RECIPES FOR LOW CARBON, ADAPTABLE DESIGN

by

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Abstract

The thesis contributes a more lucid understanding of the potential for interaction amongst different facets of 'sustainability' in the context of building design, providing evidence that the assimilation of diverse and often seemingly unconnected aspects of sustainability is not the unassuming process implicit in the current sustainability discourse. Working inductively and with a focus on two sustainable principles (the current UK government sponsored sustainability agenda, low carbon design, and an alternative interpretation, adaptable design, whose literature is framed in a sometimes complementary, at others antagonistic fashion to the former), this thesis develops an understanding of interaction in building design processes, using publically available documentary evidence and a comparative case-study approach.

The thesis describes and categorises instances of interaction arising in the twenty-three case study building design processes, demonstrating both the empirical existence of interaction and improving the theoretical conceptualisation beyond basic ideas of synergy and conflict. Interaction is noted as arising from both technical incompatibilities and project actors' interpretation of the agendas themselves: a socio-technical issue.

The thesis distinguishes multiple approaches adopted by design teams to managing the entanglement encountered. Interpreting these interaction strategies in their case context, factors driving the selection of a particular approach are inductively derived and combined to form a tentative conceptual framework. This framework aides a systematic comparison across project cases, facilitated by the crisp set qualitative comparative analysis (csQCA) technique. Projects are described as configurations of the identified conditions and, by operationalizing interaction in a manner consistent with case study observation and the existing literatures of adaptable and low carbon design, assessed for successfulness in reconciling the agendas. The technique identifies three causal pathways to successful reconciliations of adaptable and low carbon design.

Finally, the thesis makes a methodological contribution, through an evaluation of the application of QCA to a novel problem space (socio-technical, project-orientated problems of the built environment). Through the richness of documentary data obtained for study, it also demonstrates the potential effectiveness of documents as primary sources in the field of building design, where they are often relegated to a supporting role.

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1 INTRODUCTION

1.1 INTRODUCTION

In the UK sustainable buildings are increasingly typecast as low carbon and energy efficient (Moncaster, 2012; Moore, 2012; Oliveira, 2012), reflecting the pressing need to reduce global emissions and avoid catastrophic climate change (IPCC, 2014). However, these low carbon ideals are far from the only claim to a sustainable built environment. Sustainable buildings are variously described as green (Leaman & Bordass, 2007), naturally ventilated (Krausse et al., 2007) and ultimately "*just good architecture*" (Guy, 2005). They should be built from ethically sourced, recycled materials (Saghafi & Teshnizi, 2011; Schultmann & Sunke, 2007), flexible in use (Schneider & Till, 2006) and resilient to the oncoming effects of climate change (Bullen, 2004; Williams et al., 2012). Overall despite decades of work the multi-faceted nature of sustainability means it remains an inherently contested concept (Guy, 2005; Hopwood et al., 2005; Renukappa et al., 2012), with no universal definition of a sustainable building.

Yet, as Guy (2005) notes "*somehow seemingly coherent problems are distilled out of this 'jamboree of claims and concerns*". Somehow despite disagreeing over what it is we should be doing and how we should be doing it, construction has been busy getting on with it: regular press releases announce completion of the latest sustainable building, award ceremonies venerate industry's sustainable achievements and sustainability rating schemes certify numerous buildings annually. As Schweber (2013) suggests:

> *"While policy-makers and scholars debate the 'correct' or 'best' definition … building professionals are busy giving content to these concepts on the ground, through the specification of new standards and the construction of new types of buildings."*

This leads to the interesting question of what, exactly, are building professionals doing? Research on the implementation of sustainable design frequently focuses on discrete design aims, implying these can be separated out and independently optimised. Work which looks at implementation more holistically tends towards the opposite extreme, with sustainability as some vaguely defined term stymied by a lack of knowledge, skills and long term thinking (Häkkinen & Belloni, 2011; Williams & Dair, 2007). Few studies have considered the implications of designing for multiple, possibly contradictory, sustainability goals simultaneously despite frequent calls for integrated approaches (Häkkinen & Belloni, 2011; Lowe, 2003; Williams & Dair, 2007) and cautionary messages on the dangers of not doing so (Davies & Oreszczyn, 2012).

The remainder of this chapter returns to these ideas in more detail, discussing the ascendancy of low carbon, the contested nature of sustainability and the disconnect evident in both research and policy related to it. It argues that, in order to produce sustainable buildings, professionals are both encountering interaction and managing it. Furthermore, due to the long lifetime of our buildings and infrastructure (Cooper, 1999; Gorgolewski, 2005), these interaction management actions will have lasting consequences for the sustainability of our built environment.

1.2 THE DOMINANCE OF LOW CARBON

Increasing global awareness of the need to limit greenhouse gases and the potentially catastrophic effects of sustained and substantial climate change (IPCC, 2014) has meant an increasing focus for policy makers on the setting of global and national targets for emissions reduction. In the UK there now exists legislative commitments at international (Kyoto Protocol), European (EU Emissions Trading Directive 2003) and national (Climate Change Act 2008) levels. The latter of these imposes an ambitious legal commitment to reduce UK emissions by 80% against 1990 levels by 2050.

Buildings are large greenhouse gas (GHG) emitters in both their construction and operation: 37% of UK emissions in 2013 are attributable to the use of buildings (Committee on Climate Change, 2014), Figure 1-1. Estimates by BIS (2010) suggest construction, maintenance and demolition account for a further 10% of UK emissions.

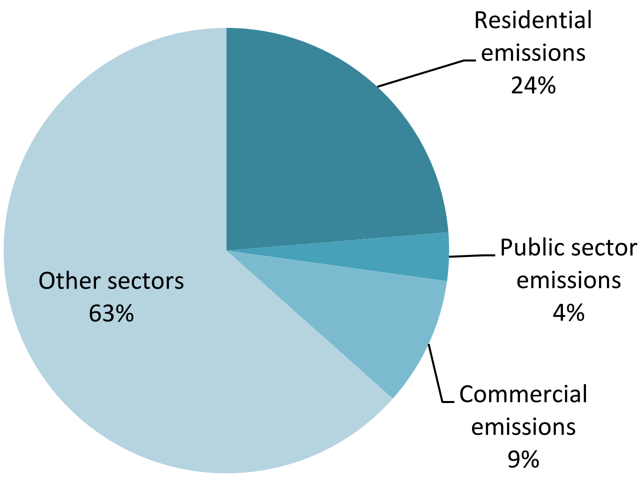

Figure 1-1 2013 GHG Emissions from buildings (total UK emissions 564 MtCO2e) (Committee on Climate Change, 2014)

The high percentage of emissions for which they account, coupled with a perception of comparatively ‘easy’ wins compared to other sectors (e.g. European Commision, 2010; Skea, 2012) has made buildings an obvious target for carbon efficiency polices (Department of Energy and

Climate Change, 2010; Jones & Hammond, 2008; Oreszczyn & Lowe, 2010). UK, US and EU governments have all made commitments, or published intentions, to develop low carbon or low energy buildings[1] in the coming decades. In the UK a range of legislative measures have been implemented (e.g. updates to building regulations Part L, the 'Green Deal', the Climate Change Levy and Energy Display Certification), and government continues to promote decarbonisation through a range of polices. For example, the 2025 Industrial Strategy for Construction (BIS, 2013) describes "*low carbon and sustainable construction*" as a strategic priority. These measures have resulted in a significant awareness of low carbon issues in the construction industry and an incentive to act to benefit from, or mitigate the impact of, the low carbon issues.

Despite the recent reductions in the onerous nature of its 'Zero Carbon' definition (Treasury, 2015) the preoccupation of government with energy efficiency policy and legislation has filtered into the industry's consciousness. Research describes the 'urgency' of decarbonising the built environment (e.g. Davies & Oreszczyn, 2012; Oreszczyn & Lowe, 2010; Skea, 2012; Williams & Dair, 2007; Zapata-Lancaster, 2013) with an accompanying steady rise in the number of energy related papers submitted to construction research journals (Schweber & Leiringer, 2012). BREEAM, the industry's most high profile voluntary sustainability scheme, devotes 19% of its total credit to "Energy" aspects, almost half of which are awarded for energy efficiency specifically (BRE, 2011). The low carbon agenda has come to dominate the popular idea of a sustainable building (Edwards & Turrent, 2000; Moore, 2012; Oliveira, 2012).

1.3 DISCONNECTED AGENDAS FOR SUSTAINABLE DESIGN

Although prolific, climate change mitigation and associated carbon reduction agendas are not the only approach to sustainability. As noted above, a variety of issues and proposed design solutions lay claim to sustainable credentials which has allowed a multitude of sustainable definitions to proliferate (Guy, 2005). While this may reflect a need for contextualised solutions (Farmer & Guy, 2010), from a practical perspective it has resulted in our understanding of sustainability becoming "*so broad and varied that it is possible to claim that almost any new building is 'green' on the grounds that it ticks a few boxes*" (Low Carbon Innovation and Growth Team, 2010).

The difficulty in defining a sustainable building begins with problems defining sustainable development. Bruntland's (WCED, 1987) deliberately vague (Hopwood et al., 2005), but frequently quoted definition of sustainable development has allowed a wealth of interpretations to proliferate. As Palmer et al. (1997) note, sustainability and sustainable development have become *"fuzzy*

[1] Despite important differences, the terms low energy and low carbon are generally used interchangeably in UK construction (e.g. Low Carbon Innovation and Growth Team, 2010). This will be considered in chapter 2.

buzzwords: terms that appear to encapsulate a discrete notion but which actually have multiple interpretations". In response many search for consensus and shared understanding, identifying the confusion as a barrier to sustainable construction that needs to be overcome (e.g. Häkkinen & Belloni, 2011). Others suggest "*abandoning the search for a true or incontestable definition of sustainable buildings*" (Guy & Farmer, 2001). Whichever position one sides with, it is clear this plurality of definitions creates:

> *"a clear tension between the normative need for establishing a clear understanding of sustainable development from which consistent and coherent goals and actions can be stimulated and the reality of multiple, often discordant, views of sustainable development" (Sexton et al., 2009)*

As a result building research lurches between the competing demands of consensus building which acknowledges the contested, multi-faceted nature of sustainability on the one hand (Farmer & Guy, 2010; Wilkinson, 2013), and the practicalities of implementation on the other, with few authors considering how different elements might relate to one another. Work that looks at the implementation of sustainable construction more holistically similarly "*tends to side step the issue*" (Guy & Farmer, 2001) of competing ideas, preferring instead to opt for ambiguous definitions while making vague references to a need for more integrated design (e.g. Häkkinen & Belloni, 2011; Williams & Dair, 2007).

This disconnect is not the sole preserve of researchers, the National Planning Policy Framework (NPPF) for example describes how "*to achieve sustainable development, economic, social and environmental gains should be sought jointly and simultaneously*" (Department for Communities and Local Government, 2012a), yet then proceeds to describe these economic, social and environmental goals sequentially. Similarly Hensel (2012) criticises the reductive approach of architectural design, purportedly dissolving the complexity of sustainability into "*manageable tasks*" (Hensel, 2012) without retaining a clear idea of how these should be re-assimilated.

This disconnected, often reductionist approach to the implementation of sustainability in much of the contemporary discourse suggests an implicit assumption: that the assimilation of diverse and often seemingly unconnected aspects of sustainability is an unassuming, rational process. Design teams simply get on with it. Yet evidence would suggest this is not the case; while the various sustainability ideals may often happily coexist, there are also significant opportunities for synergy and conflict between them (see section 3.2).

1.4 INTERACTING AGENDAS

This thesis "*problematizes*" (Alvesson & Sandberg, 2011; Sandberg & Alvesson, 2010) current approaches to understanding sustainable design. It is intended to contribute a more lucid understanding of the interaction amongst different facets of 'sustainability', by providing evidence that the assimilation of its diverse and often seemingly unconnected aspects is not the unassuming process implicit in much of the contemporary sustainability discourse. It will focus on design decisions made as a result of the interaction of two sustainability principles and examine the outcome of those decisions by assessing the completed designs. The two sustainability principles are the current UK government sponsored sustainability agenda, low carbon design, and an alternative interpretation of sustainability, adaptable design, whose literature is framed in a sometimes complementary, at others antagonistic fashion to the former (see 3.2).

The low carbon agenda's prevalence makes its interfaces of significant interest – such a pervading concept has influence beyond its immediate boundaries and provides both opportunities and problems for other issues that may be mobilised within the wider discourse of the construction industry. This is reflected in the fact that some scholars have begun to draw attention to the potential for "*unintended consequences*" (Davies & Oreszczyn, 2012) of the "*huge experiment*" (Davies & Oreszczyn, 2012) that is the UK's decarbonisation programme. Adaptability is a useful comparison for a number of reasons. Similar to low carbon, it makes claims to sustainability on a number of grounds – an appeal to social sustainability using references to urban regeneration (Love & Bullen, 2009), continuity of space (Leupen et al., 2005) and the provision of sustainable buildings for all (Kendall, 1999) but also environmental sustainability through potential for reductions in waste to landfill. Taking a long term perspective, adaptability and low carbon ideas appear to have considerable synergies (see section 3.2.3), while in the short term adaptability desire for vague, changeable spaces may sit uncomfortably with low carbon design's requirement for accurate modelling (see 3.2.2). Adaptability's transformative properties also provide an interesting juxtaposition to the low carbon research agenda's claims of "*little room available for correction*" (Summerfield & Lowe, 2012) – as Fisk (2001) suggests, a building underperforming by today's standards of sustainability "*is not necessarily a disaster*" if it has the potential to perform well in the future.

1.5 A COMPARATIVE APPROACH

Early design decisions are frequently highlighted for their importance in sustainable design (Kershaw & Simm, 2014; Williams & Dair, 2007). This key phase in building's lifecycle was therefore selected as the focus of this study. A case based approach was adopted in order to study how interaction affected building professionals and other stakeholders and how this influenced the decisions they made and the type of sustainable building they produced. However, traditionally case orientated approaches are extremely limited in the number of cases which can be examined (Eisenhardt, 1989; Ragin, 1989). A multiple case study approach potentially creates a "*more compelling*" (Yin 2003) evidence base, but is intensive and resource demanding (Yin, 2003; Eisenhardt 1989) and there is a risk that theorists loose "*their sense of proportion as they confront vivid, voluminous data*" (Eisenhardt 1989).

Qualitative comparative analysis (QCA) asserts itself as an alternative, set theoretic approach to case study research that maintains the view of cases as holistic entities (Rihoux and Lobe 2009) while allowing a larger number of cases to be considered and compared. It has been tentatively used by a small number of scholars in the built environment (Boudet et al., 2011; Forsythe, 2012; Gross, 2010; Jordan, Javernick-will, et al., 2011), but has yet to gain significant traction in the field despite positive reviews of its applicability to built environment problems (Jordan, Gross, et al., 2011) and increasing use in other fields. The method's potential for expanding our ability to deal with complexity of case based data in a manageable way without entirely decomposing was appealing, however little was known about its methodological implications for construction research or its practicalities. Therefore, the decision was taken early in the study's development to embark on a 'method experiment'. This means that, in addition to its theoretical contribution, the thesis is intended to make a methodological contribution, through an evaluation usefulness of QCA to the socio-technical type problems frequently encountered by construction researchers.

1.6 SUMMARY AND THESIS STRUCTURE

This introductory chapter has described the multifaceted and contested nature of sustainable design. It has challenged current approaches that focus on consensus building or the implementation of discrete and disconnected approaches and suggested that to fully understand sustainable design it is necessary to look at the ways in which its various facets interact.

This thesis's overall aim is to:

> *Understand how interaction between sustainability principles influences design and its outcomes, in particular the type of sustainable buildings produced.*

Key questions posed by the thesis are derived in chapter 3, however in brief the thesis considers three research questions. To what extent is it possible for a building to be both adaptable and low carbon? Is the simplistic presentation of interaction effects in the literature (see section 3.2) accurate in a construction design context? How are designers managing interaction, and what impacts on their ability to do so?

To address these questions the thesis presents evidence in relation to five objectives:

> *OB01 – Demonstrate the existence of interaction by locating, describing and categorising examples of interaction in real building design processes, comparing the empirical findings to theoretical interaction types.*
>
> *OB02 – Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.*
>
> *OB03 – Identify important factors in the selection of approach for each identified interaction, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.*
>
> *OB04 – Operationalise the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successfully reconciling low carbon and adaptability principles.*
>
> *OB05 – By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, proposed pathways to successful reconciliation of adaptable and low carbon design.*

In addition to the above, due to the unusual use of QCA as a research design, a sixth objective is also included:

> *OB06 – Conduct a method experiment to assess the usefulness of QCA as a research tool for problems of a socio-technical type within the built environment.*

The structure of the remaining chapters is as follows.

