	Site clearance, etc.
Construction of asset	Including infrastructure, fixtures, fitting-out, commissioning, valuation and handover
Initial adaptation or refurbishment of asset	Including infrastructure, fixtures, fitting-out, commissioning, valuation and handover
Taxes	Taxes on construction goods and services (e.g. VAT)
Other	Contingencies

Figure 6-5: Cost of construction

Source: ISO 15686 – Part V (2008)

Priority is given to understand what adaptable cost might be considered if the building is designed for potential adaptations (change of use). It is necessary to learn the changes to elements (flow/size/capacity) at the beginning and incorporate them in the adaptable design. This consumes extra costs.

b) Maintenance cost

The cost required to maintain the building during its whole lifespan is defined as the maintenance cost. This cost can be obtained from available databases (for example the Building Maintenance Cost Information Service - BMCIS) or from historical data; however, 'base cost estimates have to be supplemented with expert opinions in order to perform WLA' (Boussabaine and Kirkham 2004 p.20).

Maintenance management	Cyclical inspections, design of works and management of planned service contracts
Adaptation or refurbishment of asset in use	Including infrastructure, fitting-out, commissioning, validation and handover
Repairs and replacement of minor components/small areas	Defined by value, size of area and contract terms
Replacement of major systems and components	Including associated design and project management
Cleaning	Including regular cyclical cleaning and periodic specific cleaning
Grounds maintenance	Within defined site area
Redecoration	Including regular, periodic and specific decoration
Taxes	Taxes on maintenance goods and services
Others	

Figure 6-6: Maintenance costs

Source: ISO 15686 – Part V (2008)

A negligible cost increment could be expected in the maintenance cost category to maintain the adaptable features. For example, the change of use potential demands larger spans and also a higher storey height. This will lead to extra maintenance costs in the categories of cleaning, painting and decoration.

c) Operational cost

As the time span increases, the operational cost becomes less certain due to uncertainty in energy costs, maintenance, fees, staff and regulatory changes (Boussabaine and Kirkham 2004). In the context of adaptability, an extra cost might be added to this category to operate extra space (heating, cooling and air condition) used in the adaptable building. The typical sub-categories for operational costs are illustrated below.

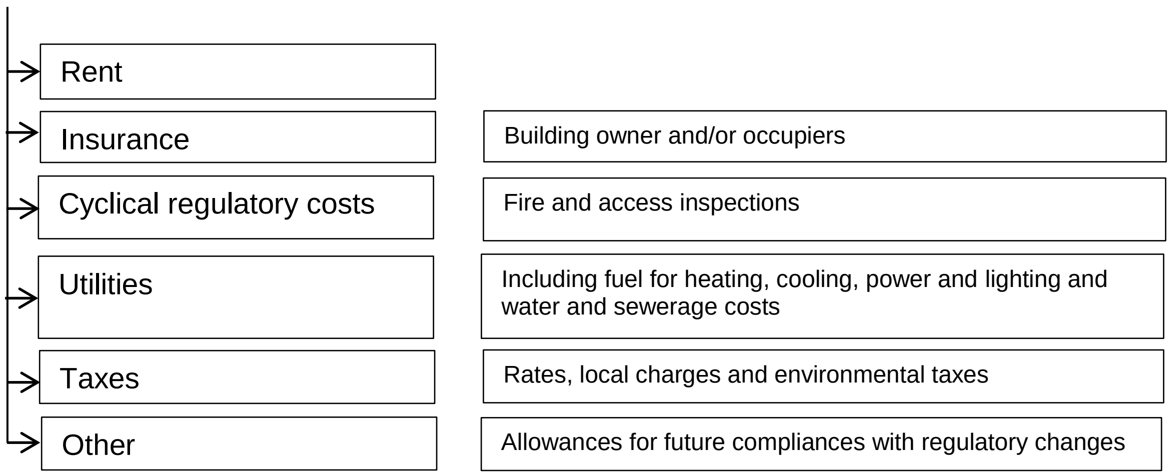


Figure 6-7: Operational costs

Source: ISO 15686 – Part V (2008)

The literature proposes different cost ratios between the initial capital costs and the operation and maintenance cost of a building. These cost ratios provide a good indication of the total cost contribution from initial capital and recurrent costs to the WLC. Hughes *et al.* (2004) identifies that the cost ratio may help clients focus on improving building quality to reduce lifetime maintenance costs without intimidating them about the expense of including quality in the original construction. There are different ratios for identifying the cost contributions of different building typologies; however, none have been developed for adaptable buildings, which is particularly important to show the relation between design choices and the resulting lifetime cost (i.e. energy, maintenance and operation cleaning) (Kotaji *et al.* 2003). Having considered office buildings, Evans *et al.* (1998) proposes a ratio of 1: 5: 200 (initial capital cost of construction: maintenance and operation cost: business operating costs) for office buildings that have typical lifespans of over 20 years. Moreover, Saxon (2002) explains that in net present value terms, the ratio is less dramatic (1: 1.5: 60). Hughes *et al.* (2004 cited Stone 1980) state that the running costs of a building are three times as great as the first costs and that energy costs are two or three times as great as maintenance costs and equivalent to a substantial proportion of structural costs. However, these ratios are not constant and are not possible to change with the type, function and the lifecycle of a facility. Arguably, Hughes *et al.* (2004) disagree with the above ratios and further explain that they are based on ill definitions, lack originality and do not give precise answers for WLA in office buildings or any of the facilities under investigation. Ive (2006) critically argues that 1: 5: 200 proportions are exaggerated and that the difference in mean ratio between buildings of different functions is sufficient to require a function-specific ratio. The importance of introducing such ratios for adaptable buildings is identified; however, difficulties may arise in finding a reasonable adaptable building sample to collect the data. In a way, these ratios help to compare the total cost of adaptable and traditional (maladaptive) options.

d) End of life cost

The cost of demolition/disposal and environmental costs (e.g. landfill) need to be considered in this section. Adaptable buildings provide good benefits over scrapping and rebuilding at the end of their lives. The sub-categories for end of life costs are illustrated in Figure 6-8.

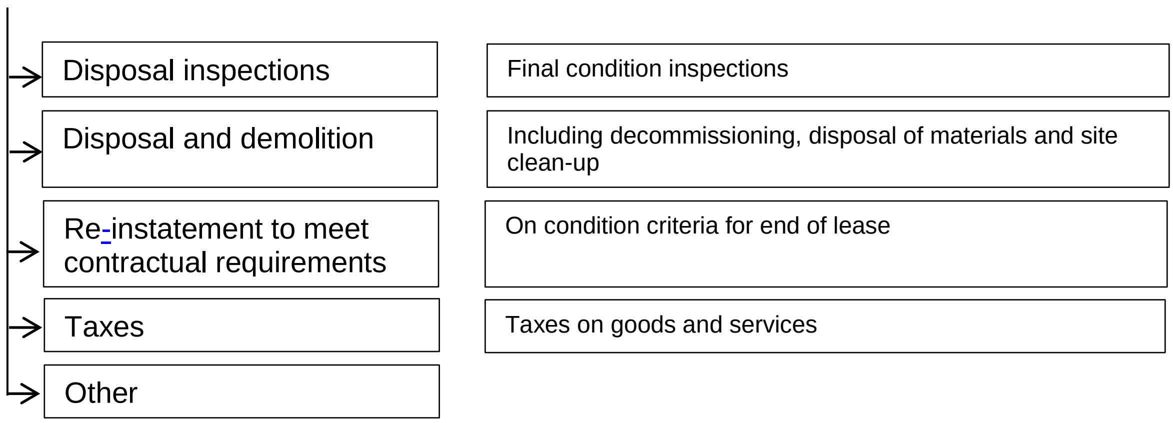


Figure 6-8: End of life costs

Source: ISO 15686 – Part V (2008)

3. Externalities

Externalities highlight the possible future risk and reward costs associated with an asset that are not necessarily reflected in the transaction costs between the provider and the consumer (e.g. staff costs) (ISO 15686 – V 2008).

4. Income

Income generated through renting, leasing or selling the building is considered in this category. The present value of future income is taken into consideration in WLA.

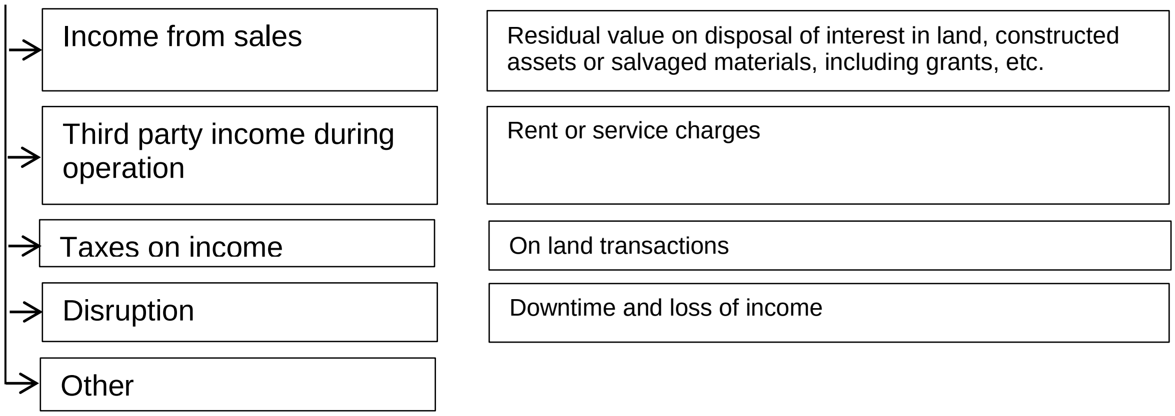


Figure 6-9: Income categories

Source: ISO 15686 – Part V (2008)

Adaptable buildings have a greater chance of appealing to different markets. Thus, the expected rate of redundancy is seemingly low in adaptable options, so income can be better generated than in maladaptive options. Moreover, the residual values of adaptable buildings are considerably higher because they are able to adapt to different scenarios.

6.3.1.2 Timing considerations

WLA considers different timings in its evaluations. The design lifespans of buildings and their components and the timing of different cash flows play important roles in the analysis process. The lifespan of a building is determined as the total age of the building in which it is physically robust, or the time between construction to demolition. Within this time frame, buildings usually pass through different functional and economical lifespans. The lifespans of building components/layers also play a vital role in WLA. These timings are needed in WLA to understand the potential timings for component replacement. 'Building components have widely different life expectancies depending upon whether the physical, economic, functional, technological or social and legal obsolescence is the paramount factor influencing their life' (Ashworth 2008 p.260).

6.3.1.3 Present value considerations

Money is a productive commodity and there is a price for its use (March 2009). This price is called interest. Interest is expressed as a percentage of a loan that the borrower must pay the lender within a specified interval of time. Present value considerations allow the conversion of all present and future costs to a single point in time (Kirk and Dell'Isola 1995). Discounting methods are usually adopted to bring future costs and incomes in line with present values. Therefore, the selection of an appropriate discount rate to be used in the WLA is highly important. Discount rates are expressed in two terms: nominal and real rates. The nominal (market) rate considers inflation and the real earning power of money invested over time and the real rate does not consider inflation (Flanagan and Jewel 2005). Inflation is defined as the general increase in the prices of the same goods and services over time (Kirk and Dell'Isola 1995), and it influences the discount rate. If the cash flows are to be estimated at the nominal rate, they should be discounted at the nominal discount rate (Ashworth 2008). Net present value (NPV) calculation is an approach for measuring the net value of an investment in building assets in today's money (Boussabaine and Kirkham 2004). The NPV formula is represented below.

$$NPV = \sum [PV(b) - PV(c)]$$

$PV(b)$ - discounted present value of benefits

$PV(c)$ - discounted present value of costs

The present value considers the discount rate (rate of return), which depends on the client's cash flow. A high rate of return diminishes the present value. The formula below is used to measure the present value of future cash flows.

$$PV = \frac{Future\ Value}{(1+r)^n}$$

r - discount rate/rate of return

n - number of periods

There are a variety of economic evaluation methods used in practice to undertake WLA for built environment facilities. However, the scope of this study was to identify the cost and benefit requirements for adaptability in buildings. Therefore, the study does not explain all the economic evaluation methods available for undertaking WLA but evaluates them in two major categories that are more effective for undertaking WLA in adaptable building contexts. The two main categories are discounted cash flow (DCF) methods and real option analysis (ROA).

Discounted cash flow methods:

This is an EE method that is very popular in WLA in estimating the attractiveness of an investment opportunity. The method considers future cash flows and discounts them to arrive at present values. The method assumes that the investment is an all-or-nothing strategy and does not account for managerial flexibility (Mun 2006). Sensitivity analysis is frequently undertaken to identify the associated risk and uncertainty of decisions based on the DCF. There are many EE techniques that use DCF approaches in decisions. The application of these techniques in built environment decisions is discussed in the literature (Kishk *et al.* 2003, Boussabaine and Kirkham 2004, Pasquire and Swaffield 2006).

Real option analysis:

ROA is used for 'valuing real physical assets, as opposed to financial assets, in a dynamic and uncertain business environment where business decisions are flexible in the context of strategic capital investment decision making, valuing investment opportunities, and project capital expenditure' (Mun 2010 p.8). It is frequently adopted in financial theory but poor in construction costing. This method considers different options, where the better option may be selected in a particular situation. The generic real options are the 'option to expand', the 'option to reduce', the 'option to switch', the 'option to abandon' and the 'option to defer' (Francis and Bjornsson 2010). A suitable option is selected by analysing market conditions. The characteristics of DCF and ROA are explained in Table 6-2.

Table 6-2: Characteristics of economic evaluation methods

Discounted cash flow methods	Real option analysis
• Simple, clear, consistent and widely accepted method • Quantitative, decent level of precision and economically rational • Passive approach • Considers the time value of cash flows • No flexibility is considered • Need extra tools and techniques to calculate risk and uncertainty • Pre-determined plan • Need to select most appropriate discount rate • Ignores upside potential of added value through flexibility and innovations • Makes implicit assumptions concerning a certain expected scenario	• Complex method • Flexibility of options is considered • Can be effectively exploited in dynamic environments • Active approach • Series of options that are continually being exercised to achieve both short and long-term returns on investment • Decisions are based on market conditions (favourable markets) • Considers different corporate investment decisions and the financial feasibility of strategic decision pathways • Method is appreciated in the sustainable agenda • Uncertainty is considered with the option

Source: Adapted from Yeo and Qui (2003), Mun (2006)

6.3.1.4 Risk and uncertainties

Risk is the possibility of a forecast not being accurately fulfilled by the actual occurrence of the cost or receipt of revenue and uncertainty deals with the possibility of the occurrence of an event that cannot be budgeted for and that would defeat the project's aims or for which no reliable basis for a forecast exists (Boussabaine and Kirkham 2004). Statistical methods, simulation and sensitivity analysis are proposed as reasonable methods for identifying the risk and uncertainty of construction facilities (Hutchinson 1993). The reflection of certainty, flexibility and irreversibility of these evaluation approaches are considered in the literature, which is illustrated in Figure 6-10.

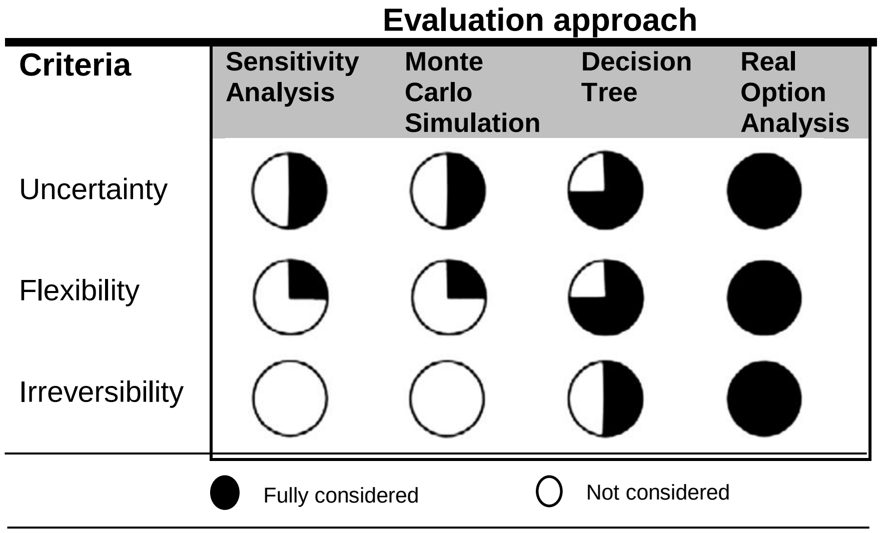


Figure 6-10: Risk and uncertainty considerations of evaluation

Source: Hulsmann *et al.* (2007)

Sensitivity analysis is a simple and popular method for determining how the value of WLA is affected by variations in the values of dependable parameters (interest rates and the discounting factor). It is necessary to undertake sensitivity analysis with WLA because many of the inputs to WLA are based on different assumptions.

6.3.2 Whole life analysis for adaptable buildings

To survive in a competitive business, investors are required to pay attention to various strategies for optimising their investments by reducing unnecessary costs. Building users expect an efficient, reliable and low-running cost for their facilities, which should be flexible and easy to adapt (Flanagan and Jewell 2005). A good design leads to optimal performance in meeting current needs and requirements (Mayr 2006). The cost of adaptability is a preliminary concern that helps to identify the correct economic decisions at the design stage of a project. Douglas (2006) suggests that the cost of adaptation depends on the size, quality, time, complexity and location of the work. WLA provides an initial basis for understanding the immediate and long-term benefits of increasing capacity to accommodate change (Dell'Isola and Kirk 1983). Although there are a number of cost models available for evaluating WLA in buildings (Durairaj *et al.* 2002, Sherif 1982), no-one has attempted to evaluate the total cost changes of building adaptations. The correct application of this technique for adaptable buildings might provide hitherto unimagined economic benefits to investors. To complete WLA for adaptable buildings, it is necessary to identify the costs and benefits of adaptable buildings, their timings, present vales and the associated risks and uncertainties. However, adaptable buildings have a short history in construction; thus the amount of information available to undertake WLA is limited.

The economic life of a building can be best extended by adaption, rather than just maintenance (Douglas 2006). Thus, adaptable buildings provide economically sound benefits over the long term. Williams (1984) states that, in many cases, the cost of adapting existing buildings is greater than the cost of building them from scratch. It clearly seems that building adaptation is a cost-consuming process when adaptable features are not incorporated in the initial design. Therefore, there is an immediate need for integrating an appropriate level of adaptable features within new construction for market-oriented building customisation. Figure 6-11 describes the typical expected lifecycles of adaptable and standard facilities.

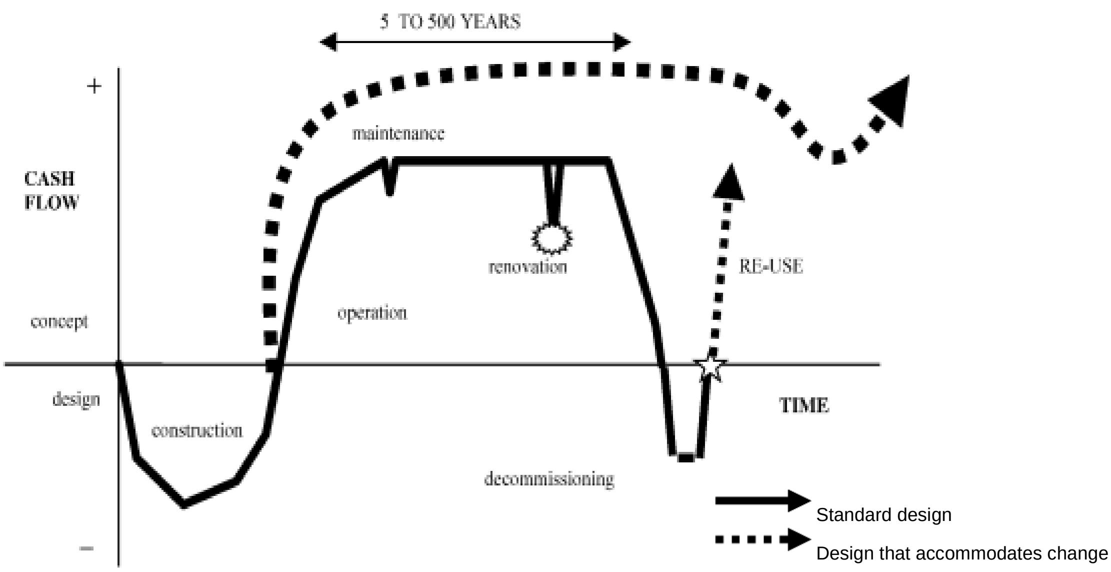


Figure 6-11: Expected lifecycles of facilities and potential impact of design accommodating change

Source: Slaughter (2001 p.209)

The design that has high flexibility for potential changes over its whole lifecycle brings more positive cash flows than the standard design. Arge (2005) states that developers do invest in adaptability to a certain degree; however, the cost difference between what can be considered 'best practice' and 'worst practice' is somewhat minimal. The real benefit depends on how early and how often the need to change occurs in terms of function, space or components.

As previously discussed in chapter 5, a growing demand for adaptable buildings is apparent in the UK property market. Thus, economic evaluation for adaptable buildings needs to be undertaken to provide the 'hard' evidence showing that these buildings are more economically sound alternatives to typical fit-to-use solutions. The shorter development period of adaptable buildings reduces the cost of financing and the effect of inflation on construction costs, so organisations that do not wish to relocate have less disruption to operations and cash flow, reducing temporary accommodation expenses (Langston *et al.* 2008). Arge (2005 p.126) concludes that the 'initial cost of adaptability can be high and the benefits are uncertain and only show over time' because of the extra costs due to generality and flexibility. In contrast, Schenk *et al*. (2009) explain that adaptability does not have a high influence on building costs. Despite the time advantages, the cost of converting a building is generally less than new construction because many of the building elements already exist (Langston *et al.* 2008). By analysing the results of three practical housing projects in the Netherlands, Voordt (1990 p.33) supports the above argument: 'if the design has been well formulated, adaptable building need not be much more costly than non-adaptable building'. Shipley *et al.* (2006) explain that the cost of adapting older buildings for new uses is higher than renewal costs and is not economical. The literature explains the continuous growth in adaptable buildings and the importance of evaluating the economic costs and benefits of them.

6.4 Benefits and challenges of WLA

As previously discussed, WLA is seemingly an important approach for evaluating the economic costs and benefits of built environment facilities. However, when evaluating product performance, it is important to answer the questions '*what has happened', 'why has it happened', 'is it going to continue'* and *'what are we going to do about it'* (Shaw 1999). The UK government made the decision to make all its construction procurement choices on the basis of whole life cost (WLC), as stated in the HM Treasury guidance (BSRIA 2008). Also, WLA has started to become an important approach because of environmental concerns and the concept of sustainability (Kirk and Dell'Isola 1995, Bakis *et al.* 2003, Flanagan and Jewell 2005, Ruddock 2007). Moreover, the capability of the WLA approach to cope with sustainability issues and WLC considerations whilst dealing with future risks and uncertainties has been clearly identified. Hence, it is of interest to evaluate the practicality of undertaking WLA for adaptable buildings whilst identifying the benefits and challenges of the approach.

In fact, WLA is a dynamic approach that provides up-to-date forecasts on cost and performance throughout the building's life (Boussabaine and Kirkham 2004). The variety of benefits and challenges of exploiting WLA in built environment facilities is discussed in the literature (Flanagan and Jewell 2005, Ive 2006, Constructing Excellence 2008, ISO 15686 – Part V 2008). However, very few attempts have been made to apply the technique to adaptable buildings. The likely benefits and challenges of applying WLA to adaptable buildings are pointed out below.

Benefits

- The final decision derived from WLA represents the total cost commitment of a facility, risk and performance, rather than limited to the initial cost only.

- Identifies alternative ways to reduce unnecessary costs.

- A higher degree of flexibility to react to changing business needs. Hence, the developer can get an idea of how much more he/she needs to spend for a new function.

- The provision of a framework within which to compare options at all stages of development.

WLA is considered a complex and time-consuming endeavour, presumably because of the limited applications in built environment facilities. Many reasons have been put forward, including difficulties relating to data and information management, the limitations of current analysis tools, the fragmented nature of the industry and lack of understanding and motivation on the part of clients (Al-Hajj *et al.* 2001).

Challenges

- Adaptable buildings (specifications written to a set of guidelines, with specific design intent) are new to the building industry; hence the practical application is poor.

- Ignorance by the client and lack of awareness of importance of future costs (e.g. maintenance and cost of adaptation).

- Involves a level of risk regarding future application and depends on market demands and existing supply.

- Lack of framework for collecting relevant data, together with standard techniques for modifying 'rule of thumb' data for specific projects.

- Lack of availability of adaptable building projects and reliable cost data.

- The complex and theoretical relationship between money now and money spent or received in the future.

- The interval between the design process and data on running/operating costs becoming available.

- High number of unpredictable variables used in the calculation (March 2009).

The benefits and challenges of adopting WLA in adaptable buildings are explained. The stakeholders' contribution to the success of WLA in built environment facilities is also noticeable.

6.5 Summary

Adaptable buildings are proposed as a principal requirement for the UK construction market. Therefore, modern construction industry-led approaches need to consider how adaptable features could be included at the earliest possible phase of design. The literature reveals the initial capital cost of adaptable building as a critical challenge, although the cost in-use is comparatively low in adaptable buildings. Therefore, analysis of the whole life cost and the benefits of adaptable building are critical milestones in long-term decision making. In a sense, designing buildings for a long structural and short functional life is identified as an economically and environmentally well-balanced requirement.

The study identifies the merits and demerits of WLA to undertake economic evaluation for adaptable buildings. The discounted cash flow methods and real option analysis were proposed as the most appropriate techniques for quantifying the costs and benefits of adaptation. The unforeseeable risk associated with adaptable buildings seems to be a critical concern of adaptable buildings. Sensitivity analysis is a reliable method for identifying the risk and uncertainty of built environment facilities; it is frequently considered alongside the DCF methods. In addition, real option analysis is adopted in financial theory to make economic decisions that consider the flexibility of different options to adapt to a given situation. Seemingly, ROA may be popular as a strong tool for identifying the economic considerations for adaptability in buildings.

Chapter Seven

7. UNDERSTANDING BUILDING CHANGE– HISTORICAL CASE STUDIES

7.1 Introduction to chapter seven

The chapter explains the data collected and its analysis in order to achieve the first objective of this research endeavour. The overall chapter follows two sections. The first section is based on two case studies (macro and micro level), a secondary data analysis of Adaptable Futures case studies and interviews to explain how the uses and functions of the built environment and its supporting infrastructures have changed over a period of 100 years. The findings of these case studies (undertaken within a semi-rural borough in England, UK) were used to establish that building change occurs over time and to identify the economic implications. The second section is used to discuss the critical findings of the case studies and secondary data analysis. Moreover, the same section explains how these findings link with the second objective of this study.

7.2 A historical review of building change of use

The literature discusses the different types of change in built environment assets and acknowledges 'design for adaptations' (DFA) as one of the more robust solutions for defeating the problem of building redundancy/premature retirement (Kincaid 2002, Hashemian 2005, Douglas 2006). However, economic considerations and planning and policy issues are considered to be the most likely limitations to implementing these solutions in the built environment. Thus, this study was designed to explore the economic considerations for adaptability in buildings to help owners/developers in decisions on DFA. Many studies have examined the different criteria for building adaptation and researchers have exploited a case study approach based on in-depth analysis of a relatively limited number of cases (Blakstad 2001, Heath 2001, Kincaid 2002, Arge 2005, Remoy and Voordt 2007, Wilkinson et al. 2010). Similarly, two in-depth case studies were undertaken in this study to investigate building change of use at the macro and micro levels. Moreover, the macro level study was used to understand the different types of building change (i.e. size, function, location and task) and to identify the most influential change type through documentary and empirical evidence.

The town of Loughborough (with an approximate population of 58,000 in 2004) was studied to provide a snapshot of the changes to buildings over the last century. Historical maps of Loughborough were analysed to identify the types of change that had occurred in buildings and the apparent changes were noted in the matrix of chronological building change attached in appendix F. Five different buildings (A, B, C, D and E) were randomly selected from the Loughborough maps to identify chronological changes to buildings over the last century. Among these changes, the metadata of the historic maps illustrated that 'change of use' was the dominant change in buildings over the last century. Apparently, some buildings have changed their 'size' from time to time; however, this fact was not as highly remarked upon as their 'change of use'. Thus, the case study focused on change of use in buildings instead of other changes.

Loughborough was selected because of its convenient location and because it is typical of a small rural town in the heart of the United Kingdom. The available historic maps and documents were collected from Leicester Record Office (historic maps older than ten years) and Loughborough public library (recent maps not older than ten years). The use typologies of buildings were identified under residential, commercial, industrial, social and leisure categories. Residential included detached and semi-detached houses and apartment blocks. Commercial comprised offices, banks, public houses, hotels and retailers. Industrial included buildings for manufacturing and warehouses. Social covered schools, churches, clubs, hospitals and buildings that were built for the purpose of maintaining community wellbeing. Leisure included parks and other recreational facilities. A macro level expansion in built environment facilities could be identified within the historic maps of Loughborough. Many of the agricultural fields and bare lands were developed for new buildings and their associated infrastructure networks. The top half of Figure 7-1 shows the overall changes to the town and the bottom half identifies the building change of use in a specific cluster. The findings of this case study were published as a chapter (Manewa *et al.* 2009) of the book *'Smart Building in a Changing Climate'*.

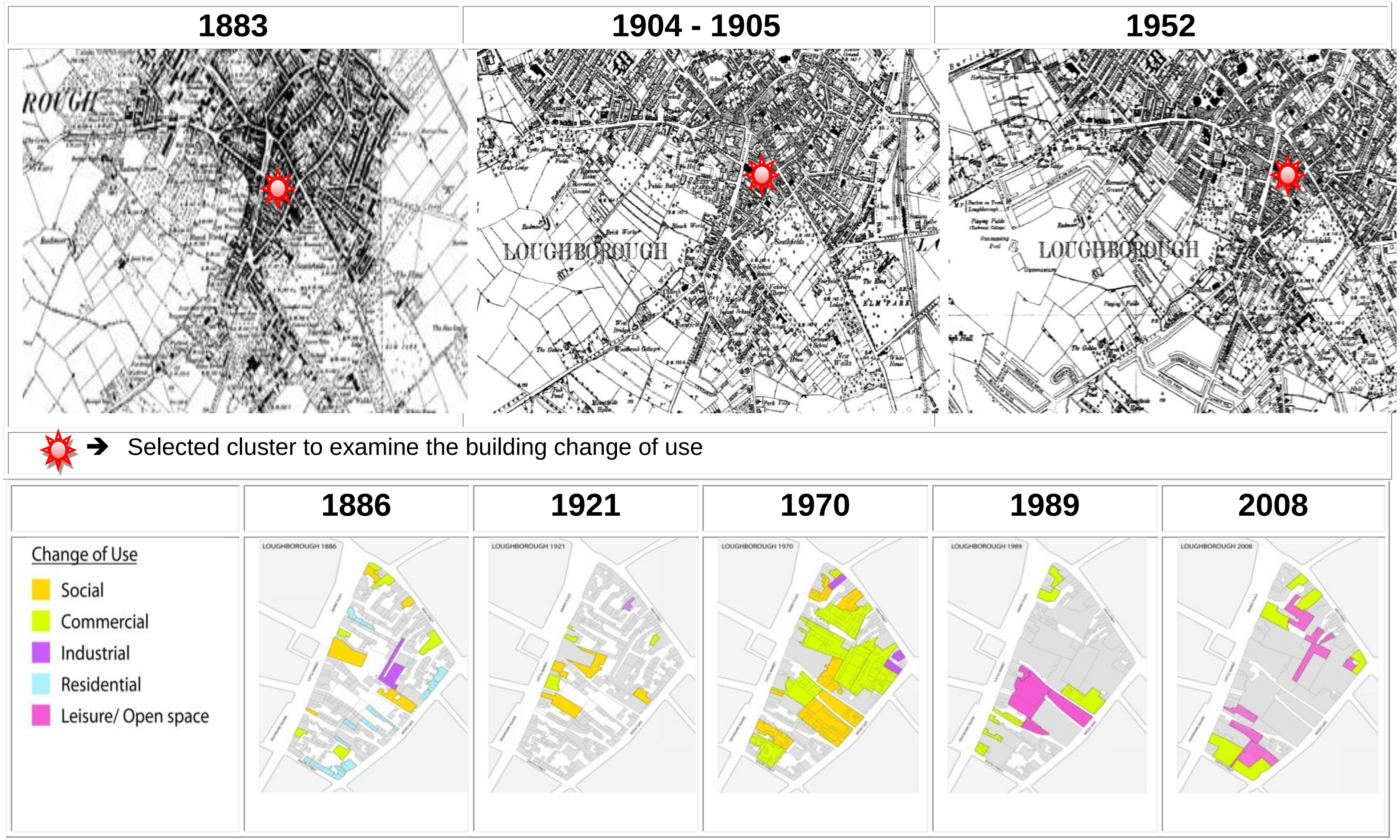


Figure 7-1: Change of use in buildings (macro level)

Following the initial observation of building change over a period of 100 years in Loughborough, the selected case study was used to analyse how building functions have changed and to further investigate the factors behind these functional transformations through a typo-morphological analysis. Typo-morphological analysis is a technique confined to the narrow historical study of urban form (Lloyd-Jones and Erickson 2007). A frequent application of this technique appears in urban planning and design, where it is necessary to identify the inter-relationships between elements (i.e. plot, space, open space and street). Ariga (2005) undertook a research study using typo-morphological analysis on adaptable physical settings and flexible mixtures for liveable urban communities in the city of San Francisco. The study focused on functional clusters and their adaptability with changing conditions. Similarly, typo-morphological analysis was exploited in this study to identify the pattern of change in building function/use in a selected building cluster in Loughborough during the last century. This analysis enables the identification of how new buildings could adapt for potential change of use through the lessons learned. The forthcoming sections explain the macro level (a set of buildings) and the micro level (a single building) change of use in buildings over the past century and the underlying economic impacts of both scenarios through two case studies. The second case study was further used to identify the successes and failures (if any) of particular changes of use (i.e. industrial to classroom), and the lessons learned (technical and design parameters) are brought forward for designing new buildings towards potential changes of use.

7.2.1 Case study 1: Macro level change of use

The selected cluster is located in the commercial hub of the town of Loughborough. The cluster comprised the area bounded by Market Place, High Street, Woodgate and South Street. A semi-structured interview (appendix B: interview guide, appendix I: interviewee 1) was conducted with one of the development and control officers at the Local Authority (Charnwood Borough Council) and one unstructured interview was undertaken with a senior planner of Leicester City Council to obtain before and after data for the study of building change of use in the selected cluster. Table 7-1 summarises their professional experiences. These interviews further supported the selection of the specific case study area (the cluster) in the town and the explanation of typical building change in two different geographical locations. In addition, there was encouragement to select the particular cluster itself because many of the buildings in the cluster clearly showed their functional use in all the maps. More importantly, a mixture of all the functional units was seen in the selected cluster, more so than in the other possible clusters.

Table 7-1: Interviewees' professional experiences (Case study 1)

Method of data collection	Interviewees	Professional experience (years)				
		Less than 5	5 to 10	10 to 15	15 to 20	More than 20
Case study 1: Building change (macro level) Semi-structured and unstructured interviews	Development control officer				✔	
	Senior planner					✔

7.2.1.1 Data collection for case study 1

Historic maps to a scale of 1'' = 88ft for the years 1886, 1901, 1921, 1968, 1970, 1974, 1981, 1989 and 2008 were used to study the pattern of building use change over the years. From these maps, critical differentiations in functional uses were identified between 1886, 1921, 1970, 1989 and 2008. Other historic documents were also accessed to identify the factors (social and economic) behind these transitions. Moreover, direct observations were undertaken in mid-2008 to identify the most recent uses in the selected cluster. These observations revealed which buildings had been replaced recently as the construction technology was clearly less than 60 years old and also helped to estimate the percentage of alterations in buildings and their functions. Building change of use in the selected cluster over the century was noted by comparing each building with its previous use. Colours (yellow - social, light green - commercial, purple - industrial, sky blue - residential, pink - leisure and recreational, grey - buildings with no change of use and white - open space) were assigned to represent the change of use in buildings in comparison to their previous use. As previously mentioned, the significant change of use in buildings during 1886, 1921, 1970, 1989 and 2008 is explained in this section and the reasons behind these changes of use are discussed in the data analysis section.