Chapter 2 looks more closely at existing literatures for low carbon design and adaptability. Chapter 3 describes our existing understanding of interaction and postulates how this might relate to interaction between adaptability and low carbon ideas in construction design. Chapter 4 describes the research design developed to address the objectives derived in chapters 2 and 3.

Chapter 5 presents results demonstrating interaction between adaptability and low carbon design ideas evident in the documentary evidence of 23 case study buildings. It identifies the range of interaction types and describes the strategies the various design teams adopted to manage them. Chapter 6 considers how effective the 23 cases were in reconciling adaptability and low carbon in their designs while chapter 7 combines the results of the previous two chapters in order to undertake a cross case comparative analysis and identify three 'recipes' for reconciling the two design approaches.

Chapter 8 compares findings to existing work and briefly discusses potential implications for sustainable design. Chapter 9 summaries the study's findings and draws four main conclusions:

- There is interaction between the separate low carbon and adaptable approaches to sustainable design when pursued together.
- That interaction can take a variety of forms, sometimes being perceived as helpful and at other times as problematic.
- Despite this, it is possible to reconcile the two approaches using a range of interaction management strategies.
- QCA provides an alternative, systematic approach for exploring socio-technical problems across multiple cases, but does not obviate the need for robust data processing procedures and qualitative description.

Overall this thesis will provide a novel contribution by improving our understanding of how sustainable design is implemented in construction and the consequences of interaction effects for sustainability theory in the build environment

2 TWO DISCONNECTED AGENDAS

2.1 INTRODUCTION

This chapter considers the two sustainable design agendas selected to study interaction. Describing each separately, it provides a foundation for the next chapter's exploration of potential links between them.

The chapter is split into two halves, the first (section 2.2) considers the low carbon agenda, while the second (section 0) deals with adaptability. Each agenda is first defined, followed by descriptions of the main approaches to design in the field and an overview of evaluation techniques. The latter of these will be used in chapter 6 to assess how successful the cases study buildings were in achieving the sustainable goals of each agenda.

2.2 LOW CARBON

2.2.1 WHAT IS A LOW CARBON BUILDING?

England and Wales[2] have seen various definitions of carbon in the built environment since the idea of "zero carbon" buildings was first mooted. As originally stated, zero carbon meant zero emissions from "*heating, lighting, hot water and all other energy uses*" (Department for Communities and Local Government, 2006). However, following a change of government, protest by industry (Georg et al., 2011) and concern over the cost and readiness of the renewable energy technologies required, the definition was revised in May 2011 (Department for Communities and Local Government, 2011a). This new definition excluded the energy required by appliances, significantly reducing the need for renewable sources of electricity. Further revisions were made in 2013, when, under increasing pressure to remove barriers to house building amongst a growing housing crisis, "*allowable solutions*" (Department for Communities and Local Government, 2013a) were to be permitted. "*Effectively a form of carbon offsetting*" (McLeod et al., 2012), this element of the definition was never fully described and was quietly abandoned in 2015 (Treasury, 2015) together with the target for all new homes to be zero carbon by 2016.

The UK's current legislative position on carbon in buildings, which forms the basis of the low carbon agenda described in chapter 1, is an interpretation of the European Performance of Buildings Directive (recast), or EPBD. This legislation defines a *"nearly zero-energy building"* (adopting the energy focus typical outside the UK) as one *"that has a very high energy performance, as determined*

[2] Because of international differences in definition and measurement (Wilford & Ramos, 2009), this thesis will focus on the approach adopted in England and Wales.

in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (European Commision, 2010). Annex 1 describes what should be included when calculating a building's energy performance, essentially determining what should be allocated to the building and what should not (and therefore what should be considered within the control of design).

The following paragraphs outline the various exclusions from the EU's view of a low carbon building as they are understood in the UK context, generating a definition aligned with the dominant legislative discourse for use in this study.

2.2.1.1 *EMBODIED AND OPERATIONAL EMISSIONS*

Buildings generate carbon emissions through their construction, use, maintenance and ultimate demolition (Szalay, 2007). These emissions are of two types: embodied and operational. Embodied carbon emissions arise from the process of building and demolishing and include things such as the carbon generated by extracting raw materials, processing them and bringing them to site. Operational emissions result from building occupation– turning on the heating and lights or plugging in equipment for example. These activities require energy, which is generally provided by burning fossil fuels: the "*problem of energy demand and* CO_2" (Lomas, 2010) where "*energy also corresponds to emissions*" (Szalay, 2007).

Several commentators have produced low carbon definitions that include both embodied and operational carbon (Hernandez & Kenny, 2010; Marszal et al., 2011) and there is growing popularity for whole life cycle studies among academics (see for example, Thormark (2002) or Yohanis and Norton (2002)). However, difficulties with the definition and calculation of embodied energy (Buchanan & Honey, 1994; Hernandez & Kenny, 2011) mean these remain largely proof of concept studies. Embodied energy gains are also seen as marginal compared to the perceived easy wins of operational energy (European Commision, 2010; Skea, 2012). While this may change in future as current legislation takes effect and operational savings become more difficult (Low Carbon Innovation and Growth Team, 2010), it has meant current low carbon design ideals are dominated by operational efficiency goals, with limited reference to embodied carbon (Dixit et al., 2010; Hernandez & Kenny, 2010).

2.2.1.2 *TYPICAL USE*

A building's energy consumption is affected not just by how it is designed, but also its environment and the way it is operated (Cheshire & Menezes, 2013). For example, buildings use more energy for heating in winter (Bordass et al., 2001) and a longer, colder winter is likely to result in increased energy consumption and carbon emissions versus a short, mild one. Similarly the amount of people, the time they arrive, the temperature they set the thermostat and the equipment they use will all lead to significant variability in emissions (Cheshire & Menezes, 2013). This is a problem for legislators and to some extent researchers, who require a means to compare buildings.

The solution has been to define performance in terms of typical use, allowing "*comparisons between buildings on the basis of their intrinsic properties rather than the user's operating patterns*" (Johnson, 2010). Buildings are modelled using standard weather (generally CIBSE's TRYs, which simulate 'typical' weather encountered over a 30 year period (Kershaw et al., 2011) and standard occupancy assumptions for a range of standard use classes. This has the effect of divorcing design estimates from the realities of occupancy (Crosbie & Baker, 2010; Oreszczyn & Lowe, 2010) and has been criticised for promoting "*highly specialized buildings that are theoretically net zero but, due to dissatisfied occupants and a fragile technical design, have an increased risk that relatively small deviations from the design expectations will make the building more energy intensive than a conventional solution*" (Donn et al., 2012). It is however the basis of the UK's national calculation methodology (Department for Communities and Local Government, 2010a) and therefore for the purposes of this thesis, to be low carbon, a building should generate low emissions under typical use.

2.2.1.3 *REGULATED EMISSIONS*

Operational energy used (and therefore carbon produced) by buildings is composed of a number of elements: energy used for heating, cooling, ventilation and lighting; energy for the many appliances and gadgets we use ('plug in loads' or small power) and in non-domestic buildings, energy to power any large pieces of plant. Figure 2-1 shows a breakdown for a typical office building.

While equipment based energy use generates a significant portion of carbon emissions (Figure 2-1), regulatory methodologies typically exclude the energy consumed by equipment or appliances from their definitions (Marszal et al. 2011). This creates a significant disconnect between the results of design stage modelling for compliance and in-use energy measurement, but is intended to focus improvement on the construction process rather than allow the industry to mitigate its responsibility through the use of more energy efficient plant and appliances (Szalay, 2007),as well as reflecting industry concerns regarding their lack of control over occupant behaviour (Georg et al., 2011). Energy uses governed by the UK's building regulations are generally referred to as regulated, while those associated with equipment 'unregulated'.

Thus we can conclude that the UK's definition of a low carbon building is one that generates low emissions under typical operation of regulated energy sources.

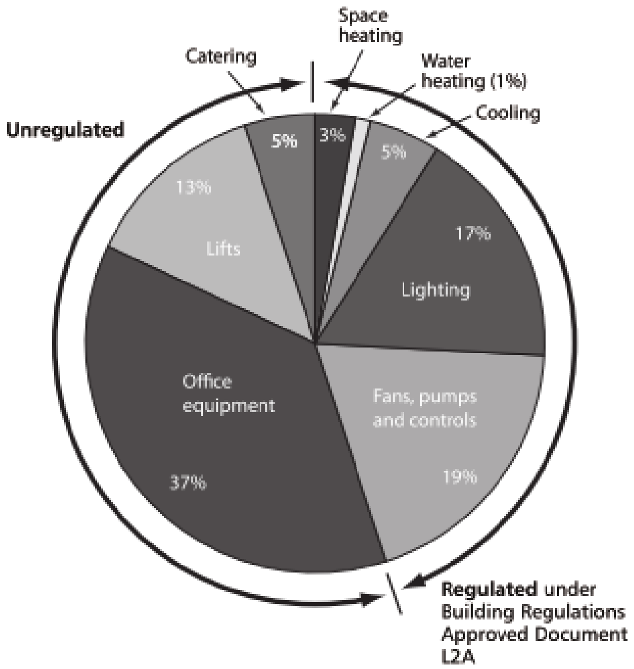

Figure 2-1 Breakdown of typical energy use in an air-conditioned office building (CIBSE, 2012)

2.2.2 HOW LOW IS LOW?

Almost all definitions forgo reference to absolute values – Torcellini et al. (2006) talk of buildings "*with greatly reduced energy needs*", European legislation of "*very high energy performance" (European Commision, 2010),* while the Carbon Trust opt for a building *"that uses significantly less energy and emits less carbon than current industry benchmarks"* (Carbon Trust, 2011). There are exceptions, predominantly in the more homogenous housing sector: both Thormark (2002) and Panao et al. (2013) exclude housing with an energy use above 70 kWh/m^2 (although they opt for different definitions of operational carbon) and the Passivhaus standard insists on performance of 120kWh/m2/yr or better. Several European governments have adopted performance targets,

Table 2-1, while in the UK the recent introduction of a fabric efficiency standard (Department for Communities and Local Government, 2013b) essentially sets minimum energy performance targets for regulated energy in new homes. However, for definitions intended to capture buildings of varying types, the difficulties in setting a single value across buildings containing different activities and occupied at different densities inevitably leads to the more ambiguous definitions referred to above.

Table 2-1 Examples of proposed NZEBs targets reported across EU (Zero Carbon Hub, 2014)

COUNTRY	BUILDING TYPE	METRIC	ENERGY USES INCLUDED	ENERGY PERFOR-MANCE	RENEW-ABLE ENERGY SHARE	NATIONAL LEGISLATION PROVIDING THE DEFINITION
Cyprus	Residential	Primary Energy	Regulated energy	180 kWh/m²/ year	25%	NZEB Action Plan
Belgium (Brussels)	Residential	Primary Energy	Heating, DHW, appliances	45 kWh/m²/ year	-	Brussels Air, Climate and Energy Code
France	Residential	Primary Energy	Regulated energy	50 kWh/m²/ year	-	RT2012
Denmark	Residential	Primary Energy	Regulated energy	20 kWh/m²/ year	51-56%	BR10
Latvia	Residential	Primary Energy	Regulated energy	95 kWh/m²/ year	-	Cabinet regulation No383 from 09/07/2013

NZEB definitions in Europe , REHVA Journal – March 2014

Instead, as the carbon trust definition alludes to, low is often defined by reference to similar buildings – benchmarking. Benchmarks are typically reported for different uses and for unit area (Choudhary, 2012) as these "*explain the major part*" (Bruhns & Wyatt, 2011) of energy consumption. The following sections detail three significant sources of benchmarking data: in-use measurement, sustainability certification schemes and legal compliance methods.

2.2.2.1 *IN-USE MEASUREMENT*

In use measurement typically relies on metered energy use, for example Krausse et al. (2007) use data taken from a building energy management system (BEMS). It is a significant source of benchmarking data, although data is still scare enough to make statistical generalisation difficult (Shipworth et al., 2010). Sources include:

- Carbon Buzz (www.carbonbuzz.org), an ongoing project to collect energy performance data
- CIBSE TM46 (CIBSE, 2008), which provides typical values for 29 categories of building.
- CIBSE Guide F (CIBSE, 2012)
- The UK's publically available Display Energy Certificate (DEC) database
- The PROBE (Bordass et al., 2001) studies

Values vary widely depending on the source, building type and whether the benchmark represents typical or best practice. CIBSE (2012) for example quote values from as low as 112 kwh/m2/yr to as high as 618 kwh/m2/yr, DEC data suggests an average of 248 kwh/m2/yr including DECs registered in all years but a lower value when considering only the most recent full year (229 kWh/m2/yr in 2014) (Department for Communities and Local Government, 2015a). There are also differences in units – Carbon Buzz data is available only in kgCO2/m^2/yr (52 -82 kgCO2/m^2/yr for educational uses, 69 kgCO2/m^2/yr for office developments (Carbon Buzz, 2015)) for example. This makes choosing an appropriate benchmark more difficult than perhaps might be expected.

Display Energy Certificates (DECs) are required for all public buildings where "*the total useful floor area of the building exceeds 250m2 and which is frequently visited by the public*" (Department for Communities and Local Government, 2015b), although the level of compliance is believed to be low (Bruhns et al., 2011; Zero Carbon Hub, 2011). DECs provide energy ratings "*from A to G, where A is very efficient and G is the least efficient and are based on the actual amount of metered energy used by the building over the last 12 months*" (Department for Communities and Local Government, 2015b). Average performance results in a rating of 100, zero carbon buildings (regulated and unregulated loads, although with some exclusions) a rating of 0. There is "*no differentiation for servicing strategy*" (CIBSE, 2008) which means naturally ventilated buildings are grouped with mechanically ventilated buildings of similar use. As of 2015 D ratings were the most common (scoring 76-100), with only 6% of buildings achieving a B rating (50 or less) or higher (Department for Communities and Local Government, 2015c).

Liddiard et al. (2008) note a number of problems with non-domestic benchmarks including the fact that the source of the data is frequently not reported making it difficult to establish accuracy or sample sizes (which may be small and therefore unrepresentative), there is often difficultly establishing what assumptions have been made and the fact that benchmarks reliant on surveys are frequently snapshots in time and that they often measure different things or categorise buildings in different ways. Post-occupancy measures are also arguably inappropriate to evaluate design performance, as they include emissions from unregulated sources (see 2.2.1.3) and differences caused by operation rather than design (see 2.2.1.2). While differences in weather and occupancy can to some extent be corrected for (e.g. TM46's (CIBSE, 2008) method) they make comparisons between designs difficult. These benchmarks also generally present typical values representative of the existing stock, rather than best practice making them unsuitable for use with new build designs (CIBSE, 2012). This is made worse by some sources now being considerably outdated – the well referenced PROBE studies for example are now over a decade old.

2.2.2.3 *SUSTAINABLE CERTIFICATION*

Sustainability certification schemes such as BREEAM and the Code for Sustainable Homes (CSH) are intended to evaluate designs, identify best practice and promote sustainable buildings. Energy focussed credits are typically the most numerous – 10 of LEED's 69 credits are allocated available for optimising energy performance (Sullivan & Oates, 2012) while BREEAM allocates around 20% of its credits to energy matters (depending in the building type and location) (BRE, 2014). This makes them a potential useful tool for benchmarking performance.

For domestic buildings CSH provided the original 2006 definition of a zero carbon home via its code level 6. Dwellings rated code level 4 represent a 25% improvement over 2010 legal requirements, Level 5 a 100% improvement, while Level 6 requires "*zero net CO2 emissions*" (Department for Communities and Local Government, 2010b). Unlike the other levels, code level 6 includes energy from appliances. CSH also includes minimum fabric efficiency requirements for code 5 and 6 (≤46 kWh/m2/yr for end terrace / semi / detached and ≤ 39 kWh/m2/yr for apartments and mid terrace homes).

Originally developed in Germany as an "*ultra-low energy construction standard*" (Hodgson, 2008) PassivHaus is an international certification scheme for highly insulated homes and increasingly, commercial buildings. It sets stringent targets for heating requirements (≤15 kWh/m^2/yr) and air tightness, as well as overall energy demand (≤120 kWh/m^2/yr). PassivHaus includes regulated energy sources plus "*all of the projected appliance consumption*" (Building Research Establishment, 2011), it is therefore a more onerous standard than compliance with building regulations and in most situations BREEAM or the CSH. While some have criticised the scheme for creating summer overheating problems (McLeod et al., 2013) it is nonetheless widely considered to indicate exemplary level performance (McLeod et al., 2013).

BREEAM includes a number of energy related credits, although it is ENE01 that is of most useful in energy benchmarking. Until BREEAM 2011, BREEAM used a building's asset rating (see below) to determine its ENE01 score. The more recent 2011 and 2014 version use a more complicated system (still based on the outputs required for part L compliance) in an attempt to "*promote designs that minimise energy demand and consumption in buildings, and then to reduce the carbon emissions resulting form that energy use*" (BREEAM, 2011). Similar to the CSH, BREEAM includes a number of mandatory requirements for its higher awards including minimum energy efficiency standards. BREEAM Excellent requires 6 credits from ENE01, outstanding 10 credits. Buildings must also be sub-metered and for excellent and outstanding ratings achieve at least one renewable energy credit. It is therefore possible, knowing only the overall rating, to establish a buildings minimum performance in the mandatory categories. Lee and Burnett (2008) suggest BREEAM excellent buildings "*belong to the top 5% of the marke*t", while the schemes manual claims an excellent rating corresponds to best practice and the top 10% of buildings (outstanding is reserved for "innovator" status, and the top 1% of new buildings) (BRE, 2014).

The danger in relying on sustainable certification to indicate carbon performance is firstly that the majority of schemes include elements of sustainable performance other than energy and therefore only elements of each system provide a reliable assessment of carbon or energy performance. There is also a certain amount of what Cole (2005) refers to as "*gaming*", "*whereby design teams explore the requirements within an assessment system for interpretations that will yield the greatest score for the least cost and effort*" rather than those that are most appropriate or effective. While this is less likely to be problematic when using individual credit scores to understand energy or carbon performance for schemes which mirror legal requirements, schemes such as LEED which require considerable additional work to convert legal compliance calculations to an acceptable format might suffer if project teams chose to pursue other, simpler requirements.

2.2.2.4 *LEGAL COMPLIANCE*

While the majority of benchmarking information available is either of the in-use or sustainable certification type described above, there are a smaller number of data sources aligned with the UK's carbon definition and intended to compare design data. Carbon Buzz includes a small number of design values, but the most significant source is the now publically available data for Energy Performance Certificates (EPCs). EPCs are required when a building is constructed, sold or let (Department for Communities and Local Government, 2008) and show a rating based on a buildings performance modelled in accordance with part L of the Building Regulations.

With the exception of the fabric energy efficiency standards (FEES) for new homes which specifies absolute values, Part L makes use of relative measurement through comparison with a notional building "*of the same size and shape*" (HM Government, 2013) as the proposed building. The notional building is specified using materials defined in either SAP (for dwellings) or SBEM (non-dwellings). This notional building's specification is intended to produce a building that would just comply with current regulatory targets, "*expressed in terms of a Target Emissions Rate [TER] in kilogrammes of carbon dioxide per square metre per year (kgCO2/m2/yr)"* (Department for Communities and Local Government, 2013a). The TER is used to demonstrate legal compliance, while an additional value, the Standard Emissions Rate (SER). Similar to the TER the SER is calculated based on a notional building, however unlike the TER, which is varied at intervals to create more stringent performance requirements, the SER remains static ensuring an buildings asset rating does not change unless its energy efficiency does.

It is important to note that TERs and SERs[3] vary depending on the building size and shape but also the building type (as the model makes different assumptions about occupancy) and therefore while EPC certificates appear to present a homogenous rating system, the underlying methodology used to allocate the ratings makes allowances for different building types.

Different types of ratings are allocated depending on whether a building is residential or non-domestic:

- Non domestic buildings receive asset ratings. Ratings below 0 receive an A+ rating. Buildings achieving the SER would achieve a score of 50 and sit at the B/C rating boundary while the lowest rating, for buildings scoring 150 or greater, is G. All ratings are based on carbon emissions.
- Domestic buildings receive two ratings, an Environmental Impact Rating, which is based on carbon emissions and similar to an asset rating (although with the numerical element of the scale reversed) and an Energy Efficiency Rating, based on the cost of energy required under predicted operation.

There are problems with the EPC database. EPC assessors can make errors that result in incorrect classifications (Tronchin & Fabbri, 2012), a problem that is amplified by data entry errors. There are also questions over whether the various approved software choices produce consistent results (Raslan & Davies, 2010). However, the statistics are sufficient to give an overall picture of the EPC ratings issued to buildings since their introduction in 2008. Figure 2-2 shows the trends in environmental impact rating (EIR) for residential buildings.

[3] Terminology differs slightly between Part L1A and Part L2A (domestic regulations use a Dwelling Emissions Rate (DER) rather than Building Emissions Rate (BER)) however the principles remains broadly similar.

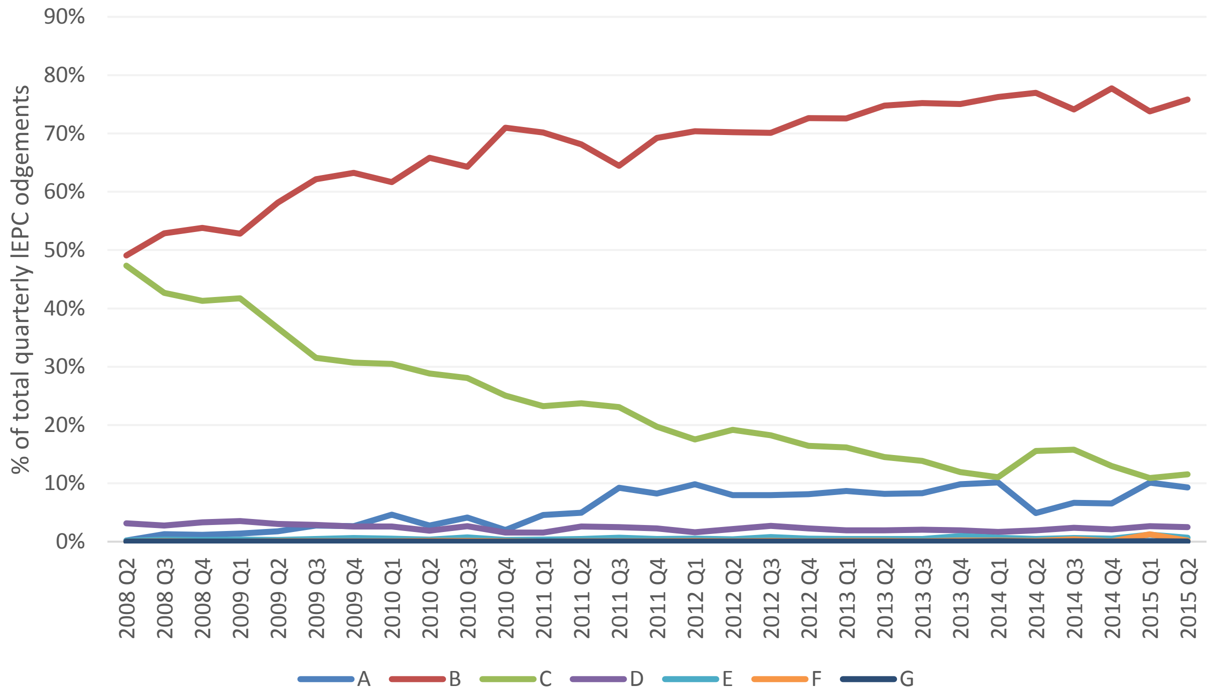

Figure 2-2 Changes in the proportion of new domestic EPCs for each environmental impact rating (Department for Communities and Local Government, 2015d)

Figure 2-2 shows the percentage of new dwellings[4] receiving an EPC EIR of C has decreased dramatically since the introduction of EPCs in 2008, from almost half of all new dwellings to a little over 10% at the end of 2013. In comparison B ratings are now substantially more common – rising from 50% of quarterly lodgements in 2008 to around 75% in 2008. A ratings have also increased, from less than 100 buildings in 2008 (<1%) to circa 10% in the first half of 2015. These observations are in line with the gradual tightening of building regulations (Table 2-2) and suggest B and high C ratings are required to meet legislative requirements in the majority of cases.

Table 2-2 Recent percentage improvement in building regulations part L for new buildings (Committee on Climate Change, 2007)

Year	New domestic buildings	New non domestic buildings
2013	6% aggregate increase on 2010[1]	9% aggregate increase on 2010
2010	25% increase on 2006 (Department for Communities and Local Government, 2013a)	25% aggregate increase on 2006

[1] 2013 also saw the introduction of fabric energy efficiency standards (FEES) for domestic buildings and a move to an aggregate approach in line with non-domestic buildings

[4] Only aggregate new and existing EPC data is available for non-domestic buildings

Combining the above EPC data with the Carbon Trust definition's requirement for buildings to "*use significantly less energy and emit less carbon than current industry standards*" (Carbon Trust, 2011) would suggest (for housing at least) buildings should exceed the current building regulations requirements for new build. They would therefore be in the main achieving A grade asset ratings or higher. However, this overlooks the increasing difficulty (and expense) of making further carbon gains in new buildings. While the green press and many high profile clients are still pushing the boundaries of what can be achieved, the UK government has increasingly been seen to slow the impetus for further new build savings (section 2.2.1). Figure 2-2 also shows only those EPCs issued to new buildings. Arguably, when there is a substantial number of existing buildings which provide a better benchmark of standard performance.

Figure 2-3 shows data for both domestic and non-domestic (new and existing buildings) lodging EPC's since 2008.

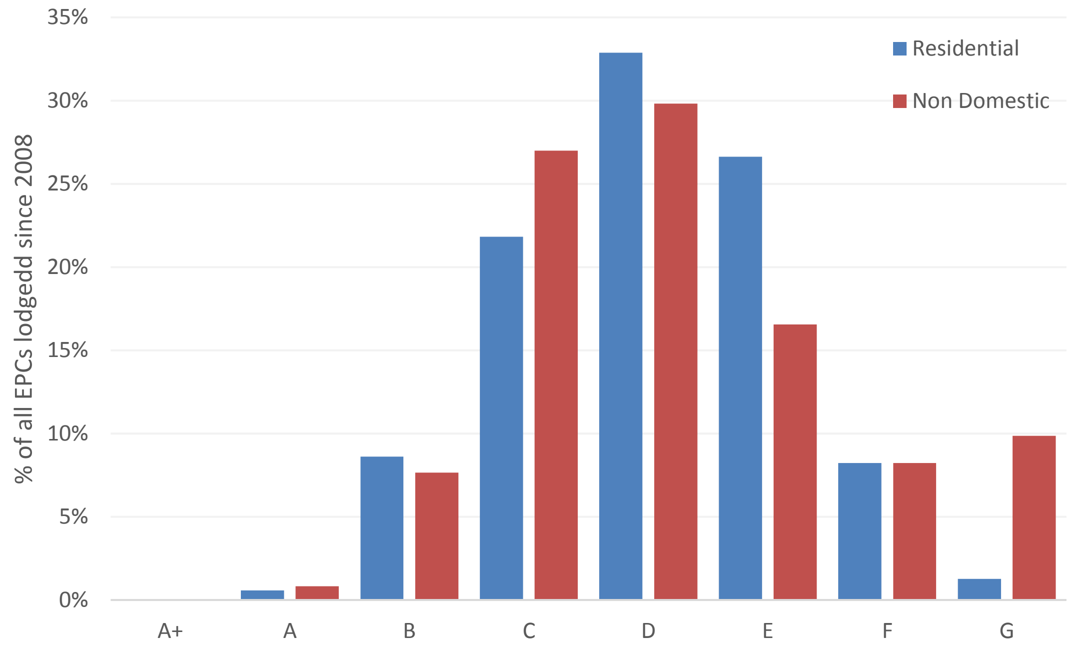

Figure 2-3 Percentage of total EPC lodgements per rating 2008 – mid 2015 (Department for Communities and Local Government, 2015d)

This chart reinforces the rarity of A and A+[5] ratings – only 1% of either build type achieving the rating. Ratings of B or better have been awarded to fewer than 10% of buildings. In contrast C, D and E ratings are the most common, collectively encompassing 70% (non-domestic) – 80% (domestic) of EPCs lodged since 2008. This would suggest that to be better than the majority of buildings, only a B rating or higher is required.

[5] A+ ratings are applicable to the non-domestic stock only, an A rating is the highest possible for domestic EPCs

2.2.2.5 *OTHER METHODS*

While the above three sources of benchmarking data are perhaps the most significant, other methods of establish carbon or energy performance do exist. There are a number of simulation tools that can be used to predict building energy performance (Donn et al., 2012; Raslan & Davies, 2010). While generally used to demonstrate legal compliance these sophisticated dynamic simulation models can be manipulated to include non-regulated loads, different occupancy assumptions as well as alternative climate files (CIBSE, 2012). This can provide a means to compare different variants of the same building.

2.2.3 LOW CARBON BUILDING DEFINTION

The above sections have outlined the UK's rather narrow interpretation of a low carbon building and the various standards applied to understand if a building's carbon consumption is small enough for it to be considered 'low' carbon. Despite general agreement over what should be counted, there is no agreed absolute standard of performance. This thesis will therefore adopt the following definition of a low carbon building(adapted from the Carbon Trust (2011) definition):

> *"Buildings which are designed to use significantly less regulated energy and emit less carbon than current industry standards in their typical operation".*

2.2.4 LOW CARBON DESIGN

The UK's building regulations for energy efficiency are intended to be "*technology neutral*" (Department for Communities and Local Government, 2013a) however, the approach is based on a hierarchical principle, whereby reduction in operational energy required is the primary consideration before the addition of renewable and other low carbon technologies (Department for Local Government and Communities, 2008), Figure 2-4. This hierarchy encompasses the three main approaches to low carbon design – fabric first or passive design, energy efficiency and addition of renewables.

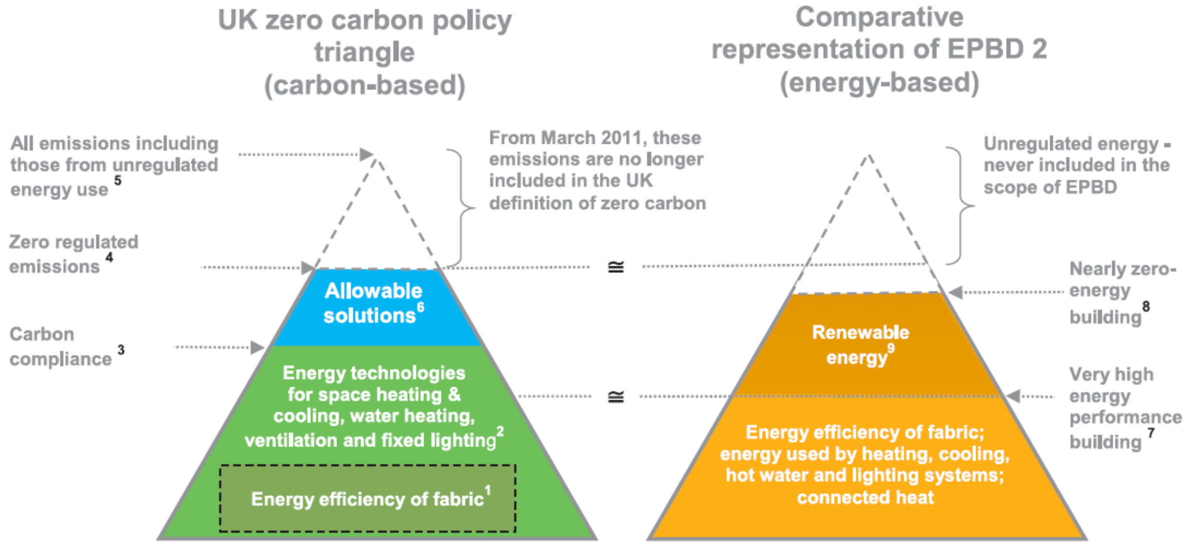

Figure 2-4 UK and EU Energy hierarchies (Zero Carbon Hub, 2011)

2.2.4.1 *FABRIC FIRST AND PASSIVE DESIGN*

Fabric first is the cornerstone of the English building regulations' (HM Government, 2013) approach to low carbon design, requiring designers to reduce a building's need for energy as far as possible before looking to increase efficiency of a buildings systems or provide low carbon sources of energy (see figure 2-4, above). It is a key component of the broader passive design approach which aims to minimise the amount of heating, cooling and lighting required without resorting to mechanical systems.

Fabric first approaches are synonymous with increased insulation which, in combination with improved air tightness, keeps heat inside during winter and out during hot summers, reducing heating and cooling requirements respectively. More generally, passive buildings make use of natural ventilation, daylighting and passive cooling techniques including shallow plan depths (Bordass et al., 2001), openable windows, exposed thermal mass (Chartered Institute of Building Service Engineers (CIBSE), 1998) and night purge ventilation (Krausse et al., 2007), improved glazing specifications that reduce solar gain and "*careful window placement*" (Krausse et al., 2007).