Figure 7-2: Building change of use - Loughborough in 1886

It appears from the above map that almost all the residential buildings placed along Woodgate and South Street were semi-detached houses. Most of the detached houses seem to have been scattered across the middle part of the cluster. The town hall and police court can be identified under the social category. There were commercial buildings, such as banks, hotels, small shops and a few public houses, and the industrial buildings were surrounded by the residential units in the centre.

Figure 7-3: Building change of use - Loughborough in 1921

Spatial extensions in social (the town hall) and commercial buildings (a bank and hotels) are recognisable in the 1921 map. A new picture theatre and a National Westminster bank had been added to the social and commercial building categories, respectively. Nevertheless, no remarkable alteration to the remaining building stock could be seen in 1921. Furthermore, the impact of World War I (1914 – 1918) is not noticeable.

Figure 7-4: Building change of use - Loughborough 1970

By 1970, many changes are seen on the map. Since 1921, new building and extensions had taken place in all functional categories. Specific new construction (Corporation Yard, Woolworths and a police station) and conversions of existing buildings (part of an existing police station becomes a magistrates' court, Midland Horticultural Works becomes Clemerson's Storage) are significant during this period. More spaces were also allocated for commercial, social and industrial buildings. Some of the Victorian[5] residential buildings were demolished and some were easily converted to other functions. The cluster started to commercialise after World War II, adding growing employment opportunities for the people of Loughborough. As a result, the town economically stabilised in 1970. It can be seen that

[5] Victorian architecture: architecture in England during the reign of Victoria (1837-1901), characterised by lavish ornament and eclectic styling of all types of buildings (Davies and Jokiniemi 2008).

spaces were added primarily to the existing commercial stock from 1970. The other functional units replaced all the residential buildings.

Figure 7-5: Building change of use - Loughborough in 1989

Remarkably, a larger area had been allocated to leisure and recreational space in 1989 compared to 1970. However, there is little evidence of significant development in the existing stock or new construction.

Figure 7-6: Building change of use - Loughborough in 2008

Figure 7-6 illustrates building change of use in the selected cluster in 2008. When analysing the historical maps throughout the last century, a remarkable growth in commercial, social and open spaces can be identified in the 2008 map. Approximately half of the area was developed as commercial buildings and the remaining area was allocated for social and open spaces.

7.2.1.2 Analysis of case study 1

All categories of functional mixes can be identified within the cluster during 1886. Looking at these functional changes, the cluster seems to have started to commercialise in 1970. Apparently, residential buildings were totally shifted away from the cluster and more commercial and social buildings were accommodated. Policy makers strived to separate the residential sector from the market segment. As a result, some of the existing residential houses were required to convert to offices or public houses and some were totally replaced by 1970. The growth in local population, increase of spending power, implementation of new planning policies, sustainable concerns, changing user demands and building obsolescence can be identified as key factors behind these transitions.

In the aftermath of World War II, the sudden growth in all sectors in Loughborough is noteworthy. The shifting of houses to discrete residential zones and the mushrooming developments in commercial zones are significant. The improvements in spaces for banking show the growth in monetary transactions compared to earlier periods. As one of the largest prospective employers, Loughborough University plays a vital role in this regard. In 1886, only a Lloyds bank can be found on the map; in 1921, a National Westminster bank was added to the commercial network. In 1970, the expansion of both banks can be seen and another branch of National Westminster was added to the cluster. By 2008, there are HSBC, National Westminster and Lloyds banks in the cluster. Thus, the growth in banking and some expansions of social buildings are significant changes within the cluster. These improvements are likely to have affected the economic booms in Loughborough during the periods under study.

The changing distribution of the industrial buildings within the cluster is significant when analysing economic growth in Loughborough. Midland Horticultural Works provided employment opportunities to people in the surrounding areas of Loughborough in its early years. This space was then used as storage for Clemerson's. Even though the function changed from industrial to commercial (retail), the same building structure was able to serve the new function. Moreover, a continuous growth in social and leisure buildings can be identified within the cluster. Extensions in the town hall building and the construction of a new police station, together with the renewal and partial conversion of the existing police station to a magistrates' court, are notable. Growth in population is one of the leading factors that drive expansions, leading in the long term to social improvement, sustainable goals and improved community wellbeing.

Noticeably, the previously mentioned change of use has had a macro level impact on Loughborough's economy. The industrial revolution in the 19th century caused rapid developments in the town based on hosiery, other textile productions, and various manufacturing and engineering industries (e.g. The Brush Works). It appears that the Charter of Incorporation in 1888 was largely the result of the industrial prosperity of Loughborough (Deakin 1974). Although relatively undamaged physically by the First and Second World Wars in the first half of the 20th century, there was a disruption to the growth pattern of the town during these periods, whilst the growth of public policies in the late 20th century has favoured changes in space use patterns.

It was derived from the interviews and observations that economic, social and environmental considerations, allied with building obsolescence, are the key demanding factors for building change and conversions. Either factor can create significant demand for change. In particular to this cluster, interviewee 1 further explained that *'demand for housing and social amenities', 'growth of listed buildings', 'character of the town', 'new planning policies'* and the fact that *'redundancy was economically viable rather than demolition'* were the key driving factors for building change of use. Moreover, interviewee 11 explained that many of the industrial buildings were easily adapted/converted for new uses and *'one of the reasons that the Leicester mills in particular were ideal for conversion was that they're very solidly built, hand-made bricks. What we'd say today: over-engineered, over-specified. In the days when they were built, things were either built and fell down within 6 months or they were built to last 600 years and obviously built to take huge machinery. They are extremely strong, have very strong steelwork, big timbers, seasoned timbers, handmade brickwork, everything, and also lend themselves to residential conversion because they have big windows'.*

Many buildings in the selected cluster were demolished but old industrial ones were able to be adapted and so were not demolished. In other words, if the building was listed then demolition and rebuild would not be an option. However, many older buildings, although not listed, are important visually and some people would argue that they have far better architectural merit than some new buildings erected today (Watson 2009). Moreover, interviewee 1 explained that the *'instability of building structure'*, *'difficulties in internal space reconfigurations', 'social, environment and economic volatility'* and buildings being *'incapable to fit for a secondary purpose'* are the major reasons for demolition. *'When buildings are built, they're pretty much static for at least about 70 or 80 years and if there's a change of ideas halfway along the line, after 30 or 40 years, moving buildings around is just obviously impossible'* (interviewee 11). Presumably, these difficulties could be limited to a certain extent if the initial design precautions for adaptation had been undertaken at the early stages of design. By instinct, it was assumed that undeveloped technologies, less commercialisation and value considerations were the likely influential factors that affected the decisions on adaptable building technologies in that era. However, new buildings that can be adapted to new functional goals (adaptable buildings) have been identified as the solution to cater for growing demand. The term *'adaptable'* is a multi-faceted concept. It is about managing 'change' in the context of buildings, which can occur from either exogenous (external) or endogenous (internal) influences (Douglas 2006). The next case study attests the micro level change of use in built environment structures.

7.2.2 Case study 2: Micro level change of use

The second case was used to study how practically this change of use was undertaken in one selected building, which switched from industrial function to classroom. The selected building (Stewart Mason) originally functioned as a foundry at Loughborough College of Technology (1952 – 1956) but now holds the functions of teaching and learning for students at Loughborough University. This change of use (industrial to teaching and learning) was analysed to learn lessons for designing new buildings for future potential conversions. The original building was constructed in the mid-20th century and the building structure (framed) is more than 50 years old. A major structural adaptation was undertaken to the foundry's structure in 2005 in order for it to survive the myriad challenges faced by the university.

From a technical college to a university, the population of the educational institution has increased by nearly eight times over the last century. The historic maps and the facts and figure data are used to explain this growth of student population, changes to existing buildings and improvements in associated infrastructure facilities and further to illustrate newly constructed facilities for Loughborough University. In the early 20th century, it had ten buildings altogether, which provided teaching, learning, recreation and accommodation facilities for technical college students and staff. Today, the number of buildings has increased to 107 (www.lboro.ac.uk 2011) and the total space is shared between university students and staff (the estimated university population in 2011 was 21,000). The relationship between the growth of the population and the space used is notable. The main reason for selecting this particular building for this study was due to the apparent evidence of building change of use (from a foundry to a teaching and learning unit). Moreover, the convenient access to available data (building maps, project documents, progress pictures and human resources) was the preliminary concern for selecting the specific case. The next two sections explain the collected data and the way it was analysed to achieve the specific objectives.

7.2.2.1 Data collection for case study 2

The second case study is used to explain building change at the micro level and further to identify the design parameters for building change of use. The data was collected from two semi-structured interviews (interview templates annexed in appendices B and C) with the director of the change project at Loughborough University and the senior maintenance engineer (appendix I: interviewee 7) for the Department of Facilities at Loughborough University to understand the decisions/factors usually affecting building change, the lifecycle extendibility of existing buildings and facility maintenance. In addition, an unstructured interview was undertaken with the project engineer for the Stewart Mason conversion to identify the structural changes to the existing structure. Their professional experiences are summarised below in Table 7-2.

Table 7-2: Interviewees' professional experiences (Case study 2)

Method of data collection	Interviewees	Professional experience (years)				
		Less than 5	5 to 10	10 to 15	15 to 20	More than 20
Case study 2: Building change (micro level)	Director of the change project			✔		
	Senior maintenance engineer				✔	
	Project engineer				✔	

In addition, project documents were used to collect relevant technical data on this conversion. The structural adaptation was undertaken to the original foundry building in order for it to survive the challenges faced by Loughborough University. The space used for the foundry in the mid-20th century is now functioning as a teaching and learning unit for postgraduate students at Loughborough University. The new building (Steward Mason) has two main floors and a mezzanine floor that provides access to the James France building. Figure 7-7 shows how the original structure was changed to respond to the required new use.

Figure 7-7: Structural adaptation to original structure

The historic maps of the foundry building reveal that the ground floor (size: 50m x 35m) was used as a welding laboratory, pattern shop, fettling shop and for material storage. The mezzanine floor was connected to the loading and unloading bays of workshop engineering. The first floor (size: 50m x 17m) space was used for laboratories (polymer, plastic and timber) and office facilities.

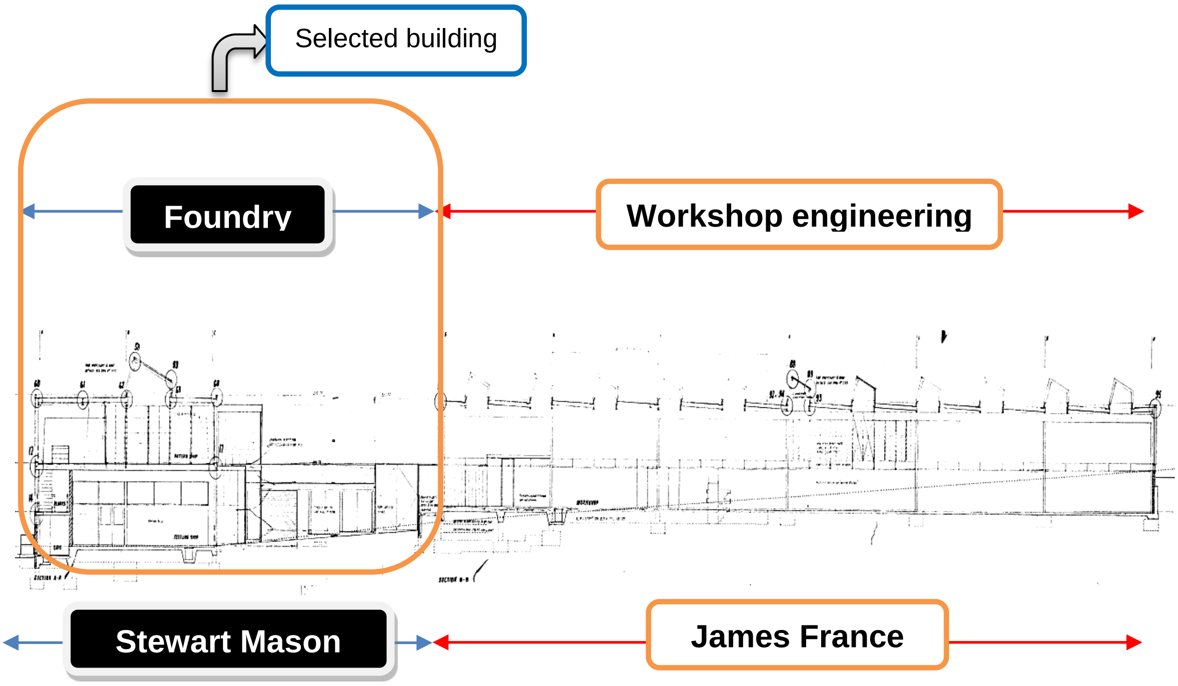


Figure 7-8: Cross-sectional view of foundry and workshop engineering (1957)

The plans for the ground floor and the first floor of both the foundry and the Stewart Mason building are illustrated in Figures 7-9 and 7-10. A steel framed structure with deep beams and larger columns was used on the ground floor and the portal framed structure can be seen on the first floor of the foundry, which was designed to carry heavy loads (dead, imposed and wind) of industrial engineering. The typical technical spans are 7.5m and 15m on the ground and first floors, respectively.

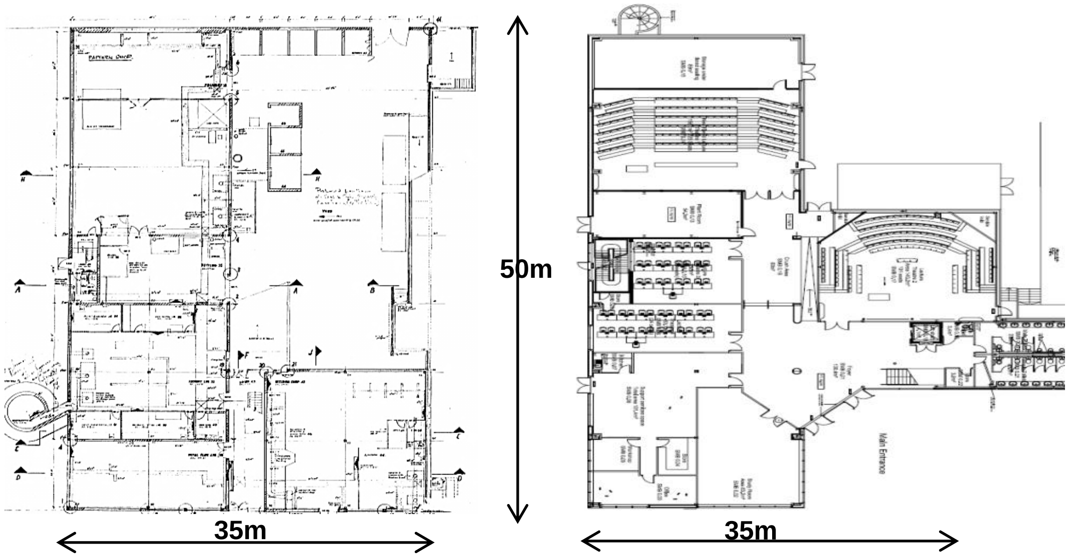


Figure 7-9: Ground floor plan of the foundry (1957) and the Stewart Mason building (2005)

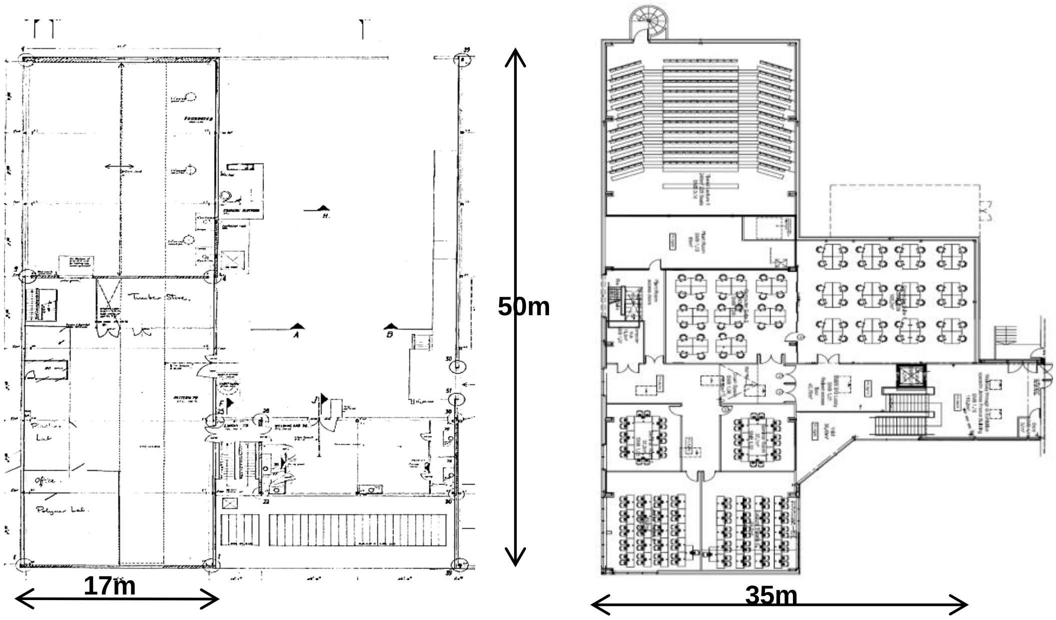


Figure 7-10: First floor plan of the foundry (1957) and the Stewart Mason building (2005)

7.2.2.2 Analysis of case study 2

There was no significant change in the gross floor area (usable space), except the addition of a new lecture theatre to the first floor of the Stewart Mason building. The project engineer further explained that *'it was not difficult to have vertical extensions because the original structure was designed for carrying a huge load of industrial engineering'.* He further appreciated the ability of framed structures (columns and beams in this scenario) to adapt for new teaching and learning environments. In a way, it adds a strong point to the existing grounds of adaptable buildings. A significant change has been undertaken to the original storey heights of the foundry during its conversion to a teaching and learning facility.

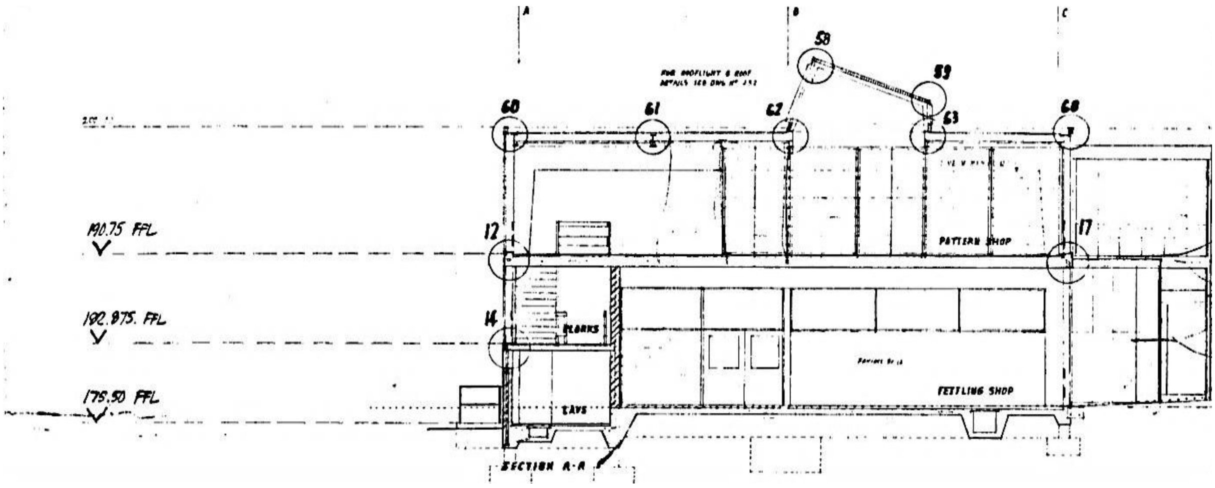


Figure 7-11: Cross-section of the foundry

Thus, attention was paid to identify in which ways the original storey height was adjusted to serve the new function. The floor to ceiling height of the ground floor of the foundry was 4.0m, which included a mezzanine floor at 2.2m height. The floor to ceiling height of the first floor was 3.2m. The floor to ceiling heights of the introduced ground and first floors for the Stewart Mason building are 3.5m and 2.5m, respectively. This change can be observed in floor to ceiling heights and the service zones. The Stewart Mason building was adjusted to a lower floor to ceiling height with deeper structural and service zones. This was a health and safety requirement and there are additional cost requirements for maintaining the extra non-usable space. For example, maintenance and operation costs can be increased if the volume to be heated and/or cooled is high. The structural and service zone (SSZ) increased by more than double the original SSZ of the foundry. The Stewart Mason building is able to facilitate space for approximately 500 – 600 students at a time, so the services system (heating and cooling units, lighting equipment, service pipes and accessories, and under floor heating systems) functions to provide a comfortable teaching and learning environment. Thus, the structural and service system has increased the size of the original zones. The foundry had a high storey height and it was a reasonably easy conversion. However, the conversion process might have been difficult if it was the other way round (from lower to higher floor to ceiling height). From an economic perspective, height, width and depth can be considered to be the basic morphological factors that contribute to building costs. In fact, service components are notable as the most cost-consuming building element, which this study does not detail.

In short, the macro and micro level changes of use were examined through two single case studies. The Loughborough town centre study granted a clear overview of building change of use at the macro level and the Stewart Mason building conversion was used to learn about micro level changes of use in a building (design and practical issues). The next section explains the economic impacts of built environment changes.

7.2.3 Economic impact of building change of use

The typo-morphological analysis illustrates a demand for different types of uses in buildings that change over time. Having analysed these demands, it was appropriate for this study to examine the overall economic impacts that took place in Loughborough through its building change of use. To this end, four economic indicators were identified and this analysis might help interested parties to realise the seriousness of the problem of building change of use.

7.2.3.1 Growth in the industrial and manufacturing sectors

Growth in the industrial sector a century ago demanded a change in building type to fit the new purpose. The historical maps indicate that in the 19th century and early 20th century, many of the buildings in the cluster were utilised for manufacturing lace, bells, cranes and electrical products, along with heavy industries such as iron foundries, corn mills, warehousing and goods handling on canal wharves. It seems that the Brush Engineering Company Ltd. was Loughborough's largest manufacturing group in that era. Other employment opportunities were offered by John Taylor's bell foundry in 1839, Ladybird Books Ltd. in 1873 and Davy Morris's crane works in 1903 (Wix *et al.* 1994).

7.2.3.2 Growth rate of population

Growth of population is one of the most significant economic factors that drive the need for extra housing. The change in population growth in Loughborough compared to the English national average during the last century was calculated to gauge its influence on the local built environment. The census and statistics regarding the England and Loughborough populations were obtained from the updated records of the Office for National Statistics (www.statistics.gov.uk), the atlas of the Borough of Charnwood (Read 1990 p.51) and Leicestershire Country Council (www.leics.gov.uk). The growth rate of population was calculated through the formula of:

$$Growth\ Rate = \left\{\left(\frac{Population\ in\ ending\ year}{Population\ in\ beginning\ year}\right)^{1/Number\ of\ years} - 1\right\}\%$$

Source: www.measuringworth.com/growth/#

The graph below shows the population growth of Loughborough to be largely higher than the national growth rate, only dropping below the national rate in 1845 and 1865. The local growth rate trend has followed the national one but the difference between the two growth rates has noticeably diminished over time. The local rate is more erratic, although this is likely to be due to the increased sensitivity of the smaller numbers involved in its calculation. More recent digression in the trends occurred in 1946/1956, caused by WW2 and in 1970/ 1975, caused by the establishment of the university and its associated influx of employees.

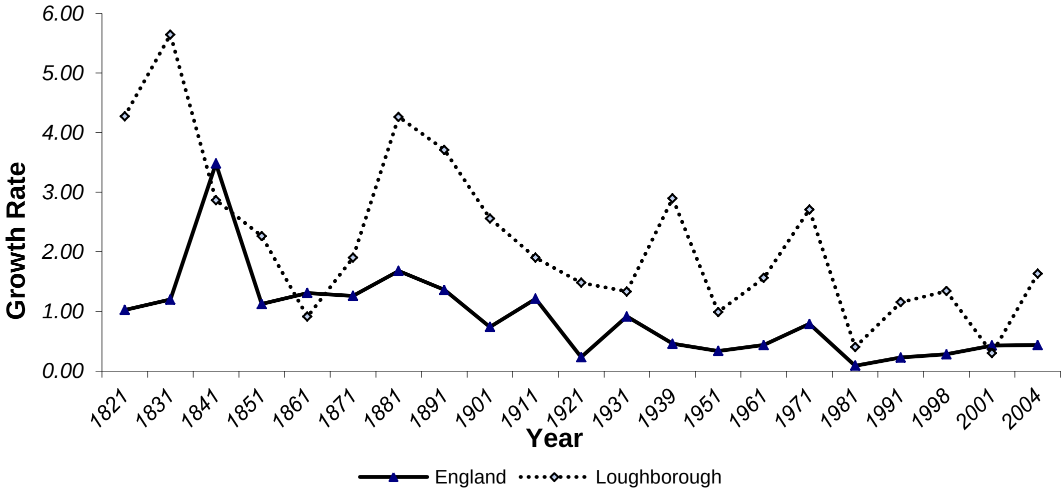


Figure 7-12: Growth rate of populations (England and Loughborough)

The growth of the population in Loughborough created many challenges for the built environment and for policy makers. The expansion of buildings to continue their existing functions, the demolition of redundant buildings and the functional conversion of most of the buildings in the cluster was parallel to the population growth and the allocation of space arising from new building developments for residential purposes.

7.2.3.3 Growth of higher and further education

A significant development in the higher and further educational sectors in the town occurred in 1966 with the university's Charter of Incorporation. This placed the new university on one of the largest single site campuses anywhere in the UK and made it the largest employer in the town of Loughborough (Herbert 1996). Statistics regarding the number of university staff and students were collected from facts and figures published by Loughborough University (1980-2008). Derived from this data, the growth rate of the student population during the last two decades is illustrated in the following figure.

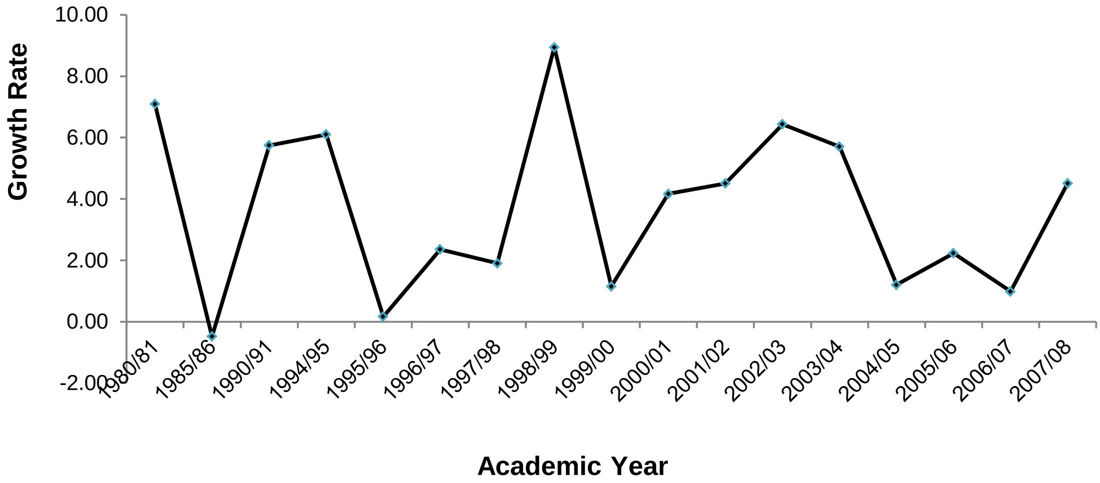


Figure 7-13: Growth rate of student population at Loughborough University

Source: www.lboro.ac.uk/admin/ar/planning/stats/factsfigures/index.htm

The growth shown above has demanded additional space for student accommodation and associated commercial and leisure facilities within the selected cluster. Further, it has outstripped the availability of existing facilities, resulting in significant new build programmes to cater for the community's needs and wants. The increase in the growth rate of student numbers in different periods (1988-1995, 1996-1997, 1998-1999, 2000-2003, 2005-2006, 2007-to date) is highlighted in Figure 7-13.

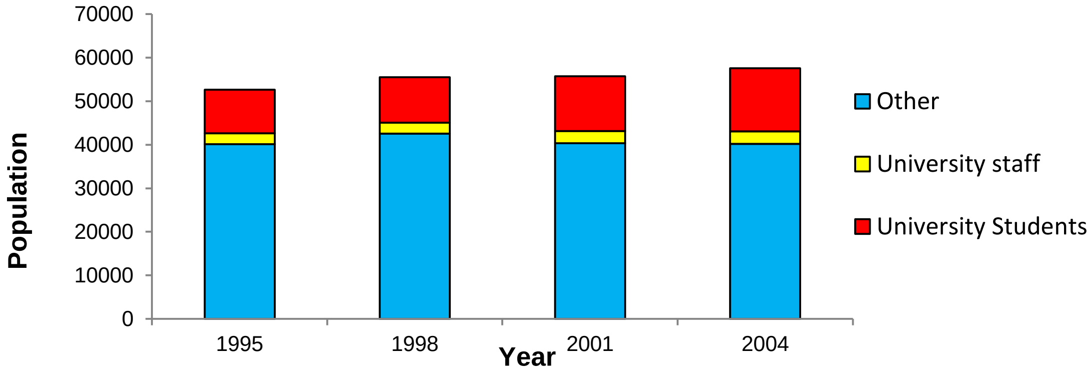


Figure 7-14: Estimated population of Loughborough (1995 - 2004)

Source: www.lboro.ac.uk/admin/ar/planning/stats/factsfigures/index.htm

Consequently, the above figure illustrates the population distribution of Loughborough in the last decade. The university population represented 23.75%, 23.42%, 27.52% and 30.11% of the total population in 1995, 1998, 2001 and 2004, respectively. It is currently around a 1/3 of the total population of Loughborough. According to recent university publications, the total staff and student population was 19,156 in mid-May 2008: up from 17,334 in 2004. This growth might affect Loughborough's economic growth because of the increased purchasing power of the students and staff. However, a lack of published data on student, staff and other categories in remaining years caused there to be no identifiable link with the cluster developments. On one hand, a positive trend can be seen towards commercialisation of the particular cluster and, on the other hand, the continuous growth of Loughborough University's population is highly noticeable. However, there is no reasonable evidence to clarify the inter-relationship between these two growths.

7.2.3.4 Planning policies

Considerable effects of planning policies on building construction can be seen in Loughborough after the formation of Charnwood Borough Council in 1974. All buildings are now constructed according to the county's Structure Plan (Wix and Keil 2002). The policies are derived from a two-tier activity. The national government policy statement sets the framework for the whole country and local authorities then apply it to work in their regions.

Most of the policies are concerned with environmental sustainability. The policies are biased towards increasing 'brownfield' development (reuse and redevelopment of previously developed land) and limiting 'greenfield' development (new construction on previously undeveloped land). Moreover, the policies favour an increase in housing to meet the fast expansion of the elderly, single parent and disabled population in the county (Wix and Keil 2002). Seemingly in contradiction to this, a critical growth and transition in commercial and industrial zones can be identified through the historical plans. This has directly affected Loughborough's traffic system, and new plans and regulations were developed to keep the market town away from the residential zones. Presumably, there has been a shifting of residential buildings to locations further away from the cluster area and this has paved the way for this part of the town to become a commercial hub for Loughborough.

Secondary data analysis of the interviews is used to explain how existing planning policies could help/resist the design of buildings for potential adaptation. One of the interviewees (a development control officer) explained that *'planners on average are relatively resistant to change. The planning system is relatively resistant to change, basically because the British planning system, being different from that in the rest of the world, is not designed around what you can do, but designed around what you can't do. The planners don't use master plans or don't pre-plan. They come up with rules that you must avoid doing and that inevitably means that the general – well the general public want planning to be a protection against change. Now that therefore means that, however much we try not to, we do tend to start with a negative mindset. And so anyone suggesting keeping and adapting is more likely to find rapid approval than somebody that's proposing to knock down and replace'.* This attests the resistance of the existing planning system and planners to plan adaptable buildings.

From the planners' point of view, a senior planner explained that *'one of the key policies under the urban design section is adaptability, but when it came to the planning section's urban design team advising the people who write short local plan policies on adaptability, we found that defining it is not that easy. There is real talk about how it ought to be but in terms of how the builders and developers can pick up this policy and make sense of it, and build buildings that are adaptable, it seemed to be not quite as straightforward as it would seem'*. Both empirical evidences can be used to explain the difficulties of existing policies in addressing 'adaptability' in buildings.

7.2.4 Generalising the findings of the case studies and interviews

In short, case studies 1 and 2 explain building change in two different clusters in Loughborough and how the development of Loughborough University was affected by building change in the town. Similarly, secondary data analysis attests how the development of De Montfort University was influenced by building change in Leicester. In general, building change can be seen in four different sequences. They are:

- Small changes + improvements (same use)
- Large changes + refurbishments (same use)
- Large changes (different use)
- Demolition

The historical review showed a frequent change of use between the typologies of social, commercial, residential and industrial. The possibility of converting old buildings for potential new uses is noted and it was interesting to clarify this intuition with empirical evidence. The findings of these cases and secondary data analysis could be used to generalise that the pattern of change and the sequence of change is likely to be different in every case and it can be concluded that change does happen in buildings. The next section discusses the adaptable potential of old buildings, which was apparent in the Loughborough case study.

7.3 Discussion of findings

The Loughborough town centre case study describes how some of the aged buildings (industrial and residential) in the selected cluster were easily converted to office and other commercial facilities. Interviewee 1 (appendix I) explained that the possible reasons behind the conversions were that these buildings had higher floor to ceiling heights, so the structures were easily adapted for new uses. Also they are desirable because they are aged/heritage properties and people pay a premium for these; as a result, they are clearly going to be redeveloped rather than demolished. However, some of these aged buildings were demolished because of structural decay and the problems of maladaptive service systems.

Moreover, secondary data analysis of the interviews undertaken by the Adaptable Futures project is supportive, stating that '*the buildings that have proved to be most adaptable over the longest period tend to be the oldest, or the older buildings. Buildings from the 19th century and earlier appear to have a longer lifespan than many put up in the 1970s and 80s, possibly because they were designed around an expectation of a longer life and therefore a need to have greater adaptability, possibly because they were more standard building solutions that had had less innovative, or sorry, less ingenuity involved in the process of their production and design'* (Interviewee 11). In conclusion, the following findings were derived from the findings of case studies.

- Building change occurs over time and change of use appears to be the most dominant change in buildings.
- Some aged buildings have good potential for future adaptations.
- Design parameters play a vital role in designing new buildings for adaptability.

7.4 Summary

A revolution in agricultural and industrial sectors in the 18th century wrought a remarkable change in social, cultural and economic lifestyles in the UK. As a result, major changes could be seen in patterns of land ownership and land use during the last century (Butlin 1994). By the turn of the 21st century, however, it could be seen that most of the industrial buildings had been converted to other functional units, such as residential, commercial, social and retail facilities with certain improvements.