There are practical problems that can prevent the implementation of passive solutions, for example natural ventilation can be hampered by noisy, polluted inner city sites that require sealed facades. However, the technical aspects of low carbon design are now generally well understood (Lomas, 2010) and it is instead organisational and process challenges that limit uptake (Häkkinen & Belloni, 2011). These include a lack of appropriate skills (Carbon Trust, 2009; Department for Business Innovation and Skills, 2011) and design tools (Donn et al., 2012), fragmented procurement resulting in key expertise being appointed too late to have a meaningful impact (Häkkinen & Belloni, 2011; Kershaw & Simm, 2014) and difficulties in convincing clients that benefits outweigh risks.

2.2.4.2 *ENERGY EFFICIENCY*

In contrast with fabric first and other passive approaches, energy efficiency is active. Its focus is on reducing the amount of energy required by improving the efficiency of a building's systems, rather than removing them. Examples of energy efficiency measures include daylight dimming, presence detection that automatically switches off lights when a room is empty, zoning systems to allow areas to be turned off when not in use (Bordass et al., 2001) and using systems compatible with low power fans and pumps.

Energy efficiency is a key part of any low carbon strategy, as it will be impossible to eliminate energy requirements entirely. Where applied in combination with thoughtful passive design, energy efficiency can significantly reduce the amount of energy a building requires to operate (Chartered Institute of Building Service Engineers (CIBSE), 1998) and therefore the need for expensive renewables. However, it requires commitment by manufacturers to develop energy efficient products (Osmani & O'Reilly, 2009) and can be difficult to get right in practice – users are intolerant of systems that turn lights on too quickly or too slowly and may override systems such as daylight dimming (Leaman & Bordass, 2001).

2.2.4.3 *RENEWABLES AND GREEN BLING*

Sources of renewable energy ('renewables') are a key component of the EPBD definition of a low energy building (European Commision, 2010) and have been a focus for the UK government keen to capitalise on what it sees as an emerging green market (BIS, 2013). While cleaner energy can be produced on a national scale, the term renewables in buildings typically refers to small scale installations designed to produce power or heat on a local scale: photovoltaic and solar thermal panels, wind turbines and earth tubes.

Renewables provide clean, free energy (electricity or heat) and are a necessary component of any true zero carbon building. However, they are typically expensive (Banfill & Peacock, 2007) and can be difficult to operate: over complicated buildings with multiple low carbon technologies frequently fail to perform well in use (Carbon Trust, 2011). They are also not suitable for all sites – shaded inner city buildings will struggle to benefit from solar or wind power for example.

In addition to costs and difficulties of successful implementation, there has been criticism of the addition of renewables to buildings for purely aesthetic or promotional reasons, so called "*green bling*" (Low Carbon Innovation and Growth Team, 2010). This approach capitalises on the ability of renewables to be bolted onto an otherwise underperforming building in order to suggest sustainable credentials or meet imposed carbon reduction targets. The recent introduction of a fabric energy efficiency standard (FEES) for new domestic buildings has explicitly targeted this practice of *"individual building fabric elements with poor insulation standards being offset by renewable energy systems with uncertain service lives*" (HM Government, 2013), due to it resulting in what the UK government believe are "*excessive and inappropriate trade-offs*" (HM Government, 2013)

2.2.4.4 *EMBODIED ENERGY*

While the UK's government has declined to enforce embodied energy reduction in buildings, despite calls to do so (Low Carbon Innovation and Growth Team, 2010), tools nonetheless exist and are being tentatively employed by some organisations. For example British Land completed a full lifecycle analysis (LCA) of their flagship sustainable development, Ropemaker Place (Deloitte, n.d.).

To reduce embodied energy designers typically source local materials to reduce transport related emissions (Bennett, 2010), avoid materials produced through energy intensive processes (such as steel or concrete), reduce the total amount of material required and select durable components that will not require frequent replacement. Recycled materials are popular (Saghafi & Teshnizi, 2011; Thormark, 2002) due to their low embodied energy. Timber's ability to sequester carbon (Committee on Climate Change, 2011) makes it similarly attractive for use in building frames in comparison to carbon intensive concrete or steel.

There are a number of barriers to designing lower embodied energy buildings. One of the most significant is a lack of suitable tools to determine which materials and methods are effective. Piroozfar et al. (2012) employ the BRE developed tool, ENVEST 2, in their comparison of two schools but the method is somewhat opaque with the results presented as 'Eco points' rather than a recognised carbon metric. BRE also offers a simpler, elemental approach via its Green Guide ratings (BRE, 2015) that is used by many projects but is similarly vague, includes issues other than embodied energy (e.g. pollution) and tends to encourage individual material 'swaps', rather than a holistic approach. For those looking for more accurate results, bespoke lifecycle analysis approaches are the main option, however these are time consuming and expensive to undertake. Databases such as the Inventory of Carbon and Energy (ICE) database developed at the University of Bath (Hammond and Jones, 2011) can reduce the workload, but require constant updating. Overall this means embodied energy design is largely based on substitution of known high embodied energy materials for lower ones rather than a more holistic approach such as proposed by Hernandez and Kenny (2011).

2.3 ADAPTABILITY

2.3.1 WHAT IS AN ADAPTABLE BUILDING?

Adaptability has various definitions *"depending on its application and context*" (Schmidt et al., 2010). These include, but are not limited to:

- Those that emphasise accessibility, as promoted by the Lifetime Homes standard (Goodman, 2011)
- Buildings designed to react to their occupants or environment, for example Leatherbarrow's (2005) performance based architecture or the increasing number of buildings where lighting, ventilation and other services are controlled by a series of sensors connected to a building management system.
- Buildings resilient to the effects of climate change (Gething, 2010)
- Buildings "*designed for choice at the design stage*" (Schneider & Till, 2006) and able to be manufactured in a variety of colours and configurations to suit user tastes (Gibb et al., 2007).
- Any ability to change a building: "*all works to a building beyond its maintenance… including alterations, extension, improvements as well as conversions and renovations*" (2006), relocating buildings (Kronenburgh, 2007; Schmidt, 2014) and the "*use of space for various purposes without physical change*" (Altaş & Özsoy, 1998).

To further complicate matters various terms are used interchangeably with adaptability. Douglas (2006) describes convertible, expandable, flexible buildings capable of being dismantled "*efficiently and speedily*". Kronenburg (2007) references "*transformable*" buildings, while Arge (2005) lists generality (change without a change in building properties), flexibility (changing properties easily) and elasticity (the ability to be extended or partitioned). Others talk of upgrading (Bullen, 2007; RICS, 1981), versatility (Canadian Standards Association (CSA), 2007; Teasdale, 2000) and durability (Kincaid, 2002; Minami, 2007). There has been little attempt to apply terminology consistently and the various terms frequently overlap in meaning (Schmidt et al., 2010), the result of which is a "*state of happy confusion*" (Wilkinson, 2012).

There are however a range of common features that can be identified across the various terms and definitions (Schmidt et al., 2010). Most talk about change (Schmidt, 2014) – a building should be capable of being something different. Some make a distinction between change that can be accommodated without physically altering the building, and change that requires some form of building work although the terms used are by no means consistent (see for example Arge (2005) and Kincaid's (2000) use flexibility). Schmidt (2014) suggest of the numerous types of change noted by adaptability scholars, six broad types exist:

- Adjustable – change of task (e.g. using a school sports hall as a dining space)
- Versatile – change of space (e.g. the size, shape and layout of rooms)
- Refit-able - change in performance (e.g. upgrading mechanical systems, redecorating)
- Scalable – change of size (making a building bigger or smaller)
- Moveable – change of location

In addition definitions frequently talk of the need for change to be accommodated easily (Douglas, 2006; Fernandez, 2003; Gorgolewski, 2005) and at little expense (Cowee & Schwehr, 2009; Leaman et al., 1998; Slaughter, 2001). Most of the work on expense has been undertaken by those studying adaptive reuse. These studies focus on the relative costs of conversion compared with new build – the greater the savings achieved the more adaptable the building (Cowee & Schwehr, 2009; Douglas, 2006; Kincaid, 2002). Lastly many of the definitions make some reference to a time component – adaptable buildings are intended to have long lives (Bullen, 2007; Schmidt et al., 2010; Slaughter, 2001; Till & Schneider, 2006), adapting in response to some future requirement. Thus adaptable design is inherently about designing for the future.

This thesis will adopt the position that an adaptable building is one with the ability to be something other than it was when completed, with minimal difficulty and expense. It will align itself with the concept of adaptability as a design characteristic, something intrinsic to the building rather than the more inclusive definitions of Schmidt (2014) and others (e.g. Gann & Barlow, 1996) that rightly note a building's ability to adapt will be "*dependent on both factors concerning the building itself, but also a number of external factors*" (Heath, 2001). This deliberate bounding of the definition is intended to limit the study to the aspects of adaptability that are important during design.

2.3.2 ADAPTABLE DESIGN

2.3.2.1 *APPROACHES TO ADAPTABLE DESIGN*

A number of author's have attempted to classify approaches to adaptable design. Slaughter (2001) identifies three primary actions of separating major building systems, prefabricating elements to make assembly and disassembly easier, and designing systems "*significantly overcapacity*". Arge (2005) refers to Scandinavian structuralism's three variants of adaptability which she suggests are addressed using spatial strategies and technical solutions. Leupen (2005) suggests there are "*three ways to deal with time and uncertainty*": make building polyvalent (multipurpose spaces), make buildings that are part permanent, part changeable (base and infill) or make semi-permanent buildings such as the Dutch government's IFD approach (Zeiler & Quanjel, 2007). Schmidt (2014), noting a high correspondence between his three strands and Leupen's (2005) strategies suggests the primary approaches can be summarised as spatial (loose fit and open plan), component design and capacity (industrial, kinetic, unfinished designs) and configuration (based on layers, levels or system hierarchies). Combining these perspectives suggests three primary themes which are discussed below - spatial adaptability or polyvalency, separation/demountability and technical approaches.

2.3.2.2 *POLYVALENT BUILDINGS*

A large proportion of the adaptability literature deals with what can be loosely classified as spatial strategies, concentrating on the form of buildings and the functionality of the spaces they create. These strategies focus on providing spaces that can be appropriated in a variety of ways, with little change to the building's basic configuration. They tend to be what Schneider and Till (2007) describe as "soft", empowering building owners and users to appropriate a building's spaces.

Redundancy is a key concept, in room dimensions (e.g. Bijdendijk, 2005; Gorgolewski, 2005), structural capacity (Canadian Standards Association (CSA), 2007; Gorgolewski, 2005; Slaughter, 2001), circulation (Nutt, 1988) and service provision (Brand, 1994). Other tactics include providing open plan spaces (for instance by increasing column spans (Bijdendijk, 2005), moving circulation and services outside of the main floor plan and avoiding awkward plan shapes (Douglas, 2006)), and providing generic space (Lynch, 1958) that can be used for a number of activities. Speculative office building relies heavily on spatial techniques to provide spaces that can be fitted out to meet a particular tenants needs without prior knowledge of the tenant, although Lynch (1958) also sees spatial adaptability in London's generously proportioned terraced housing which is capable of being extended horizontally and vertically, "*knocked through, divided and joined up again and used for countless other purposes*" (Till & Schneider, 2006).

While much practical design guidance promotes loose fit design principles (Department for Education and Skills, 2007; NHS, 2009, 2013), spatial strategies are not without their critics. Brand (1994) and others (Lynch, 1958; Till & Schneider, 2006) caution against the provision of large, empty spaces which provide users with little inspiration of how to adapt spaces. Other critics note that extensive use of these spatial tactics results in "*programmatically neutral, characterless buildings…synonymous with blandness"* (Leupen et al., 2005) a feature particularly evident in the generic spaces of modernist, post war architecture. Thus there is something of a balance to be struck between the tight fit functionalism of non-adaptable designs and the loose fit vagueness of spatial adaptability.

2.3.2.3 *TECHNICAL APPROACHES*

Technical approaches achieve adaptability through the use of technology – moveable components, "*plug and play building elements*" (Arge, 2005), kits-of-parts (Schmidt, Vibæk, et al., 2014) and increasingly the high-tech control systems of intelligent and performative buildings (Leatherbarrow, 2005). Because these moving parts are normally capable of only a predefined range of change, the designer retains some degree of control – changes can only be made that were envisaged as part of the original design. Thus Till and Schneider (2006) see this approach as one where "*the designer works in the foreground, determining how spaces can be used over time*".

Technical approaches are often attractive to researchers and designers as they produce marketable products – in the kit of parts case study described by Gibb et al. (2007) for instance we see the development of something that is clearly intended to be sold. However, while a number of common technical solutions for small changes exist, whole building approaches have struggled to gain traction (Till & Schneider, 2006) with limited evidence (e.g. Minami, 2007) that users actually wish to engage with their environments (Till & Schneider, 2006).

2.3.2.4 *SEPARATION BASED APPROACHES*

Separation based approaches conceptualise adaptability as a problem of connectivity – if components can be more easily separated, making changes will be simpler and less destructive (Brand, 1994; Schmidt, Vibæk, et al., 2014). These approaches often conceptualise buildings as systems of components (e.g. Durmisevic, 2006) or layers (Brand, 1994; Duffy, 1990) that change at different rates. Brand's model (Figure 2-5) is perhaps the most famous, proposing six layers: structure, skin, services, space plan and stuff. Stuff is the shortest lived, changing as often as daily while structure is expected to change rarely. Brand suggests that "*a design needs to allow slippage between the differently paced systems … otherwise the slow systems block the flow of the quick ones, and the quick ones tear up the slow ones with constant change*" (Brand, 1994).

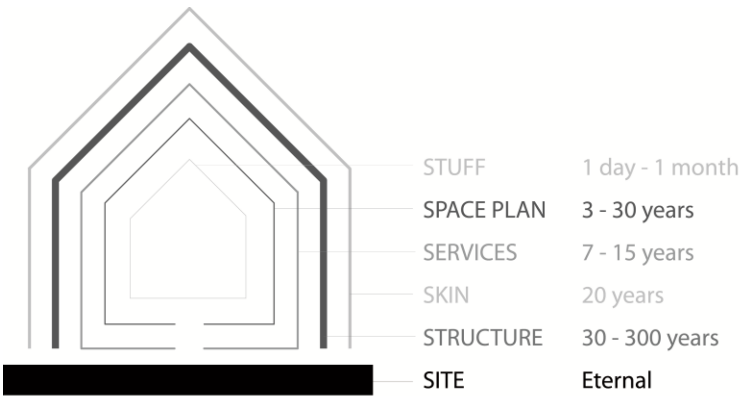

Figure 2-5 Building conceptualised as a series of shearing layers (Brand, 1994)

The nature of connections within buildings is an important topic for many – Slaughter (2001) for example notes interactions between building elements are not just physical, but also spatial and functional. Isaac and Sadeghpour (2012) draw similar conclusions terming the two types direct and indirect while Rush (1986) extends this further identifying 5 types of connection from remote to fully unified.

On a simplistic level separation approaches are often concerned with making building components accessible – for example avoiding services "*buried into walls or floors*" (Schneider & Till, 2006) where they are difficult to access to upgrade. However, two movements associated with this approach have had a particular influence on adaptable design – Open Building and manufacturing's Design for Disassembly.

2.3.2.4.1 Open Building

Kronenburg (2007) describes Open Building as a "*new set of design principles that actively supported the probability of change*". Originating in the work of Habraken (Kendall & Teicher, 2000), Open Building uses the concept of decision making 'levels'. Levels differ from layers in that they are intended to represent differences in ownership, between public and social property. Open Building levels are still manifestly related to the physical however: tissue (urban), support (base building) and infill (fit out) (Kendall & Teicher, 2000). They are also generally interpreted in much the same manner as layers (Eguchi et al., 2010): the support structure is designed to fulfil long term functions, while infill should meet the needs of short term changes in individual requirements (Geraedts, 2001).

Open Building's key innovation is in imposing a "*general set of guidelines*" to ensure continuity between levels (Friedman, 1997; Habraken, 2005). It assumes the need for change a lower levels will be more frequent than that of higher ones (Zeiler & Quanjel, 2007), and thus that decisions made at higher levels should not constrain those of the lower ones. However, as Leupen (2005) notes, the emphasis in open building has come increasingly to be not on what can be changed, but on what should be permanent and long lasting.

Key principles of Open Building are separating the support (base build – structure, envelope and primary service distribution) from the infill (fit out – the partitioning, layout and finishes of a particular demise). This is commonly achieved using framed construction (Kendall & Teicher, 2000), designating 'common' areas for service distribution (Geraedts, 2001) and the use of technical, industrially produced systems (Schmidt et al., 2010).

Perhaps because of its frequent reliance on bespoke solutions Open Building has failed to penetrate mainstream construction practice (Gibb et al., 2007) despite uptake by both Japanese and Dutch governments. It has perhaps a greater affinity with commercial buildings where, as Kendall (1999) suggests, the landlord owned base build and tenant owned fit out replicate many of Open Building's main principles.

2.3.2.4.2 Design for Disassembly (DfD)

Design for Disassembly or Design for Deconstruction (DfD) is primarily concerned with reversibility, and the fundamental assumption that a building should be decomposable into a series of constituent parts. While DfD in construction is evident historically in the modernist architecture of the post war era (Guy & Shell, 2002) DfD ideas originate in manufacturing (Pulaski et al., 2004) and have been primarily ported to construction in an effort to reduce waste associated with change and demolition (e.g. Durmisevic, 2006). The provision of adaptability is something of a side effect, albeit one which has been capitalised on by the adaptability literature in both construction (e.g. Schmidt et al., 2011; Vibæk, 2011) and product design (e.g. Li et al., 2008) fields.

DfD's focus on separating building elements leads to tactics focused on reversible, non-damaging connections and/or reducing the number of connections (Cuperus & Brouwer, 1992; Gorgolewski, 2005; Utida, 1983). Emphasis on the process of demolition leads to suggestions for easier access to components (Slaughter, 2001), handle-able component sizes (Fernandez, 2003) and careful choice of materials (Israelsson & Hansson, 2009). Other tactics, such as frequent calls for prefabricated, mass produced components (e.g. Canadian Standards Association (CSA), 2007; Pulaski et al., 2004; Slaughter, 2001) are primarily concerned with maximising recycling potential and of limited use for adaptable design.

Decomposition is considered at various scales; Fernandez's (2003) diversified lifetimes allows staged disassembly of a compartmentalised building for instance, while other sources tend towards suggesting hierarchical implementation of the principles e.g. Guy's (2002) "*whole-building, elements, components, sub-components, and materials*". Some theorists (Shabtai Isaac & Navon, 2011; Schmidt et al., 2011) have found merit in applying modularity principles to buildings, suggesting the links between layers are the more important for adaptability than those within them.

Overall DfD type approaches bring considerable benefits to adaptable design when used in combination with other strategies. However, as the soles means of understanding and providing adaptability in buildings, the huge number and complexity of connections in our built environment restricts their usefulness to niche applications (e.g. the temporary building described by Schmidt et al. (2014)).

2.3.2.5 *OTHER STRATEGIES*

There are of course other approaches. Till and Schneider (2006) suggest limiting the complexity of buildings so change can be made without "*specialised and multiple skills*" –architecture promoting DIY. Co-opting users in the process of adapting is also a common theme, through the provision of guidance (Canadian Standards Association, 2007) and incitements (Gorgolewski, 2005) to interact and alter the buildings they occupy. Some chose to focus on the reasons why someone might go to the expense and effort of adapting a building – because it is well loved or well made (Leupen et al., 2005). These later strategies tend however to emphasise the goal of long life rather than the means of adaptation.

Further inspiration for those seeking to create adaptable structures can be found in the reuse literature. This rarely concerns itself with adaptable design, but offers useful insights into how buildings could be made more adaptable through examination of the characteristics of buildings which are adapted and the processes by which this occurs. Many of these characteristics relate to 'spatial' aspects (see, for instance, Gann and Barlow's (1996) identification of characteristics that affect the simplicity of conversion from office to residential uses, Davison et al.'s (2006) review of the success of vernacular housing types and Kincaid's (2002) suggestions of redundancy, ambiguity and flexibility), but other factors are also uncovered such as a buildings location, financial, market based factors, and the type of demand (Kincaid, 2002). This body of evidence also serves to highlight to often contradictory nature of adaptability guidance. For instance Kincaid (2002) suggests the total removal of M&E systems renders them less problematic than assumed, while Gann and Barlow (1996) suggest that M&E provision to individual flats from an office use distribution is "*one of the most difficult and expensive technical aspects of conversion*".

2.3.3 MEASURING ADAPTABILITY

Given that adaptability has no fixed definition, assessing whether or not a building is adaptable is problematic. Confusion over the nature of adaptability leads some to use single attribute measures (e.g. component connectivity), others multiple attributes (e.g. Conejos, 2013). Some, such as Schmidt's (2014) approach, could be considered multi-dimensional. Definitions inclusive of social and aesthetic criteria (see, for example Leupen et al., 2005; Schmidt, 2014) further complicate matters, requiring (inherently difficult to measure) qualitative components. Assessment is further complicated because of the requirement for some knowledge of what will be useful features in the future when change is needed (Russell & Moffatt, 2001). Usually this is achieved by reference to the past and what has previously been useful (e.g. Wilkinson & Reed, 2011). However, as commentators (Robert & Kummert, 2012; Russell & Moffatt, 2001) have noted, this is an inherently dubious strategy given "*long-term forecasts are notoriously inaccurate*" (Russell & Moffatt, 2001). Thus buildings judged adaptable by one era's standard frequently fail by another's - with the benefit of retrospect:

> *"often so called flexible design is only so on paper. In reality, few designs offer strategic flexibility for building use. Only flexibilities that are capable of practical realization by the client and user are of value."* (Nutt, 1988)

Despite these difficulties there is a lively literature attempting assessment in both the construction and engineering product design literatures. These attempts largely adopt one (or a mixture of) four approaches[6]:

1. Post occupancy evaluation
2. Scenarios
3. Checklists
4. Case study approaches

2.3.3.1 *POST-OCCUPANCY EVALUATION (POE)*

Post occupancy methods use data obtained once a building has been constructed and handed to the tenant or client for use. Examples include Minami's (2007) longitudinal survey of resident's use of a moveable partition system and Atlas and Ozsoy's (1998) examination of changes to apartments by comparison with the original floor plans - Figure 2-6.

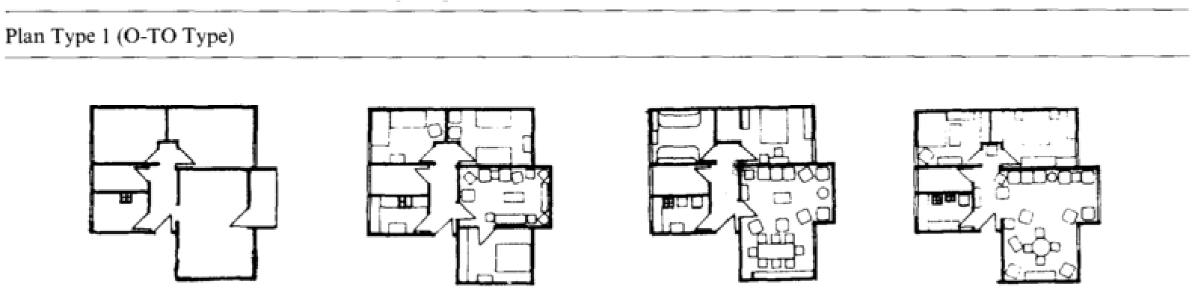

Figure 2-6 Observed changes made to 2 bed apartments (original plan on the far left) (Altaş & Özsoy, 1998)

POE methods benefit from the availability of empirical change evidence, in contrast to others approaches which need to speculate on the feasibility of change. They also measure both the feasibility of change and its desirability as they consider only those changes occupants have made. However, they are only applicable to buildings which have been use for some time, and are

[6] This categorisation is to allow comparison of similar approaches only, and not intended to be either definitive or the sole means of classification.

therefore not a design evaluation tool. Further post occupancy methods are limited to the time period prior to the evaluation, excluding any adaptable potential that has yet to be realised.

2.3.3.2 *SCENARIO METHODS*

Scenario techniques assess adaptability by ‘testing’ a design against a range of scenarios, exploring the range of change a building or product is capable of assimilating. Limits on factors such as cost (Lansley et al., 2005; Saari & Heikkilä, 2008), quality of the resulting space (Wong, 2010) and environmental impact (Bernier et al., 2010) may be used where a change is technically feasible but otherwise undesirable.

Buro Happold’s collaboration with the Adaptable Futures project (Buro Happold, 2011) demonstrates the approach for a school building, Figure 2-7. A range of change scenarios are assessed for feasibility, with major and minor retrofits determining the degree of cost and disruption allowable. While time consuming to implement, the method illustrates the range of what a proposed design can and cannot do with regards adaptability.

	Minor Retrofit		Major Retrofit	
	Shared Use	Single Use	Shared Use	Single Use
Optimising Form and Orientation				
Alter building form	○○○	●●○	●●○	●●○
Alter building orientation	○○○	○○○	●○○	●○○
Optimise glazing orientation	○○○	●○○	●●○	●●○
Add new openings	●○○	●○○	●●●	●●●
Improving Envelope Performance				
Replace building frame	○○○	●○○	●●○	●●○
Insulate walls	●●○	●●●	●●●	●●●
Insulate roof	●●○	●●●	●●●	●●●
Insulate floors	●○○	●○○	●●○	●●○
Upgrade windows	●●○	●●●	●●●	●●●
Improve air tightness	●○○	●○○	●●○	●●●

○○○ not feasible ●○○ not easily feasible ●●○ somewhat feasible ●●● easily feasible

Figure 2-7 Extract of Buro Happold (2011) scenario assessment

Lansley et al. (2005) is perhaps the most developed of the published scenario studies examined, combining “*an extensive survey of older people about their experience of the adaptability which had been carried out in their homes*” with an examination of the cost and feasibility of providing a range of packages of adaptations (change scenarios) to a set of buildings representing a defined population. There are however other examples. Wong (2010) uses a spatial approach to examine a range of proposed alterations to residential apartment layouts. Wong imposes constraints in the form of usability – sufficient room for movement between items and adequate daylighting for certain functions. Schmidt et al. (2014) assess the feasibility of 30 simple change scenarios on a simple modular building . They use two techniques – path tracing of component linkages using a (DSM[7]) model of the building, and assessment by a "*system expert*" (Schmidt, Vibaek, et al., 2014) familiar with the buildings construction. A similar modelling approach is adopted by Grinnell et al. (2012) who present results showing the effects of four different scenarios on a retail building.

Both Grinnell et al. (2012) and Schmidt et al.'s (2014) approaches lean heavily on work in the engineering design sector, such as Giffin et al.'s (2009) identification change propagation paths associated with changing particular elements or clusters of elements. Ross, Rhodes and Hasting's (2008) 'tradespace' that attempts to define all possible variants of a given product is also a noteworthy contribution to adaptability measurement by this sector.

The primary advantage of scenario methods is their ability to produce comparable results across buildings or other products by using the same test scenarios for each. They therefore eliminate the inherent bias in POE measures towards older buildings (which rely on actual changes made). This is however at a cost - there is no guarantee the scenarios chosen will be likely or relevant in future. Some element of relevance may be reintroduced by the careful selection of scenarios: Wong (2010) for example selects scenarios based on interviews with occupants to ascertain what sorts of changes were most desired. However, scenario methods are also difficult to apply generally; typically not all scenarios will be relevant to all types of building or building uses. This limits the technique to comparing similar buildings, something which is evident in the examples cited which limit themselves to one, or a small number of similar, buildings.

There are also other problems. Typically these approaches rely on data that is either unavailable or difficult to collect in a construction context (Schmidt, Vibaek, et al., 2014), for example the costs of changes (e.g. Olewnik & Lewis, 2006; Schmidt, Vibaek, et al., 2014) or knowledge of all proposed changes during a product's lifetime (e.g. Ross et al., 2008). They are also time consuming to apply. These difficulties mean that, although more common in the manufacturing literature, uptake in construction has been limited.

2.3.3.3 *CRITERIA BASED*

Criteria based approaches assess whether a design has certain properties that are held to be compatible with adaptability and are the most prolific adaptability assessment type in the construction literature. Various methods are employed to obtain these criteria: expert interviews

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[7] DSMs (dependency or design structure matrices) are grids capable of indicating connections between all components in a building or product.

(Conejos, 2013; Manewa, 2012; Remøy et al., 2011), building surveys (Kincaid, 2002; March et al., 2012; Wilkinson & Reed, 2011) and literature reviews (Conejos et al., 2013; Wilkinson et al., 2009) being among the most common, although case studies have also been employed (Schmidt, 2014).

In the manufacturing literature approaches specify their criteria on the basis of the configuration of components – the product architecture. Criteria include the connectivity of elements (Fletcher et al., 2010; Tilstra et al., 2009), the nature of the connections (Rush, 1986) and the level of modularity (Schmidt et al., 2011). While popular in engineering design settings (e.g. Keller et al., 2009; Shah et al., 2008; Tilstra et al., 2009) product architecture approaches have not been successfully ported to construction design, despite tentative efforts (Shabtai Isaac & Navon, 2011; Mohyuddin et al., 2008; Schmidt et al., 2011). Most assessments of this type rely on models of the interconnectivity of components, which become very complex when dealing with the high number of components in a typical building, making them time consuming to construct and difficult to use once complete. Conceptualising buildings as a series of shearing layers (Brand, 1994) has been trialled by some (Schmidt et al., 2011; Schmidt, Vibaek, et al., 2014) in attempt to reduce the level of detail required, but met with variable success, perhaps reflecting the limited understanding of modularity's conceptual usefulness in adaptable building design.

In the building literature the wealth of guidelines for adaptable design creates disagreement over which criteria should be included or given the most weight. Examining all identified sources, academic and industrial, of adaptability guidance produced 1018 characteristics of adaptable buildings from 107 sources, appendix 2A. (Only limited attempts were made to restrict the sample from a quality perspective, and no judgement on the appropriateness of the suggestions was made.) Excluding 96 generic statements and grouping those remaining to remove duplication results in the identification of 65 distinct characteristics of adaptable buildings, Figure 2-8. The figure makes two important points. Firstly that some of the criteria are somewhat contradictory – e.g. although simpler servicing strategies do not preclude generous floor to ceiling heights and adequate space provision for future plant they are unlikely to be required together, regular shaped buildings are not generally not associated with aesthetically pleasing design. This makes it difficult for criteria approaches to be simultaneously comprehensive and coherent measures. Secondly only three of the resulting 65 characteristics were identified by more than 25% of the sources examined: floor to ceiling heights, floor loadings and component connection types. This demonstrates the lack of consensus in the field as to the basic features of an adaptable building and emphasises the difficulty inherent in any approach that seeks to evaluate by comparison to them.

Compliance is assessed in several ways. Some methods specify criteria in terms of general principles an adaptable building should exemplify but allow the assessor some discretion in how these are measured and combined to determine the overall result (e.g. Gann & Barlow, 1996; Russell & Moffatt, 2001; Schneider & Till, 2007). These forms have a high degree of similarity with case study type assessments (see below). Others choose more replicable methods. For instance, Conjeos (2013) uses a Likert type scale to assess the degree of agreement with a series of statements.

Results are also presented in a variety of ways. Non numerical outcomes include Kincaid's (2002) "*use comparator*" which produces a list of conversion options and Geraedts and de Vrij's (2004) transformation meter's rudimentary cost benefit analysis and risk checklist. Using numbers, several studies combine component scores to produce a single value, for example Langston's ARP score (Langston & Shen, 2007), March et al.'s (2012) Building Adaptability Score (BAS) and Conejos's (2013) AdaptSTAR. Others chose not to aggregate results and instead employ methods to visualise components separately but in a manner that facilitates comparison; radar charts are commonly used for this purpose (e.g. Cowee & Schwehr, 2009; Geraedts, 2008; Schmidt, 2014).

Unlike the other assessment types considered, criteria assessments tend to be practical to apply and applicable to a range of building types. However, perhaps for commercial reasons, several of these tools are reported in an abbreviated form making it difficult for others to reuse them. For example insufficient detail in the reporting of the Multiconsult 'Multi Map' tool (Larssen & Bjørberg, n.d.) makes a complete assessment impossible using the explanation provided. Cuperus and Brouwer's (1992) "*capacity to change index*" (CTC) is so sparsely articulated it seems unlikely it could ever be reliably applied. Others, while reported in full, frequently use criteria that are difficult to calculate. Cowee and Schwehr's (2009) tool for example requires estimates of refurbishment rates and costs per square metre of extension. While undoubtedly relevant, as for the scenario measures above these figures are difficult to calculate, particularly where they refer to costs that may not be incurred for some time. Of the remaining assessments, many originate in the conversion (sometimes referred to as adaptive reuse) literature (e.g. Conejos et al., 2013; Geraedts & de Vrij, 2004; Kincaid, 2002; Langston, 2012). This leads to a focus on capacity for conversion and major refurbishment, overlooking more short term change such as furniture and space re-planning.

2.3.3.4 *CASE STUDY APPROACHES*

The adaptability literature has a growing body of case studies providing best practice examples (e.g. Schneider & Till, 2007) and critiques of more mundane designs (e.g. Kelly et al., 2011). While these cases are not designed to provide assessment, the processes by which the authors describe their presented cases as adaptable or otherwise does require some implicit form of differentiating between adaptable and not. Borrowing from other approaches is common – Kelly et al. (2011) describe their cases performance against 6 change types (scenario method), Schneider and Till (2007) outline a range of adaptable practices (checklist method) before relating their cases.