Today, the UK government tends to promote the optimum use of the existing building stock through mixed use in urban centres and encourages the conversion of redundant office and retail space into leisure, service and/or residential uses, rather than renewal. Therefore, it is important to analyse ways of utilising the existing building stock as mixed or sole use developments because building functions have limited lives, they are expensive to build and the cost of replacement is high and clearly unnecessary where they are physically robust and adaptable. This encourages greater innovation in the design of new buildings to allow for change of use throughout the structure's lifetime. Design for adaptation is a present day solution for a knowledge-based, profit-orientated economy with rapidly changing product ranges. The reusability created by designing for adaptable buildings would significantly contribute to economic sustainability. The adaptability of buildings in some way has to be tuned into the adaptability of the place where they are; the degree of adaptability of a building in a maladaptive place should be less.

This chapter examined two levels (macro and micro) to understand the significant change of use in buildings over the last 100 years and the economic implications. Floor to ceiling height is identified as an influential design parameter for building change of use. To accommodate such changes, interest was paid to identifying means and ways to design new buildings towards potential adaptability. However, the economic considerations should be one of the critical factors addressed in owners'/clients' decision-making protocols. Thus, the next chapter elaborates on the economic considerations for adaptability in buildings.

Chapter Eight

8. ECONOMIC CONSIDERATIONS FOR ADAPTABILITY IN BUILDINGS

8.1 Introduction to chapter eight

The previous chapter revealed the historic change of use in buildings and the economic impacts whilst concluding that the current need is to design new buildings more towards potential adaptations. This chapter investigates solutions to the second, third and fourth objectives of this research inquiry. The chapter has four main sections. The first section summarises the methods used to collect data to meet the research objectives. The second section of this chapter identifies the most influential design parameters to be considered when designing new buildings towards potential change of use (objective 2). The third section then explains how adaptable buildings could respond to this extended functionality (objective 3). The last section provides empirical evidence for the economic considerations (costs and benefits) for adaptability in buildings (objective 4).

8.2 Overview of collected data

This section summarises the adopted research methods to address research objectives 2, 3 and 4. The data was collected from semi-structured interviews, secondary data analysis of Building Cost Information Service (BCIS) cost data and three web-based surveys (WBS1, WBS2 and WBS3). The findings of the case studies and semi-structured interviews, which were explained in the previous chapter, suggest that there was an apparent strong influence of '*floor to ceiling height'* on '*change of use'* in buildings of the selected cluster: Higher floor to ceiling height increases the potential for change of use. Thus, this issue was considered within objective 2.

Survey WBS1 (appendix D1: a mix of questions in the fields of both architecture and quantity surveying) was designed and circulated to architects and quantity surveyors from the 100 leading construction practices in the UK. The main aim was to identify how the floor to ceiling height would help to achieve building change of use. Altogether, 13 respondents completed the survey (9 quantity surveyors and 4 architects). The uncompleted answers and low rate of response after two follow-ups denoted the ambiguity of the questions used in WBS1. This led to the development of WBS2 (appendix D2) and WBS3 (appendix D3). Surveys WBS2 and WBS3 aimed to identify the design considerations and the economic considerations for adaptability in buildings, respectively. One hundred architects were specifically invited to take part in WBS2 and 32 did so. Similarly, 100 quantity surveyors were also invited to complete survey WBS3 and 42 did so. The 32% and 42% response rates were considered to be acceptable for this type of survey. The lengths of experience of the respondents in both architectural practices (Figure 8-1) and quantity surveying practices (Figure 8-2) varied from less than 5 years to more than 20 years, demonstrating a good spread of experience.

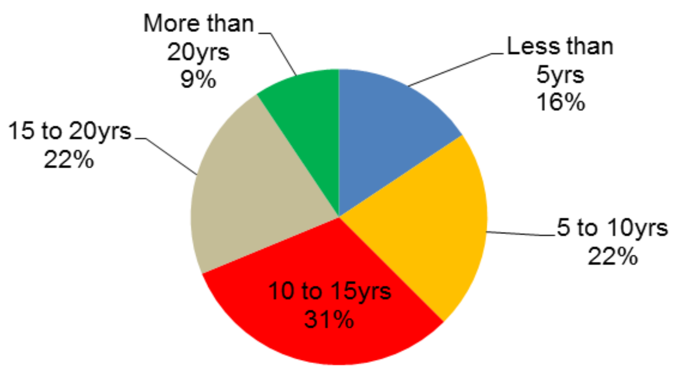


Figure 8-1: Experience of the architectural respondents to WBS2

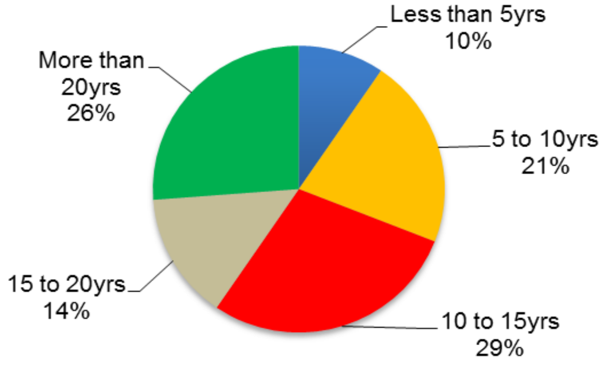


Figure 8-2: Experience of the quantity surveying respondents to WBS3

In addition to the above surveys, data for objectives 2, 3 and 4 was collected from four semi-structured and five unstructured interviews (see Figure 3-3 of chapter 3). The semi-structured interviews were undertaken with a quantity surveyor, a facilities manager and two structural engineers (see appendices C and E for interview questions). Five in-depth unstructured interviews were undertaken with a services engineer, a project manager, two architects and a senior planner to understand the issues of design, planning, economics, building maintenance and services integration for adaptability in buildings.

Table 8-1: Interviewees' profiles and experiences

Discipline	Purpose of interview	Professional experience (years)				
		Less than 5	5 to 10	10 to 15	15 to 20	More than 20
Structural engineering (interviewee 4)	to identify the structural issues and technical options for adaptability in buildings			✔		
Structural engineering (interviewee 10)			✔			
Quantity surveying (interviewee 6)	to identify the generic cost (initial capital + maintenance) and benefit considerations for adaptability in buildings				✔	
Facilities management (interviewee 7)						✔
Architecture (interviewee 5)	to understand the design and sustainable considerations for adaptability in buildings		✔			
Architecture (interviewee 9)				✔		
Project management (interviewee 3)					✔	
Services engineering (interviewee 8)	to identify the services integration required for adaptable buildings and cost changes					✔
Urban and building planning (interviewee 11)	to identify the planning and policy issues related to building change					✔

Secondary data from the Building Cost Information Services cost data of previously constructed buildings was analysed to model the initial capital costs of building elements. Detailed information about this analysis is explained in section 8.5.1. The next section elaborates the design parameters for adaptability in buildings.

8.3 Design parameters for adaptability in buildings

The design strategies and parameters for adaptability in buildings are explored in the literature and elucidated in chapter 5. Among these adaptable strategies, change of use in buildings was selected as one of the most important strategies to address in this study, as change of use was the most frequent type of change in buildings of the selected cluster (Loughborough). In addition, the literature explains the new trend in building change of use in the UK (Kincaid 2002, Douglas 2005). The data collected from WBS1 and WBS2 was analysed to complete the second objective of this study, which was to identify the principal design parameters for designing new buildings towards potential change of use. The generic design parameters for adaptability in buildings were identified from the literature review and the influence of these design parameters in building change of use was tested in WBS2. The respondents were specifically asked to select the level of influence of each design parameter on building change of use. A seven scale (0-6) Likert index was used to get the attitude scale in ordinal data and zero was assigned for 'not sure' answers. The results are presented in Figure 8-3.

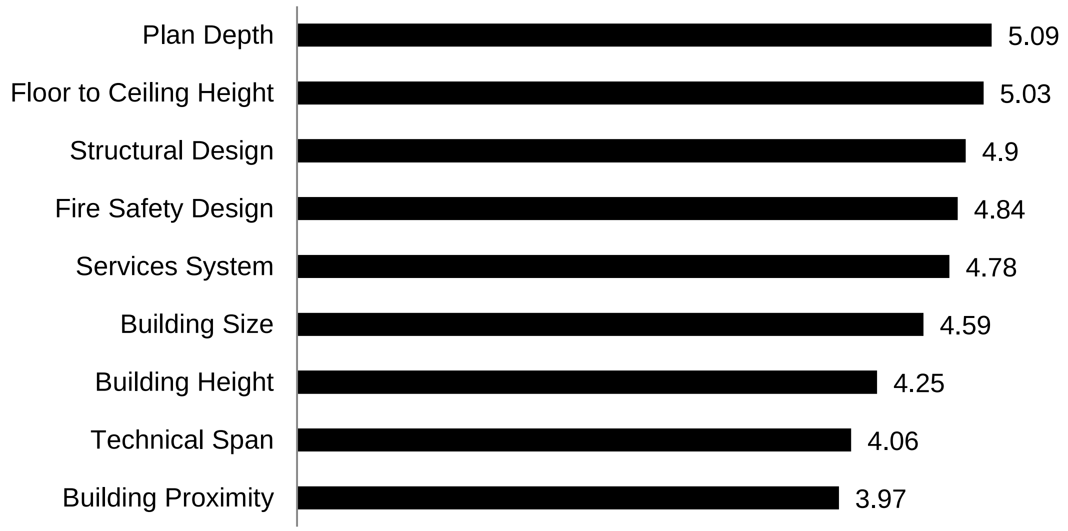


Figure 8-3: Influence of design parameters for building change of use

The results explain that 'plan depth' and 'floor to ceiling height' are the most influential design parameters for building change of use. Other design parameters also have a considerably positive influence on building change of use. Building morphology explains the cost influence of building/storey height, width and depth (Ferry *et al.* 1999, Ashworth 2004, Lowe *et al.* 2007). However, this study focuses on explaining a single parameter: how high 'floor to ceiling height' provides good potential for future change of use whilst assuming the constant impact of other design parameters on building change of use. The rationale for selecting 'floor to ceiling height' to study in this investigation is stated below.

- The Loughborough town centre case study explains how the buildings were adapted in the selected cluster and how the 'floor to ceiling height' of aged buildings helped to make these adaptations easier. For example, interviewee 1 stated that *'it was easy to convert Victorian terraced houses to office use because they had large floor to ceiling heights and extra load bearing capacity'.* Moreover, this finding was retested by secondary data analysis (interviews and documents) of the Adaptable Futures research project and WBS2.

- The Stewart Mason case study attested that the higher floor to ceiling height of the old foundry facilitated its conversion into a teaching and learning facility for Loughborough University.

- The WBS2 results depict floor to ceiling height as one of the most influential design parameters for building change of use.

- The AF project has given first priority to studying how floor to ceiling height can be perceived as a limitation for adaptability in buildings.

With these rationales in mind, the next section discusses each of them in detail.

8.3.1 Influence of floor to ceiling height in building change of use

3DReid (2006) explains that the majority of people in the UK live in buildings that were built during the last century or even earlier, whilst reasoning that there are sentimental values attached to aged buildings and it is expensive to demolish and rebuild them. Moreover, Gregory (2008) argues that it is significant that the aged buildings best suited to adaption are those with the most generous floor to ceiling heights. In addition to this literature, the previous case study (Loughborough town centre) indicates that the floor to ceiling height was a key design parameter for change of use in buildings whilst having the example of easy conversions of Victorian buildings for new uses. Thus, this section is used to compile this evidence to explain the influence of floor to ceiling height on building change of use.

First, the Loughborough case study indicates that the potential of aged buildings to adapt for new uses is because of their high floor to ceiling height and structural stability. Supporting this, two interviewees (appendix I: 3 and 11) explained that the longevity of aged industrial buildings and higher floor to ceiling height are in favour of change of use in historic buildings. Moreover, interviewee 11 explained that in *‘the previous era, the floor to ceiling heights were so minimal that they couldn’t put raised floors in. When people moved away from cellular offices to group working, those buildings had to be demolished simply because their floor to ceiling heights were inadequate for changes in technology. But equally, it is not that difficult now to foresee a time when there won’t be any cables for anything other than power anyway, and therefore building in excess height and volume into the buildings, which all has to be heated and serviced’.* Noticeably, this evidence explains the importance of high floor to ceiling height in facilitating different uses/tasks, as well as the limitations of high floor to ceiling height in building maintenance.

In addition, the secondary data of the Adaptable Futures case studies was used to explain a conversion of older Georgian buildings to new office use. In detail, this Georgian terraced house (located at 42 Portland Place, London) was built about 200 years ago for the purpose of accommodating a wealthy family with servants. Over its lifetime, it has been adapted to serve small and medium-sized consultancy businesses and has been sub-divided to provide small one or two beds flat at the same time. The loose fit concept, storey height and relatively generous room sizes of the Georgian town house allowed the uses of high quality residences, flats sub-divided on a floor by floor basis, office space for small businesses and hotel premises (Multispace 2006). This past evidence highlights the importance of considering higher floor to ceiling height in designing new buildings to respond to future potential changes of use.

Survey WBS2 was used to retest and generalise the statement that ‘the often higher floor to ceiling height in Victorian/Georgian architecture is responsible for their extended use’. The majority of respondents (15/32) agreed with this statement and 5 strongly agreed. However, 6 did not agree, 1 strongly disagreed and 5 were neutral. See Figure 8-4 for further details.

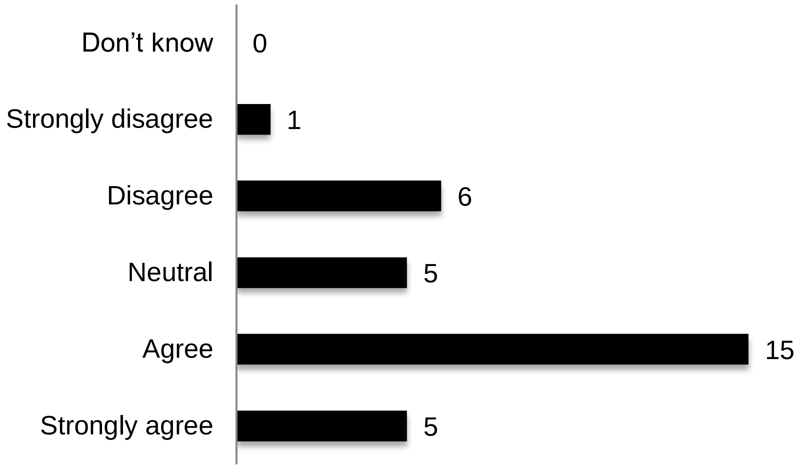


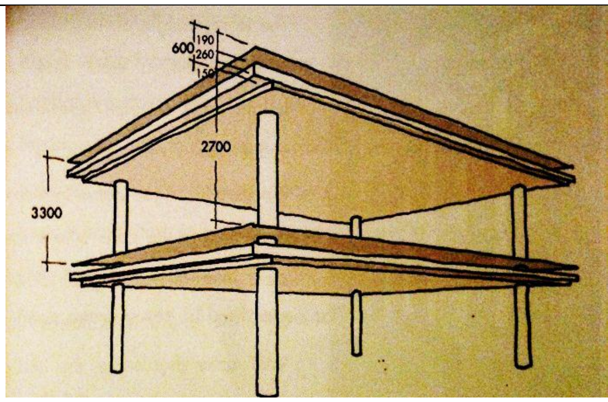
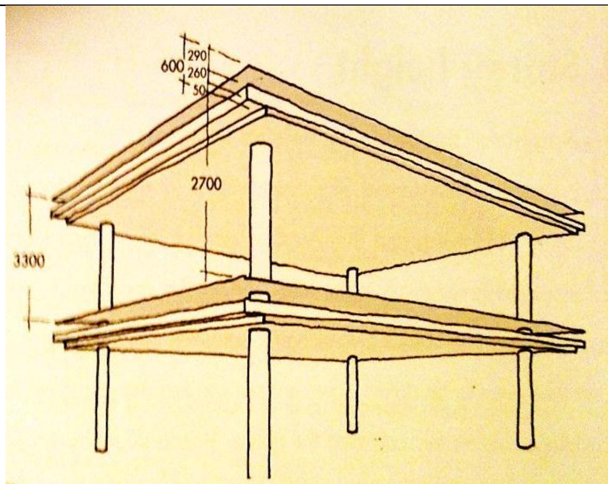
Figure 8-4: Respondents' attitudes on the significant influence of floor to ceiling height in aged buildings

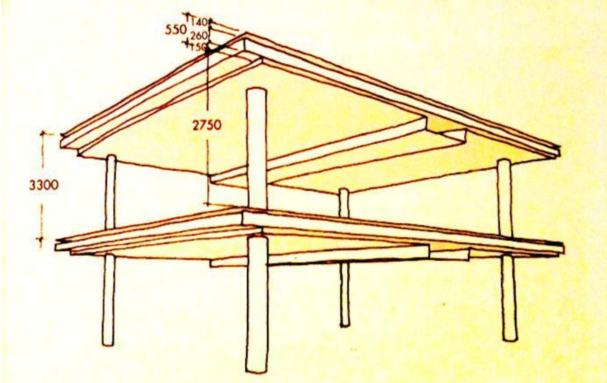
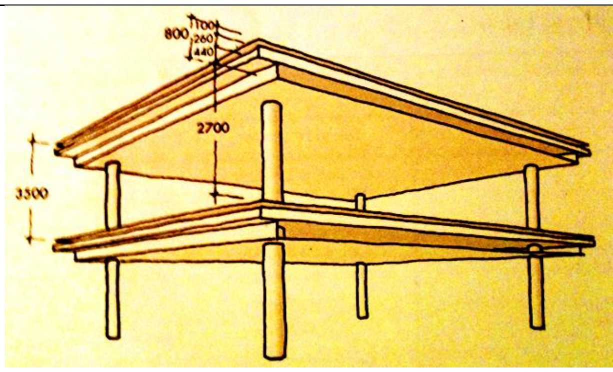
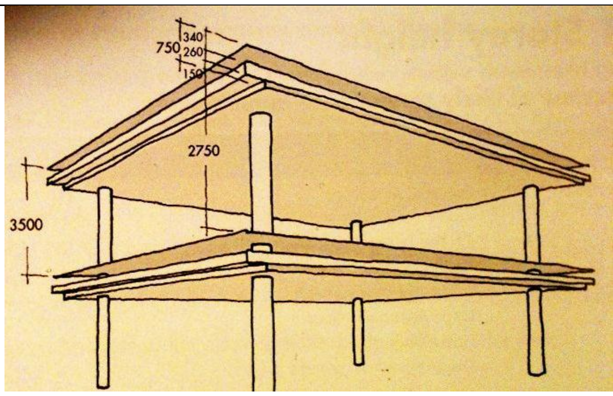
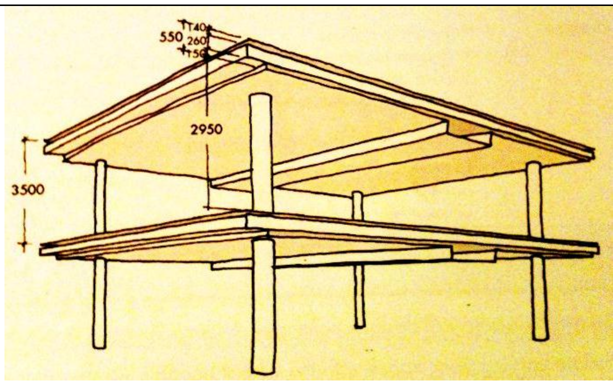
Hence, it is proposed that floor to ceiling height is the design parameter with the greatest influence on the potential for change of use. The majority of the respondents to WBS2 and the interviewees confirmed that floor to ceiling height could be considered to be a 'critical' design parameter for building change of use. In a way, the secondary data analysis supports this by highlighting that *'storey height'* has been at the heart of the problems of building change of use, which should be 'well enough to accommodate all proposed uses, yet low enough to avoid waste' (3DReid 2006 p.13). The Stewart Mason building study explains how floor to ceiling height practically helps the potential for change of use (in this case industrial to classroom) in buildings. The successful factors were the *'higher free ceiling height'*, *'larger spans'* and the *'higher load bearing capacity'* of the foundry structure. Supporting this, the findings of the web-based questionnaire surveys and the interviews clearly emphasise that floor to ceiling height plays an important role whilst being a critical design parameter for building change of use. This evidence supports this study by concluding that high floor to ceiling height boosts the possibilities for change of use in buildings. Therefore, designers should endeavour to design new buildings for adaptable economic heights.

8.3.2 Review of floor to ceiling height for adaptability

Generally, it is necessary to design buildings for economical/optimum floor to ceiling height. Higher floor to ceiling heights are not always encouraged in the economic agenda, though they attract several use typologies. If a building is designed to attract different use typologies to respond to potential change of use in the future, then the most appropriate (common for all uses) floor to ceiling height needs to be selected in the design. This study considers the facilitation of four use typologies: residential, hotel, office and retail. The secondary data analyses of the Multispace Design Guide (2006), WBS1 and WBS2 were used to identify the most economical heights for the aforementioned use typologies. Table 8-2 summarises how storey heights of 3.3m and 3.5m can be used to achieve a good level of adaptability.

Table 8-2: Review of storey heights for adaptability in buildings

Storey height	Space/Function	Sketch
3.3m	**<u>Office A</u>** 150mm suspended ceiling zone - lights and smoke detection only 2700mm clear internal ceiling height 190mm raised floor zone - Flexsys under-floor cooling, power and data supply 260mm flat slab	
	<u>Office B</u> 50mm ceiling zone – finish and smoke detection only (pendent uplights) 2700mm clear internal ceiling height 290mm floor zone – Flexsys/HIROSS under-floor A/C, power and data supply 260mm flat slab	

Storey height	Space/Function	Sketch
3.3m	**<u>Residential/Hotel bedroom uses</u>** 150mm ceiling zone – recessed lights and smoke detection (450mm dropped corridor zone; 2450mm high ceiling in corridor) 2750mm clear internal ceiling height 140mm floor zone – finishes (option for power and local drainage) 260mm flat slab	
3.5m	**<u>Office A</u>** 440mm suspended ceiling zone - fan coil A/C 2700mm clear internal ceiling height 100mm raised floor zone - power and data supply 260mm flat slab	
	<u>Office B</u> 150mm ceiling zone – recessed lights and smoke detection only 2750mm clear internal ceiling height 340mm floor zone – Flexsys/HIROSS under-floor A/C, power and data supply 260mm flat slab	
	<u>Residential/Hotel bedroom uses</u> 150mm ceiling zone – recessed lights and smoke detection (450mm dropped corridor zone) 2950mm clear internal ceiling zone 140mm floor zone – finishes (option for power and local drainage) 260mm flat slab	

Source: Multispace Design Guide (3DReid 2006)

The above table encapsulates how storey heights of 3.3m and 3.5m provide good adaptability for residential, hotel bedroom and office uses. The internal ceiling height is designed to change by facilitating the most appropriate service systems (HVAC and ICT). The depth of the structural slab is 260mm and it remains constant in all the derivatives.

Question 2 (Q2) of WBS1 was used to identify the generic floor to ceiling heights of residential, hotel bedroom, office and retail uses. The majority of the 13 respondents to WBS1 proposed 2.4m for residential, 2.7m for both hotel bedroom and office use and 3.6m for retail as typical internal floor to ceiling heights used in their practices. As previously noted, higher floor to ceiling heights improve the potential for facilitating multiple uses in a single space. However, it is worth considering these design provisions in the initial design rather than wasting money after conversion/demolition only if this height addition does not create an extra cost to the developer/owner.

Table 8-3: Typical floor to ceiling heights for different use typologies

Use	**Typical floor to ceiling heights**								**Total respondents**
	Less than 2.4m	2.4m	2.7m	3.0m	3.3m	3.6m	3.9m	More than 3.9m	
Residential	0	**7**	4	2	0	0	0	0	13
Hotel bedroom	0	3	**6**	1	3	0	0	0	13
Office	0	0	**7**	2	2	2	0	0	13
Retail	0	0	0	2	3	**6**	1	1	13

Having considered the findings of the secondary data analysis (Multispace Design Guide) and WBS1, it was interesting to identify that a floor to ceiling height of 3.5m (which provides higher flexibility for services integration) would be the optimum height to facilitate all four uses. Therefore, a question (Q8) was inserted into WBS2 to clarify this intuition. Of the 32 respondents to WBS2, 17 agreed with this statement and 5 disagreed; 10 respondents were neutral on this issue. See Figure 8-5 for more details.

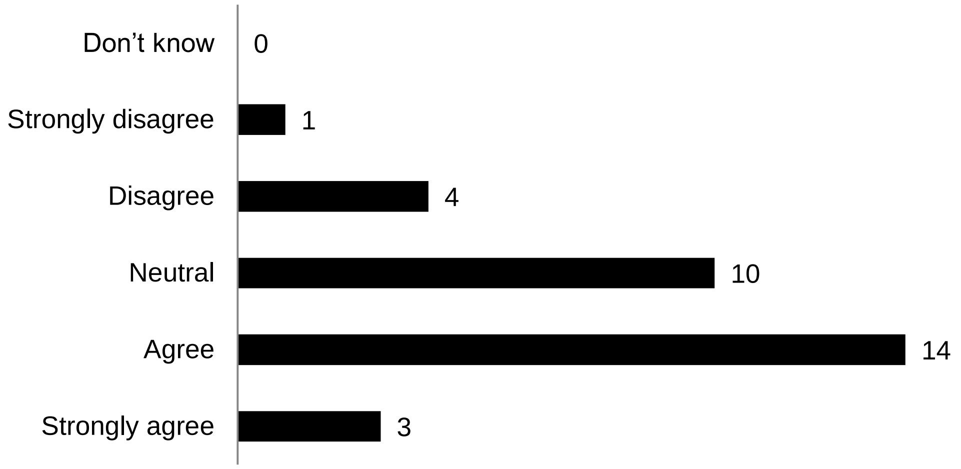


Figure 8-5: Respondents' attitudes to choosing 3.5m as the optimum floor to ceiling height

All these confirmations can be used to conclude that high floor to ceiling height provides a good opportunity for building change of use. In other words, floor to ceiling height can be considered to be a critical design parameter for building change of use. However, this needs to be tested through empirical evidence by comparing it with other design parameters for adaptability in buildings. In this regard, the establishment of adaptable height is highly important in the process of design for adaptation. Owners/developers are given much flexibility at the design stage to envisage the potential use typologies for their buildings. Sometimes, the potential use typologies may exceed the original building height if there are no more alterations to the structural and service zones. This information is needed in advance to calculate the total height of the building where height restrictions appear in planning regulations.

In short, the data derived from the web-based questionnaire surveys, semi-structured interviews and the case studies highlights floor to ceiling height as an influential design parameter for building change of use. The economic floor to ceiling heights for different use typologies were identified from WBS1 and WBS2. The next step is to explain the lifecycle extendibility of adaptable buildings, which is the third objective of this study.

8.4 Lifecycle extendibility of adaptable buildings

The application of adaptable techniques, tools and products is highly appreciated in the manufacturing, service and production industries when the products are driven from mass production to mass customisation. These innovative techniques (i.e. loose fit, plug and play) are often exploited in built environment facilities to extend their lifecycles. The ability to respond to future change is considered as innovative architecture (RIBA 2009) and adaptable buildings have high potential to respond to future changes. In this realm, design for change of use is assumed to be innovative and a good long-term investment. These issues were tested by analysing the opinions of the 32 architects and 42 quantity surveyors who responded to WBS2 and WBS3, respectively. See Figures 8-6 and 8-7 for more details.

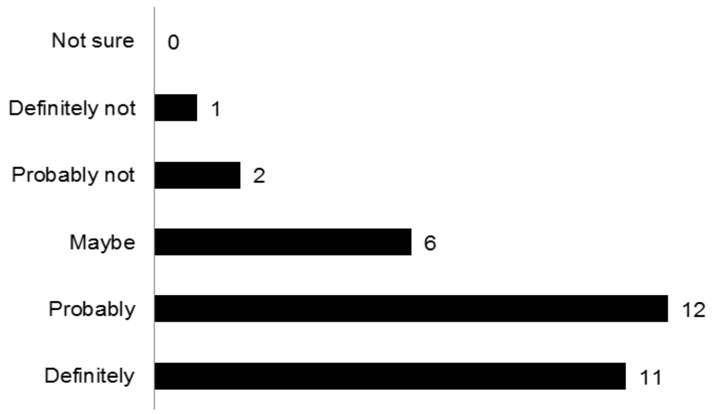


Figure 8-6: Architects' views on the statement "designing buildings for change of use represents innovative architecture"

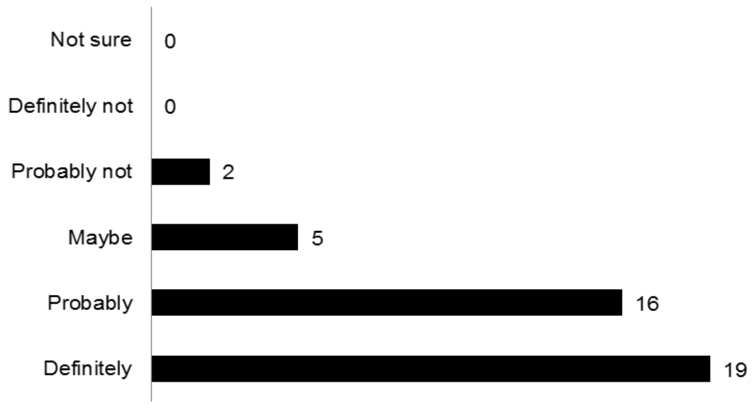


Figure 8-7: Quantity surveyors' views on the statement "designing buildings for change of use represents a good long-term investment"

Only three architects and two quantity surveyors disagreed with the assertion that designing new buildings to facilitate future change of use represents innovative architecture, with the strong majority of both groups considering that the statement was either definitely or probably true. Thus, this study concludes that designing buildings to facilitate future change of use represents innovative architecture, which provides good long-term investments to its owners/developers. Moreover, the respondents were asked about their attitudes on 'increasing the floor to ceiling height of a typical building (e.g. from typical residential to commercial heights) would be a good way of increasing its future convertibility'. Their attitudes on this issue are illustrated in Figures 8-8 and 8-9.

Figure 8-8: Architects' views on increasing floor to ceiling height increasing building convertibility

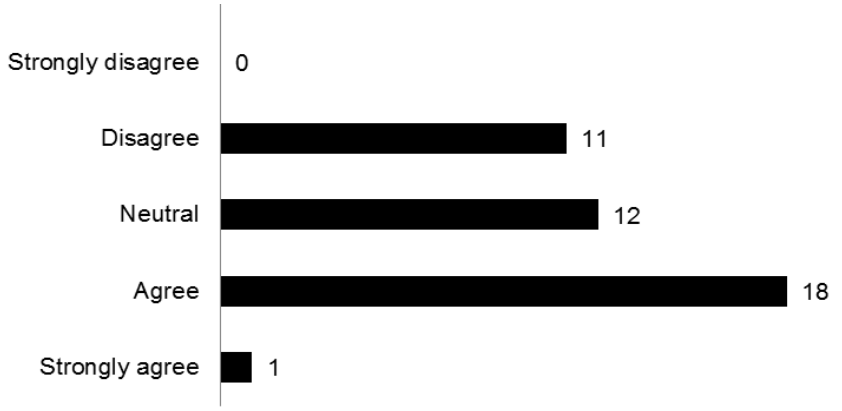


Figure 8-9: Quantity surveyors' views on increasing floor to ceiling height increasing future convertibility

Similarly, there was support for the statement that increasing floor to ceiling height increases future convertibility. However, this support was not as strong as for the previous assertion. Altogether, 32 (n_1) architects and 42 (n_2) quantity surveyors views were taken into consideration. The results explain that 10 of the 74 respondents strongly agreed, 31 agreed, 21 were neutral and 12 disagreed with the above statement. However, these views were taken from two different samples and it is necessary to analyse the variance of their ideas. Thus, the t-test was used to compare the mean values of two samples with 72 (n_1+n_2-2) degrees of freedom. The null hypothesis was 'there is no difference between the views received from architects and quantity surveyors for the above statement'. The calculated t-value was 3.65 and this exceeds the tabulated values (t-test table) for $p = 0.05$ and 0.01, as well as 0.001. Thus, the result has a 99.99% level of significance.

In short, this section concludes that practitioners' views on increasing the future convertibility of buildings include designing higher floor to ceiling heights. The next section elaborates the practical options for increasing the floor to ceiling heights of buildings.

8.4.1 Practical options for increasing floor to ceiling height

As elucidated before, the possibility for building change of use is evaluated in terms of floor to ceiling height. The ultimate need is to make the building more adaptable for future change of use, which primarily depends upon its designed floor to ceiling height. More importantly, other design parameters (plan depth, design loads, structural span, etc.) need to be considered in a flexible manner for prospective change of use. Typical scenarios for increasing the floor to ceiling height of a multi-storey building were considered in WBS2. First, respondents were asked about their views on the statement: '*running building services through the structural beams in a multi-storey framed building is an effective way of maximising finished floor to ceiling height without increasing the overall height of a building'*. For the results, see Figure 8-10.

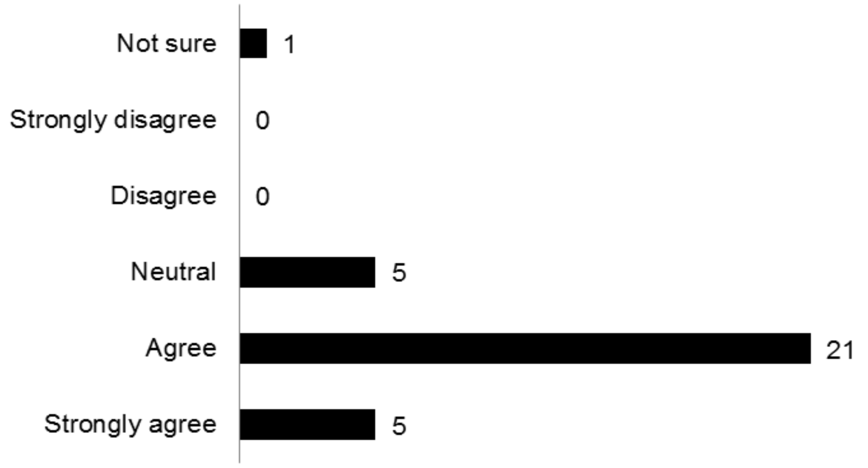


Figure 8-10: Architects' views on increase floor to ceiling height by integrating services and structural systems

Highly positively, 5 respondents strongly agreed with the above statement and 21 of the 32 respondents agreed. However, 5 were neutral and 1 respondent was not sure about his/her answer to the statement. Second, the respondents were requested to give their views on the statement: *'increasing the structural floor to floor height and thus the overall height of the building is the most frequent way of increasing the finished floor to ceiling height'.* Two strongly agreed with this statement and 17 respondents agreed with it; 9 had a neutral attitude about this statement, 3 disagreed and again 1 was not sure (see Figure 8-11).