Case approaches add something new to the methods that they borrow from in the use of examples – Brand's (1994) portrayal of adaptability is depicted in the description of change across a variety of building types, while both Schneider and Till (2007) and Kronenburg (2007) make frequent comparisons to existing buildings they believe to be accepted as adaptable construction – terraced housing, traditional Japanese housing, speculative offices. These case comparative techniques are a potentially powerful method of assessment, but they suffer from being relative – it is possible to say that one building is the same, or more, adaptable than another, but not if one either actually warrant the label 'adaptable', or how the cases examined might relate to a wider sample of buildings. They are also time consuming to perform and rely on the assessor understanding the most important characteristics to compare – i.e. the assessor needs a good knowledge base of cases to compare with to be confident in their assessment.

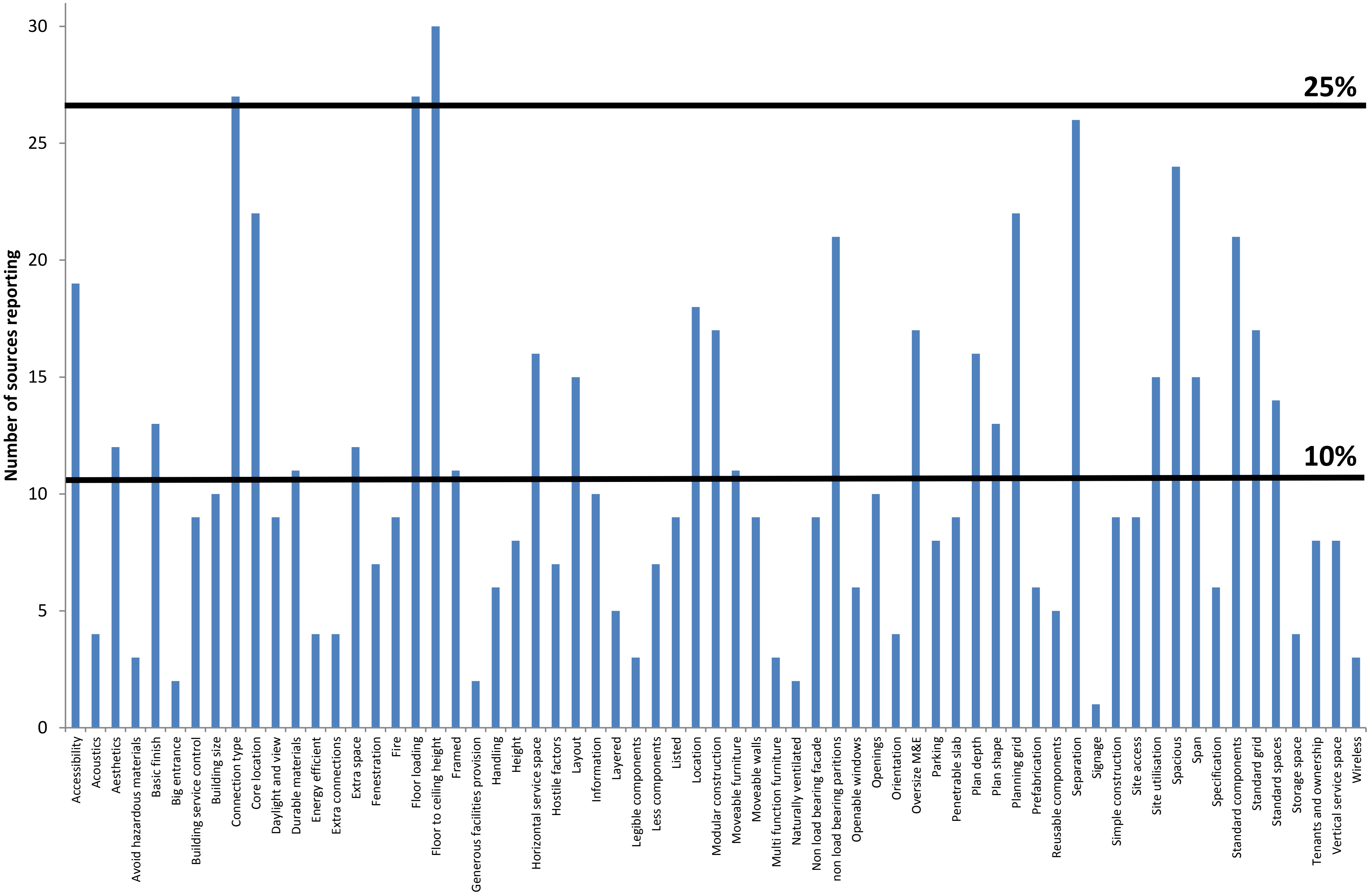


Figure 2-8 Generic characteristics of an adaptable building

2.3.3.5 *VALIDATION AND BENCHMARKING*

Pragmatically, criteria approaches offer the greatest potential for simple benchmarking of adaptability during design, but relatively few cases are published with each assessment scheme and the assessments are rarely reused by others. Schmidt (2014) examines 75 cases, but only 15 are subjected to the characteristic (CAR) evaluation. March et al. (2012) analyse a number of buildings but amalgamate the results and present only two 'neighbourhood' values. POE and scenario approaches often appear to generate more data, but this is often due to repeated examination of a particular design – Atlas and Ozsoy (1998) for example state 398 cases, but these represent only 4 apartment types. This makes it difficult to generalise to other building types or compare results.

Perhaps as a result of the lack of comparative data, few models attempt validation to ensure they are, in fact, measuring adaptability. Exceptions include Langston's (2012) comparison of the ARP model to a second model, IconCUR. This is of limited use for those interested in assessing building designs however, as both models are primarily designed to assess obsolesce and identify the ideal point to maximise investment in reuse. Conejos (2013) uses Langston's ARP model to validate AdaptSTAR, but given the models measure different things this seems rather odd. Rarely are unadaptable buildings evaluated, with Conejos's (2013) opinion of there being "*no benefit, other than for model calibration, to investigate unsuccessful examples of adaptive reuse*" seemingly fairly typical. This means in the main the models remain un-calibrated and determining what should be considered adaptable impossible. Of the measures examined only two explicitly provide some indication of what values could be considered adaptable. Lansley et al.'s (2005) study imposes a cost limit based on a value (£25,000, the available disabled facilities grant in the UK at the time of the study) theoretically relevant to their study of adaptations for older persons. They also chose two further values, one a social landlord "*would commonly expect to pay*" and a much lower value designed to identify the most adaptable buildings. While Lansley et al.'s study demonstrates the feasibility of calibrating models theoretically, it is highly specific; the chosen value relates only to the adaptation of dwellings for the needs of older people and would not be appropriate for say, a supermarket or office. Schmidt (2014) identifies a range of "*key characteristics*" a building should possess if it is to embody each of Schmidt's six adaptability "*types*" (see 2.3.1) as well suggesting a cut off for projects fulfilling more than 60% of more characteristics associated with a particular type. There is however no guidance as to how one might combine these scores, reflecting Schmidt's (2014) conceptualisation of adaptability as multi-dimensional.

What is evident is that no single method of separating adaptable designs from the unadaptable is in widespread use. Instead a variety of metrics exist, replicating the variety of definitions. Some methods, particularly those originating in the manufacturing literature emphasise separation of components, others adopt broader definitions. Reflecting the notion of adaptability as a multi-dimensional concept there are methods focussed on a single type of change (e.g. Conejos, 2013; Kincaid, 2002), and others attempting to aggregate a variety of change types into a single measure (Cowee & Schwehr, 2009; Grinnell et al., 2012; Schmidt, 2014). It may be that, similar to other concepts like value and design quality, "*the problem resides with the ambition to find objective or universal quality standards*" (Dewulf & van Meel, 2004) a point that has been argued by several authors (Finch, 2009; Saari & Heikkilä, 2008; Schmidt, 2014).

2.4 CHAPTER CONCLUSION

This chapter has defined and described the main features of low carbon and adaptable design. As a result several similarities and differences are apparent. Firstly, both agendas have a range of established design approaches (2.2.4 and 2.3.2) for reaching their respective design goals. With the possible exception of the promoted fabric first approach to low carbon design, none of these methods is considered as the best or only choice for either agenda and in practice ideas from multiple approaches are likely to be combined to produce a bespoke solution. Thus, there are likely to be multiple, alternative methods of reconciling the agendas by mixing solutions from each.

Secondly, there are differences in how the agendas are evaluated. Carbon is a measureable quantity and while the appropriate bounds are still subject to debate, there is a general level of consensus over what a low carbon building is and what should be measured to demonstrate this. In contrast, adaptability is a much more ephemeral quality. Scholars are yet to agree what an adaptable building is in concrete terms making any efforts to evaluate it as a property of buildings inherently difficult and open to dispute. This raises the interesting question of whether carbon, "*one of the most tangible sustainability issues*" (Lützkendorf & Lorenz, 2011), would dominate in field plagued by exhortations for "*clear measurable objectives*" (Egan, 1998).

Lastly, adaptability's goal of facilitating future change places much of its emphasis on the long term, in contrast to the much more immediate concerns of low carbon design. This provides an interesting juxtaposition for the purposes of this study – are immediate gains from low carbon design in reducing fuel poverty and reducing energy bills for consumers more valued than investing in solutions for change that may not be used for several years or decades, if at all?

The next chapter will explore these overlaps and contrasts in more detail, considering plausible interaction between the two agendas during design and what might influence design choices when faced with conflict or the potential for synergies.

3 INTERACTION

3.1 INTRODUCTION

Chapter 1 argued that the various sustainability agendas will interact and as a result influence how buildings are designed and the sustainable outcomes obtained. This chapter looks at the evidence base for this. Building on the work presented in chapter 2 which described two sustainable design approaches separately, this chapter first considers how the two might overlap, interact and conflict in both the immediate and long term (2.2). Concluding that these observed overlaps are unlikely to represent the full possibilities for interaction, section 2.3 then looks at the wider body of theoretical work on interaction. Section 2.4 reflects on how these noted interaction effects might influence the design process.

3.2 OVERLAPS IN LOW CARBON AND ADAPTABLE DESIGN

3.2.1 INTRODUCTION

The previous chapter described the main features of adaptable and low carbon design, approaching them in the typical fashion as distinct and separate ideas. However, it was possible to identify a small number of interesting similarities and differences (section 2.4). This section elaborates on those overlaps and contrasts, first by considering the way in which the two design types are achieved (section 3.2.2) and then any obvious alignment in their sustainability goals (section 3.2.3)

3.2.2 CONTRADICTORY REQUIREMENTS

3.2.2.1 *OVERSPECIFICATION*

While the adaptability community has largely moved away from suggesting universal overdesign due to the additional costs involved (Pinder et al., 2011), ensuring there is sufficient capacity in structural and other long life elements remains widely promoted as an adaptability principle (see 2.3.2.2). However, a number of studies have highlighted the negative implications of this practice for low carbon design. Moynihan and Allwood (2014) found buildings could be safely designed with as much as 40% less steel than currently used, significantly reducing embodied carbon in a buildings frame. Research undertaken on behalf of British Council of Offices (BCO) suggests even in intensively used offices small power loads (plug in items such as computers, local task lighting, photocopiers etc.) are 24% lower than design guidance recommends (Construction Manager, 2014), reinforcing an earlier finding by Dunn and Knight (2005) that small power loads could be overestimated by "*at least 24% and, in the worst case 650%*" leading to *"reduced energy efficiency, increased emissions, higher capital and running costs*". As Lynch (1958) notes, "*there seems to be a continuous conflict between future adaptability and present efficiency*".

3.2.2.2 *BUILT FORM*

Chapter 2 noted that built form is important for both adaptability (2.3.2) and low carbon (2.2.3.1) design. However, the two generally adopt conflicting views on the most appropriate option. Natural ventilation generally requires a narrow plan, as air will typically penetrate only 6-10m (depending on floor to ceiling heights) without mechanical assistance (CIBSE, 2012). Conversely adaptability, particularly in non-domestic buildings, tends to favour deep plans which provide space to accommodate a number of activities (Arge, 2005; Kincaid, 2002). While alternatives are available that provide natural ventilation solutions in deep plan buildings (e.g. the use of stack ventilation, atria and chimneys (CIBSE, 2012)) these tend to require 'holes' scattered throughout the floor plan which one might expect to conflict with adaptability's requirement for clear open spaces (Gosling et al., 2013; Guy & Shell, 2003; Schneider & Till, 2007).

3.2.3 CONVERGENCE AND DIVERGENCE IN LONG TERM GOALS

3.2.3.1 *EMBODIED CARBON*

Adaptability proponents commonly argue that from a whole life perspective, adaptability reduces material consumption (Bullen, 2007; Douglas, 2006; Gosling et al., 2011) and therefore embodied energy compared with a demolition and rebuild scenario. However, this argument relies on a number of largely unproven assumptions. First and foremost of these is that successive alterations and refurbishment consumes less embodied energy than replacement.

Due to the complexity and confusion surrounding embodied energy and carbon calculation (Hernandez & Kenny, 2011), many studies simply assume savings. No studies have compared the lifecycle embodied energy of adaptable and unadaptable buildings, although some sources have compared demolition and refurbishment scenarios (Itard & Klunder, 2007; Preservation Green Lab, 2011) and there have been a limited number of attempts to quantify the energy used in progressive maintenance and refurbishment cycles (Thormark, 2002; Yohanis & Norton, 2002). These studies suggest the structural elements of a building are responsible for the majority of embodied carbon (Jeong et al. (2012) find 85% of their Korean apartment's embodied carbon is associated with the structure while Dimoudi and Tompa (2008) suggest structure contributes 60-67% of embodied energy). These findings support the embodied energy claims of adaptation because the structure is normally retained during refurbishment and alterations (Kincaid, 2002). However, Treloar et al. (1999) find up to 30% of lifetime embodied energy in office buildings could be attributable to high churn fixture and fitting elements.

There is also the issue of whether substantial numbers of buildings are being demolished – i.e. is there embodied energy to be saved? Because of "*scant statistics*" (Thomsen et al., 2011) little is known about how much demolition occurs in the UK. In 2007 only 17,000 of the UK's 25 million dwellings were demolished (Boardman, 2007), representing "*an imperceptible turnover*" (Boardman, 2007) and reflecting comments that large scale demolition is "*slow, costly and unpopular*" (Power, 2010). No data is available for commercial buildings, although they are generally believed to have shorter lifetimes than domestic housing (Brand, 1994). However, what is known is that demolition and construction of new buildings combined generate large quantities of waste, Figure 3-1.

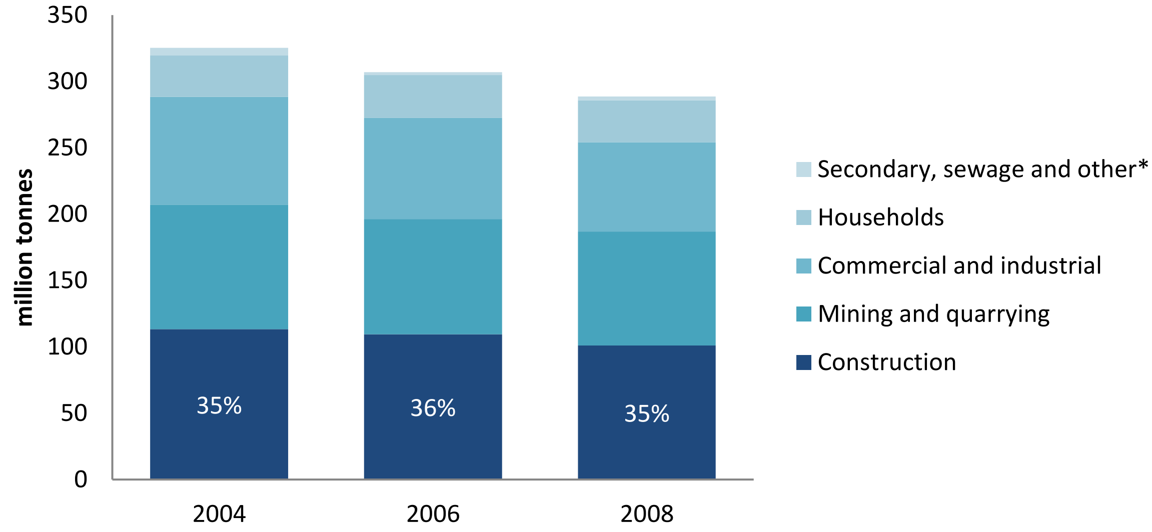


Figure 3-1 Total UK waste generation by sector, 2004 to 2008 (DEFRA, 2011)

Thus even if only relatively small numbers of buildings were demolished annually, as adaptability is believed to reduce vacancy (Ellison & Sayce, 2007) buildings could be expected to remain in service longer and reduce the need to build additional structures. This is a view shared by the UK government who made changes in 2012 (Department for Communities and Local Government, 2012b) to the planning system to make the conversion of commercial buildings to much needed housing more straightforward. Between 1998 and 2005 vacancy in commercial buildings averaged 7 to 9% (Department for Communities and Local Government, 2011b) and these buildings are seen as a significant, exploitable resource:

> *"… there are buildings which no longer function as intended in their existing locations. There are offices built in locations where the demand for office space has moved on or the need is for buildings with higher specifications that are better able to deliver for modern businesses. Similarly, there are industrial buildings which are no longer suitable for manufacturing which have struggled to find new uses but which offer good opportunities for conversion."*
> (Department for Communities and Local Government, 2012b)

Lastly, whether or not adaptability saves carbon over a building's lifecycle is also dependent on the amount of energy the building consumes in use. Due to the progressive increases in building efficiency required by law (see section 2.2.2.3), new buildings are now considerably more efficient than older buildings. Older buildings can of course be upgraded to deliver improved energy performance, but there is disagreement over whether such buildings are likely to match best practice in new build. Bullen (2004) presents evidence suggesting that the renovation of existing buildings is potentially just as successful at delivering operational carbon reductions as new build, although Ball (1999) finds "*an apparent tendency to accept lower performance on most parameters when it comes to reuse*" and a "*greater allegiance to energy efficiency in new build*". Boardman (2007) has argued that even accounting for new build embodied energy "*the gap between refurbishment and new build remains substantial*".

Overall the picture is a confusing one. Adaptable buildings offer an opportunity to reduce material wastage associated with demolition and re-construction, but on the other hand the lack of conclusive evidence on material savings makes it difficult to predict whether these will outweigh gains from new building's increased energy efficiency.

3.2.3.2 *RETROFITTING*

The UK will not make 'zero carbon' buildings mandatory until 2020 or beyond. This means that, since the introduction of energy efficiency targets in the 1980's we have been and will continue for some time, to build homes and workplaces that perform better than average, but still less than some low carbon supporters would like (e.g. Boardman, 2007). Many simple adaptations can be undertaken on existing buildings to improve energy efficiency, such as replacing outdated boilers, insulating loft spaces and adding solar panels (Committee on Climate Change, 2011). However, a number of building types are increasingly labelled "*hard to treat*" (Low Carbon Innovation and Growth Team, 2010). For these buildings energy efficiency measures are unlikely to be cost effective at current prices. There are also problems with encouraging owners and occupiers to upgrade their buildings because retrofit activities are seen as disruptive (Bernier et al., 2010). This seems an ideal niche for the promotion of more adaptable buildings, which are argued to reduce the costs and disruption associated with change (Ball, 2002; Bullen, 2007; Douglas, 2006).

However, aside from Kincaid (2002) and Bullen (2004) who both allude to it, the low carbon retrofit movement has attracted limited attention as a potential opportunity. This is perhaps because while incremental improvement has been promoted by some (e.g. Sunikka-Blank & Galvin, 2012), it might be seen as harmful in the context of the urgency so often associated with decarbonisation. Others argue an incremental approach delays work, reducing total savings (Boardman, 2007), and there is the inevitable risk that owners may not pursue the upgrades at all. Summerfield et al. (2010) find owners of energy efficient homes built in the 1980's undertook few improvements to maintain performance and conclude:

> *"Energy-efficiency measures should be carried out to maximum effect, rather than in half measures, since once they have been implemented and provide comfort with lower energy costs, little evidence is found of the occupants undertaking further improvements, not even increased loft insulation or renewed draft stripping, unless forced by component failure."*

There is also the possibility that occupiers might use the increased changeability of their buildings to make unhelpful changes. Ravetz (2008) describes homeowners "*still seeking new and exotic links from indoors to outdoors, involving conservatories, summer houses, gazebos*" which they then heat "*counter to all energy efficiency advice*", reiterating Summerfield et al.'s (2010) findings that at least three of their sample of 29 houses had dining rooms converted to office spaces between 1987 and their 2010 study "*with the accompanying electrical equipment, such as multiple computers, internet routers, second televisions*". This trend leads them to conclude that:

> *"Building extensions (including adding conservatories) may allow for refurbishment of the existing dwelling up to current standards, but they also provide an opportunity for the occupants to drive increased energy consumption with more space heating and more appliances." (Summerfield et al., 2010)*

3.3 WHAT MIGHT INTERACTION LOOK LIKE?

The passages above identify a number of potential conflicts between the basic principles of adaptability and low carbon design, as well as illustrating a more complicated picture of the potential for tensions and synergies in their long term aims. However, it is apparent that the majority of these are speculated rather than proven, will not arise in every project and are unlikely to represent to the full range of interaction effects given these two approaches are known (see chapter 2) to influence numerous aspects of what is built and how it is designed. As a result, our understanding of the potential advantages and disadvantages of pursuing an adaptable, low carbon sustainable strategy is somewhat limited. Furthermore, the wider sustainability literature is of limited help in furthering our understanding given the very limited number of studies considering interaction effects.

Despite occasional implied or alluded to interactions between different design goals, an extremely limited number of authors (e.g. Davies & Oreszczyn, 2012; Edum-Fotwe et al., 2004; Hiete et al., 2011) tackle the subject explicitly. More work has been undertaken at a policy level, where authors have mused on interaction effects in planning policy (Williams, 1999), energy poverty (Ürge-Vorsatz & Herrero, 2012), climate change adaptation and mitigation (Klein et al., 2007) and air pollution (Leinert et al., 2013). However, these studies consider interaction at very different spatial scale to those that would be of interest to building design. More relevant is the growing literature exploring overlap in the previously separate climate adaptation and climate change mitigation fields where researchers increasingly concerned with the potential for "*unintended consequences*" (Davies & Oreszczyn, 2012) of low carbon design have begun to speculate on (mostly negative) effects. These include overheating (McLeod et al., 2013) and consequential worsening of the urban heat island effect, poor indoor air quality (Nicol & Stevenson, 2013) and fuel poverty (Ürge-Vorsatz & Herrero, 2012). Generally these studies concentrate on technical aspects of implementation rather than softer issues such as process, Williams et al. (2012) is a rare exception as "*apart from the typical technical aspects they also consider the societal aspects*" (de Wilde & Coley, 2012).

What can be established from the work available is that interaction is normally perceived as generating either synergy or conflict, although definitions of the two terms differ slightly between sources. Synergy is where ""*the effect on both … point in the same direction*" (Ürge-Vorsatz & Herrero, 2012) or when their *"combined effect [is] greater than the sum of their effects if implemented separately*" (Klein et al., 2007) and is, with the exception of Urge-Vorsatz and Herrero's (2012) negative synergy, generally seen as positive. As a result researchers in some fields such as climate change have begun to develop list like examples of synergies (e.g. Mills, 2003) although few have done so comprehensively. Others such as Hiete et al. (2011) have considered the implications for sustainable rating systems. Often however, claims to synergistic links seem more opportunistic attempts to piggyback on a more popular agenda - what Urge-Vorsatz and Herrero (2012) describe as "*trying to sell a less sexy subject in a more popular packaging*".

In contrast to synergy, conflict is something to be avoided. Examples in the built environment includes Edum-Fotwe et al.'s (2004) "*incongruities*" between innovation and standardisation in the pursuit of construction improvement, William's (1999) critique of compact cities in UK planning policy and Williams and Dair's finding that it is often impossible to optimise for all sustainability objectives meaning "*one sustainability measures was forgone in order to achieve the other*" (Williams & Dair, 2007).

Other less obvious themes in interaction literature are the distinctions made between when the effect occurs (now – a trade-off, or later, a consequence) and how obvious it is (Davies and Oreszczyn's (2012) known and unknown consequences, and Hiete et al.'s (2011) direct and indirect relationships). Trade-offs have immediate, known impact on the ability to deliver a second goal, while consequences are largely "*unintended*" (Davies & Oreszczyn, 2012), "*side effects*" (Leinert et al., 2013) not anticipated when the decision to pursue a course of action was taken. Considering the strength or impact of interaction effects is relatively rare, with only Hiete et al. (2011) and Pyke et al.'s (2012) exploration of links between sustainability rating system credits exploring the issue.

What is apparent is that while policy would has begun to produce simple typologies and muse on effects – at the scale of the individual building there is little to no understanding of interaction's influence on design. The obsession with pursing a holistic idea of a sustainable built environment (Guy, 2005) has overlooked what could be a significant obstacle, or benefit. Thus, while there are a number of arguments supporting the integration of low carbon and adaptable design's in the long term (3.2.3), we know very little about how adaptable and low carbon principles interact in practice or the implications of those interactions for design. This leads to a number of questions. Firstly, given the possibility of both helpful synergies and problematic conflict, to what extent is it possible for a building to be both adaptable and low carbon? Secondly, while the interactions identified in section 3.2.2 and 3.2.3 broadly fit within the synergy / conflict model implied by existing interaction theory, are these the only ways the agendas interact? And do these interactions actually appear in practice? Answering these questions would provide important contributions to our understanding of how interaction affects sustainable design and therefore forms the basis for two of this study's objectives:

> *OB01: Demonstrate the existence of interaction by locating, describing and categorising examples of interaction in real building design processes, comparing the empirical findings to theoretical interaction types*

> *OB04: Operationalize the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successful in reconciling low carbon and adaptability principles.*

3.4 FACTORS INFLUENCING INTERACTION STRATEGIES

3.4.1 INTRODUCTION

Assuming interaction is encountered, how should designers engage with it? Generally it seems expected that they will capitalise on synergies and avoid conflict. McEvoy et al. (2006) for example discuss the "*appeal of creating 'win-win' solutions*" while Leinert et al. (2013) ask policy makers to be "*cognisant of the possible negative side effects*". There is however little in the way of guidance to suggest how to go about this. Some (McEvoy et al., 2006; Mills, 2003) suggest identifying synergies and conflicts but few sources do so comprehensively. While some interactions may be obvious, "*indirect interdependencies, i.e. influences via other criteria, are more difficult to identify*" (Hiete et al., 2011) and more likely to be missed. In perhaps the most researched area of interaction, between climate mitigation and adaptation actions, Davies and Oreszczyn (2012) note we know little about known consequences, let alone unknown ones.

There is even less advice where conflict is unavoidable. Williams and Dair's (2007) findings point to a need to trade sustainable objectives, but how might design teams determine which is more important? Pyke et al. (2007) note a majority of sustainability decision tools frame the problem as one of information – given sufficient information, design teams would always make the 'best' choice. Yet this approach assumes an optimum choice exists. In reality, "*design is a messy kind of business that involves making value judgements between alternatives that may each offer some advantages and disadvantages*" (Lawson, 2005). The few sources discussing interaction also tend towards considering each interaction as isolated events whereas in reality, designers are likely to encounter multiple opportunities for synergism and conflict. The problem then becomes "*how to know when all of their incremental decisions have reached an optimum level … in terms of sustainability*" (Williams, 1999).

What therefore, might influence how interaction effects are exploited and overcome? This next section explores the few factors postulated to influence interaction directly, as well as the much more numerous circumstances known to influence sustainable, adaptable and low carbon design independently.

3.4.2 LEGISLATION AND CERTIFICATION

It is common for legislation and policy to call for multiple objectives "*without providing clear delivery mechanisms*" (Williams et al., 2013). For example the NPPF's requirement to avoid "*development in areas at risk of flooding*" while admitting there may be "*wider sustainability benefits to the community that outweigh flood risk*". As a result legislation often requires clients and designers to consider potential interaction effects, but provides them with little guidance as to how they might do so. Its primary impact is therefore in the ways it prioritizes different aspects of sustainability. As described in section 1.2, there is considerable government support for low carbon building design and a wealth of legislation exists to either promote (e.g. the CRC energy efficiency scheme) or mandate it (e.g. Building Regulations Part L, National Planning Policy Framework). Conversely, there is little if any government push for adaptable design, and it has until recently been overlooked by the majority of the most popular sustainability certification schemes, perhaps due to difficulties with measuring its implementation (see 2.3.3).

There are pros and cons to becoming a government promoted, certifiable aspect of sustainability. On the one hand, adaptability does not benefit from certification schemes such as BREEAM or LEED that allow buildings to demonstrate their credentials and command a price premium (Fuerst & McAllister, 2011; Peterman et al., 2012). On the other, legislation and certification encourage use, but can also constrain it (Cole, 2005; Moncaster, 2012; Williams & Dair, 2007). While the UK's building regulations are intended to be performance based and technology neutral (Department for Communities and Local Government, 2010a), the emphasis in new domestic legislation on FEES and the imposition of backstop u-values create an environment in which a fabric first methodology (see 2.2.3) is promoted. Further, the SBEM and SAP software used to demonstrate compliance restricts designers to those low carbon technologies that have been approved and can be reliably modelled (Low Carbon Innovation and Growth Team, 2010) – potentially stifling innovative approaches (Häkkinen & Belloni, 2011).

These steering effects are not limited solely to legislation, others have noted certification schemes such as BREEAM encourage particular interpretations of sustainability (Cole, 2005; Schweber, 2013; Wallhagen & Glaumann, 2011). As energy dominates certification schemes their use arguably fosters an energy-centric approach to sustainable design (Moncaster, 2012). Further, as Hiete et al. (2011) and others (Pyke et al., 2012) demonstrate, interdependencies between different criteria encourage users to focus on criteria influential on others, to minimise the effort associated with a given rating. While this is not necessarily a bad thing, where a large number of inter-related criteria are present it is likely to encourage their pursuit rather than more disparate objectives.

3.4.3 COST AND VALUE

Several sources suggest competition for resources, in particular funding, to be a cause of conflict. Sustainability is often perceived as expensive (Häkkinen & Belloni, 2011; Morton et al., 2011; Williams & Dair, 2007) and despite conflicting evidence this largely holds true for adaptability (Fuster et al., 2009; Leupen et al., 2005; Russell & Moffatt, 2001) and low carbon (Kershaw & Simm, 2014). While some argue that increased costs are a misconception (Pinder et al., 2011) and adaptability "*can cost less than traditional construction process*" (Kendall & Teicher, 2000), other sources quote between a 2% (Israelsson & Hansson, 2009; Slaughter, 2001) and 25% (Arge, 2005) uplift over traditional design. Similarly for low carbon design "*the unproven nature of the technology, inherent risk and uncertain outcomes of implementation*" (Peterman et al., 2012) can result in increased costs. This however merely highlights that sustainability is in direct competition for funds with more basic requirements. To understand how competition might result in one sustainable agenda losing out to another, it is necessary to look at why each might be included. What makes adaptability and low carbon design valuable to clients?

Both agendas argue they save money – low carbon directly through reduced energy bills and adaptability through reduced costs for refurbishment and maintenance (Duffy, 1990; Leupen et al., 2005; T. Schneider & Till, 2007). Indirectly, adaptability should reduce disruption during works (Kendall & Teicher, 2000; T. Schneider & Till, 2007), reduce building vacancy periods (Israelsson & Hansson, 2009; Wilkinson et al., 2009) and result in more productive spaces better matched to their use (Schmidt, 2014). Low carbon design has been argued to increase employee satisfaction (Leaman & Bordass, 2001), future proof buildings against future green taxes and energy price rises, and provide a "*reputational gain*" (Pellegrini-Masini & Leishman, 2011) to those seen to be engaging with it. However, for adaptability measured benefits are largely unproven. Evidence for savings in building maintenance and renovation costs (Arge, 2005; Davison, Goodier, et al., 2006; Duffy, 1990; Kendall & Teicher, 2000) is often taken from isolated cases, or simply unsubstantiated. Bijdendijk (2005) for instance suggests reductions in transformation costs of 60-70% but presents no data to support such claims and Pinder et al. (2011) draw attention to the lack of discounting in Slaughter's (2001) results. Low carbon benefits are more measureable through reduced energy bills, although savings are often inconsequential compared to costs in other areas: "*companies, despite becoming more energy conscious, still regard energy costs as a negligible part of their business costs*" (Pellegrini-Masini & Leishman, 2011), often as little as 1-2% (Carbon Trust, 2009). There is also the problem that both increase capital costs to generate savings in operational budgets which may be allocated to separate funding streams or, particularly in the case of adaptability, fail to materialise should change not occur.

In addition to difficulties substantiating benefits, authors in both fields (Arge, 2005; Fischer & Guy, 2009; Gorgolewski, 2005; Pellegrini-Masini & Leishman, 2011; Peterman et al., 2012; Pinder et al., 2011) note the difficulties in convincing developers to invest in measures that will not benefit them but the ultimate owner, particularly where there is little evidence that such measures increase the desirability of a building. Developers have "*no incentive to add costs to the property they develop, unless the market value increases by doing so*" (Arge, 2005). The is what the Carbon Trust (2009) describe as the "*circle of inertia*" and Peterman et al. (2012) as "*broken agency*" and leads to a conclusion in both fields that only those with both a long term perspective (owner occupiers) will find the approaches sufficiently valued to merit inclusion.