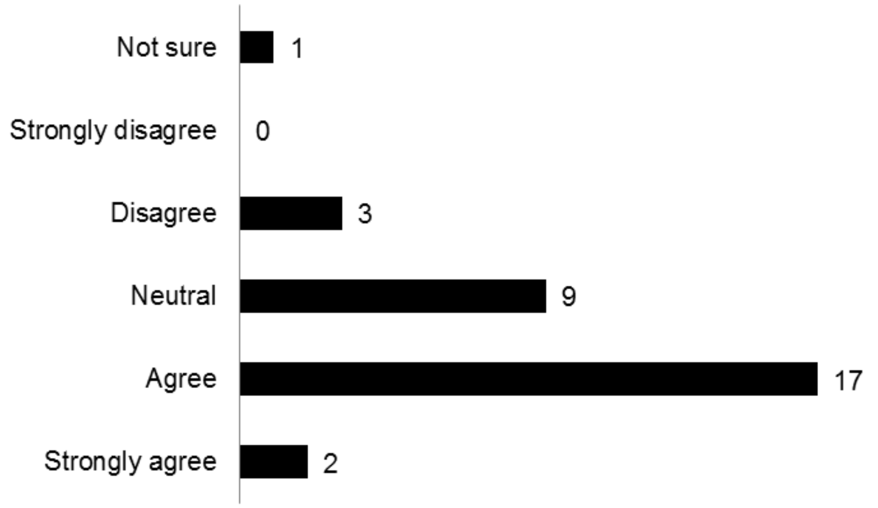


Figure 8-11: Architects' views on increasing floor to ceiling height by increasing structural floor to floor height

The majority of the respondents to WBS2 believed that integrating services and structural systems is an effective way to increase the floor to ceiling height of a building. On the other hand, they stated that increasing the structural floor to floor height and thus the overall height of the building would be the most frequent way of increasing the finished floor to ceiling height. However, the most popular choice (increasing the total height of the building) would not often be appreciated in the planning and building regulations process. Thus, the respondents to WBS2 and WBS3 were questioned on their attitudes on '*increasing the overall height of a building in a town centre is not usually an option due to planning restrictions'.* Of the 32 architects, 15 agreed with the statement. However, 10 disagreed: 1 of whom strongly disagreed (see Figure 8-12).

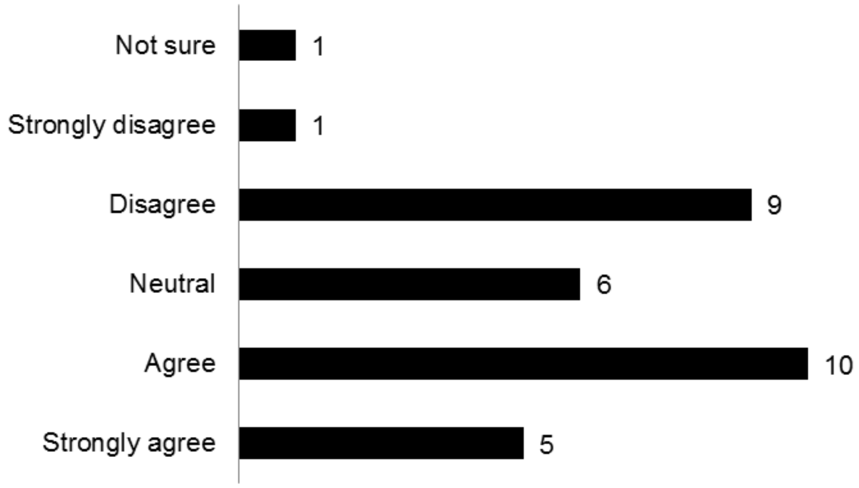


Figure 8-12: Architects' views on planning restrictions affecting the increase of building heights in town centres

Moreover, question 6 of WBS3 (see appendix D3) was used to understand quantity surveyors' views on how planning restrictions would affect the height increases of buildings in town centres. Of the 42 quantity surveyors, 3 strongly agreed that increasing the overall height of a building in a town centre is not usually an option due to planning restrictions. A further 20 agreed and 10 disagreed with this statement, whilst 9 responded neutrally. The results are illustrated in Figure 8-13.

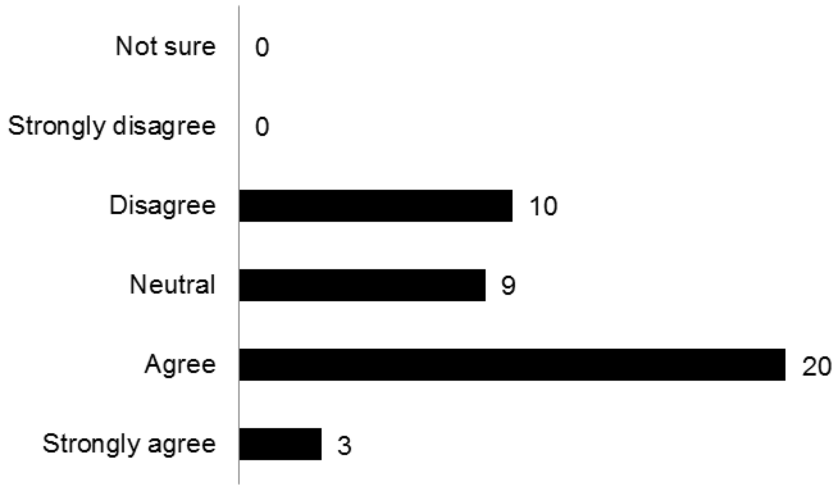


Figure 8-13: Quantity surveyors' views on planning restrictions affecting the increase of building heights in town centres

Again, the t-test was used to compare the mean values of both architects' and quantity surveyors' attitudes on the above issue. The calculated t-value was 0.73 and this exceeds the tabulated values (t-test table) for p = 0.25. Thus, the result has a 75% level of significance.

This section explained the lifecycle extendibility (potential for change of use) of buildings with high floor to ceiling heights. The most frequent and effective ways to increase the floor to ceiling heights of new buildings were proposed through empirical evidence. The next section explains the economic considerations for adaptability in buildings.

8.5 Economic considerations for adaptability in buildings

This section aims to identify the economic considerations for adaptability in buildings. The data was gathered from two main sources. First, BCIS (Building Cost Information Service) cost data of four use typologies (residential, hotel bedroom, office and mixed use) was analysed to identify the most cost-consuming building elements. Amplified elemental cost analyses were used to categorise the costs into their *'shearing layers'* (Brand 1994) to identify how the initial costs of building layers may vary with their lifespans. Secondly, the survey WBS3 was undertaken with quantity surveyors to identify the most significant cost and benefit considerations for adaptability in buildings. The typical scenarios considered in section 8.4.1 were used to identify the cost of increasing floor to ceiling height.

8.5.1 Analysis of initial capital costs of buildings

The cost data of buildings (residential, hotel, office and mixed use) of 4 – 12 storeys was collected from the Building Cost Information Service (BCIS) online database to model the initial capital costs of building elements. The main purpose of this analysis was to recognise the costs of significant building elements and then to include them in WBS3 to identify their influence on the cost of adaptation.

The original costs of previous projects were brought in line with present day costs by using the tender price index (TPI) of 249 (fourth quarter of 2008) and the UK mean index 100 to make adjustments for price and location, respectively. However, it is not practical to estimate the costs of building elements prior to detail drawings. Therefore, priority should be given to identify the cost-significant elements according to the Pareto principle, which is that 80% of cost is represented by 20% of building elements. In other words, it is necessary to distinguish between the *‘vital few’* and the *‘trivial many’* items (Ahmed 1995).

Regarding adaptability, the amplified (sub-elemental) cost analyses were used in this study to understand the costs of building layers in association with their lifespan considerations. When designing buildings for potential adaptations, building decomposition is highly renowned as a key consideration for adaptability. Many authors use the terms ‘structure’ or ‘shell’ to define the structural system (this study identifies the frame, upper floors and external walls as the components of a structure), ‘skin/exterior enclosure’ for the external façade, ‘services’ for the service system and ‘space plan’ for the internal walls and partitions (Rush 1986, Duffy 1990, Brand 1994, Slaughter 2001). With buildings that are purpose built and difficult to adapt, the cost of refurbishment can be as high as building anew. It is more sensible to design buildings that can serve a variety of needs with minimal work to the shell/structure and easy for the fit-out (3DReid 2006). The structure and fabric of the built environment is a value-generating asset, increasing over time, whereas the internal fit-out is consumable and devalues over time (Gibb *et al*. 2007).

The element unit costs of 17 residential, 15 office, 5 hotel and 12 mixed-use buildings were identified within the category of 4-12 storeys, which were constructed during the last 20 years (see appendix H for detailed information). However, the missing data of building elements, composite building costs and undefined structural and service systems were found to be a major difficulty in terms of splitting the total costs into their elements/shearing layers. The buildings with these difficulties were not considered in the shearing layer cost analysis.

Apart from two buildings in the residential sample, the superstructure (frame) of all the other buildings consisted of reinforced concrete, precast concrete or steel. Cross-wall construction was used in the superstructures of two buildings; however, those were not taken into consideration because they are not acknowledged in the context of adaptability. The precast and reinforced concrete upper floors were represented as high cost in the selected sample. The external façades invariably consisted of facing bricks and block cavity walls. Block internal walls, timber stud partitions and central and local heating systems with natural ventilation can be identified within the selected residential sample. However, undefined service components were found in three buildings. Under these circumstances, 7 of the 17 residential buildings were considered in the shearing layer analysis (see Figure 8-14).

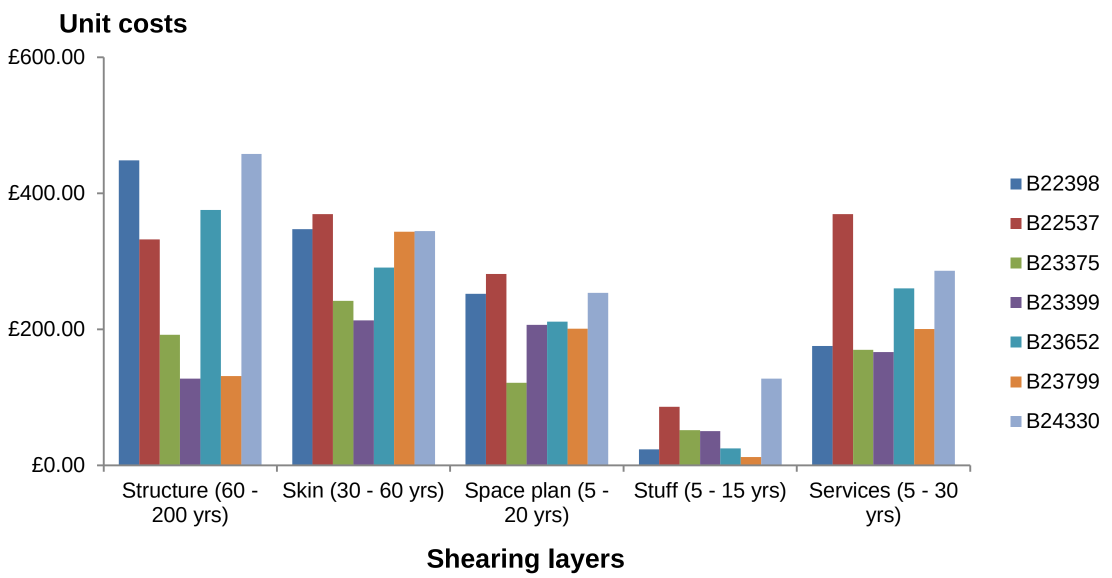


Figure 8-14: Costs of shearing layers (residential)

The average unit costs for the structure, skin, space plan, stuff and services of the selected residential buildings were £295, £307, £218, £53 and £232, respectively. Except the 'stuff' layer, all the other layers have similar average unit costs. However, no remarkable pattern could be seen between the unit costs and the lifetime of each layer. Similar analyses were undertaken for office, hotel and mixed-use buildings to identify the costs of shearing layers.

All the office buildings in the selected sample were supported by structural frame systems. Eight of them consisted of steel, six were precast concrete and one used a composite system. Many of the upper floors were made of precast concrete slabs. The external façade was of facing bricks with either curtain walling or cladding in-fills. Block walls were used internally, while glazing and plasterboard were commonly used on metal studs as partitions. Gas central heating and mechanical ventilation systems were the most popular HVAC systems in many of the selected office buildings. Even though there were 15 office buildings in the elemental analyses, 10 buildings were considered in the shearing layer analyses. The main difficulty arising from the selected building sample was the presence of undefined and composite elemental costs. The cost of service systems highly dominates the initial capital costs of offices in the selected building sample. In addition, the structure and skin represent a considerable portion of the total construction cost. The unit costs of the shearing layers regarding the office buildings are illustrated in Figure 8-15.

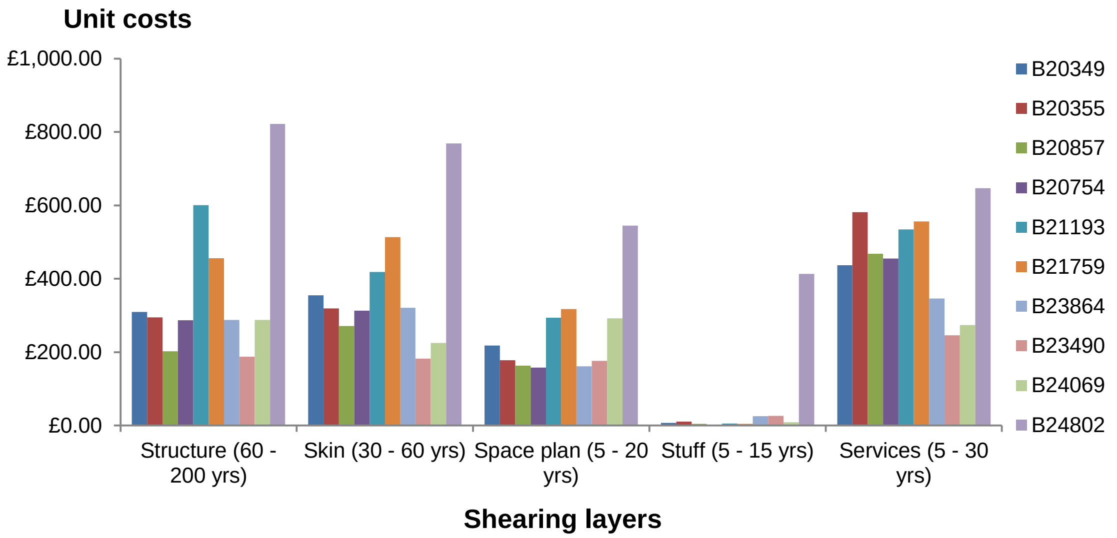


Figure 8-15: Costs of shearing layers (office)

The average unit costs of the structure, skin, space plan, stuff and services of the selected office buildings were £373, £368, £250, £50 and £454, respectively. The unit cost of the services layer was high compared to the other layers.

Moreover, five hotel buildings were considered in the BCIS elemental cost analysis. The superstructures (frames) of them consisted of reinforced concrete and steel. Reinforced concrete for upper floors can be seen frequently within the selected hotel sample. The external walls were made of facing bricks and blocks with cladding façades. However, no clear specifications were available about the adopted service systems, which remained an undefined service system. Thus, the cost analysis in respect to shearing layers was limited to two hotel buildings because of the undefined elemental costs (see Figure 8-16).

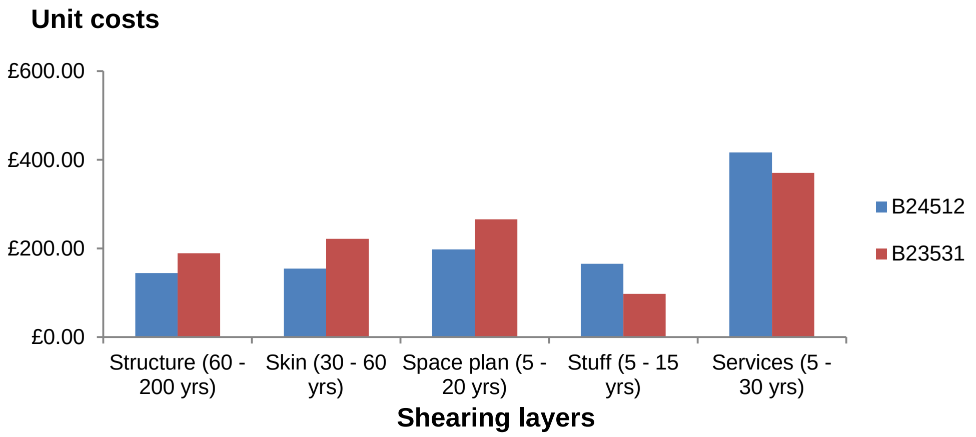


Figure 8-16: Costs of shearing layers (hotel)

The average unit costs of the structure, skin, space plan, stuff and services of the selected hotel buildings were £167, £188, £232, £131 and £394, respectively. The unit cost of services is noted as the most cost-consuming element in the selected hotel buildings. However, by having only two hotel buildings in the sample, it is difficult to make such conclusions.

Many of the structural frames of the 12 selected mixed-use buildings were constructed of in-situ reinforced and precast concrete. Many of the upper floors were made of precast concrete and the external walls had facing bricks/blocks with curtain walls or metal cladding façades. Electric and gas heating systems were very common within this sample. Block internal walls and metal/timber stud partitions seem quite popular within the selected mixed-use buildings. Of the 12 mixed-use buildings, 6 were considered in the analysis of the costs of shearing layers (see Figure 8-17).

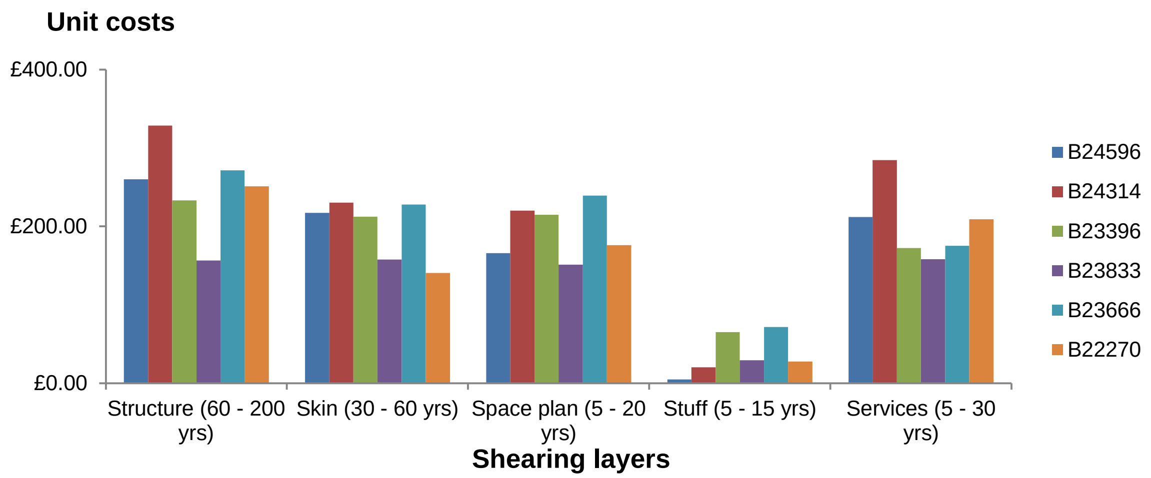


Figure 8-17: Costs of shearing layers (mixed use)

The average unit costs of the structure, skin, space plan, stuff and services of the selected mixed-use buildings were £250, £198, £194, £37 and £202, respectively.

Figure 8-18 summarises the unit costs of the shearing layers of the four selected use typologies.

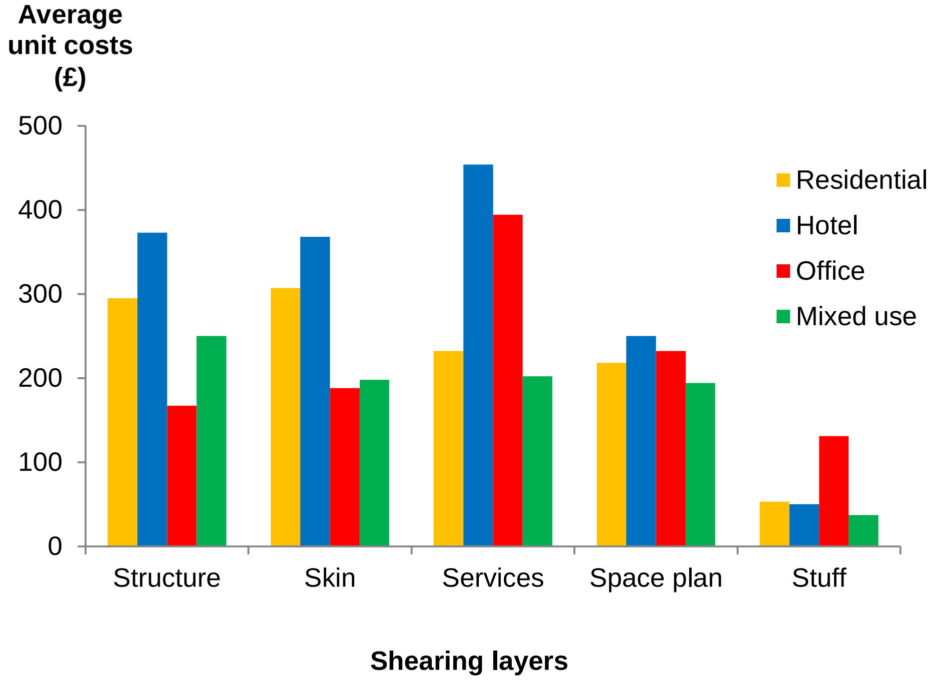


Figure 8-18: Unit costs of the shearing layers of the four use typologies

In summary, the cost analyses detailed in this section were used to identify the most cost-significant building elements and the unit costs of respective shearing layers. This analysis identified that structure, skin, services and space plan are the most cost-consuming shearing layers of buildings. Thus, these four elements were included in the web survey (WBS3) to study the cost variation of these elements when designing buildings to respond to potential change of use. The next section explains the cost of building change of use.

8.5.2 Total cost of building adaptation

The previous section (8.4) detailed how the lifecycle extendibility of buildings can be achieved by designing them for optimum floor to ceiling heights. The same section discussed two scenarios (i.e. most effective and most frequent) ways for increasing the floor to ceiling heights of typical buildings. This section explains the total cost consideration for adaptability in buildings. The data was gathered from WBS3. The respondents (42 quantity surveyors) were invited to rank the level of significance of generic building costs by assuming that the building is designed to respond to future changes. A seven point Likert scale was used to evaluate their attitudes towards cost of adaptation (significant = 6, high = 5, moderate = 4, low = 3, very low = 2, none = 1 and not sure = 0). See Figure 8-19 for more details.

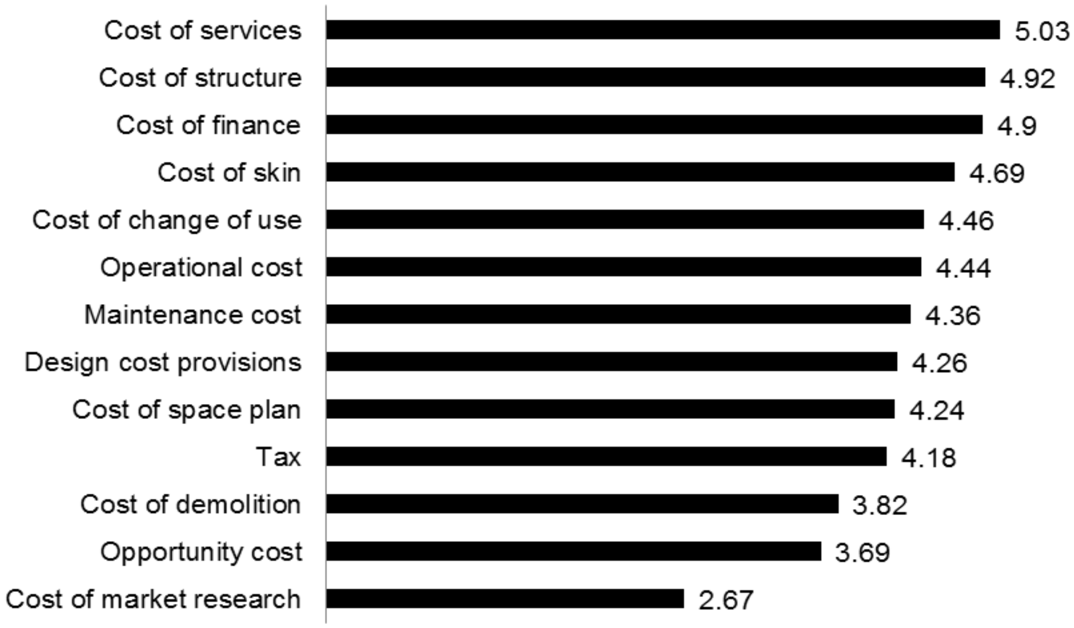


Figure 8-19: Level of significance of building costs for change of use

Of the 42 quantity surveyors, 39 completed this question. The results explain that the initial cost of building services, the structure cost, the cost of finance and the initial cost of skin have a high level of influence on the adaptability of buildings. Regarding the cost of change of use, it seems that timely adaptation (e.g. cost of staff relocation and alterations to the building) also influences building change of use. In addition, operational cost, maintenance cost, design cost provisions (e.g. space and load provisions for potential adaptation), cost of space plan and tax levels reflect high (4 of 6) levels of significance. The cost of adaptation determines the total lifecycle cost that will increase when designing buildings to respond to future changes. Moreover, interviewee 6 explained that *'some form of adaptability should be incorporated in the original design. In essence, the 'cost of adaption' is an encouraging factor in the design of new buildings in so far as it relates to the extension of their life/use. A cost plan for a client should include all costs, including costs for adaptation, so the client can make an informed decision regarding the project that he is preparing to invest a significant amount of money in. It increases the desirability and provides additional options for the end-user to consider and also provides the investor with potentially an increased multi use space'*.

Next, the respondents were asked for their views on '*running building services through the structural beams in a multi-storey framed building is an effective cost-effective way of maximising finished floor to ceiling height without increasing the overall height of a building'.* A total of 42 respondents completed this question and the results are shown in Figure 8-20.

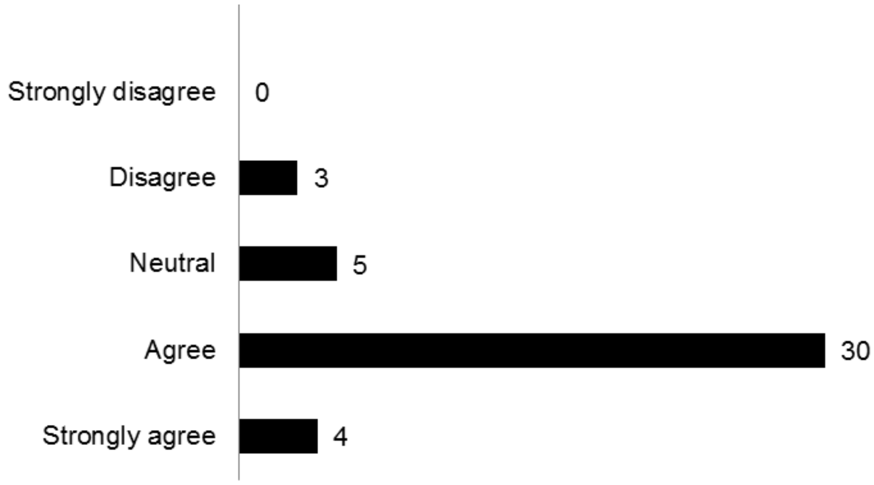


Figure 8-20: Quantity surveyors' views on the statement that increasing floor to ceiling height by integrating services and structural systems is cost-effective

Of the 42 respondents, 4 strongly agreed, 30 agreed, 3 disagreed and 5 were neutral regarding this statement. Moreover, they were asked about the cost-effectiveness of the most popular option for increasing floor to ceiling height (i.e. '*increasing the structural floor to floor height and thus the overall height of the building is the most frequent way of increasing the finished floor to ceiling height').* The results are shown in Figure 8-21.

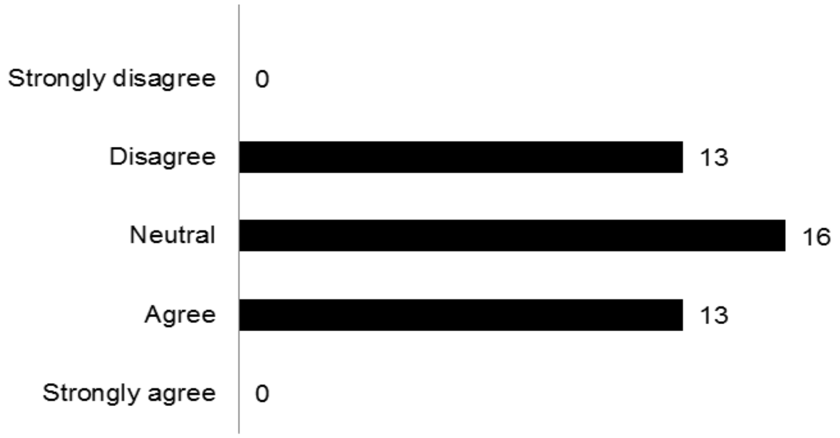


Figure 8-21: Quantity surveyors' views on the statement that increasing structural floor to floor height is a cost-effective way to increase floor to ceiling height

Interestingly, 13 of the 42 respondents agreed with the statement whilst 13 disagreed. No respondents strongly agreed or strongly disagreed. A total of 16 respondents had neutral views on this issue.

Having compared the views of the same respondents in two different scenarios, it can be concluded that quantity surveyors believe that increasing floor to ceiling height by integrating services and structural systems is a cost-effective endeavour for future change of use in buildings. In summary, the economic considerations for adaptability in buildings play a vital role in clients' financial and economic agendas. The cost of building services, the structure cost, the cost of finance and the cost of skin influence the total cost of adaptation.

Moreover, interviewee 7 explained that *'the cost of adaption is not significantly considered in the design of buildings because developers and banks are only interested in short-term gain. It should not be a critical factor in new buildings because current design should appreciate modern, quick, modular systems that have much shorter design lifespans. Significant reductions in relative build costs to date and in the future means we should demount and rebuild, not adapt. For instance, to allow for larger floor to ceiling heights, a possible result of this is that the cost to heat the property could be perceived as extremely expensive in the* *current climate of high fuel costs whilst also seen as not an environmentally sound building'*. The next section elucidates the expected benefits of designing new buildings to respond to potential adaptation.

8.5.3 Expected benefits from design for adaptation (DFA)

The literature reveals the potential benefits of designing buildings for future adaptations. This study also gives priority to identifying the benefits of potential adaptations because economic considerations seemingly play an important role in the client's decision-making protocol. The survey WBS3 was used to rank the potential benefits of design for adaptation. Of the 42 respondents, 40 completed the question and the results are shown in Figure 8-22.

Figure 8-22: Expected benefits from design for adaptation

The results reveal that 'potential income' by selling, letting or leasing is the most prominent benefit that would be received from DFA. In addition, economic, environmental and social sustainability can be boosted through DFA. The tax concessions of DFA are also acknowledged. In addition, the respondents noted the flexibility for internal reconfiguration as a good benefit; however, the important issue is to identify who is responsible for undertaking post-construction changes to particular buildings. Therefore, it is important to identify/define stakeholders' responsibilities at the design stage. In fact, several environmental and social benefits are perceived to come from adaptable buildings. There would be fewer redundant buildings in a neighbourhood, thus contributing to reduced crime rates, which would improve the social wellbeing of the area. The demolition rate would be reduced because the building has the potential of accommodating new uses in addition to its original use. Certainly, this could help to minimise the amount of demolition waste taken to landfill sites, which would lower the carbon footprint. Almost all the benefits elucidated lead towards the lifecycle extendibility of buildings.

Moreover, the respondents to surveys WBS2 and WBS3 were asked about their views on the question: *'Would it be good, sustainable practice to build city centre residential blocks in such a way that they could be more easily adapted for other uses in the future?'* Altogether, 32 architects and 42 quantity surveyors completed this question. The results were analysed individually and are illustrated in Figures 8-23 (architects) and 8-24 (quantity surveyors).

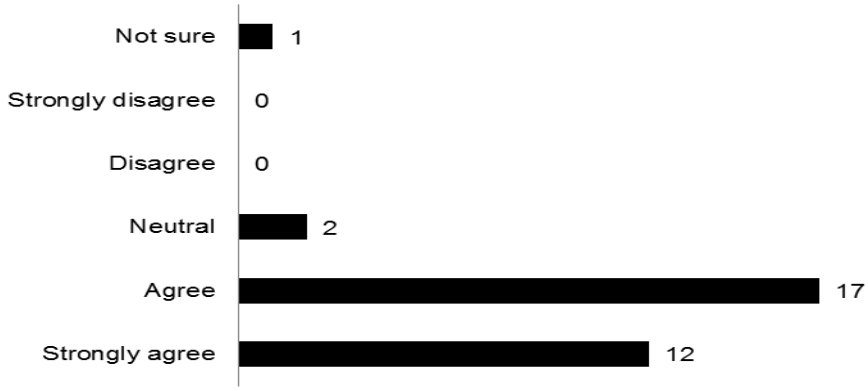


Figure 8-23: Architects' views on adaptable buildings being sustainable

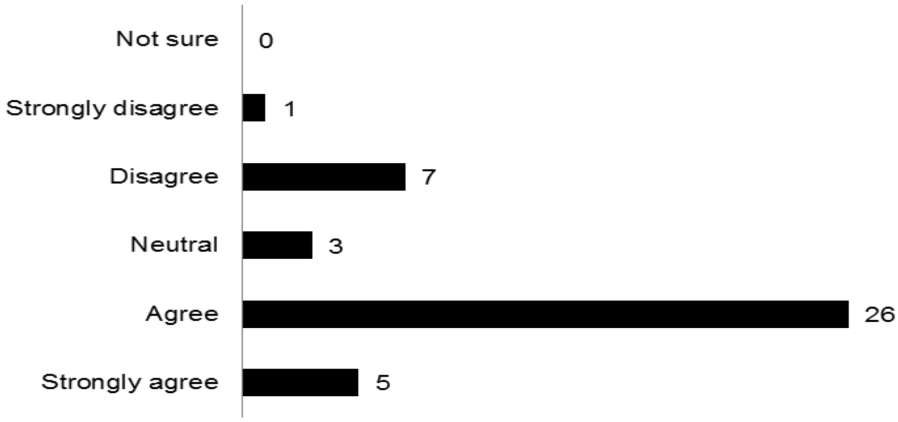


Figure 8-24: Quantity surveyors' views on adaptable buildings being sustainable

A total of 74 respondents answered this question: 17 strongly agreed with the statement, whilst 43 agreed. A further 5 respondents were neutral, 7 disagreed, 1 strongly disagreed and 1 was not sure. Moreover, the t-test was calculated to find any variance between the answers given by the architects and the quantity surveyors. The t-value was 2.50 and this exceeds the tabulated values (t-test table) for $p = 0.10$ and 0.05 with 72 degrees of freedom. Thus, the result has a 95% level of significance. In addition, the unstructured interviews with interviewees 5 and 9 point out that residual value is one of the benefits of adaptable buildings; however, the risk associated with adaptable decisions seems to be a dis-benefit.

The above empirical investigations identified the cost and benefit considerations for adaptability in buildings. The identified cost categories specific to adaptable buildings were inserted in the ISO 15686 – Part V (2008) cost breakdown structure. The cost of market research is categorised as a non-construction cost and the initial cost of adaptation is inserted under the category of construction cost, as it is reflected through the costs of the structure, external façade, service system and the internal walls and partitions. The cost impacts of maintenance, operational and end of life costs were identified and listed under the particular categories. This cost breakdown can be seen in Table 8-4.

Table 8-4: Cost breakdown structure for adaptable buildings

Cost category	Description	Level of cost significance (adaptable buildings)
Non-construction	Site cost	-
	Cost of finance	**High**
	Research and development	Low (market research)
	Cost of preliminaries	Low
	Grants and concessions	Depends
	Opportunity cost	Moderate
	Occupancy cost	Low
Lifecycle		
- **Construction**	Professional fees (inc. design)	Depends
	Temporary works	-
	Cost of structure	**Significant**
	Cost of services	**High**
	Cost of skin	**High**
	Cost of space plan	**High**
	Initial adaptation or refurbishment	**High (cost of space and load provisions)**
	Cost provisions for future adaptations	**High**
	Tax	**High** (initial loan is high)
- **Maintenance**	Replacements of major systems	-
	Adaptation or refurbishment	**High**
	Repairs and minor replacements	Low
	Maintenance management	Low
	Cleaning	Low (extra space)
	Grounds maintenance	-
	Redecoration	As expected
	Taxes	Low
	Other (user definable)	-
- **Operation**	**Rent/energy costs**	**High** (heat/cool extra space)
	Insurance	Low
	Cyclical regulatory costs	-
	Services to extra space	Low
	Taxes	Low

	Future regulation	Low
	Other (user definable)	Depends
- **End of life (functional/ economic)**	Disposal inspections	-
	Disposal and demolition	Moderate
	Change of use/adaptations	**High**
	Reinstatement	-
	Taxes	Negligible (promote reuse)
	Staff relocation	Low (high marketability and staff relocation)
	Other (user definable)	-
Income	**Rent**	**High** (inbuilt adaptable potential)
	Residual value/grants	**High** (adaptive reuse)
	Third party income (service charges)	Low (sustainable)
	Income tax	Moderate
	Disruption (down time)	-
Externalities	Other associated costs (social and environmental costs)	Low

Source: Adapted from the ISO 15686 – Part V (2008)

The cost breakdown structure enables the identification of the specific cost and benefit (monetary) categories of adaptable buildings.

8.6 Summary

There is a real pattern of building change of use. New planning policies and regulations support this strategy (design for adaptation) whilst paying much attention to sustainable requirements. However, little evidence shows that existing buildings are fully capable of accommodating this change. The practice of converting existing buildings for new uses, even when unplanned, has continued to become even more prevalent in recent times, in spite of the fact that their structures, fabric and services were not designed to readily accommodate such conversions or adaptations (Madden and Gibb 2008). In this study, it was identified that there is an urgent need to design new buildings for future potential change of use and *'floor to ceiling height/free ceiling height'* appeared as the most influential design parameter for building change of use.

The dominant cost and benefit categories of adaptable buildings were identified under the ISO 15686 – Part V (2008) standard cost breakdown structure. The research and development cost is an essential cost component for identifying the potential future markets for adaptable buildings, which is categorised as a non-construction cost. The semi-structured interviews and the findings of the web-based surveys were exploited to confirm the results. The cost of construction, maintenance, operation and end of life play a major role in the category of the lifecycle cost of adaptable buildings. To identify such influences, BCIS cost information on the selected use typologies was remodelled into individual shearing layers, which were structure, skin, services, space plan and stuff. The costs of structure, skin, services and space plan highly influence change of use scenarios. Reasonable increments in the costs of maintenance and operation could be expected in adaptable buildings. The benefits are gained at the end of life (the residual value) and the potential income from inbuilt adaptations. The suitability of discounted methods and real option analysis for evaluating the whole life analysis of adaptable buildings is discussed in the literature; however, no such evaluation was undertaken in this study. The findings of chapters 7 and 8 are integrated in chapter 9 and a conceptual framework is developed and tested for its suitability in adaptable contexts.

Chapter Nine

9. DEVELOPMENT AND VALIDATION OF CONCEPTUAL FRAMEWORK

9.1 Introduction to chapter nine

This chapter explains the development and validation process of a conceptual framework for evaluating the economic considerations for adaptability in buildings. The framework incorporates the findings of the first four research objectives (1 - 4) and guides the users (clients/owners/developers) towards an understanding of the cost and benefit aspects of adaptable buildings during the early stages of design. The first section justifies the need for developing a conceptual framework to identify the economic costs and benefits in relation to adaptability in buildings. The second section elaborates the development process of the conceptual framework and the rationale behind integrating its key features. The third section explains the validation of the developed conceptual framework, pertinent issues and proposed assumptions to be used in its practical application. The last section of this chapter is an evaluation of benefits and limitations of this framework.

9.2 Need for developing a conceptual framework

A real need for designing new buildings to facilitate potential adaptations was discussed in Chapter 2. When compared to manufacturing and production industries, the application of adaptability tools and techniques in built environment facilities is poor. From the clients' perspective, designing buildings for potential adaptation is merely a case of making economic decisions for immediate and long term futures. From the designers' perspective it is a value added decision for owners and users where, frequently, market demand determines the value. Thus, it is important to assist clients/owners/developers on 'what to do' to identify this 'value' at the design stage of a project, which would then support the decision to continue or abandon the design for adaptation (DFA). A framework is related to making recommendations of 'what to do' and 'what should be done' (McIvor 2000). On the other hand, it acts as a benchmark, providing a frame of reference (Male *et al*. 1998). However, no developed tools are available to evaluate the costs and benefits of adaptations; as the owners/developers are reluctant to invest in adaptable designs. Adaptable building designs provide a myriad of benefits over maladaptive designs (Watson 2009). Therefore, there is a necessity to understand cost and benefit aspects of adaptable buildings at the project's preliminary stage as these can be used to determine the value of the buildings.

The literature supports the need for such a tool/framework to identify economic costs and benefits of adaptability in buildings. There is a vital need to understand what physical and economic criteria should be considered in designing new buildings to respond to the potential change. Such identification should offer an opportunity to bring the empirical knowledge and evidence to develop this framework. There are several frameworks for evaluating the adaptable potential of existing buildings (Geraedts and Vrij 2003, Shen and Langston 2010, Bullen and Love 2011). For example, Bullen and Love (2011) propose a framework to make decisions on adaptive reuse by evaluating the economic, social and environmental aspects of existing building. However, current construction practices lack a tool or framework to predict the adaptable potentials and their economic considerations for new buildings. Thus the development of such a framework would help to provide economic advice to its users regarding costs and benefits for adaptability in new buildings. In general, conceptual frameworks are proposed to support understanding of an issue or area of study, provide structure, communicate relationships within a system for a defined purpose, and support decision making and action (Phaal *et al.* 2004).

The conceptual framework being proposed here contains elements linking concepts from literature and empirical evidences to support the determination of value through design for adaptation. The case studies and empirical investigations described in previous chapters provide pertinent evidence to explain the real need for designing new buildings for potential change of use (see section 2.4) and underline the specific design, physical (see sections 7.2 and 8.3) and economic criteria (see sections 8.4 and 8.5) for adaptability in buildings. The purpose of this chapter is to combine the outcomes of each of these endeavours to construct a practice-grounded conceptual framework in order to determine economic considerations for adaptability in new buildings.

9.3 Conceptual framework development

The importance of developing a conceptual framework for identifying the economic considerations for adaptability in buildings is explained in the previous section. An early identification of these costs and benefits for adaptation facilitates correct decisions in terms of both finance and economic grounds. Many of the inputs to the proposed conceptual framework were identified through the previous studies discussed in chapters 7 and 8, which include case studies, web-based surveys, secondary data analysis, and both semi-structured and unstructured interviews. Having collected all the information in a particular order, a desk study was used to interlink the most appropriate 'physical' and 'economic' criteria for potential adaptations. The framework exploited a whole life analysis approach (see section 6.3) for evaluating the economic costs and benefits for adaptability in buildings. Moreover, the suitability of 'discounted' and 'real option' methods for measuring the costs and benefits of adaptation was discussed in Table 6-2. The aim of this conceptual framework is to support clients and developers in their economic decisions on design for adaptation. The key objectives are:

- to explain how the choice of adaptable technology, materials and design in designing new buildings can facilitate potential change of use (design/physical criteria);

- to identify the incurred costs that clients, owners and developers might have to bear and the benefits they will receive from designing new buildings to respond to future potential changes of use (economic considerations); and

- to assist clients and developers regarding what cost increments (initial and operating) will be necessary to take place, how and when they need to be allowed for (whole life analysis).

The framework consists of four main phases. The first phase helps determine the design/physical criteria for adaptability in buildings. The second phase explains the integration of economic criteria, which were derived from the empirical investigations. The third phase encapsulates the process of economic evaluation for adaptability in buildings. The final phase informs the decision on whether to design the building to adapt or not. The developed conceptual framework is illustrated in Figure 9-1 and its development is explained thereafter.

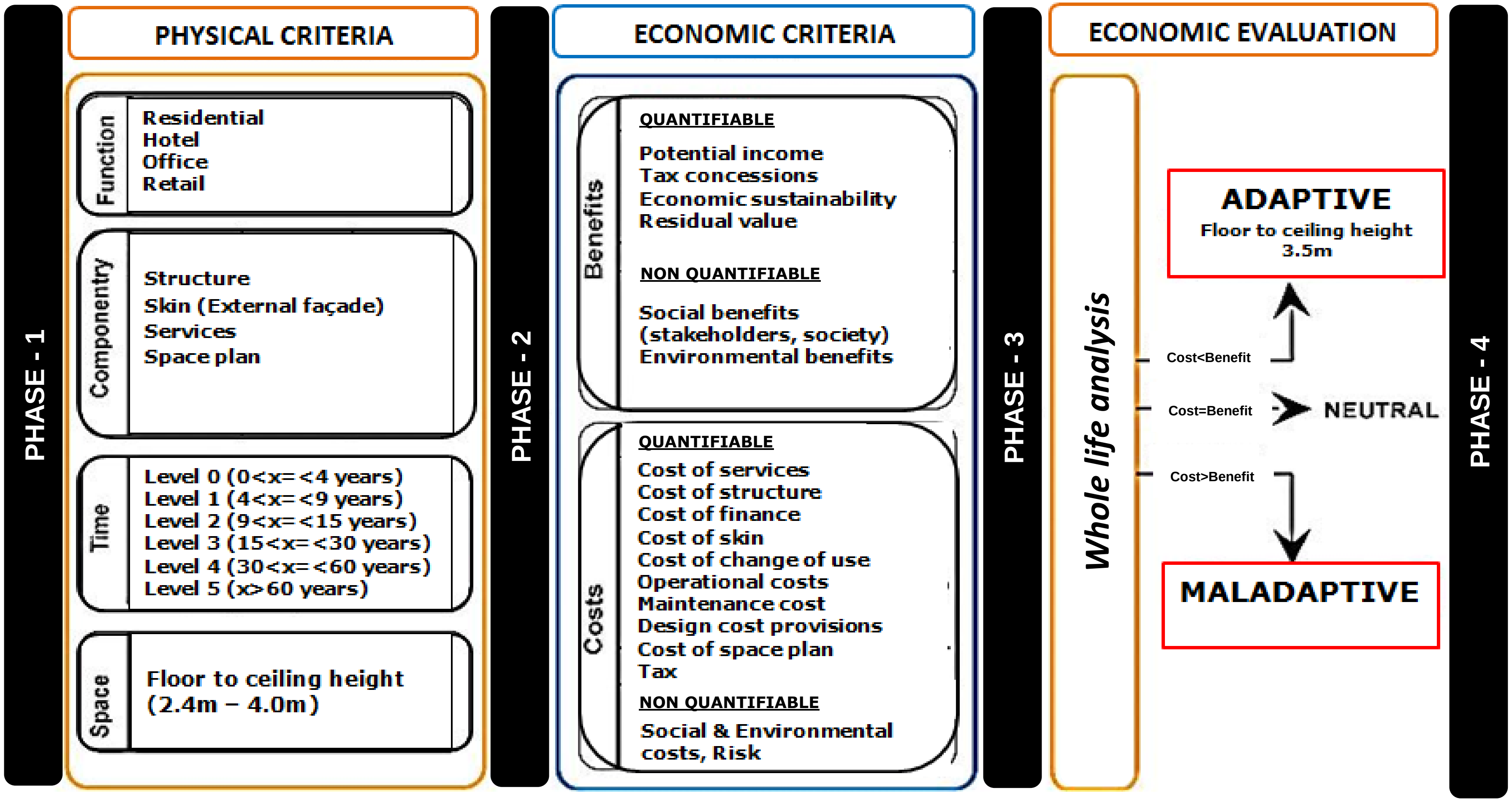


Figure 9-1: Conceptual framework

The first phase of the framework helps determine the physical criteria (perspectives of adaptability) for adaptability in buildings. Four criteria were considered by the Adaptable Futures project as explained in section 9.3.1.

9.3.1 Physical criteria (perspectives of adaptability)

The traditional criteria for building design are space, function and componentry. Time is rarely considered. The model shown in Figure 9-2 was developed by the Adaptable Futures project team (2009) to stress the importance of the perspective of time in the design of built environment facilities. Schmidt-III *et al.* (2010) discuss two implications from the time-based perspective in construction. The first is to select durable materials to build componentry with an intention to let the building age well. Secondly, the time dimensions to determine the building performance and the demands for different uses and functions should be considered.

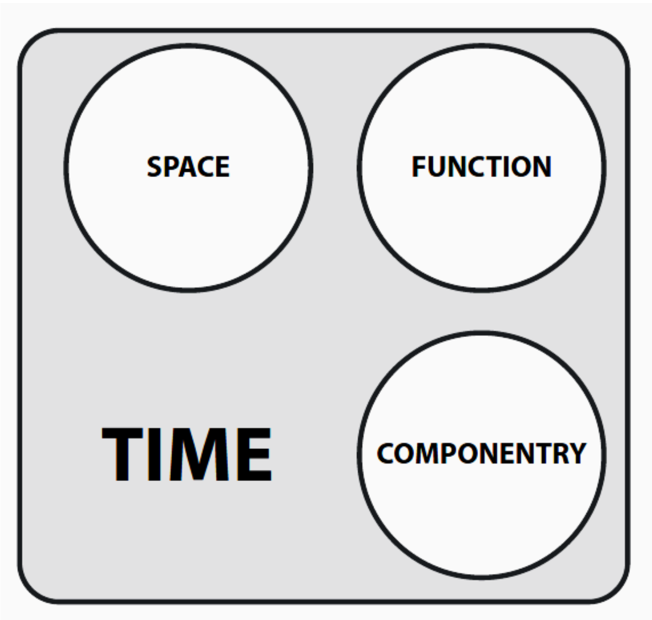


Figure 9-2: Perspectives of adaptability

Source: Adaptable Futures (2009)

This preliminary model (perspectives of adaptability) was used to determine the physical/design criteria for the conceptual framework. The appropriate dimensions for the sub-elements of physical criteria (which are space, function, componentry and time) were identified through empirical investigations. Sections 9.3.1.1 to 9.3.1.4 explain these four design criteria while describing how the empirical work could be used to populate them when designing new buildings to respond to the potential change of use.

9.3.1.1 Space

This is the most important physical criterion for building change of use considered within this study. Plan space is important but falls outside the scope of this thesis. However, the significance of floor to ceiling height in determining the use options is central to this thesis. The typical floor to ceiling height for four different use typologies (i.e. residential, hotel, office and retail) were ascertained through the empirical investigations (see section 8.3.2). The findings explain that the generic floor to ceiling height of selected use typologies varies from 2.4m – 4.0m. In this realm, the intention was to design the building for an optimum economic height that allows for all four uses without too much redundancy in the design. Thus, a web-based questionnaire survey (WBS2) was used to identify the most economical floor to ceiling height for these functions (see section 8.3.2). The findings strongly confirmed 3.5m as the optimum floor to ceiling height to facilitate all four functions of residential, hotel, office and even retail (although it would not be ideal for retail alone).

9.3.1.2 Function

This conceptual framework evaluates the economic considerations for designing new buildings to facilitate four use typologies or functions. The required information was collected from two different sources to determine the potential functions that could be easily facilitated in a single space. The results of the Loughborough town centre case study illustrated in section 7.2.1 of chapter 7 and the secondary data of 3DReid's Multispace Design Guide (2006) (see section 4.4.2.1 of chapter 4) were used to identify these functional typologies. The result clustered residential, hotel, office and retail typologies together as they showed similarities in their design, procurement and the unit cost. On economic grounds, the cost per gross floor area was in-line with these use typologies. The framework allows four uses and the preliminary design should consider the space and load provisions for future potential change of use.

9.3.1.3 Componentry

Buildings are dynamic systems and the capacity to accommodate change depends upon the components and their mutual permutations. Building components have different lifespans and it is necessary to cluster them under their designed lifespan. Specific to the above use typologies, the unit costs (BCIS) of different building components were analysed. The main aim of this analysis was to identify the cost-significant (in terms of initial capital cost) building layers and further to compare the cost differences of selected use classes. The results describe structure (frame), skin (external façade), services and space plan (internal walls and partitions) as the cost-significant building layers to be considered in change of use scenarios (see section 8.5.1).

9.3.1.4 Time

The whole lifespan of a building and its componentry is a significant consideration in adaptable buildings. The 'lifespan' can be varied from 0 to 60+ years (componentry to building) in modern day (21st century) buildings. The need for designing buildings towards adaptation is more relevant when the building has a longer lifespan and different business (functional) cycles. For example, Figure 9-3 from the main Adaptable Futures project explains two typical scenarios that can be usually expected in buildings. The first curve illustrates the capacity of an adaptable building to respond to the different business cycles. The second curve illustrates how the same building cycle allows for a single business cycle, while keeping the remaining cycles redundant. Design for adaptation allows the optimal use of the building throughout its entire lifespan.

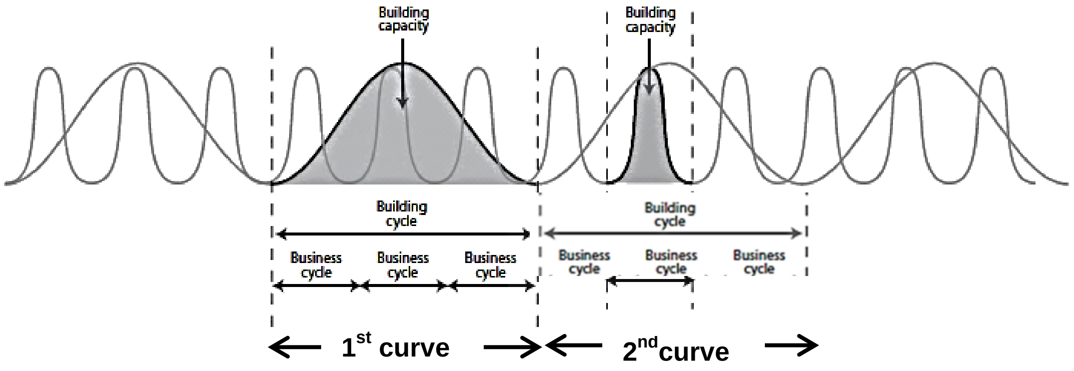


Figure 9-3: Different lifecycles of a building

Source: Schmidt-III *et al.* (2010)

Section 9.3.1 encapsulated the dimensions for determining the physical criteria for adaptability in buildings. In short, the adaptable building considered in this study facilitates four use typologies and floor to ceiling height was considered as the key design parameter used to determine the potential uses. Section 9.3.2 explains the economic criteria for adaptability in buildings.

9.3.2 Economic criteria for adaptability in buildings

The most influential cost and benefit criteria for adaptability in buildings were identified through two surveys (WBS1 and WBS3), secondary data analysis of BCIS cost data and two semi-structured interviews with a quantity surveyor and a facilities manager. These costs and benefits were included in the conceptual framework to assist clients/owners and developers in their decisions on DFA. Section 9.3.2.1 explains the most significant cost factors and section 9.3.2.2 elucidates the benefits.

9.3.2.1 Cost considerations

Total cost considerations for adaptability in buildings were identified in section 8.5.2 of chapter 8. Having considered the level of significance (WBS3), the most influential cost categories were inserted in the quantifiable cost category. Altogether 10 cost categories were identified with a ‘high’ level of significance, which $\alpha>=5$ was considered as ‘significant’, $5>\alpha>=4$ was considered as ‘high’ $4>\alpha>=3$, $3>\alpha>=2$, $2>\alpha>=1$ and $1>\alpha>=0$ were assigned as ‘moderate’, ‘low’, ‘very low’ and ‘negligible’ respectively. Moreover, Table 8-4 in chapter 8 illustrated the cost breakdown structure for adaptability in buildings and their level of significance. In a way, clients/owners and developers are interested to know how much extra money they should pay to integrate adaptable potentials into their new designs. Thus, the aforementioned cost categories would help them understand which elemental costs are important for designing buildings for future potential adaptation (change of use). In order to understand the timing of these costs, three critical decision points (CDP) were considered within the building lifecycle (see Figure 9-4).

- How much to invest initially (CDP1):

  This identifies the initial cost requirements to build the facility, which is intentionally designed to respond to future changes. In the adaptable context, this cost includes the initial costs and cost provisions for potential adaptations (e.g. cost of finance, cost of structure, services, skin, space plan, cost provisions for future adaptations). These costs depend on the functional typologies that possibly fit into a particular building (functions), the way they can be fitted together (space), and their functional lifespan (time). Compared to traditional maladaptive buildings, adaptable buildings typically have a higher initial capital cost because of the integrated performances of adaptability/flexibility. Thus, adaptable buildings are able to respond relatively quickly to the potential change of use.

- How much to invest to run the building/facility through its life-cycle (CDP2):

  CDP2 considers how much needs to be invested for the upkeep of the facility during its economic lifecycle. In this regard, maintenance and operational costs and tax were prioritised. Further attention needs to be given to understand the building maintenance policy and stakeholders' responsibilities towards the process of regular maintenance.

- How to handle an aged building (CDP3):

  CDP3 considers four typical options for handling the building at the end of its first/original use. The recommended options are functional adaptation (option A), continued sub optimal use (option B), sell (option C) and/or scrap and rebuild (option D). If the building design has adaptable qualities, then the cost of functional adaptation (change of use: e.g. staff relocation) is lower. The proposed financial options A and B describe the potential lifecycle extendibility of an aged building and the options C and D consider 'sell' or 'scrap and rebuild' if these prove more economical. Therefore, economic analysis is essential to select the best alternative among those options and further to identify whether adaptable options provide economically sound solutions. In fact, these cost categories and their time of occurrence play an important role in whole life analysis, which will be discussed in section 9.3.3. The section 9.3.2.2 elaborates the immediate and long-term benefits of DFA.

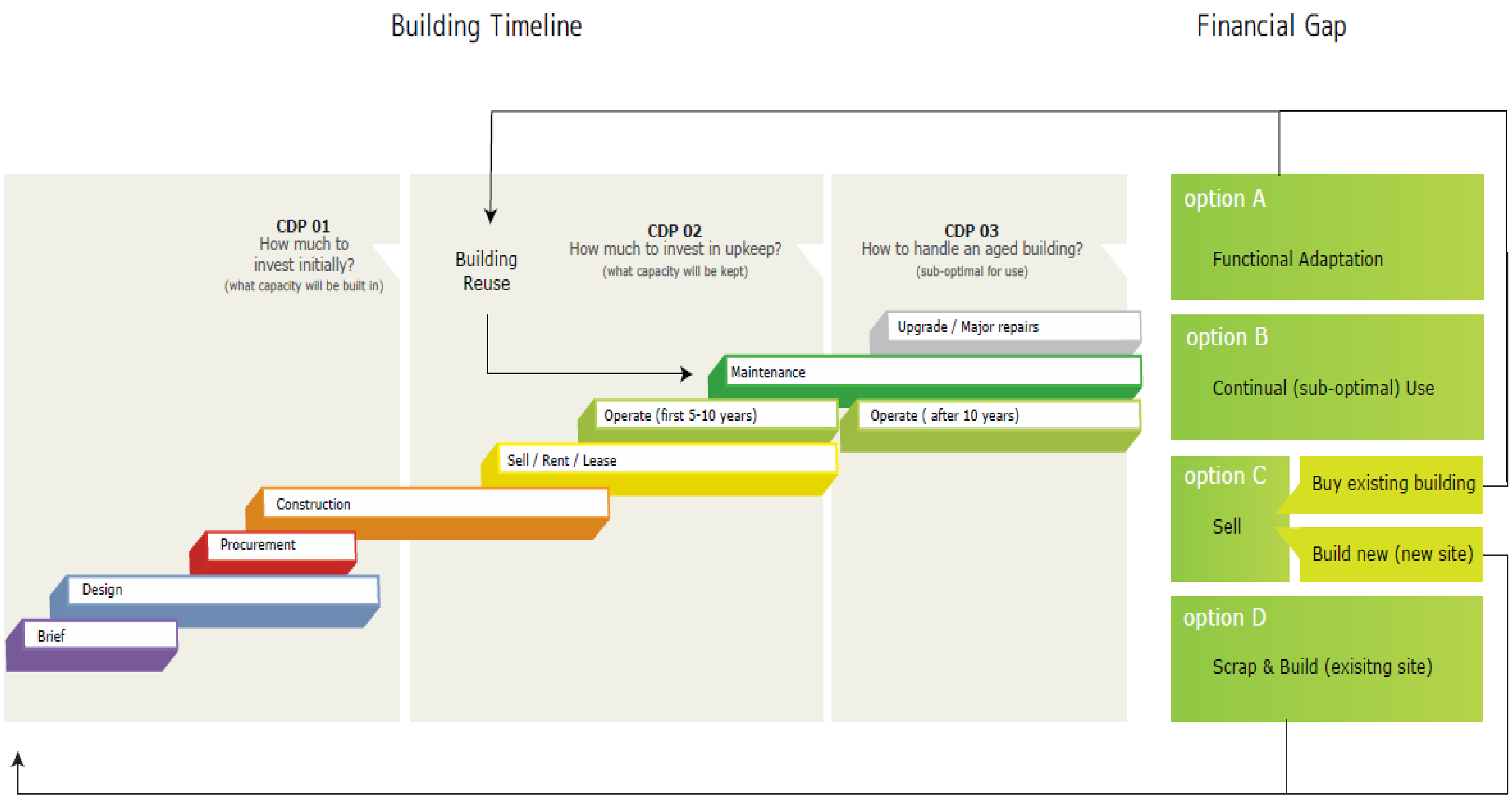


Figure 9-4: Critical decision points for adaptability in buildings

9.3.2.2 Benefit considerations

Section 8.5.3 of chapter 8 identified the key benefits of DFA. These benefits were integrated into the conceptual framework to provide clients/owners/developers with a clear picture of economic considerations for adaptability in buildings. Building owners/developers are able to realise various benefits by designing their buildings to respond to potential changes. The key benefit of adaptation over demolition and rebuild is that the costs are usually lower (Watson 2009). The convertibility of adaptable buildings provides good markets and boosts the income (rent, sale, lease) while minimising the rate of building redundancy. In addition, the Government tax concessions for adaptive reuse encourage the DFA. The end of life value (residual value) is another benefit that adaptable buildings provide to stakeholders. Apart from those quantifiable benefits, the social and environment benefits are also important.

9.3.3 Economic evaluation

Having identified the most significant cost and benefit criteria for adaptability in buildings, an economic evaluation needs to be undertaken to support better economic decisions. Chapter 6 explained the approaches often used to undertake economic evaluation for built environment facilities. Specifically, section 6.3 of the same chapter identified whole life analysis as a better approach for evaluating economic costs and benefits for adaptability in buildings. The section further exemplifies the suitability of both discounted and real option methods for WLA.

Section 8.4.1 explained the potential change of use of a typical building depending on its floor to ceiling height. Moreover, section 8.3.2 reveals that 3.5m as the optimal floor to ceiling height to facilitate all four functions i.e. residential, hotel, office and retail. Purpose-designed single use buildings are cheaper at lower floor to ceiling heights; however they fail to respond to future adaptations. A benefit-cost ratio is proposed as an indicator used to evaluate the value for money in project investments, which considers discounted present values (explained in section 6.3.1.3 of chapter 6) of all benefits and costs. Higher rates boost the project value by determining the economic viability of a facility. It assumed that adaptable buildings have greater potential to bring benefit to the owners/developers compared to maladaptive options. For example, if the benefit to cost ratio is higher than 1 (benefit>cost) it is considered as adaptable and they have approximately 3.5m floor to ceiling heights.

Figure 9-5 compares the typical value changes of traditional and adaptable systems. The study uses the same details to show how DFA could provide higher return to their stakeholders by optimising the value.

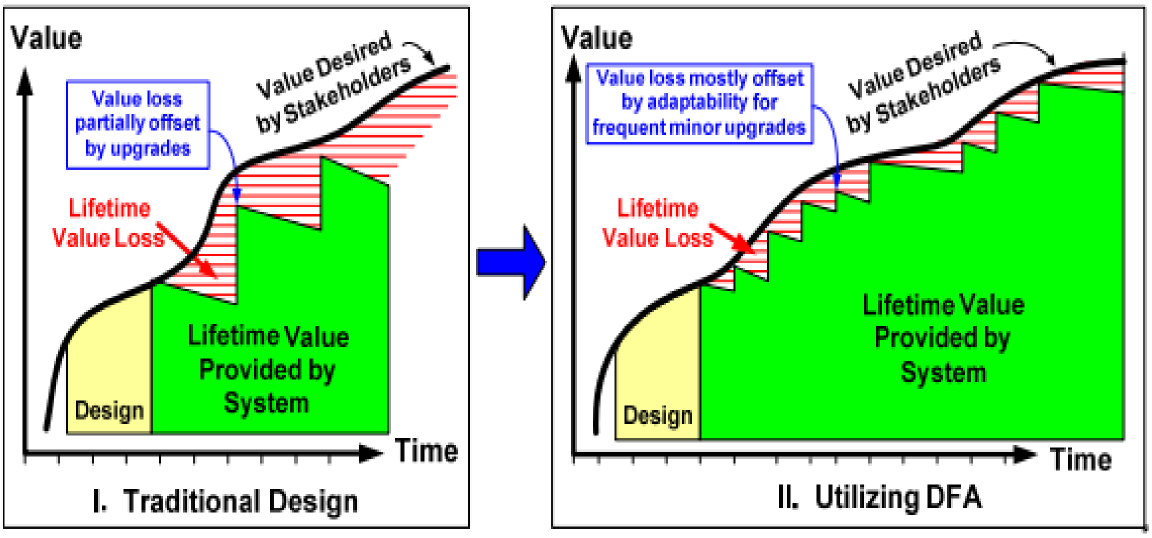


Figure 9-5: Value changes of traditional and adaptable designs

Source: Engel and Browning (2008)

The cost of design is apparently similar, but cost of adaptation (upgrades) is comparatively very high in the traditional scenario. In the manufacturing sector, there are many opportunities for adaptations. However, in the built environment, these tend to be far less.

9.3.4 Decision support prototype

The conceptual framework illustrated in Figure 9-1 identifies the expected costs and benefits of a building which is designed for adaptation. Having considered these findings, an automated decision support prototype was developed to compare the costs and benefits of the original (the buildings proposed initially without any idea about future adaptation) and adaptable (which considers potential adaptations in the future) options. This comparison helps clients/owners and developers to compare their original design with an adaptable design in terms of costs and benefits (see appendix J). This prototype was developed in an Excel-2010 platform and macros were used to code the syntax. However, due to a shortage in available time, the prototype itself was not tested for its validity and reliability in a real case scenario.

9.4 Validation of proposed conceptual framework

The method used to validate the conceptual framework was discussed in section 3.4.3.8 and the rationale for selecting a 'workshop' method was explained in Table 3-5 (under objective 5) of the same chapter. This section explains the findings of the validation and the resulting improvements to the framework in its real case application. The workshop to validate the framework was undertaken by Adaptable Futures project collaborators. The team comprised 12 participants in the disciplines of architecture, quantity surveying, structural engineering and research and development. Their professional experience is noted in Table 9-1.

Table 9-1: Professional experience of the project partners' to workshop2

Project Stakeholders	**Discipline**	**Professional experience (years)**				
		Less than 5	**5 to 10**	**10 to 15**	**15 to 20**	**More than 20**
Industry partners	Architecture (5)			✔ ✔	✔ ✔	✔
	Structural engineering (3)				✔	✔ ✔
	Quantity surveying (3)		✔	✔	✔	
Client	Research and development			✔		

This framework is an integration of the findings of the four research objectives (1-4) discussed in chapter 1. This sample was purposely used to validate the framework because the framework integrated a set of multi-disciplinary inputs (design, economic and social) in adaptable contexts. The discussion elements of the workshop were treated like a focus group, with specific questions being asked and discussed by the participants. First, this framework was presented in this workshop through a PowerPoint presentation. Then each element of the framework was enlarged to explain how these sub-elements (physical and economic criteria) were integrated to develop the conceptual framework. Moreover, the inputs from other work packages of the Adaptable Futures project (WP1: Critical design parameters for adaptable buildings, WP2: Potential product architectures, WP3: Exemplar adaptable building design solutions, WP4: Life cycle economics, WP5: Business case and impact of processes and people, and WP6: Innovation diffusion) were acknowledged. The workshop participants were asked the following questions and the responses to each question are noted below:

1. *Do you think this framework provides a formative guidance to its users (clients/owners/developers) about 'design for adaptation'?*

   This question was posed to get an overall idea about the presentation, the depth of information used and to identify the readability of proposed conceptual framework. Almost all the architects (5) who attended the validation workshop2 agreed that the integrated physical components (space, function, componentry and time) of the framework can be used to determine the adaptable performance of a typical building. In other words, the 'physical criteria' illustrated in the first phase of the framework could provide a frame of reference to its users about design for adaptation. Perhaps sometimes these physical criteria can be used to compare his/her original design (which is not intentionally designed to respond to future change) with a typical adaptable building.

   Moreover, three quantity surveyors attending the validation workshop2 agreed that the listed cost components are highly influential in designing new buildings to respond to the potential change of use. From a client's perspective the benefits noted in the framework encourage the clients to think about adaptability and this framework could provide initial and formative guidance to its users. Two quantity surveyors further noted the importance of timing in relation to each cost and benefit when undertaking the whole life analysis. Phase 3 of the conceptual framework requires some analytical skills to evaluate the costs and benefits of adaptations and clients need to get financial advice from a quantity surveyor to complete the economic evaluation. The participant group proposed that each section and category of the framework needs cross referencing and an indication of its importance in order for the diagram to have a sensible hierarchy. The required modifications were undertaken in the preliminary format of the conceptual framework and the latest framework is illustrated in Figure 9-1. This was retested by two informal discussions with the project partners of the Adaptable Futures project.

2. *How could this conceptual framework be implemented in the real case scenario?*

   The purpose of this question was to identify the issues of practicability of implementing this framework for real-world projects. The design phase application was recommended because many of the variables (physical and economic) used in the framework need to be completed at the design phase of the building lifecycle. As illustrated in Figure 9-1 the framework consists of four main phases.

   Phase 1 determines the physical dimensions (space, function, componentry and time) for adaptability in buildings. In essence, the dimensions for each physical parameter need to be identified. Hence, design expertise is needed to complete Phase 1. Phase 2 explains the economic considerations (costs and benefit) for adaptability in buildings. In this regard, the expertise on costing is important to identify the specific cost factors and their influence for adaptability in buildings. Phase 3 is used to undertake the whole life analysis. Cost information and the timing of its occurrence are the key consideration in Phase 3. However, the limitations to access the maintenance and operational cost databases may create some difficulties in this phase. Therefore, the cost advice from a quantity surveyor/cost engineer is highly appreciated within Phase 3. The final phase is Phase 4. While comparing the lifecycle costs and benefits, which were identified in Phase 3, Phase 4 deals with the decision making for future potential adaptations. The application of this framework in the right environment should provide economic credibility to its end-users. Moreover, there are future opportunities to use this framework in a practical case and get clients' and developers' feedback on how this conceptual framework would help them to make their decision for DFA.

3. *What further improvements are needed in the framework?*

   Further improvements to this conceptual framework were discussed within the validation workshop and the validation interviews. More than half of the participants at the validation workshop highlighted three critical points for future improvements in this framework. First, the logical relationship between each phase was suggested by one validation workshop attendee and supported by the rest of the group. As a result, four phases (as illustrated in Figure 9-1) were introduced to the original format. Secondly, three of the quantity surveyors at the validation workshop suggested the importance of integrating cost databases (BCIS, BMCIS) in Phase 2 to provide a good point of reference to its users. This will help to identify the available resources to obtain cost information to undertake the process of whole life analysis. Finally, they explained that clients and developers should be interested to know how much money they need to pay extra (as a percentage of total construction cost) to enable this adaptation in their buildings. If these three points could be considered within this framework, then there would be a good possibility to develop a computer aided prototype to help clients make important economic decisions. Section 9-5 explains the benefits and limitations of the proposed framework.

9.5 Benefits and limitations of developed framework

Key benefits could be expected by adopting this framework in the design stage of the building lifecycle. The physical variables (space, function, componentry and time) for adaptable buildings need to be determined at the very early stage of design and this certainly would lead to the identification of the specific cost and benefit attributes for adaptability in buildings. This framework provides formative guidance to the various stakeholders. For building owners it is about the different costs that they are going to be paid or benefits that they are about to receive from adaptable designs. In a sense, this conceptual framework helps clients/owners in their preliminary decision-making protocols. Having noted the physical attributes for adaptable buildings, the framework guides the architects/designers to identify the optimum design measures for improving adaptability in buildings. For example, if the building is intended to adapt for different uses over its life-cycle then architects need to work on the optimum dimensions for each physical attribute and flexible methods of construction and materials must be used for the proposed design. In addition, the cost and benefit attributes help quantity surveyors/cost engineers to establish realistic cost targets for proposed designs. Moreover, this framework considers the whole life cost for economic decisions, which helps clients plan their cash flows. Thus, the framework would be able to advise the owners/clients/developers/designers and quantity surveyors on making long term economic decisions on adaptable buildings by identifying the expected costs and benefits of potential adaptations.

However, there are some limitations in the conceptual framework. The framework works only for buildings with 4 to 12 storeys. The shortfall in accessibility and availability of maintenance and operational cost information is highly likely to affect the accuracy of economic decisions. In a way, this may pressurise clients to pay extra costs to obtain accurate cost estimates.

The limitations (length, complexity, accuracy, information) in the whole life analysis process also affect the economic decisions. However, the framework was not tested in a real case scenario to identify the practical difficulties (if any) and to understand the further improvements to be required in practical application – this is one of the proposals for future work. The validation interviewees suggested that the owners/developers should be interested in receiving a straightforward value as the final answer but expertise is required to work towards that target.

9.6 Summary

This chapter discussed the process used to develop and validate a conceptual framework for identifying economic costs and benefits for adaptability in buildings. The surveys (WBS2 and WBS3) were used to define the physical and economic criteria for this framework. The physical criteria for adaptable buildings were reflected through four sub-elements: space, function, componentry and time. The appropriate measures for each sub-element were identified by WBS2. These physical criteria determine how the choice of adaptable technology, materials and design are affected when designing new buildings for potential change of use. This determines that residential, office, hotel and retail are the common uses that could easily and frequently be interchanged. The components: structure, skin, services and space plan are the significant cost components in terms of their initial capital costs. In addition, framed structures provide maximum adaptability for potential change of use. Services systems and space plan (internal walls and partitions) typically vary with the use typology. However, durable materials need to be identified for each component to respond to the potential change of use. The framework then identifies different costs and benefits that the clients, owners and developers are liable to pay or receive because of the DFA. The economic evaluation considers at what cost increment (initial and operating) should this adaptation be undertaken and when should it be done for an economically viable solution.

In short, the framework identifies the pertinent physical and economic criteria for designing new buildings to respond to potential change of use. This conceptual framework was tested for its usability and validity through a workshop and two informal discussions by industry partners for the Adaptable Futures project. This validation provided an opportunity for retesting the findings of each research objective. The application of this framework in the design stage of the project lifecycle encourages the owners/clients/developers to consider the adaptable potential of their new facilities.

Chapter Ten

10. DISCUSSION

10.1 Introduction to chapter ten

Chapter ten provides an overall discussion of this research endeavour. Priority is given in this chapter to explaining how the research objectives were achieved within the specified research boundaries and the credibility of the results. Moreover, the chapter compares the similarities and differentiations of the research findings with the current state of knowledge.

10.2 Overview of the research

This study focused on the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects. Five interwoven objectives were considered. Having studied the nature of the research question, the study exploited the theoretical position of pragmatism (see section 3.2.2 of chapter 3) and different empirical investigations were undertaken to collect, analyse and validate the data. A comprehensive literature review and a series of informal discussions with Adaptable Futures project partners were preliminarily investigated to define the research aim and objectives. The dominant purpose of this study was explorative in nature. However, as previously mentioned, some aspects of descriptive and explanatory traditions were partially exploited to accomplish objectives 3 and 4.

The overall research followed two main phases. The first phase exploited a case study design and the second phase used a survey design to obtain relevant data. The case study design exploited three semi-structured interviews, one unstructured interview, archival analysis, secondary data analysis (census and statistics) and several informal discussions with Adaptable Futures project partners to collect data. A workshop was undertaken with multi-disciplinary professionals (architects, quantity surveyors, structural engineers and property developers) to validate the findings of the case study design. The data required for the second phase of this investigation was obtained from three web-based surveys (WBS1, WBS2 and WBS3). In addition, BCIS cost information, four semi-structured interviews and three unstructured interviews were used to support this phase. The overall research exploited a multi-method approach to collect the data, and morphological analysis and descriptive statistics methods were used to analyse the collected data from the case studies and the web-based surveys. The concentration was further extended to develop a conceptual framework for articulating these findings in a logical sequence and the framework was validated for its suitability in the change of use scenarios by a workshop.

The collected data was analysed to establish the cost and benefit considerations for adaptability in buildings. One of the respondents to WBS3 argued that the issue of cost of adaptation would only be relevant in the speculative market and even then the developer would have his building geared to a specific market. On the other hand, developers are in business to make money and maximise their return on investment. In reality, they would concede to incorporating features in their buildings that tick the eco/sustainability box, but mostly only if they do not cost extra. Therefore, to have a market where we design for future adaptability, current entrepreneurs need returns in their lifetimes, not in the future. There are no concessions to achieve this. The whole structure of businesses, companies and nations is run on achieving annual financial targets and there is little investment in a sustainable future, no matter what most companies may preach.

The findings from survey WBS3 depict that the initial capital cost required for service systems, cost of structure, cost of finance, cost of skin (external façade) and the cost of change of use are the most significant costs (an average rating higher than 4.5 out of 6 was considered significant) that need to be considered in designing new buildings for potential change of use. The cost of undertaking market research and cost provisions for future adaptations were identified as an extra cost to the owner/developer when designing buildings for potential adaptations. Maintenance and operational costs play a vital role in the lifecycle extendibility of buildings. Noticeably, adaptable buildings have significant potential to boost the benefits of marketability (income from sale, let and lease) and both economic and environmental sustainability. The strengths, weaknesses, opportunities and threats of this investigation are explained in the next section.

10.3 SWOT analysis of research

The SWOT (strengths, weaknesses, opportunities and threats) analysis (Figure 10-1) represents the overall positions that are bound by this research investigation in terms of objectives, adopted methods, findings, rigour and conclusions. The richness of a study can be crystallised through its strengths. This study is strong in several aspects, including the contributions to the body of knowledge in terms of exploring economic considerations for change of use in buildings within the context of adaptability. The nature of the research problem (applied research) and the exploitation of a multi-method approach to find answers are notable. Furthermore, the response rates for WBS2 and WBS3 have put the results in a strong position. The multi-method approach used in this endeavour provided a good opportunity for collecting, testing and retesting the findings through triangulation. In addition, the development of a conceptual framework is another plus point of this study that would guide building owners and developers in their future economic decisions.

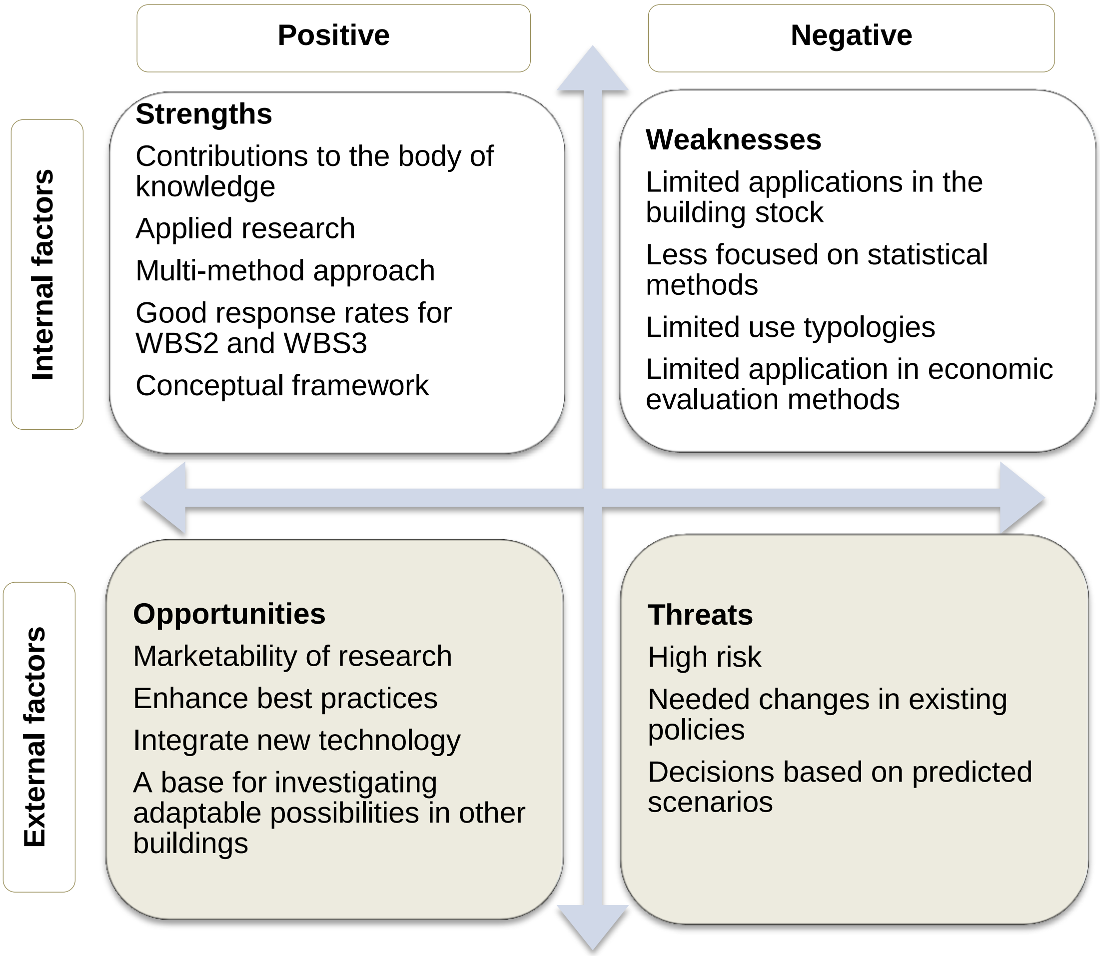


Figure 10-1: SWOT analysis of research

However, the limited applications of adaptable strategies in the existing building stock and the lack of robust methods for evaluating economic decisions for the future seem to be the main barriers for this investigation. The BCIS cost data collected for achieving objective 4 is time-sensitive. The overall study was based more on qualitative data and provided limited opportunities for applying statistical methods.

The results of this study may encourage the design of new buildings to respond to potential adaptations, as adaptable buildings will be able to attract prospective markets in the near future. The increasing interest of owners/clients/developers in investing in futuristic buildings is acknowledged as a driver for adaptable buildings. In this regard, the identification of economic costs and benefits at the design stage of a building may provide the opportunity for better economic decisions. Perhaps their interests will demand the quantification of the costs and benefits of total adaptation, which needs to be addressed in further research. Nevertheless, the risks involved in future decisions and the essential amendments to existing planning policies can be highlighted as the major threats to this study. Apart from these strengths and opportunities, the study positively connects with sustainable approaches, which almost appreciated in economic and sustainable agendas.

10.4 New directions

The new directions and the implications of this research emerged from the responses to the semi-structured interviews, workshops and web-based surveys.

10.4.1 The necessity for designing new buildings towards adaptations

There is great potential to enrich our city centres with a new generation of adaptable buildings that have much longer lifespans and contribute to a significant reduction in wasted resources (Gregory 2008). The case studies (Loughborough town centre and the Stewart Mason redevelopment) provide examples of change of use in buildings over the last century. In addition, industry practitioners were shown to support the real need to design new buildings for potential change of use. They further emphasised that traditional buildings are maladaptive in nature and are sole user oriented. They do not react to diverse demands and are unable to attract different customers. This creates long-term socio-economic problems, which are building redundancy, urban sprawl and sustainable degradations (carbon footprint, space reuse, energy use and landfill waste). As a mitigating measure for many of the above problems, design for potential adaptation should be considered. For example, designing buildings for change of use creates potential for accommodating different use typologies in the same space, which will enhance reusability, reduce building redundancy and minimise the contribution to demolition waste. Indeed, the findings of this study establish the real need for the design of new buildings towards potential adaptations.

10.4.2 Contribution to sustainability

Global construction, including civil works, is one of the largest material consumers in many countries (Fernandez 2003). This influences sustainability in different ways. For example, considering construction materials, the process from extraction to demolition creates many negative impacts on the environment. Characteristically, adaptable buildings are sustainable in terms of environmental, social and economic grounds. Legislative, economic and commercial forces have converged around the need to improve business sustainability, creating an imperative for change in the UK property market (Craven 2011). A positive contribution to environmental sustainability can be achieved through the spectrums of energy efficiency, waste minimisation, reusability, recyclability and carbon footprint reduction. Adaptable buildings optimise their embodied energy content by allowing subsequent adaptations for new uses without scrapping and rebuilding the original building. In a way, this will highly contribute to minimising the carbon footprint and landfill waste. The respondents' gut feelings were that adaptable buildings are energy efficient. However, little evidence is available to confirm this. Thus, further investigations are urgently needed to explore whether adaptable buildings are energy efficient and sustainable. In the social context, the adaptive reuse potential of adaptable buildings minimises the rate of redundancy, which improves the sustainability of the neighbourhood. Vacant buildings are deemed safe places for theft and vandalism. Hence, adaptable buildings improve the socio-environmental performance of the built environment. Having studied the growing pattern of building change of use, a positive demand for adaptable building is expected in the near future.

10.4.3 Stakeholders' perceptions

The adaptable building approach seems to be an emerging area in the built environment to respond to potential changes in buildings. However, stakeholder motivation towards the design of adaptable buildings is considerably less than for traditional purpose design buildings and interviewee 11 explained the difficulty of the building industry responding to the change: *'the building industry is very aggressive. It's also extremely conservative - they like to stick to what they know and they know what they know very well, inside and out. They have standard house types and they know exactly how many bricks, bags of mortar, nails and planks of wood go into exactly each and every house and they don't like change, they don't like deviating from that'*. Moreover, Saker (2011) identifies stakeholders' perspectives towards the implementation of adaptable considerations in their buildings. The owners and end users explained that *'they would like to have adaptable buildings because they are cheaper to run and increase their well-being, but there are very few available'*. From the investors' point of view, *'they would like to invest in adaptable buildings because adaptable buildings give better returns and higher value growth potentials, but there is no demand for them'*. Moreover, developers stated that '*investors won't pay for it'* but that '*these buildings are easier to sell, achieve higher prices and more resistant to obsolescence'*. In addition, designers and contractors explained that they *'can build or retrofit buildings in an adaptable way, but developers don't ask for it'*.

Reliable information, methods and techniques for adaptable buildings improve real-world applications. In this regard, stakeholders' positive contributions towards the implementation of adaptable buildings are highly appreciated. The RIBA (Royal Institute of British Architects) plan of work explains the responsibilities of construction industry stakeholders in a well-structured manner. Similarly, stakeholders' responsibilities need to be defined for the betterment of adaptable building futures.

However, developers are not interested in over-designing today for the unforeseeable benefits of tomorrow. They do not have reliable information about whether end users are willing to pay for any inbuilt adaptations. Therefore, it will add extra burden to developers to continue such inbuilt adaptations whilst exploring the profitable markets. Certainly, there can be benefits to introducing this adaptable approach to owner-occupier properties.

10.5 Reliability of research findings

The establishment of the 'reliability' and 'validity' of the end results in a scientific investigation is considered necessary. This can be obtained through exploiting reliable data sources and methods. This study used different methods and a variety of data sources to identify the economic considerations for adaptability in buildings. This section recaps the issues of reliability and validity with regard to this research endeavour.

- Established that building change occurs over time and identified the economic implications:

  Reliability: The original maps of a selected building cluster in Loughborough were gathered from the Leicester Record Office and analysis was undertaken without any changes to their originality. The census and statistics data published by the Office for National Statistics, UK was used to obtain the national and local (Loughborough) populations over the analysed period. In addition, the semi-structured interviews were undertaken with experienced professionals to clarify the unclear issues of change of use and required adaptability in buildings. In a way, the secondary data analysis performed by reputable organisations (e.g. the UK government and Leicester Record Office) has a pre-established degree of validity and reliability, which need not be re-examined by a researcher who reuses such data. The findings were validated in a workshop of multi-disciplinary industry collaborators to the Adaptable Futures project.

- Identified the most influential design parameters for adaptability in buildings:

  As discussed in chapters seven and eight, real case studies of building change of use, two web-based surveys and two unstructured interviews were undertaken. The response rates for surveys WBS1 (focused on both architects and quantity surveyors) and WBS2 (architects) were 13% and 32%, respectively. The respondents to these surveys strongly agreed that the design of new buildings to facilitate future change of use represents innovative architecture. Moreover, their knowledge and experience on adaptable building construction encouraged the implementation of adaptable building practices in current designs. The data collected from these three methods confirmed that plan depth and floor to ceiling height are the most influential design parameters for change of use in buildings. The triangulation method was used to validate the results of the second objective.

- Identified the lifecycle extendibility of adaptable buildings:

  This objective was accomplished through two web-based surveys (WBS1 and WBS2), a comprehensive literature review, two semi-structured interviews, four unstructured interviews and the data obtained from Adaptable Futures project collaborators. The selected literature had high citation ranks. The response rate for WBS2 was considerably high and 84% of the respondents had more than 5 years of professional experience in the industry (see Figure 8-1). Therefore, it was assumed that the data sources that were used to complete this objective were reliable.

- Identified the economic considerations for adaptability in buildings:

  Analysis of cost data published by the Building Cost Information Service (BCIS), web-based surveys (WBS1 and WBS3) and two semi-structured interviews were undertaken to identify the lifecycle cost of adaptations and their benefits. However, the flexibility given by the BCIS for subscribers to upload individual project costs seems a loophole to exploit this data in economic decisions. The similarities shown in the unit costs of building elements/shearing layers reinforced the reliability of the BCIS information. Moreover, 79% of the respondents to WBS3 had more than 5 years of professional experience in the industry. Two interviewees also had more than 15 years of experience in their professions. Thus, it was assumed that the data collected from these three sources was reliable and provided a good opportunity for triangulation.

- Developed a conceptual framework:

  This framework was developed by integrating each finding of the aforementioned four objectives through a desk study. The validity of this framework was established through a workshop with a multi-disciplinary team, which was considered the most reliable method for validating the overall outcome of this research investigation (see Table 3-5 of chapter 3). In addition, two informal discussions with Adaptable Futures project partners were used to retest the validity of the improved framework. This conceptual framework was further improved as an automated prototype to assist owners/clients/developers in their economic decisions. However, time and funds were limited for prototype validation, which would need to be undertaken in a future study.

The aforementioned points explain the reliability of the data collected from different sources to accomplish this research endeavour.

10.6 Summary

This chapter encapsulated the overall conclusions, limitations, validity and reliability of the research findings of this study and proposed potential new directions. The results were compared with the current literature to identify the similarities and disparities. The results strengthen the recent literature by identifying the influence of floor to ceiling height on potential change of use scenarios. The SWOT analysis discussed the plusses and minuses of this research investigation. The informed new directions in the areas of necessity, sustainability and stakeholders' contributions to the implementation of adaptable design were remarked upon due to their value in enhancing approaches to the built environment. This study does not promote an over-designed, over-serviced or over-structured building, but merely strives to see the potential future adaptations that can be achieved for a negligible additional cost. Evidently, adaptable buildings emerged as a technologically elite solution for managing the prospective change of use in buildings. In essence, the economic considerations of potential adaptations need to be evaluated henceforth, as many future decisions will be affected by their economic feasibilities. Ultimately, the conceptual framework developed enables practitioners to identify the costs and benefits of new buildings that are designed for potential change of use.

Chapter Eleven

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Introduction to chapter eleven

The last chapter of this endeavour is designed to encapsulate the findings, strengths, limitations, implications and recommendations of this research investigation. The chapter is split into four main sections. The first section concludes the overall research and the second section explains the implications of the research findings for different stakeholders. The contribution to the existing body of knowledge is discussed in the third section and recommendations for future work are explained in the last section.

11.2 Conclusions

This study provides a clear backdrop for understanding the economic considerations for adaptability in buildings. In its wider context, 'adaptability' means the capability of a building to change its space, function/use or componentry in order to respond to evolved demand (Adaptable Futures 2009). However, this study emphasises the urgent need for designing new buildings that can incorporate a potential change of use (convertible). Priority was given to exploring the economic considerations (costs and benefits) of change of use in buildings, merely because it plays a critical role in the decision-making protocols of clients/owners/ developers. In a way, more buildings would be adaptable if there were *'legislation/regulation', 'increase in building values and rents', 'change in planning rules', 'greater standardisation', 'change in industry mind'* and, most importantly, *'clarity over cost/benefit'* and *'greater use of lifecycle cost'* (Adaptable Futures 2009). In addition to economic considerations, the benefits to society at large (the neighbourhood) and the environment were discussed. The findings in relation to the five objectives were systematically assembled to provide a coherent answer to the main research problem explained in chapter 1.

11.2.1 Completion of the first objective

The first objective of this study was to establish that building change occurs over time and to identify the economic implications. A case study research design was used and two case studies were undertaken to address the first objective. In addition, secondary data analysis and interviews were undertaken to generalise the findings of these case studies. The first case study explained building change at the macro level of the built environment and the second case explained the same phenomenon at the micro level of a specific building. Both cases were located in Loughborough. Historic maps of the selected cluster were examined to establish the pattern of building change over the last 100 years. The findings emphasise the diverse permutations of use typologies in different time periods during the last century and underline the current need for designing new buildings towards potential adaptations. The same studies were used to understand the economic impacts of change of use whilst mapping the growth of local and national populations, the impacts of policy issues and the growth of other sectors (industrial, commercial and educational) over the last century.

Growth in population has been a considerable driving force for such changes in built environment assets. Within this context, policy makers also play a vital role in overall decision-making protocols. The study further explained how existing policies and guidelines supported the replacement, conversion or rebuilding of some of the buildings within the selected cluster (see section 7.2.3.4). For example, urban planning and central government policies of the mid-20th century led residential spaces to be kept away from the commercial and industrial segments. However, today the policies have been changed and encourage mixed-use developments, which bring residential space back to commercial and industrial zones. Evidently, traditional buildings are perceived to be maladaptive/inflexible in responding to changes in technology, climate and society. The effects of obsolescence on the economics of development were identified as a critical area that needs to be studied further. However, a lack of adaptation makes buildings functionally redundant and difficult to refurbish or renew, even though these processes are not economically viable, socially responsible or environmentally sustainable.

The Loughborough town centre case study further illustrated the abilities, characteristics and tendencies of aged buildings (Victorian and Georgian - industrial and residential types) to adapt for potential use typologies (residential and office). The notable reason was that aged buildings with higher floor to ceiling heights were more easily converted compared to other buildings. This information was clarified through one of the questions of a web-based survey

(WBS2) circulated to 100 architects in the UK. The question asked whether the often higher floor to ceiling height of Victorian and Georgian architecture is responsible for their extended use. A total of 32 respondents completed the survey: 5 strongly agreed and 15 agreed with the above statement. More than half of the respondents (22/32) to the same survey said that the higher floor to ceiling height of a building is a good help for future potential conversion (see appendix J). By contrast, a lower floor to ceiling height is a design constraint for future adaptations of buildings. The findings in relation to the first objective show that:

- building change occurs over time and change of use appears to be the most dominant change in buildings;
- growth of population, developments in industrial, manufacturing and higher education businesses, and changes in planning policies highly influence change of use in buildings;
- some aged buildings have good potential for future adaptations;
- high floor to ceiling heights provide good potential for future change of use; and
- design parameters play a vital role in designing new buildings for adaptability.

These findings brought new insights to this study. Section 11.2.2 summarises the second objective, the methods used to complete the objective and the key findings.

11.2.2 Completion of the second objective

The second objective was to identify the principal design parameters for designing new buildings to adapt for future potential change of use. This objective was also strengthened by a case study, web-based surveys, secondary data analysis of Adaptable Futures project interviews, two unstructured interviews with the project engineer for the Stewart Mason redevelopment and a senior planner (see Figure 3-3 of chapter 3). The case study (the Stewart Mason building) involved the conversion of an old foundry building to a teaching and learning facility, which was used to explain how high floor to ceiling heights facilitate such practical conversions. The findings confirm that the sufficient ‘floor to floor height’ of the early foundry was the main factor behind the successful conversion. Furthermore, post-construction alterations to elements like structures/frames are a challenging and costly endeavour. Therefore, the possibilities for potential adaptations need to be considered in the initial design.

Having identified these requirements, a web-based survey (WBS2) was undertaken to identify the design parameters for change of use in buildings. The selected sample for WBS2 comprised of architects in the top 100 construction consultancy practices in the UK and a seven point Likert scale (significant = 6, high = 5, moderate = 4, low = 3, very low = 2, no influence = 1 and not sure = 0) was used to generate the ordinal data for analysis. The total response rate was 32% and the respondents ranked the factors of 'plan depth' and then 'floor to ceiling height' as the most influential design parameters for change of use in buildings. Structural design and fire safety design were ranked equal third, while service systems were also ranked as important. In a way, the findings of the second objective reinforced the existing body of knowledge by identifying plan depth and floor to ceiling height as the most influential design parameters for building change of use. However, plan depth is generally determined by a collection of multiple variables, which are: natural daylight penetration, proximity to views, spatial proportion, the space required to accommodate the smallest internal room component and the ratio of envelope area to enclosed floor area (3DReid 2006, Steadman *et al*. 2009). Apparently, many design parameters deal with adaptability; however, few specifically focus on change of use. The results from three different sources (case study, web-based survey, secondary data analysis and unstructured interviews) were used to complete the second objective of this research inquiry.

11.2.3 Completion of the third objective

The third objective aimed to explore the ability of adaptable buildings to accept change positively, whilst improving the possibilities for extending the functional lifespans of buildings. In this context, the literature discusses many strategies for the lifecycle extendibility of buildings, which are: '*generality'* (Arge 2005), '*flexibility/versatility'* (Douglas 2005), *'scalability'* (Geraedts 2008), *'movability'* (Gann and Barlow 1999), recyclability/reusability (Robertson and Sribar 2002) and *'convertibility'* (3DReid 2006). 'Convertibility' refers to the ability to change use in buildings. This objective was supported by two web-based surveys (WBS1 and WBS2), secondary data analysis of Adaptable Futures documents, two semi-structured interviews and four unstructured interviews (see Figure 3-3 of chapter 3). The critical influences of plan depth and floor to ceiling height in facilitating change of use were identified from WBS2. However, 'plan depth' was considered a constant design variable in this study because of three reasons. Firstly, plan depth depends on several independent variables, as noted in section 11.2.2. Secondly, the influence of floor to ceiling height in change of use scenarios was given high priority in the Adaptable Futures project (3DReid 2006). Thirdly, the respondents (architects: 22 out of 32) to WBS2 agreed that increasing the floor to ceiling height of a typical building is a good way of increasing its future convertibility (question 4). The same question was asked (WBS3: Q3) of the quantity surveyors to get their views on this issue: 19 out of 42 agreed with this statement, 11 disagreed and 12 remained neutral. These results have a 99.99% level of significance (see section 8.4). As a result of this evidence, this study continued to identify the economic impacts of change of use by considering floor to ceiling height as a major design parameter.

Following this, four practical options (WBS1: Q3, adaptable options A, B, C and D) for altering floor to ceiling height to accommodate different use typologies were identified from semi-structured interviews with two structural engineers (see appendix C for interview questions). The ability of these options to facilitate potential use typologies and their services integration were then discussed with two architects and a services engineer. The most practical options were included in WBS2. The results depict that running building services through structural beams in a multi-storey framed building is the most effective way of maximising the finished floor to ceiling height without increasing the overall height of a building (26 architects out of 32 agreed). However, they agreed (19 out of 32) that increasing the structural floor to floor height (and thus the overall height of the building) is the most frequent way of increasing the finished floor to floor height of a typical building. This confirmation helps designers to select better options for designing new buildings to respond to future changes of use. Whilst explaining the abilities of lifecycle extensions of adaptable buildings, Gregory (2002) notes that the '*adaptable building shell could be fitted out for different uses over a much longer lifespan without demolition'*. Moreover, an unstructured interview with a senior planner explained that existing planning policies, building regulations, industry guidelines and government strategies are key limitations for future adaptations. Thus, there is a need to revitalise these standards if such potential adaptation is to be enabled in the future.

11.2.4 Completion of the fourth objective

The fourth objective of this study aimed to explore the economic considerations for the extended functionality of buildings. A cost breakdown structure (El-Haram *et al.* 2002) was used to categorise the total costs of adaptations into the most suitable sub-categories proposed in ISO 15686 – Part V (2008). The findings of the two web-based surveys, secondary data analysis of building costs published by the Building Cost Information Service (BCIS) and two semi-structured interviews with a quantity surveyor and a facilities manager were used to complete objective 4 (see Figure 3-3 of chapter 3). The respondents to web-based survey 3 (42 quantity surveyors) and the interviewees (appendix I: interviewees 6 and 7) highly emphasised that the cost of services, cost of structure, cost of skin, cost of finance and cost of change of use (timely adaptation) are the most prioritised cost components that need to be considered when designing new buildings towards potential adaptations. In addition, the initial costs of building elements (17 residential, 15 office, 5 hotels and 12 mixed use) were accessed through the BCIS cost database; this cost data was remodelled into shearing layers of change to identify how the initial cost of a typical building varies with the longevity of building elements. Again, structure, skin, service systems and space plan were ranked as the highest cost-consuming shearing layers; however, the level of significance of each layer varies with the use typology. The literature also supports that the costs of the structure, façade and mechanical installations influence building change of use, especially when buildings switch from office to residential use (Geraedts and Vrij 2003).

However, this study also lacks strong evidence to recommend that the design of every building for future adaptation is economical, but it has created a pertinent platform for thinking about possibilities for potential adaptations allied with new buildings. In a way, this will encourage building owners/developers to reassess their original decisions and understand whether adaptation could be achieved for a negligible/agreeable cost. The potential income from selling, letting or leasing, the ability to improve economic, environmental and social sustainability and tax concessions were identified as the expected benefits from designing buildings towards potential adaptations (see section 8.5.3 of chapter 8). In addition, this study discusses the suitability of different economic evaluation techniques (discounted cash flow methods and real option analysis) for building change of use scenarios. The findings relating to the fourth objective contribute to identifying the cost and benefit aspects of building change of use over the whole lifespans of buildings.

11.2.5 Completion of the fifth objective

The last objective of this research endeavour was to develop and validate a conceptual framework for evaluating the economic considerations for adaptability in buildings. Having assembled all the findings of the previously discussed objectives, the conceptual framework was developed. Economic evaluation methods were used to evaluate the whole life cost of adaptable buildings, which provides a good understanding of the cost and benefit considerations of potential adaptations. In summary, this conceptual framework incorporates the design/physical criteria and the economic criteria for adaptability in buildings and proposes the technique of whole life analysis as the most appropriate method for evaluating the economic considerations for adaptability in new buildings. Each sub-element of the framework was tested through a multi-method approach before use in the framework. However, there are some limitations to this framework (as explained in section 9.5), which could be minimised further by applying this framework in real case scenarios and improving it through lessons learned. The framework was tested for its usability through a workshop with the project partners of the Adaptable Futures project (a multi-disciplinary team), who were interested to know the economic considerations for adaptability in buildings. Having collected their ideas, the framework was further improved in terms of its structure and clarity and its suitability was retested through two informal discussions with the project partners of the Adaptable Futures project. In conclusion, this conceptual framework provides formative guidance to its users about the economic considerations for adaptability in buildings.

11.3 Research implications

The overall research investigated the economic considerations for adaptability in new buildings. The main outcome was the conceptual framework developed for evaluating economic costs and benefits for change of use in buildings. In addition to this framework, the individual findings of each objective could help stakeholders in different ways. Table 11-1 illustrates how the results of this research investigation may benefit them.

Table 11-1: Research implications for different stakeholders

Beneficiary	Benefits
Owners/clients	• Can understand the economic costs, benefits and risks of adaptations at the preliminary stages of design. • Will help them to plan the available funds and to make correct economic decisions. • Flexibility to switch between the potential use classes when demand arises.
Policy makers	• The study emphasises the need for forming new planning policies or for alterations to existing policies in favour of adaptable buildings.
Funders/Investors	• The marketability of adaptable buildings encourages funders to invest in the field.
Society	• The benefits investigated will provide encouragement for designing new buildings for potential change of use. • Sustainable approach.
End users	• Flexibility to demand space for different (potential) use classes. • Locational benefits are achieved for a negligible cost.

The benefits to stakeholders shown by the results of this research investigation are noted in the above table. However, appropriate economic evaluation (the study proposes whole life analysis) needs to be undertaken at the early stages of design for an effective end result for adaptable buildings. The next section explains this study's contribution to the existing body of knowledge.

11.4 Contribution to the body of knowledge

The contribution to the body of knowledge from this investigation is twofold.

First, the developed conceptual framework enables one to identify the economic considerations (cost and benefit aspects) for change of use in buildings within the wider context of adaptability throughout a building's lifecycle. The most appropriate economic evaluation techniques were proposed to evaluate the economic costs and benefits of these changes, which may assist owners/clients and developers in their economic decisions on designing new buildings towards potential adaptations.

Second, the research findings strengthen the reliability of the existing body of knowledge whilst confirming the rising trend for building change of use. In addition, the findings strongly emphasise plan depth and floor to ceiling height as the most influential design parameters for change of use in buildings.

11.5 Recommendations for future research

The following recommendations are made with reference to the UK building industry, academic institutions and to research and development.

11.5.1 Relevance to industry

A positive trend towards adaptable buildings has been identified in the UK building industry (Gregory 2002). However, the lack of standard guidelines and the limitations in existing planning and zoning policies create difficulties in implementing the strategy in current building practices. Therefore, new industry guidelines for adaptable buildings need to be formed to explain the contractual relationships, sustainable considerations and the responsibilities of each stakeholder at the different stages of a project lifecycle. The contribution of the industry to overwhelm these challenges is acknowledged.

11.5.2 Relevance to academic institutions

This research has explained the capacity of adaptable buildings to respond to future challenges. Moreover, it has identified the design limitations for adaptability in buildings and the economic considerations for potential change of use from multiple studies. However, adaptability is an innovative concept that is not covered in detail in built environment teaching and research courses at present. Thus, this study recommends linking the different aspects of adaptability (risk, social, economic and environmental considerations) to the built environment teaching and research curriculum.

11.5.3 Relevance to research and development

There is an apparent positive trend for other types of building (healthcare, social and industrial) to be designed for potential adaptations. Thus, the findings of this study will provide a good base for exploring the economic considerations for adaptability in those use classes. In addition, some extra work is needed to generalise the findings for the other adaptable strategies explained in the adaptable framework (see Figure 5-5), as they are equally important in the adaptable building network. Testing the suitability of the developed conceptual framework in a real project is proposed.

11.6 Research limitations

The limitations of this study are explained on the triple grounds of sample selection, adopted methods and validation:

- The study assumed a neutral impact between floor to ceiling height and other design parameters (structural grid, plan depth and design load). Certainly, there are apparent relationships between these design parameters. Therefore, having identified these unavoidable interdependencies, the accuracy of the results could be further improved.

- The response rate for the first web-based survey (WBS1) was 13%, which is another limitation of this study. It was realised that the reason for the poor response rate was the complexity of the questions and flaws in sample selection. This poor response rate led to another two web-based surveys (WBS2 and WBS3) being distributed among the architects and quantity surveyors of leading consultancy practices in the UK. The higher response rates to these questionnaires (WBS2: 32% and WBS3: 42%) helped to refine the findings obtained from WBS1.

- The developed conceptual framework was validated by a single workshop and two informal discussions with project partners of the Adaptable Futures project. Improvements could be expected if applying the framework to a real case scenario.

In short, the previous sections clearly explained the development process of this research endeavour whilst elaborating on its contributions and limitations. However, some of the limitations were unavoidable.

11.7 Summary

This chapter concludes the overall summary of this research and makes recommendations for future work. Each component of the conceptual framework was derived from empirical investigations. On one hand, these findings generate new knowledge and, on the other hand, they reinforce the existing body of knowledge. For example, the breakdown of cost and benefit structures attached to change of use scenarios created an original contribution to the existing body of knowledge and the identified design parameters strengthen the existing knowledge. The empirical investigations helped to identify the total cost of potential adaptations under the different standard cost categories proposed by ISO 15686 – Part V: 'life-cycle costing for buildings and constructed assets' (2008). In addition, the benefit of designing new buildings to respond to future potential changes of use may bring favourable benefits to building owners, developers and society at large.

The recommendations made to the UK building industry, academic institutions, and research and development would enable the effective use of this study, minimise the limitations and further fine-tune the results. The changes required to existing policies and industry guidelines are underlined as the most important recommendation for encouraging adaptable buildings in the future.

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Appendix – A: Glossary of terms

Adaptability	capacity to accommodate a set of evolving demands regarding space, function, and componentry
Adaptive reuse	building is converted to accommodate new functions
Brownfield	potential building development that have had previous development on them
Generality	ability of a building to meet changing functional user or owner needs without changing its properties
Greenfield	previously undeveloped sites
Flexibility	ability of a building to meet changing functional user or owner needs by changing its properties easily
Elasticity	ability of a building to be extended or partitioned related to changing user or owner needs
Mixed use	allowing more than one type of use in a building or set of buildings
Modularity	system that is divided into a set of functional units/modules
Redundancy	vacancy
Refurbishment	process of undertaking large scale repairs
Retrofit	process of adding new building components by replacing out dated (in terms of technology, service) components
Restoration	little physical alterations to be made into the building

Appendix – B: Interview questionnaires for Planners and Policy-makers

Research aim

"*to identify the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects"*.

Purpose of this interview

The purpose of this interview is to gather information about the building change of use, underline factors and further, to identify its economic implications.
Interviewees were given the historic maps of Loughborough.

Objectives

i. to identify how the uses and functions of buildings have changed over time
ii. to select a reasonable cluster for studying the building change of use
iii. to identify the factors behind the change of use
iv. to evaluate the economic impacts of change of use.

SECTION A

Please provide the following information:

a) Your organisation ______________________________

b) Your name ______________________________

c) Your job title ______________________________

d) Years of experience ______________________________

e) Your email address ______________________________

SECTION B

1. What are the building typologies that could be often identified within Charnwood Borough Council? [Please tick (√) your choices]

i.	Residential	☐	v.	Leisure / Recreational	☐
ii.	Commercial	☐	vi.	Infrastructure	☐
iii.	Industrial	☐	vii.	Other	☐
iv.	Social	☐		______________________	

2. A remarkable change in buildings can be identified from the collected historic maps of Charnwood Borough Council. What are the main reasons behind these changes?

3. Can you specify the areas/clusters on these building maps that were used to change often over the last 20 – 30? Are there any reasons for this change?

4. Can you explain the typical changes to buildings (change of size, use etc.) in Loughborough over the last 10 – 20 years?

5. Do you think that the change of use/function as a critical change that many buildings usually undergo?

6. What is the planning and policy issues that required to be considered when convert those existing building to a new use?

7. What are the characteristics of existing buildings that would help them to adapt to a new use?

8. Do you think that 'Design for Adaptation' is appreciated in planning and policy reforms?

9. What are the expected difficulties/risks to design new buildings to respond the future potential change of use?

10. As a regulatory body how the Charnwood Borough Council would absorb those new challenges/trends.

Thank you.

Appendix – C: Interview guide for Quantity Surveyors/Facilities Managers

Research aim

"*to identify the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects"*.

SECTION A

Please provide the following information:

a) Your organisation ____

b) Your name ____

c) Your job title ____

d) Years of experience ____

e) Your email address ____

1. A growing demand for 'building change' is recognised in the UK property market. Do you think that economic downturn in the 2008 was a driving factor for this change?

2. Many of the existing buildings usually undergo the following changes. What are the major cost considerations to be considered in these changes?

    - Small changes with some improvements in existing buildings to continue the same use
    - Large changes with major refurbishments to continue the same use
    - Large changes to adapt for new/different use
    - Demolition

3. Do you think that the design for adaptation is a good approach to minimise the costs of aforesaid changes?

4. Do you think that design new buildings to respond the potential change is a good long term investment to its owners, clients and developers?

5. Design buildings/space to respond the potential change of use is considered as one of the economic solutions that could minimise the building redundancy. Do you agree?

6. What are the economic considerations that need to be considered when design new buildings to respond the future change?

   Costs:

   Benefits:

7. How the facilities operating and maintenance costs tend to vary by designing them to respond the future change?

8. How often do you consider the method, Whole Life Cost Analysis for evaluating economic decisions?

9. Do you think that making economic decisions based on Whole Life Analysis plays a good role in clients'/developers' economic agenda/decisions?

10. What are the associated risks of designing new buildings to respond the potential change of use?

Thank You

Appendix – D: Web based surveys

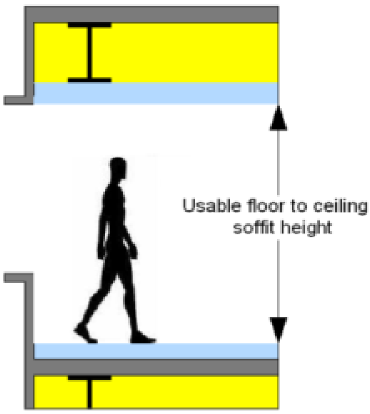
Three web based surveys (WBS) were used to collect data for this study. WBS1 is designed to collect data from both architects and quantity surveyors.

D1: Web based survey 1: (http://www.surveymonkey.com/s/XFWJZ9Q)

Achieving building change of use by altering Usable Floor to Ceiling Soffit Height (UFCSH)

The main purpose of this questionnaire is to identify the possibilities for improving adaptability in new buildings to facilitate the future potential change of use. In essence, the usable floor to ceiling soffit height (UFCSH) is taken into consideration as a key variable.

<u>The statement:</u> 'The Usable Floor to Ceiling Soffit Height (shown in the following figure) can be considered as one of the influential design parameters for building change of use/conversion'.



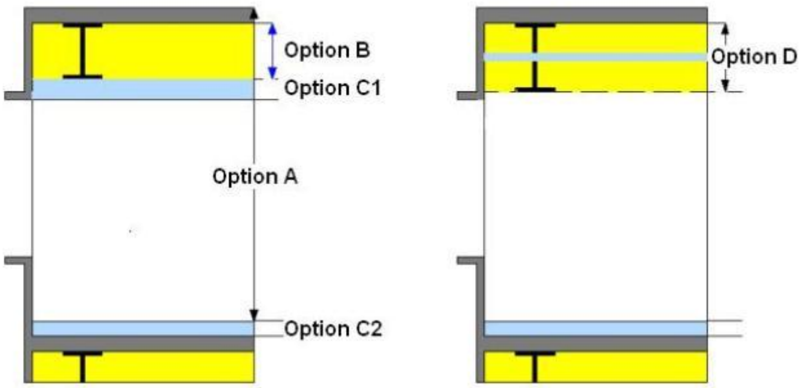
1. Do you agree with the above statement?

Strongly disagree (1)	Agree (2)	Not sure (3)	Disagree (4)	Strongly agree (5)
☐	☐	☐	☐	☐

2. A range of UFCSH is proposed as economically viable heights for given use typologies. Please select the best matching height for each use.

	Less than 2.4m	2.4m	2.7m	3.0m	3.3m	3.6m	3.9m	Over 3.9m
Residential	☐	☐	☐	☐	☐	☐	☐	☐
Hotel	☐	☐	☐	☐	☐	☐	☐	☐
Office	☐	☐	☐	☐	☐	☐	☐	☐
Retail	☐	☐	☐	☐	☐	☐	☐	☐

The options A, B, C, and D explain the ways for altering the UFCSH for a new use.



- Option A: Increase Finished Floor to Floor Height (FFFH) while keeping the same structural and services zone – and thus increase the overall height of the building

- Option B: Decrease Structural Zone (e.g by changing the structural system) while keeping the same FFFH and services zone

- Option C = (C1+C2): Decrease Services Zone (ceiling and raised floor spaces) (e.g by changing the services system (C1) and/or not having a raised floor services zone (C2) while keeping the same FFFH and structural zone

- Option D: Integrate Structure and Services to decrease the combined structural and services zone (e.g. by using castellated beams with services passing through the beam)

3. What is the most frequent option that is used in practice? Please rank the given options.

	1st Preference	2nd Preference	3rd Preference	4th Preference
Residential	☐	☐	☐	☐
Hotel	☐	☐	☐	☐
Office	☐	☐	☐	☐
Retail	☐	☐	☐	☐

4. What influence do the following have on the decision to use the options A - D?

	Major	Minor	None
Planning restrictions	☐	☐	☐
Structural and technical difficulties	☐	☐	☐
Spatial limitations	☐	☐	☐

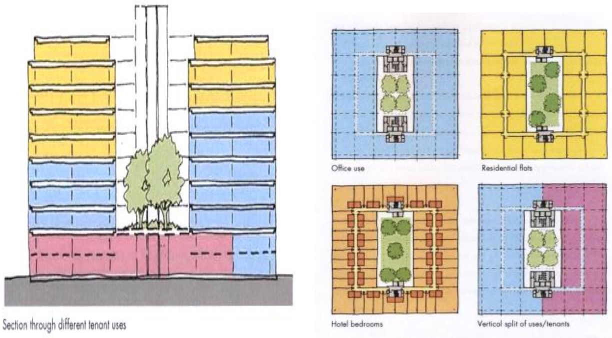
Other please specify

____

____

5. For each of the above options (A, B, C, D) what are the expected cost variations? Please consider the scenario below.

'Assume a typical 10 storey square shape building (size 56m x 56m) with a centre atrium (approximately 36mx18m) and 9m x 9m structural grid, which is proposed to design for a potential change of use. The services cores are placed separately as illustrated in the sketches. The change of use is allowed by designing the building for either adaptable option A, B, C or D. Approximate population densities of residential, hotel, office and retail are 12m^2, 10m^2, 6m^2 and 5m^2 respectively. The ground floor is double height to facilitate a space for hotel foyer, retail, restaurant, office reception and/or maisonettes. You are required to compare the life cycle cost of previously mentioned adaptable options (A, B, C and D) by assuming a specific change throughout the four options. The floor plans and elevation diagrams are illustrated below.



	Option A	Option B	Option C	Option D
Initial cost of frame	☐	☐	☐	☐
Initial cost of external facade	☐	☐	☐	☐
Initial cost of services system	☐	☐	☐	☐
Maintenance cost	☐	☐	☐	☐
Operation (energy) costs	☐	☐	☐	☐
Cost of conversion	☐	☐	☐	☐
Cost of demolition	☐	☐	☐	☐

6. Do you believe that designing new buildings to respond the future change of use is a long term cost effective endeavour? Please explain your answer.

7. Are you interested to receive the outcome of this survey? If yes, please provide your details below.

   Yes ☐ No ☐

Your name and address please?

____

____

8. Thank you very much indeed for your help. Let me know your company and profession and years of experience please?

8.1 Your company

____

8.2 Your profession and experience

____

D2: Web based survey- 2 (http://www.surveymonkey.com/s/GC7TKJV)

Architects

Exit this survey

Design new buildings for potential change of use

The main purpose of this survey is to identify the design considerations for adaptability in buildings.

1. How many years experience as an architect do you have?

○ Less than 5 ○ 5 - 10 ○ 10 - 15 ○ 15 - 20 ○ More than 20

2. Do you believe that purposefully designing buildings to facilitate future change of use represents innovative architecture?

○ Definitely ○ Probably ○ May be ○ Probably not ○ Definitely not ○ Not sure

3. To what extent do the following design parameters affect future change of use in buildings?

	Significant	High	Moderate	Low	Very low	None	Not sure
Building height	○	○	○	○	○	○	○
Building proximity	○	○	○	○	○	○	○
Building size	○	○	○	○	○	○	○
Fire safety design	○	○	○	○	○	○	○
Floor to ceiling height	○	○	○	○	○	○	○
Plan depth	○	○	○	○	○	○	○
Services systems	○	○	○	○	○	○	○
Structural design	○	○	○	○	○	○	○
Technical span	○	○	○	○	○	○	○

4. Do you consider that increasing floor to ceiling height of a typical building (e.g. from residential to commercial typical heights) would be a good way of increasing its future convertibility?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Don't know

5. Do you think that running building services through the structural beams in a multi-storey framed building is an effective way of maximising finished floor to ceiling height without increasing the overall height of a building?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Not sure

6. Do you consider that increasing the structural floor to floor height and thus the overall height of the building would be the most frequent way of increasing the finished floor to ceiling height?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Not sure

7. Do you think that increasing the overall height of a building in a town centre is not usually an option due to planning restrictions?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Not sure

8. Do you consider that 3.5m (approximately) is an optimum finished floor to ceiling height to facilitate all four functions of residential, hotel, office and retail?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Not sure

9. Do you think that the often higher floor to ceiling height in Victorian / Georgian architecture is responsible for their extended use?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Don't know

10. Would it be good, sustainable practice to build city centre residential blocks in such a way that they could be more easily adapted for other uses in the future?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree ○ Not sure

Done

D3: Web based survey- 3 (http://www.surveymonkey.com/s/TFGQ6PH)

Quantity Surveyors

Exit this survey

Economic Considerations for Adaptability in Buildings

The main purpose of this survey is to understand the costs and benefits of designing new buildings to be adaptable for potential future change of use.

1. How many years experience as a Quantity Surveyor do you have?

○ Less than 5 ○ 5 - 10 ○ 10 - 15 ○ 15 - 20 ○ More than 20

2. Do you believe that designing buildings to facilitate future change of use represents a good long term investment?

○ Definitely ○ Probably ○ May be ○ Probably not ○ Definitely not ○ Not sure

3. Do you consider that increasing the floor to ceiling height of a typical building (e.g. from residential to commercial typical heights) would be a good way of increasing its future convertibility?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree

4. Do you think running building services through the structural beams in a multi-storey framed building is an effective cost effective way of maximising finished floor to ceiling height without increasing the overall height of a building?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree

5. Do you consider that increasing the structural floor to floor height and thus the overall height of the building would be the most cost effective way of increasing the finished floor to ceiling height?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree

6. Do you think that increasing the overall height of a building in a town centre is not usually an option due to planning restrictions?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree

7. Would it be good, sustainable practice to build city centre residential blocks in such a way that they could be more easily adapted for other uses in the future?

○ Strongly agree ○ Agree ○ Neutral ○ Disagree ○ Strongly disagree

8. To what extent do the following cost categories influence design for adaptation?

	Significant	High	Moderate	Low	Very low	None	Not sure
Cost of market research	○	○	○	○	○	○	○
Design cost provisions	○	○	○	○	○	○	○
Opportunity cost	○	○	○	○	○	○	○
Cost of finance	○	○	○	○	○	○	○
Tax	○	○	○	○	○	○	○
Cost of structure	○	○	○	○	○	○	○
Cost of skin (external facade)	○	○	○	○	○	○	○
Cost of services	○	○	○	○	○	○	○
Cost of space plan (internal reconfigurations)	○	○	○	○	○	○	○
Maintenance cost	○	○	○	○	○	○	○
Operational cost	○	○	○	○	○	○	○
Cost of change of use	○	○	○	○	○	○	○
Cost of demolition	○	○	○	○	○	○	○

Any other costs and likely influence (please specify)

9. What are the likely benefits that could be expected from Design for Adaptation?

	Significant	High	Moderate	Low	Very low	None	Not sure
Potential income (sell, let, lease)	○	○	○	○	○	○	○
Tax concessions	○	○	○	○	○	○	○
Social sustainability	○	○	○	○	○	○	○
Environment sustainability	○	○	○	○	○	○	○
Economic sustainability	○	○	○	○	○	○	○

Any other benefits and their level of significance (please specify)

10. Do you think that the 'cost of adaptation' is an encouraging or discouraging factor in designing new buildings for future change of use? Please explain your answer.

Appendix – E: Interview guide for Structural Engineers

Research aim

"*to identify the economic considerations for change of use in buildings within the wider context of adaptability over the lifecycle aspects".*

Purpose of this interview

The purpose of this interview is to gather generic technical requirements of a typical building, which intentionally design to respond the future change of use.

Guidance notes

Section A asks some information about you, your organisation and Section B covers the structural design relates to particular building element/s. All questions may be answered either by a short written response or a sketch.

Thank you very much indeed.

SECTION A

Please provide the following information:

a) Your organisation ____

b) Your name ____

c) Your job title ____

d) Years of experience as a structural engineer ____________________

e) Your email address ____

SECTION B

B1 We think that the main structural frame systems for ‘typical’ multi-storey buildings are:

1. Steel columns and beams with composite in-situ concrete slab (usually on profiled metal deck)
2. Steel columns and beams with precast concrete slabs
3. Precast columns and beams and slabs
4. In-situ concrete columns, beams and floors
5. In-situ concrete columns with post-tensioned in-situ flat soffit slabs
6. Steel columns, castellated steel beams with integrated services zone and concrete slabs

What other main systems have we missed?

7. ……………………………………………
8. ……………………………………………

B2 Can you provide generic sketches for each of the types?

B3 What would be the range of structural zone dimensions for each type (given typical spans?)

1	2	3	4
5	6	7	8

B4 In your opinion, which are the main systems for each type of building (approximate % market share):

	1	2	3	4	5	6	7	8
Residential								
Office								
Retail								
Hotel								

B5 Taking type 1 as a base level, please indicate the approximate % increase (+) or decrease (-) in structural zone for the other types given a typical frame building:

1=0% 2 3 4 5 6 7 8

B6 Taking type 1 as a base level, please indicate the approximate % increase in cost of the structural frames for the other types given a typical frame building:

1=0% 2 3 4 5 6 7 8

B7 Consider a scenario where a design/client team has made some decisions on UFCH – for example to fix it at a value that would only suit residential buildings – In order to facilitate a future change of use to either commercial or retail the UFCH of the original design would need to be increased.

Rank the following in the preferred order: (1 = highest preference, ...4 = lowest preference)

- ☐ **Option A :** Increase Finished Floor to Floor Height (FFFH) while keeping the same structural and services zone – and thus increase the overall height of the building

- ☐ **Option B :** Decrease Structural Zone while keeping the same FFFH and services zone

- ☐ **Option C :** Decrease Services Zone (ceiling and raised floor spaces) while keeping the same FFFH and structural zone

- ☐ **Option D :** Integrate Structure and Services to decrease the combined structural and services zone

B8 What % of different types of buildings would you specify a raised floor

Residential ………. Commercial ………. Retail ………. Hotel ……….

B9 What would be the typical height of a raised floor (structural slab to top finished floor)

Residential ………. Commercial ………. Retail ………. Hotel ……….

B10 What typical under-beam/above ceiling services zone (m) would you expect (assuming a raised floor)

Residential ………. Commercial ………. Retail ………. Hotel ……….

B11 What typical under-beam/above ceiling services zone (m) would you expect (assuming NO raised floor)

Residential ………. Commercial ………. Retail ………. Hotel ……….

B12 What are the most likely column spacing for a multi-storey building with the following uses?

Residential ………. Commercial ………. Retail ………. Hotel ……….

B13 What are the typical live loads that you would design to for the following types?

Residential ………. Commercial ………. Retail ………. Hotel ……….

B14 What is the typical range of concrete column sizes (plan dimensions) for framed buildings?

B15 What is the typical range of steel column sizes (plan dimensions) for framed buildings?

B16 Taking residential as a starting size, what increase in column sizes (plan dims) would you expect for the different uses (due to increased live load)?

Residential = 0% Commercial ………. Retail ………. Hotel ……….

B17 Assuming residential as a base what increases (+) / decreases (-) in the % of internal load bearing walls per m2 of GFA for the following use types?

Residential = 0% Commercial ………. Retail ………. Hotel ……….

B18 Assuming residential as a base what increases (+) / (-) in the % of internal partitions per m2 of GFA for the following use types?

Residential 0% Commercial ………. Retail ………. Hotel ……….

B19 Assuming a 10 storey square shaped building (56m x 56m) with a centre atrium (approximately 36m x 18m) What is the optimum numbers and sizes for lift shafts (passenger and goods), services risers and stair cores can be proposed for this building? (Assume the population densities of residential, hotel, office and retail as 12m2, 10m2, 6m2 and 5m2 per person respectively).

Use typology	**Lifts (No and size)**	**Services riser (No and size)**	**Stair cores (No and size)**
Residential			
Commercial			
Retail			
Hotel			

Thank you.

Appendix – F: Functional transitions of buildings (Loughborough)

	Chronological building change								Remarks
	1886	**1901**	**1921**	**1968**	**1970**	**1974**	**1981**	**1989**	
A	Post office [Small]	Post Office [Big]	Post Office [Big]	Cinema	Cinema	Cinema	Club	Club	Changes in size (extensions) Baxter gate / Lemyngton street
	Social	Social- (size)	Social	Leisure	Leisure	Leisure	Social	Social	
B	Town Hall	Town Hall	Town Hall (big)	Town Hall	Town Hall	Town Hall	Town Hall	Town Hall	Changes in size (extensions) Market place/cattle market
	Social	Social	Social – (size)	Social	Social	Social	Social	Social	
C	Pub House	Pub House	Pub House	Boots Chemist.	Boots Chemist.	Boots Chemist.	Boots Chemist.	Boots Chemist.	Market place
	Leisure	Leisure	Leisure	Commercial	Commercial	Commercial	Commercial	Commercial	
D	Hosiery Manufac.	Elastic Manufac.	Elastic Manufac.	C.L.O Factory	C.L.O Factory	Car Sale + C.L.O Factory	Car Sale + C.L.O Factory	Wilkinson	Was Mill street, but changed as Market street
	Industrial	Industrial	Industrial	Industrial	Industrial	Commercial+ Industrial	Commercial+ Industrial	Retail	
E	Dye Works	Dye Works	Dye Works	Tesco Supermkt	Tesco Supermkt	Tesco Smkt/Grocery	Tesco Smkt/Grocery	Tesco Supermkt	Social Commercial Industrial Residential Leisure
	Industrial	Industrial	Industrial	Retail	Retail	Retail	Retail	Retail	

Appendix – G: Elemental specifications of selected buildings

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
Residential Buildings						
1	**B16319**	**4**	Load bearing walls	Brick & Plastering	Electric heating/ light and power, extract fans. Communal TV, CCTV	Block & Timber
2	**B20637**	**4**	RC and PCC ground floors/ PCC upper floor	Facing brick or rendered block cavity walls/	Gas HW central heating, ventilation, electric light and power	Brick, Block and timber stud partitions
3	**B21305**	**4**	PCC upper floors	Rendered block cavity walls/	N/A	Block and timber stud partitions
4	**B22398**	**4**	RC ground slab; PCC upper floors	Rendered block and facing brick cavity walls	Gas LTHW central heating; extract ventilation, electric light and power	Block and timber stud partitions
5	**B22537**	**4**	N/A	N/A	N/A	N/A
6	**B23399**	**4**	PCC upper floors	Facing brick/block walls	Electrics and local electric heating, ventilation	Block and timber stud partitions

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
7	**B23799**	**4**	Steel frame	Brick, Kalwall, Eternit cladding and curtain walling	Heating, local ventilation	timber stud partitions
8	**B24330**	**4**	Framed block with rendered	hardwood clad walls	Electric under floor heating, ventilation	plasterboard and glazed hardwood partitions
9	**B16308**	**4 & 5**	RC and PCC upper floors	Facing brick/block and double glazed Al curtain walling	Electric heating, power/ light, ventilation	Block and timber stud partitions
10	**B23375**	**4 & 5**	PCC slab; PCC and timber upper floors	Rendered block or reconstituted stone walls.	Electric power, lights and heating	Block and metal stud partitions
11	**B14840**	**5**	PCC suspended ground and upper floors	Faced brick/block cavity walls	Electrical installations	Block internal walls
12	**B18083**	**5**	PCC upper floors. Steel frame	Facing brick/block walls, part rendered; stone features	Gas LPHW central heating, local ventilation	Block and metal stud partitions
13	**B21238**	**6**	PCC beam/block upper floors	Facing brick/block, part rendered block walls	Heating and ventilation, electric light and power	Block and metal stud partitions

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
14	**B23652**	**8**	RC upper floor and frame	Facing brick, render and timber clad walls	Gas HW central heating, ventilation	Block, metal stud and glazed timber partitions
15	**B23872**	**10 & 7**	frame / suspended ground and upper floors	Rendered block, brick, cladding and curtain walling	Gas HW central heating	Block, RC internal walls, steel partitions
16	**B17465**	**11**	RC frame, floors, PCC 1st to 7th floors	Facing brick/block, Al curtain walling and recon stone walls	Air conditioning, electrics	Block and metal stud partitions
17	**B21635**	**11**	PCC cross walls	Al and timber clad walls	N/A	Timber stud partitions
Office buildings						
1	**16326**	**6**	Structural frame, upper floor and stairs	Facing brick, stone and Al curtain walling	Undefined mechanical and electrical services	Block partitions
2	**16499**	**8**	RC columns and beams, upper floors	Stone cladding or facing brick/block walls	Gas LPHW central heating; fan cooling, ventilation	Block partitions, glazed screens

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
3	**20349**	**4**	RC frame and upper floors	RC walls with PCC and Zink cladding, aluminium curtain walling	Central heating, air conditioning, electrics and lifts	RC, Metal stud and glass partitions
4	**20351**	**4**	RC and steel frame	Brick/block walls, cladding and curtain walling	Gas LPHW central heating, air conditioning	Block, cubicle and glazed partitions
5	**20355**	**5**	PCC floors	Stone, brick, concrete and curtain walling	Gas LPHW central heating, local ventilation	Block, metal stud, glazed and cubicle partitions
6	**20857**	**4**	Steel frame	Brick cavity walls; reconstructed stone, double glazed aluminium curtain walling	Gas LPHW central heating, air conditioning, ventilation	Block, concrete, plasterboard and proprietary partitions
7	**20754**	**4**	Steel frame	Reconstituted stone, cladding and aluminium curtain walling; Brise Soleil	Gas LPHW heating, air conditioning, ventilation	Plasterboard, tiles and plastic to walls
8	**20417**	**4**	Steel frame	Facing brick/block, rendered block/block and patent glazing to walls	Central heating, ventilation	Block and demountable partitions
9	**21193**	**4**	Steel frame	Brick cavity walls; aluminium curtain walling	Lump sum for mechanical and electrical services	Block internal walls

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
10	**21759**	**5 & 6**	PCC frame	Blaxter sandstone and PCC cladding double glazed curtain walling.	Electric LTHW central heating, light and power; air handling system, displacement ventilation	Plasterboard, timber panels and marble to walls
11	**23864**	**4**	Steel frame	Block/timber walls	Gas HW central heating, local/central ventilation	Block, metal stud and cubicle partitions
12	**23490**	**4**	Steel frame	Rendered block, facing brick and curtain walling	Gas HW central heating, ventilation, heating/cooling, electrics	Block and cubicle partitions
13	**24069**	**4**	Steel frame	Facing brick, Rainscreen, lead, terracotta cladding.	Local electric heating, ventilation	Block, brick, metal stud partitions
14	**24082**	**5**	RC frame	Terracotta Rainscreen cladding and aluminium curtain walling	Gas HW central heating, ventilation	Metal stud partitions
15	**24802**	**12**	Steel frame	Triple glazed aluminium wall cladding	Heating, naturally chilled ground water cooling, heat recovery, automated passive ventilation	N/A
Hotel Buildings						
1	**B19611**	**6**	RC frame	Al wall cladding.	Fan coil heating, air conditioning	Block and RC partitions
2	**B24512**	**4**	Steel frame	Brick and metal clad walls; curtain walling.	Electric light, power and heating	Partitions (no indication about the type)

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
3	**B23531**	**4**	RC frame	Dorset flint and stone facing blocks, aluminium cladding and curtain walling	Lump sums for heating, ventilation	Metal stud partitions
4	**B23116**	**8**	Steel frame	Curved copper cladding and glazed façade	Undefined heating, ventilation	Block, brick and glazed partitions
5	**B21306**	**5**	Steel frame	Roughcast and facing block/block walls	PC sums for heating	Block partitions
Mixed-use						
1	**24596**	**4**	RC frame	Facing brick/block walls	Provisional Sums for heating	Block, metal stud partitions
2	**24314**	**4**	RC frame	Limestone and block walls	Gas HW central heating, local/central ventilation	Block and metal stud partitions
3	**23396**	**4**	RC and PCC upper floor	Facing brick, rendered block walls	Gas HW central heating, ventilation	Block and timber stud partitions
4	**23833**	**4**	Precast concrete upper floors	Brick/block walls	Heating, ventilation (electricity)	Block and metal stud partitions
5	**23666**	**6**	Reinforced concrete	Brick and block walls curtain walling	Electric heating, power and lights; local ventilation	Block and metal stud partitions

	BCIS Reference number	Number of storeys	Structure / Frame	External facade	Services system	Internal walls and partitions
6	**22029**	**6**	Precast concrete upper floors	Rendered block/timber, stone and Eternit wall cladding	Gas LTHW central heating, ventilation	Block, concrete and timber stud partitions
7	**22270**	**6**	Precast concrete upper floors	Reconstituted stone, concrete blocks and rendered block cavity walls; curtain walling	Gas LTHW central heating, extract fans	Block and metal stud partitions
8	**14681**	**11**	PCC and RC upper floors, steel frame	Bespoke glass/metal clads, curtain walling, atrium glazing	Gas/oil LTHW central heating	Plasterboard, plaster, render, acrylic, stone to walls
9	**20414**	**7**	Reinforced concrete upper floors	Stone, rebder on mesh and curtain walling	PC sums for heating and electrics	Metal stud and proprietary partitions
10	**20460**	**6 and 5**	RC and PCC upper floor	Brick/ block, glass block	N/A	Block partitions
11	**21551**	**8**	Reinforced concrete upper floors	Stone, brick and curtain walling	N/A	Block and stud partitions
12	**22958**	**6 & 4**	PCC upper floors	Brick, limestone and metal cladding, aluminium curtain walling	Electric heating, ventilation	Block, timber stud and cubicle partitions

Appendix – H: Elemental cost information of selected buildings

Residential buildings

Element	BCIS Analysis Number																
	B14840	**B16308**	**B16319**	**B17465**	**B18083**	**B20637**	**B21238**	**B21305**	**B21635**	**B22398**	**B22537**	**B23375**	**B23399**	**B23652**	**B23799**	**B23872**	**B24330**
Number of Storeys	**5**	**4 & 5**	**4**	**11**	**5**	**4**	**6**	**4**	**11**	**4**	**4**	**4 & 5**	**4**	**8**	**4**	**10 & 7**	**4**
Location	**London E5**	**East Sussex**	**Whiltshire**	**London NW8**	**London E1**	**Glasgow**	**London SW5**	**Argryll & Bute**	**Manchest**	**Edingburgh**	**London E14**	**Bradford**	**Nottingham**	**London SE16**	**West Midlands**	**London SE17**	**London SW1**
Regional TPI (Tender Price Index (Base)	**203**	**121**	**130**	**134**	**142**	**164**	**180**	**173**	**153**	**197**	**190**	**234**	**227**	**217**	**225**	**190**	**217**
Regional TPI 2008 Dec	**238**	**224**	**250**	**238**	**238**	**258**	**238**	**258**	**224**	**258**	**238**	**245**	**241**	**238**	**242**	**238**	**238**
Regional Price Adjustments	**1.17**	**1.85**	**1.92**	**1.78**	**1.68**	**1.57**	**1.32**	**1.49**	**1.46**	**1.31**	**1.25**	**1.05**	**1.06**	**1.10**	**1.08**	**1.25**	**1.10**
Year of Possession	**2004 Aug**	**1996 Sep**	**1996 Aug**	**1997 Oct**	**1998 May**	**2001 Jul**	**2002 Mar**	**2002 May**	**2000 Jun**	**2004 Apr**	**2004 Feb**	**2004 Oct**	**2005 Jul**	**2006 Jun**	**2005 Aug**	**2004 Mar**	**2006 Jul**
Sub structure	£56.72	£71.00	£212.69	£335.05	£138.98	£237.41	£166.60	£33.09	£119.58	£121.69	£103.98	£50.58	£44.42	£147.26	£26.06	£139.94	£164.20
Superstructure	£381.91	£565.65	£662.33	£876.60	£890.62	£547.95	£833.81	£301.58	£388.11	£502.71	£744.85	£419.45	£416.02	£631.17	£520.74	£921.49	£738.55
Internal finishes	£119.07	£111.76	£115.40	£324.25	£289.91	£124.64	£284.56	£121.13	£57.93	£177.92	£134.29	£85.32	£86.92	£98.96	£128.99	£103.64	£153.64
Fittings and furnishing	£41.03	£24.42	£41.75	£278.82	£104.03	£23.27	£192.77	£24.16	£39.38	£23.19	£86.14	£51.61	£50.08	£24.78	£12.14	£76.80	£127.21
Services	£192.59	£252.03	£234.58	£652.95	£444.57	£145.88	£433.08	£147.05	£145.26	£175.58	£369.64	£169.69	£166.58	£260.09	£200.30	£296.75	£286.10
External works	£142.79	£135.64	£199.06	£42.45	£78.66	£112.94	£282.33	£86.09	£40.25	£81.96	£164.77	£107.22	£74.81	£249.25	£117.96	£44.69	£150.94
Preliminaries	£86.63	£135.62	£179.85	£591.39	£278.63	£224.43	£452.49	£132.64	£54.23	£162.34	£293.19	£140.37	£158.69	£254.79	£76.33	£250.40	£216.80
FACILITY CAPITAL COST	**£1,020.75**	**£1,296.11**	**£1,645.65**	**£3,101.51**	**£2,225.40**	**£1,416.51**	**£2,645.63**	**£845.73**	**£844.74**	**£1,245.39**	**£1,896.87**	**£1,024.25**	**£997.51**	**£1,666.31**	**£1,082.53**	**£1,833.71**	**£1,837.44**

Office buildings

Element	BCIS analysis Number														
	16326	**16499**	**20349**	**20351**	**20355**	**20857**	**20754**	**20417**	**21193**	**21759**	**23864**	**23490**	**24069**	**24082**	**24802**
Number of Storeys	**6**	**8**	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**5 and 6**	**4**	**4**	**4**	**5**	**12**
Location	**London**	**London**	**Berkshire**	**Berkshire**	**Berkshire**	**Manchester**	**Hertfordshire**	**West Sussex**	**Berkshire**	**Edinburgh**	**Aberdeen**	**Manchester**	**Birmingham**	**Essex**	**London**
Regional Tender Price Index (Base)	**122**	**122**	**166**	**152**	**159**	**160**	**166**	**168**	**162**	**161**	**237**	**221**	**238**	**214**	**190**
Regional Tender Price Index (2008 Dec)	**238**	**238**	**224**	**224**	**224**	**224**	**224**	**224**	**224**	**258**	**258**	**224**	**242**	**224**	**238**
Regional Price Adjustments	**1.95**	**1.95**	**1.35**	**1.47**	**1.41**	**1.40**	**1.35**	**1.33**	**1.38**	**1.60**	**1.09**	**1.01**	**1.02**	**1.05**	**1.25**
Year of Possession	**1996 Sep**	**1996 Aug**	**2001 Feb**	**1999 Nov**	**2000 Sep**	**2000 July**	**2001 Mar**	**2001 Apr**	**2000 Dec**	**2001 May**	**2006 Apr**	**2005 Apr**	**2007 Apr**	**2006 Oct**	**2003 Feb**
Element															
Sub structure	£62.74	£96.62	£99.36	£91.40	£95.09	£51.31	£81.77	£28.93	£207.37	£122.97	£62.95	£52.58	£96.04	£64.63	£325.93
Superstructure	£699.15	£888.38	£490.89	£600.19	£554.53	£461.86	£573.62	£604.09	£911.50	£951.20	£586.72	£387.83	£598.89	£508.62	£1,599.13
Internal finishes	£195.59	£161.88	£121.07	£125.19	£141.77	£122.99	£102.05	£165.41	£194.47	£213.79	£120.08	£106.23	£109.60	£86.65	£246.76
Fittings and furnishing	£35.37	£28.33	£7.58	£7.18	£10.93	£4.91	£1.01	£35.11	£5.57	£4.17	£25.51	£26.33	£8.82	£26.89	£412.83
Services	£704.27	£667.71	£436.65	£340.89	£581.51	£468.33	£455.50	£390.33	£534.46	£556.48	£346.42	£245.79	£273.91	£373.10	£647.03
External works	£22.20	£171.98	£216.81	£334.54	£352.85	£334.82	£258.13	£112.72	£172.38	£66.31	£40.13	£132.76	£136.89	£71.98	£0.00
Preliminaries	£303.08	£450.03	£179.87	£225.15	£351.09	£157.88	£157.69	£187.68	£326.50	£208.05	£190.62	£177.48	£243.06	£162.52	£491.03
FACILITY CAPITAL COST	**£2,022.40**	**£2,464.94**	**£1,552.23**	**£1,724.53**	**£2,087.78**	**£1,602.10**	**£1,629.78**	**£1,524.28**	**£2,352.25**	**£2,122.97**	**£1,372.42**	**£1,129.01**	**£1,467.20**	**£1,294.37**	**£3,722.72**

Hotels

Element	BCIS analysis number				
	B19611	**B24512**	**B23531**	**B23116**	**B21306**
Number of Storeys	**6**	**4**	**4**	**8**	**5**
Location	**London**	**South Yorkshire**	**Wiltshire**	**Glasgow**	**Aberdeen**
Regional Tender Price Index (Base)	**128**	**242**	**232**	**154**	**164**
Regional Tender Price Index 2008 Dec	**238**	**245**	**250**	**258**	**258**
Regional Cost Adjustments	**1.86**	**1.01**	**1.08**	**1.68**	**1.57**
Year of Possession	**1997 Apr**	**2006 July**	**2006 Jan**	**2000 Aug**	**2001 Jul**
Element					
Substructure	£40.79	£27.20	£53.73	£158.08	£50.59
Superstructure	£468.47	£353.10	£477.60	£766.18	£318.28
Internal finishes	£93.30	£115.20	£145.82	£83.80	£93.37
Fittings & furnishing	£116.81	£165.42	£97.70	£12.67	£12.66
Services	£473.38	£417.11	£370.85	£524.81	£382.42
External works	£82.07	£120.26	£103.93	£47.39	£46.06
Preliminaries	£224.13	£212.85	£116.08	£237.56	£131.45
FACILITY CAPITAL COST	**£1,498.95**	**£1,411.14**	**£1,365.71**	**£1,830.49**	**£1,034.85**

Mixed use

Element	BCIS analysis number											
	Housing with Shops, Offices etc.							**Offices with Shops, Banks, Flats etc.**				
	B24596	**B21650**	**B24314**	**B23396**	**B23833**	**B23666**	**B22270**	**B14681**	**B20414**	**B20460**	**B21551**	**B22958**
Number of Storeys	**4**	**5**	**4**	**4**	**4**	**6**	**6**	**11**	**7**	**6 and 5**	**8**	**6 & 4**
Location	**West Yorkshire**	**London E15**	**Devon**	**West Yorkshire**	**Cheshire**	**Avon**	**Edinburgh**	**London EC2**	**London**	**London WC1**	**London W1**	**Liverpool**
Regional Tender Price Index (Base)	**242**	**177**	**237**	**238**	**223**	**231**	**178**	**129**	**177**	**164**	**186**	**198**
Regional Tender Price Index 2008 Dec	**245**	**238**	**250**	**245**	**224**	**250**	**258**	**238**	**238**	**238**	**238**	**224**
Regional Cost Adjustments	**1.01**	**1.34**	**1.05**	**1.03**	**1.00**	**1.08**	**1.45**	**1.84**	**1.34**	**1.45**	**1.28**	**1.13**
Year of Possession	**2008 Apr**	**2001 Aug**	**2006 Mar**	**2005 Dec**	**2006 Jan**	**2005 Jun**	**2003 Feb**	**1994 May**	**2001 May**	**2000 Jul**	**2002 Feb**	**2004 Jan**
Element												
Substructure	£98.28	£100.18	£89.60	£49.99	£69.76	£59.58	£106.06	£171.36	£184.86	£124.21	£106.03	£39.88
Superstructure	£438.55	£632.88	£540.28	£496.62	£315.53	£558.16	£366.33	£1,116.70	£983.84	£710.01	£627.59	£467.12
Internal finishes	£106.45	£103.34	£117.62	£113.70	£80.40	£120.93	£95.66	£256.36	£103.00	£0.00	£179.37	£66.09
Fittings & furnishing	£5.14	£77.42	£20.44	£65.49	£29.25	£71.99	£27.74	£65.40	£24.81	£51.53	£62.14	£4.93
Services	£212.17	£212.26	£284.42	£172.52	£158.36	£175.35	£209.07	£601.73	£479.66	£133.57	£511.37	£174.49
External works	£111.37	£46.75	£53.61	£131.88	£93.51	£34.52	£72.83	£48.12	£42.68	£132.96	£146.69	£56.54
Preliminaries	£95.80	£382.43	£91.31	£205.39	£86.61	£198.69	£126.23	£209.22	£268.67	£184.04	£419.69	£130.90
FACILITY CAPITAL COST	**£1,067.77**	**£1,555.26**	**£1,197.28**	**£1,235.58**	**£833.41**	**£1,219.22**	**£1,003.92**	**£2,468.89**	**£2,087.52**	**£1,336.33**	**£2,052.87**	**£939.96**

Appendix – I: Interviewees' profile and experience

Interviewee	Organisation
(Interviewee – 1)	Development control officer, Charnwood Borough council, Loughborough (Experience in urban planning =18 years)
(Interviewee - 2)	Director of Change project, Loughborough University, Loughborough (Experience as a project Director = 12 ½ years)
(Interviewee - 3)	Project Engineer, Estate Services (FM), Loughborough University, Loughborough (Experience as a project engineer = 17 years)
(Interviewee - 4)	Structural Engineer, Buro Happold, London (Experience as a structural engineer = 11 years)
(Interviewee - 5)	Architect/Research Associate, Loughborough University, Loughborough (Experience as an architect = 8 years)
(Interviewee - 6)	Quantity Surveyor, Carillion Co. Ltd., London (Experience as a quantity surveyor = 16 years)
(Interviewee - 7)	Facilities Manager, Estate Services, Loughborough University, Loughborough (Experience as a building maintenance engineer = 22 years)
(Interviewee - 8)	Professor of Building Simulation, Loughborough University, Loughborough ([Experience in building services industry and academic = 34 years)
(Interviewee - 9)	Senior Lecturer in Architectural and Sustainable Construction, Loughborough University, Loughborough (Experience as an architect = 14 years)
(Interviewee - 10)	Programme Director for Construction Engineering Management, Loughborough University, Loughborough (Experience as a structural engineer = 8 years)
(Interviewee – 11)	Senior Planner, Leicester City Council, Welford Place, Leicester (Experience as a planner = 21 years)

Appendix – J: Collected data for WBS2 and WBS3

WBS2: (Responses received for WBS2: architects)

Response Summary

Total Started Survey: 32
Total Completed Survey: 32 (100%)

PAGE: DESIGN NEW BUILDINGS FOR POTENTIAL CHANGE OF USE

1. How many years experience as an architect do you have?

Create Chart Download

	Response Percent	Response Count
Less than 5	15.6%	5
5 - 10	21.9%	7
10 - 15	31.3%	10
15 - 20	21.9%	7
More than 20	9.4%	3
	answered question	32
	skipped question	0

2. Do you believe that purposefully designing buildings to facilitate future change of use represents innovative architecture?

Create Chart Download

	Response Percent	Response Count
Definitely	34.4%	11
Probably	37.5%	12
May be	18.8%	6
Probably not	6.3%	2
Definitely not	3.1%	1
Not sure	0.0%	0
	answered question	32
	skipped question	0

3. To what extent do the following design parameters affect future change of use in buildings? Create Chart Download

	Significant	High	Moderate	Low	Very low	None	Not sure	Rating Average	Response Count
Building height	18.8% (6)	**28.1% (9)**	**28.1% (9)**	15.6% (5)	3.1% (1)	6.3% (2)	0.0% (0)	4.25	32
Building proximity	12.5% (4)	25.0% (8)	**43.8% (14)**	3.1% (1)	6.3% (2)	0.0% (0)	9.4% (3)	3.97	32
Building size	21.9% (7)	**37.5% (12)**	28.1% (9)	9.4% (3)	0.0% (0)	0.0% (0)	3.1% (1)	4.59	32
Fire safety design	29.0% (9)	**32.3% (10)**	**32.3% (10)**	6.5% (2)	0.0% (0)	0.0% (0)	0.0% (0)	4.84	31
Floor to ceiling height	37.5% (12)	**40.6% (13)**	12.5% (4)	6.3% (2)	3.1% (1)	0.0% (0)	0.0% (0)	5.03	32
Plan depth	**40.6% (13)**	31.3% (10)	25.0% (8)	3.1% (1)	0.0% (0)	0.0% (0)	0.0% (0)	5.09	32
Services systems	25.0% (8)	**40.6% (13)**	21.9% (7)	12.5% (4)	0.0% (0)	0.0% (0)	0.0% (0)	4.78	32
Structural design	**46.7% (14)**	13.3% (4)	23.3% (7)	16.7% (5)	0.0% (0)	0.0% (0)	0.0% (0)	4.90	30
Technical span	21.9% (7)	12.5% (4)	**43.8% (14)**	12.5% (4)	0.0% (0)	0.0% (0)	9.4% (3)	4.06	32
								answered question	32
								skipped question	0

4. Do you consider that increasing floor to ceiling height of a typical building (e.g. from residential to commercial typical heights) would be a good way of increasing its future convertibility? Create Chart Download

	Response Percent	Response Count
Strongly agree	28.1%	9
Agree	**40.6%**	**13**
Neutral	28.1%	9
Disagree	3.1%	1
Strongly disagree	0.0%	0
Don't know	0.0%	0
	answered question	32
	skipped question	0

5. Do you think that running building services through the structural beams in a multi-storey framed building is an effective way of maximising finished floor to ceiling height without increasing the overall height of a building? Create Chart Download

	Response Percent	Response Count
Strongly agree	16.1%	5
Agree	**67.7%**	**21**
Neutral	16.1%	5
Disagree	0.0%	0
Strongly disagree	0.0%	0
Not sure	0.0%	0
	answered question	**31**
	skipped question	**1**

6. Do you consider that increasing the structural floor to floor height and thus the overall height of the building would be the most frequent way of increasing the finished floor to ceiling height? Create Chart Download

	Response Percent	Response Count
Strongly agree	6.3%	2
Agree	**53.1%**	**17**
Neutral	28.1%	9
Disagree	9.4%	3
Strongly disagree	0.0%	0
Not sure	3.1%	1
	answered question	**32**
	skipped question	**0**

7. Do you think that increasing the overall height of a building in a town centre is not usually an option due to planning restrictions? Create Chart Download

	Response Percent	Response Count
Strongly agree	16.1%	5
Agree	**32.3%**	**10**
Neutral	19.4%	6
Disagree	29.0%	9
Strongly disagree	3.2%	1
Not sure	0.0%	0
	answered question	**31**
	skipped question	**1**

8. Do you consider that 3.5m (approximately) is an optimum finished floor to ceiling height to facilitate all four functions of residential, hotel, office and retail? Create Chart Download

	Response Percent	Response Count
Strongly agree	9.4%	3
Agree	**43.8%**	**14**
Neutral	31.3%	10
Disagree	12.5%	4
Strongly disagree	3.1%	1
Not sure	0.0%	0
	answered question	32
	skipped question	0

9. Do you think that the often higher floor to ceiling height in Victorian / Georgian architecture is responsible for their extended use? Create Chart Download

	Response Percent	Response Count
Strongly agree	15.6%	5
Agree	**46.9%**	**15**
Neutral	15.6%	5
Disagree	18.8%	6
Strongly disagree	3.1%	1
Don't know	0.0%	0
	answered question	32
	skipped question	0

10. Would it be good, sustainable practice to build city centre residential blocks in such a way that they could be more easily adapted for other uses in the future? Create Chart Download

	Response Percent	Response Count
Strongly agree	37.5%	12
Agree	**53.1%**	**17**
Neutral	6.3%	2
Disagree	0.0%	0
Strongly disagree	0.0%	0
Not sure	3.1%	1
	answered question	32
	skipped question	0

WBS3: (Responses received for WBS3: Quantity surveyors)

Response Summary

Total Started Survey: 42
Total Completed Survey: 42 (100%)

PAGE: ECONOMIC CONSIDERATIONS FOR ADAPTABILITY IN BUILDINGS

1. How many years experience as a Quantity Surveyor do you have?

Create Chart Download

	Response Percent	Response Count
Less than 5	9.5%	4
5 - 10	21.4%	9
10 - 15	**28.6%**	**12**
15 - 20	14.3%	6
More than 20	26.2%	11
answered question		42
skipped question		0

2. Do you believe that designing buildings to facilitate future change of use represents a good long term investment?

Create Chart Download

	Response Percent	Response Count
Definitely	**45.2%**	**19**
Probably	38.1%	16
May be	11.9%	5
Probably not	4.8%	2
Definitely not	0.0%	0
Not sure	0.0%	0
answered question		42
skipped question		0

3. Do you consider that increasing the floor to ceiling height of a typical building (e.g. from residential to commercial typical heights) would be a good way of increasing its future convertibility?

Create Chart Download

	Response Percent	Response Count
Strongly agree	2.4%	1
Agree	**42.9%**	**18**
Neutral	28.6%	12
Disagree	26.2%	11
Strongly disagree	0.0%	0
answered question		42
skipped question		0

4. Do you think running building services through the structural beams in a multi-storey framed building is an effective cost effective way of maximising finished floor to ceiling height without increasing the overall height of a building? Create Chart Download

	Response Percent	Response Count
Strongly agree	9.5%	4
Agree	**71.4%**	**30**
Neutral	11.9%	5
Disagree	7.1%	3
Strongly disagree	0.0%	0
	answered question	42
	skipped question	0

5. Do you consider that increasing the structural floor to floor height and thus the overall height of the building would be the most cost effective way of increasing the finished floor to ceiling height? Create Chart Download

	Response Percent	Response Count
Strongly agree	0.0%	0
Agree	31.0%	13
Neutral	**38.1%**	**16**
Disagree	31.0%	13
Strongly disagree	0.0%	0
	answered question	42
	skipped question	0

6. Do you think that increasing the overall height of a building in a town centre is not usually an option due to planning restrictions? Create Chart Download

	Response Percent	Response Count
Strongly agree	7.1%	3
Agree	**47.6%**	**20**
Neutral	21.4%	9
Disagree	23.8%	10
Strongly disagree	0.0%	0
	answered question	42
	skipped question	0

7. Would it be good, sustainable practice to build city centre residential blocks in such a way that they could be more easily adapted for other uses in the future? Create Chart Download

	Response Percent	Response Count
Strongly agree	11.9%	5
Agree	61.9%	26
Neutral	7.1%	3
Disagree	16.7%	7
Strongly disagree	2.4%	1
	answered question	42
	skipped question	0

8. To what extent do the following cost categories influence design for adaptation? Create Chart Download

	Significant	High	Moderate	Low	Very low	None	Not sure	Rating Average	Response Count
Cost of market research	2.6% (1)	2.6% (1)	25.6% (10)	25.6% (10)	17.9% (7)	23.1% (9)	2.6% (1)	2.67	39
Design cost provisions	7.7% (3)	33.3% (13)	43.6% (17)	7.7% (3)	7.7% (3)	0.0% (0)	0.0% (0)	4.26	39
Opportunity cost	10.3% (4)	25.6% (10)	33.3% (13)	10.3% (4)	5.1% (2)	5.1% (2)	10.3% (4)	3.69	39
Cost of finance	30.8% (12)	46.2% (18)	10.3% (4)	10.3% (4)	0.0% (0)	2.6% (1)	0.0% (0)	4.90	39
Tax	10.3% (4)	35.9% (14)	30.8% (12)	15.4% (6)	2.6% (1)	2.6% (1)	2.6% (1)	4.18	39
Cost of structure	20.5% (8)	51.3% (20)	28.2% (11)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	4.92	39
Cost of skin (external facade)	10.3% (4)	48.7% (19)	41.0% (16)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	4.69	39
Cost of services	23.1% (9)	56.4% (22)	20.5% (8)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	5.03	39
Cost of space plan (internal reconfigurations)	5.3% (2)	36.8% (14)	44.7% (17)	7.9% (3)	2.6% (1)	0.0% (0)	2.6% (1)	4.24	38
Maintenance cost	7.7% (3)	46.2% (18)	30.8% (12)	10.3% (4)	2.6% (1)	0.0% (0)	2.6% (1)	4.36	39
Operational cost	10.3% (4)	35.9% (14)	48.7% (19)	2.6% (1)	0.0% (0)	0.0% (0)	2.6% (1)	4.44	39
Cost of change of use	17.9% (7)	33.3% (13)	28.2% (11)	17.9% (7)	2.6% (1)	0.0% (0)	0.0% (0)	4.46	39
Cost of demolition	10.3% (4)	28.2% (11)	12.8% (5)	33.3% (13)	12.8% (5)	2.6% (1)	0.0% (0)	3.82	39
							Any other costs and likely influence (please specify) Show Responses		2
								answered question	39
								skipped question	3

9. What are the likely benefits that could be expected from Design for Adaptation? Create Chart Download

	Significant	High	Moderate	Low	Very low	None	Not sure	Rating Average	Response Count
Potential income (sell, let, lease)	17.5% (7)	**57.5% (23)**	22.5% (9)	2.5% (1)	0.0% (0)	0.0% (0)	0.0% (0)	4.90	40
Tax concessions	5.0% (2)	17.5% (7)	**57.5% (23)**	10.0% (4)	0.0% (0)	2.5% (1)	7.5% (3)	3.80	40
Social sustainability	7.5% (3)	**42.5% (17)**	**42.5% (17)**	5.0% (2)	0.0% (0)	2.5% (1)	0.0% (0)	4.45	40
Environment sustainability	10.0% (4)	**55.0% (22)**	20.0% (8)	10.0% (4)	2.5% (1)	0.0% (0)	2.5% (1)	4.50	40
Economic sustainability	20.0% (8)	**57.5% (23)**	15.0% (6)	5.0% (2)	2.5% (1)	0.0% (0)	0.0% (0)	4.88	40
Any other benefits and their level of significance (please specify)									0
								answered question	**40**
								skipped question	**2**

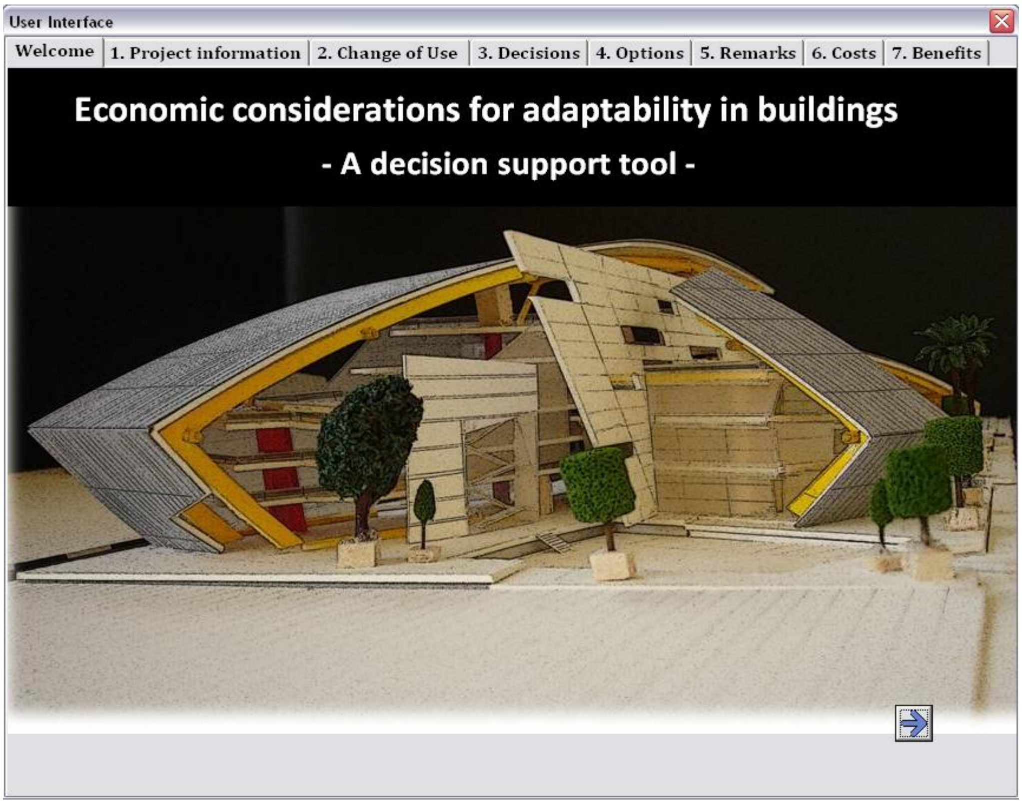
10. Do you think that the 'cost of adaptation' is an encouraging or discouraging factor in designing new buildings for future change of use? Please explain your answer. Download

	Response Count
Show Responses	24
answered question	**24**
skipped question	**19**

Appendix – K: Decision support prototype

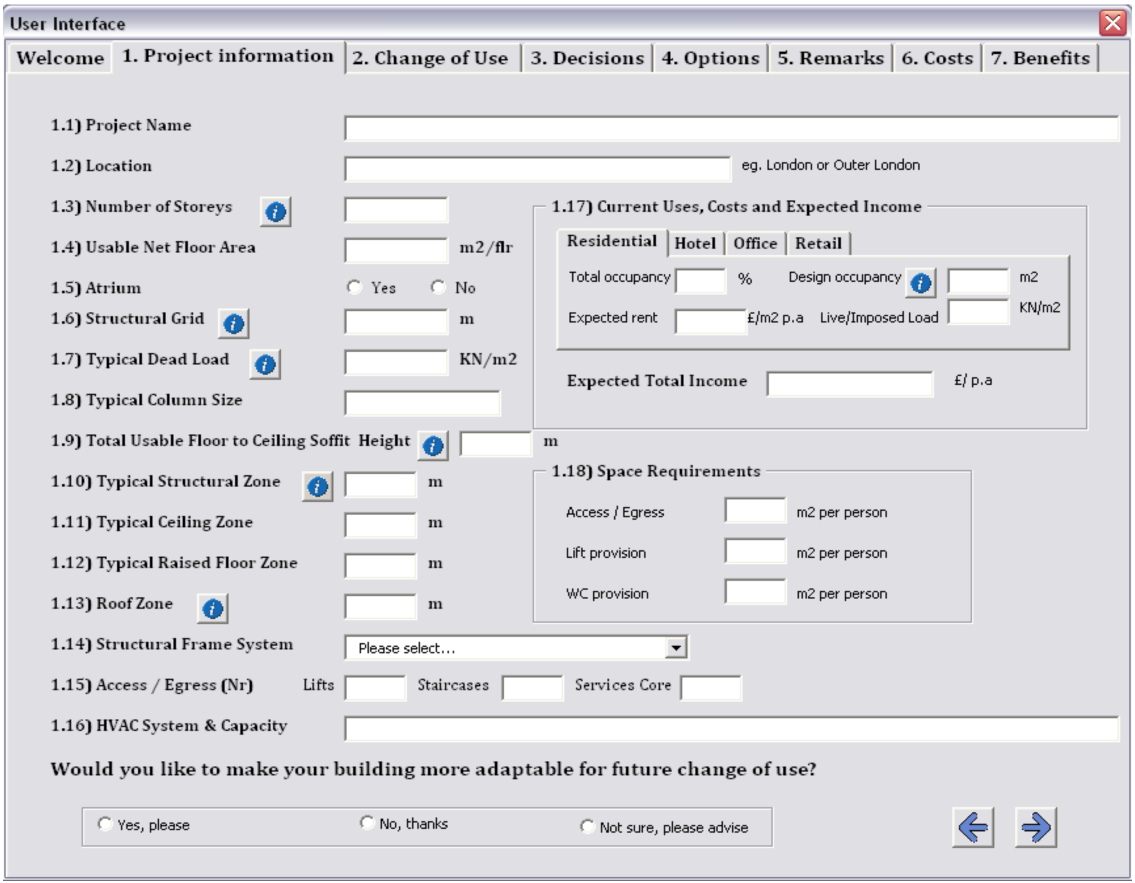
Welcome

This is the welcome interface. The command button in the bottom right guides to the next interfaces.

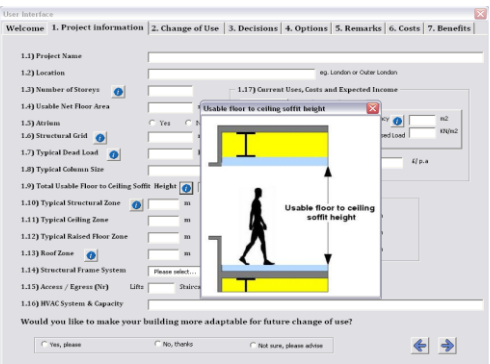


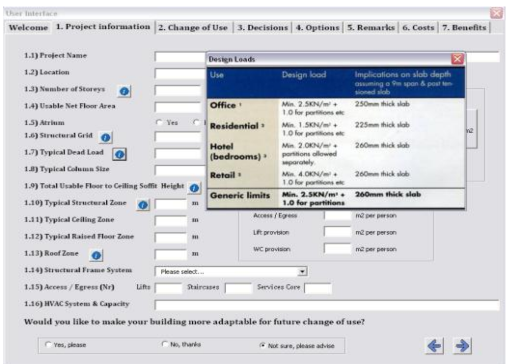
1 - Project Information

This interface is used to gather the design information of proposed project. The additional information are provided to users on .



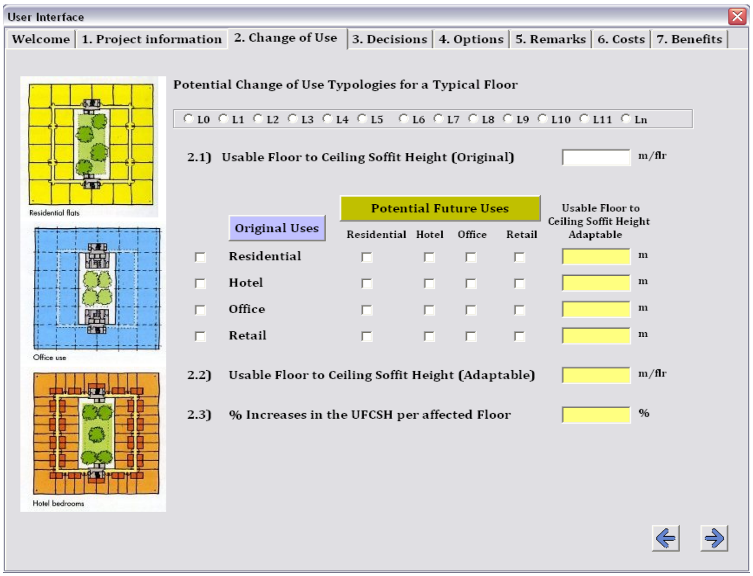
Additional information:





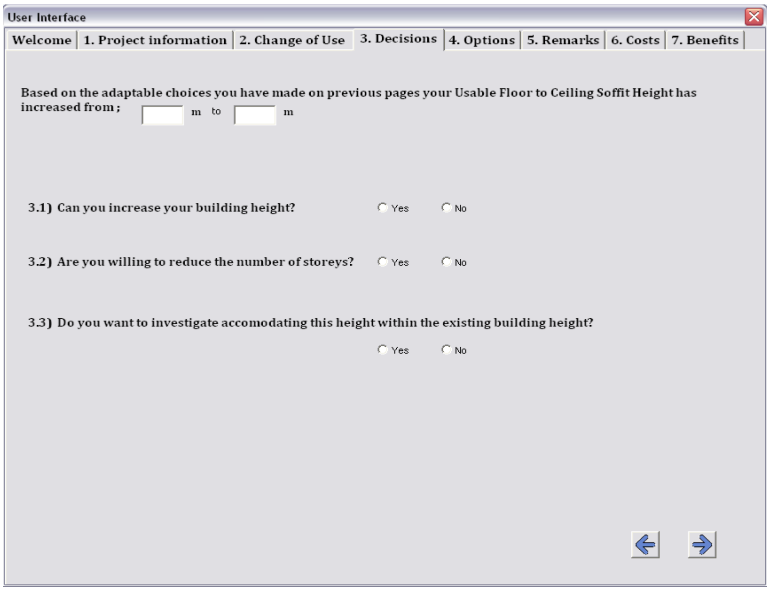
2 - Change of use

This interface evaluates the overall changes required in building to respond the potential change of use.



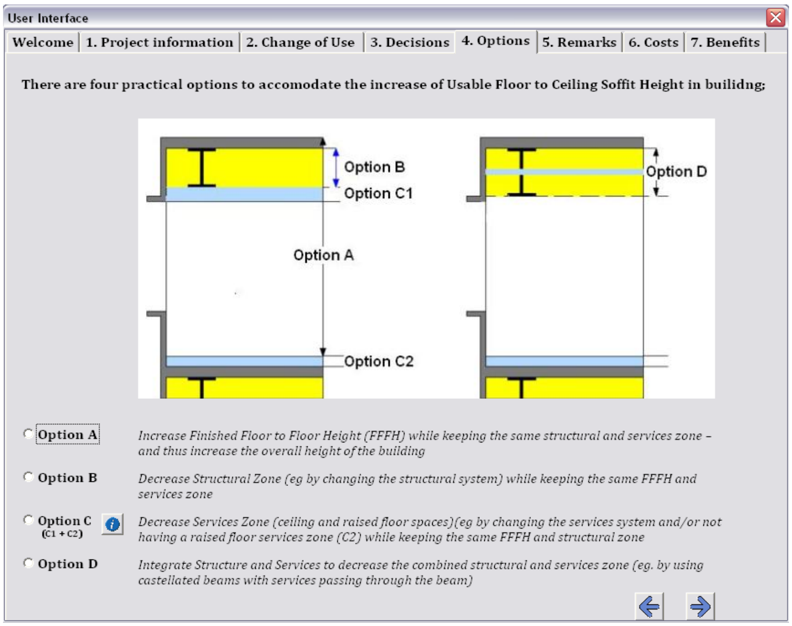
3 – Decisions

This interface seeks the user approvals to design building for potential adaptations.



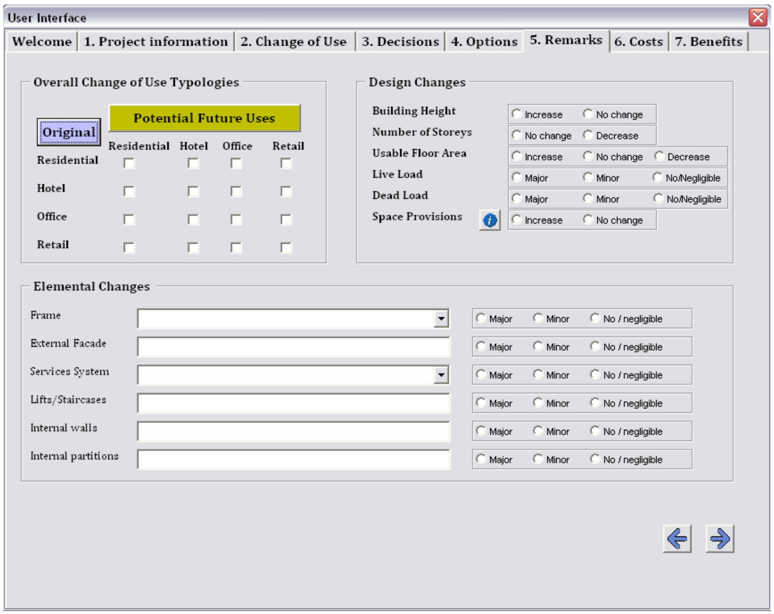
4 – Adaptable design options

The different design options to make building adaptable are considered within this interface.



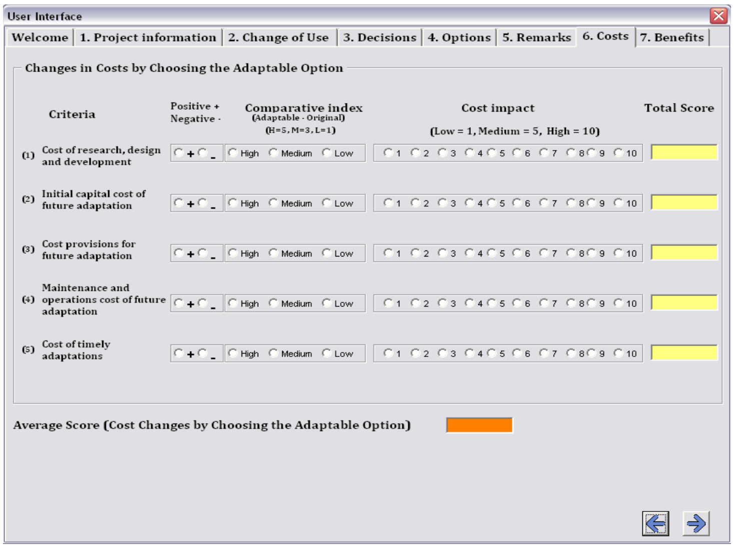
5 – Remarks

The overall changes to building or elements/layers are evaluated in this interface.



6 Cost increases through proposed adaptation

This interface used to compare the costs between adaptable and maladapable options.



7 – Expected benefits through adaptation

The benefits of adaptable option are evaluated over traditional (maladaptive) option.

Final evaluation

The decision is based on the value score. If the value is > 1, the adaptable option seems as the most desirable decision to continue.

Appendix – L: Research publications

Book chapters

1. **MANEWA, R.M.A.S**., PASQUIRE, C.L., GIBB, A.G. and SCHMIDT-III, R., 2009. Towards economic sustainability through adaptable buildings. In: A. Dobbelsteen, M. Dorst and A. Timmeren, eds, *Smart building in a changing climate.* 1st edn. The Netherlands: Techne Press, pp. 171-185.

Refereed Conference Papers

1. **MANEWA, R.M.A.S**., PASQUIRE, C.L., GIBB, A.G. and SCHMIDT-III, R., 2009. Paradigm shift towards whole life analysis in adaptable buildings, *Changing Roles: New Role; New Challenges,* 5th - 7th October 2009, Delft University of Technology, The Netherlands.

2. **MANEWA, R.M.A.S**., PASQUIRE, C.L., GIBB, A.G. and SCHMIDT-III, R., 2009. Towards economic sustainability through adaptable buildings, A. Dobbelsteen, M. Dorst and A. Timmeren, eds. *CIB International conference on smart and sustainable built environment,* 15th -19th June 2009, Delft University of Technology, The Netherlands.