Owner-occupiers are however often seeking purpose built, bespoke facilities. This can be at odds with adaptable buildings' ambiguous spaces, which have been accused of compromising the first use in the attempt to be multiple things resulting in "*programmatically neutral, characterless buildings…synonymous with blandness"* (Leupen et al., 2005). Low carbon design too has other disadvantages – it's arguable "*there is insufficient evidence to support the financial investment required*" (Adeyeye et al., 2007), while risk averse clients are reluctant to adopt new and unproven low carbon technologies (Adeyeye et al., 2007; Brennan & Cotgrave, 2014; Häkkinen & Belloni, 2011; Williams & Dair, 2007). Low carbon design also suffers from the additional disadvantage that even after initially inclusion, the "*add-on nature of many low carbon design features makes them ideal for reducing capital costs to meet budget requirements*" (Kershaw & Simm, 2014).

3.4.4 STAKEHOLDERS

Clients are arguably the most influential stakeholder in any construction project (Brennan & Cotgrave, 2014) and unless they show interest sustainable design is unlikely to be evident in a building's design (Williams & Dair, 2007). However, clients' wishes are translated by numerous designers, builders and suppliers before they become realised as buildings. It has been noted above (3.4.1) there is little guidance for professionals on interaction. What guidance there is focusses on technical incompatibilities and synergies, largely overlooking issues of process. Our professionals are therefore left with little to guide them and must rely on their own skills, knowledge and existing sustainability tools. Yet as the more general sustainability commentary notes, this is far from straightforward. A skills gap has been frequently highlighted as a problem for the industry as a whole (Department for Business Innovation and Skills, 2011; Williams & Dair, 2007), and arguably the industry has struggled to keep pace with developments in low carbon design (Carbon Trust, 2009) and building physics, evidenced by buildings repeatedly failing to match predictions (e.g. Short et al., 2009). Whether one assumes this failing is due to a lack of skill in individual areas, or a lack of skill in integrating these aspects within the larger design context there is a clear argument that the industry is insufficiently skilled to deliver sustainable buildings.

Even where sufficiently skilled designers and constructors are available, as Williams et al. (2013) note in relation to climate change related interaction, "*many professional and institutional stakeholders only work in one area*" and fail to connect the significance of their work with impacts in other areas. Despite calls for "*multi and inter-disciplinary teams with a diverse range of skill sets*" (Davies & Oreszczyn, 2012) we are still some way from the "*integrated rather than separate responses*" Lowe (2003) sees necessary for a climate adapted, low carbon built environment. This is perhaps not least because the fragmented nature of construction leads to key expertise often being appointed too late in the process to have any meaningful impact (Häkkinen & Belloni, 2011; Kershaw & Simm, 2014). In fact timing is a key theme for sustainable interaction, with commentary frequently referring to the need to design for multiple objectives simultaneously (for example the Olympic Park had no less than 12 core sustainability goals (Epstein et al., 2011)). (A different (although not contradictory) position to sustainability and low carbon (Kershaw & Simm, 2014) guidance that emphasises early consideration to maximise benefits.)

In addition to difficulties understanding how to implement multiple sustainable ideas simultaneously, there are also a number of factors influencing willingness. Construction companies pursue sustainable strategies for a number of reasons in addition to client demand. For example being able to demonstrate sustainable design delivery is an increasingly important factor for businesses when winning work (Brennan & Cotgrave, 2014), Fischer and Guy (2009) finding several of their interviewees "*remarked that they already specified buildings to higher energy-efficiency standards than regulations require as a matter of routine in order to foster the practice's green or sustainable credentials*". Others are motivated by potential performance improvement "*in terms of reducing waste and energy usage … to reduce operation and project costs*" (Boyd & Schweber, 2012) or the desire to present a green and sustainable image (Akadiri & Fadiya, 2013). These motivations have typically benefited the more visible low carbon agenda. Conversely it has been suggested (Pinder et al., 2011) there is little incentive for constructors to build more adaptably given this may extend building lifetimes and ultimately reduce the need for new construction (3.2.3.1).

3.4.5 THE BUILDING

Urge-Vorsatz and Herrero (2012) suggest that the nature of the interaction will vary "*depending on the route of the solution*". In other words, what a particular team are designing and the approach they chose to take will influence the interaction encountered and therefore the options available for dealing with it. A variety of approaches to low carbon design (see 2.2.3) and adaptability (see 2.3.2) are apparent in the literature and industry case examples. No single strategy has emerged in either adaptability or low carbon design fields, and a 'pick and mix' approach is often adopted in practice, reflecting the need for sustainable design to reflect local conditions (Farmer & Guy, 2010; Williams & Dair, 2007), but also which solutions designers and constructors feel comfortable with.

Construction has long been criticised for a culture and individuals that are slow or unwilling to change and adopt sustainable practices (Brennan & Cotgrave, 2014; Mills & Glass, 2009) which would have a particular impact on the innovative and fast moving low carbon technologies market (Kershaw & Simm, 2014; Williams & Dair, 2007). Adaptability's reliance on more mundane solutions leaves it less exposed to innovation adverse design, but other issues may influence the selection of solutions. For instance, architecture's vision of the built environment as a static, perfect product has been argued (Till, 2013) to sit uneasily with adaptabilities promotion of change and a "coproduced"

(Williams et al., 2012) built environment. Habraken (2008) describes two types of designer, those "*prepared to let go, to seek to provide a context that stimulates unforeseen results of user action*" and others who "*attempt to build in constraints intended to steer the user towards a 'good' result*". This creates two very different approaches to adaptability (Schneider & Till, 2007), one "soft", relying largely on spatial strategies and the other "hard", focusing on "*moving or folding components*" (Till & Schneider, 2006) which would presumably foster different opportunities for interaction.

3.4.6 SUMMARY

Considering the discussion above it is apparent many of the factors influencing low carbon design are also implicated in adaptable design, in part due to their 'sustainable' tags. These areas of overlap offer tentative insight into where the agendas might align and conflict, but our understanding is incomplete. For example, while it might be expected removing a barrier common to both would result in a net positive effect, would this led to the agendas competing for space, or funding? This inevitably can only be answered by looking at the wider of context of the decision, but as the text demonstrates, we know little about this as most work has looked solely at the agendas in isolation. Knowledge of interaction, its influences and associated coping strategies can be described as patchy at best; a cobbled together list of suggestions from various sources looking at interactions between different ideas at different spatial scales. Overall what we are lacking is a detailed understanding of the ways interaction can be managed and exploited by design teams and wider stakeholders to deliver low carbon, adaptable buildings. Furthermore, while integration of mitigation and adaptation design prerogatives is presumably attempted and even achieved in practice, a detailed understanding of how this process works, and indeed if it works, is lacking. There remains a process black box surrounding sustainable design when perceived as an amalgamation of approaches and goals resulting in the obvious question, how are design teams managing interaction to produce reconciled outcomes, and what influences their ability to do so?

To address these final questions, three further objectives are proposed:

> *OB02: Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.*

> *OB03: Identify important factors in the selection of approach for each identified interaction, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.*

OB05: By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, propose pathways to successful reconciliation of adaptable and low carbon design.

3.5 CHAPTER CONCLUSION

This chapter has looked for evidence of interaction between adaptability and low carbon design in both the built environment and wider sustainability literature. It has demonstrated interaction is largely expected to take one of two forms – synergy or conflict, and shown that in the long term, there is potential for considerable synergy between the two agendas studied as a result of the need to provide a low carbon future, without the certainty of knowing what that future should look like. Yet it was also noted that in the short term, beyond obvious overlaps such as redundancy (2.2.2.1) and perhaps built form (2.2.2.2), we know little about the extent to which it is possible for a building to be both low carbon and adaptable.

The second half of the chapter looked at evidence for how interaction might affect design, and design affect interaction. It established that the various studies of sustainability provide a good picture of what influences sustainable outcomes and the two agendas individually. However, what is lacking is a theoretical grounding for factors that may affect the two design approaches co-existence. Design studies and policy research into interaction contain some hints to encompassing conditions, but there is no complete theory applicable to both adaptation and mitigation design from which to draw concrete solutions of causal models. As a result of these identified shortcomings in the literature, the following objectives were proposed:

OB01: Demonstrate the existence of interaction by locating, describing and categorising examples of interaction in real building design processes, comparing the empirical findings to theoretical interaction types

OB02: Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.

OB03: Identify important factors in the selection of approach for each identified interaction, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.

OB04: Operationalize the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successful in reconciling low carbon and adaptability principles.

OB05: By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, propose pathways to successful reconciliation of adaptable and low carbon design.

The next chapter outlines a comparative research design to address these objectives. Results relating to observed interaction effects between adaptability and low carbon design are presented in chapter 5, while the extent to which the agendas are compatible is explored in chapter 6. Chapter 7 combines these earlier results to produce a number of pathways to low carbon, adaptable design while chapter 8 will discuss the implications for sustainable design in relation to the commentary above.

4 RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter describes how the objectives outlined at the end of the previous chapter will be met, by describing the methods that will be used and the rationale for the selection of these methods over others. The study is a mixed methods, comparative (multiple) case study design. Cases are building designs and the processes which create them, reflecting this study’s interest in interaction between low carbon and adaptable agendas during design, and the resulting outcome in the form of a designed building.

4.2 RESEARCH DESIGN

The research design evolved in tandem with the sample selection process, with the two informing each other. The overall aim of the study was to:

> *Understand how interaction between adaptability and low carbon sustainable design principles influence the process of sustainable design and its outcomes.*

This suggested the design processes as a unit of analysis and therefore a search was begun to locate a suitable pool of designs from which to sample (see section 4.3). Beginning in 2009 the Technology Strategy Board (TSB) initiated a funding competition entitled 'Design for Future Climate Change'. The competition provided funding for green building projects to undertake adaptation studies and deliver recommendation reports (TSB 2011). The funded projects created large volumes of readily accessible information: adaptation reports, planning applications, construction media articles and online publicity material. While the provision of funding and the nature of the competition introduced an element of artificiality, the projects nonetheless represented a unique opportunity to study the interaction of low carbon and adaptability ideals in building design.

Selecting competition entries as the study’s sampling population provided a ‘ready-made’ rich data set with which to address its objectives. However, it also presented an obvious problem with using traditional construction management methods developed for large random samples or comparative case studies. A quantitative treatment of the data would be problematic for both methodological and practical reasons: methodologically, while it would be possible to reduce the data using quantitative methods, applying content analysis or extracting structured variables, this would undoubtedly overlook the social, qualitative complexity of any design process. Practically, the data set lacked both the random sampling requirements and was too small for meaningful statistical analysis.

Considering the rich, mixed data set and desire to study interaction in a project context (Eisenhardt & Graebner, 2007; Yin, 2003), a case study approach seemed more appropriate. Compatible with the use of multiple data types the case study provides a means to examine the complexity and depth of the data.

While case studies are less well used in low carbon research (which remains characterised by positivist methodological foundations (Schweber & Leiringer, 2012), the approach is typical of the adaptability literature (e.g. Arge, 2005; Schmidt, 2014; Schneider & Till, 2007) and demonstrates sufficient penetration into both fields to be a credible research design. A single case approach would however limit the ability to build theory, which is general, by its basis in the particular (Thomas, 2011). Adopting a multiple case study approach allows for contrasts and differences between the cases to be brought to the fore and potentially creates a "*more compelling*" (Yin, 2003) evidence base. Case research is however intensive and resource demanding (Eisenhardt, 1989; Yin, 2003) and there is a risk, as with much qualitative research (Dainty et al., 1997), that theorists loose "*their sense of proportion as they confront vivid, voluminous data*"(Eisenhardt, 1989). Thus, if the study was to proceed with more than a handful of cases, what was required was a method which would deal with complexity in a manageable way, without entirely decomposing it and therefore losing the benefit of a case orientated approach.

Qualitative comparative analysis (QCA) is an alternative, set theoretic approach to case study research that maintains the view of cases as holistic entities (Rihoux & Lobe, 2011), but permits a larger number of cases to be considered and compared. It does this by describing cases as 'configurations' of relevant conditions (equivalent to independent variables in quantitative analysis or concepts in qualitative studies) and then comparing these systematically using set theory and Boolean algebra. The comparison process eliminates those conditions whose presence or absence is not associated with the outcome, allowing for more targeted case interpretation (Rihoux, 2003). In the context of a field where it has been observed there is unlikely to be a "*one size fits all solution…but rather a range of multiple pathways*" (Williams et al., 2012), QCA is appealing because of its acceptance of multiple pathways to the same outcome (Ragin, 2008; Rihoux & Lobe, 2011) and deliberate emphasis on exploring diversity (Ragin & Amoroso, 2011). Developed by Charles Ragin during the 1980's (Ragin, 1989) and subsequently refined (Ragin, 2002, 2008) the method is now well established, if not widely used, in the fields of comparative politics and some social science disciplines and has attracted recent interest from built environment researchers in the US (Chan et al., 2010; Forsythe, 2012; Gross & Garvin, 2011; Jordan, Gross, et al., 2011; McAdam et al., 2010).

QCA was attractive as a research design for a number of reasons:

1. It is structured and systematic. Qualitative research such as case studies have often been criticised for lacking scientific rigour (Bryman, 2003). Much of this criticism reflects the difficulty in describing the process undertaken to sort and analyse qualitative data and draw conclusions. By enforcing a systematic, repeatable process QCA can be viewed as a counter to these criticisms.
2. It is suitable for problems where there are multiple pathways to a single outcome (Ragin, 2008; Rihoux & Lobe, 2011). Most research on sustainable design accepts that there are multiple ways in which a sustainable building can be produced. It therefore seemed reasonable to assume that there would be multiple options available to the cases in reconciling adaptability and low carbon ideals.
3. It is able to deal with multiple cases studies (advantageous to a study where there is little prior work with which to compare results), potentially producing more compelling evidence.
4. It provides the ability to make limited historical generalisations (Ragin, 2008) for non-statistically sound samples. This is useful in cases such as the TSB competition population where there are insufficient cases to be able to form a robust statistical model.

Early on in the formation of this study it became clear that while the method had not been popularised in construction management fields, it had obvious potential for the types of socio-technical problems construction management researchers increasingly encounter. As a result, while other methods were clearly available, it was decided to pursue QCA in attempt to "test" QCA's applicability to just such a problem. An additional objective was therefore added to those given in chapter 3:

Objective 06: Conduct a method experiment to assess the usefulness of Qualitative Comparative Analysis as a research tool for problems of a socio-technical type within a Built Environment context.

Next, as very little is known about interaction between design agendas (3.3), the study was split across two phases – Table 4-1. Phase 1 is exploratory. It addresses the questions such as what does interaction look like? How much of it is there? What sorts of decisions do designers make when faced with these interactions and what influences them? Phase 1 focuses on interaction decisions within each case as the unit of analysis and is largely inductive, working from the specifics of the data to more general principles (Bryman, 2012a). Phase 2 zooms out, with the projects themselves as the focus. This phase switches to a more deductive mode, using the findings of the first phase as the basis of a theory which is tested and refined using cross case comparisons and knowledge of each project's outcome. Because of the differences in the two phases, they are based on different understandings of the nature of sustainability. During the exploratory phase sustainability is treated as constructed. Constructivism is an ontological position that "*challenges the assumption that categories such as organisation and culture are pre-given and therefore confront social actors as external realities that they have no role in fashioning*" (Bryman, 2012a). Therefore within phase 1, low carbon and adaptability are defined through the decisions taken and the socio-technical context and it is these decisions that are of interest. For phase 2 the work is more grounded in realism – here low carbon and adaptability are measureable concepts, 'out there' waiting to be attained. Therefore while phase 1 problematizes the current construction literature's approach to understanding sustainability (see chapter 1), phase 2 aligns more with the dominant research pattern of sustainability as difficult to define and measure rather than a negotiated concept. This 'multi-methodological' (Mingers, 1997) approach recognises the dual status of sustainability – as ambiguous, ill-defined and shifting concept on the one hand and the sum of measureable quantities on the other (see chapter 1).

Within phases this study also adopts multiple methods, borrowing from both qualitative and quantitative traditions. Mixing methods enables the study to examine both process and outcome (Thorpe & Holt, 2007), something central to this study's desire to understand not only whether it is possible for a building to be both adaptable and low carbon (OB03), but also the processes through which this occurs. A purely quantitative approach would have obscured the social complexity of design through the necessity to study large numbers of randomly sampled cases. Quantitative techniques also favour deductive reasoning (Bryman, 2012a), requiring robust theoretical frameworks to test that were simply not available in the exploratory phase. This made qualitative techniques more attractive. However, a purely qualitative approach would have missed the potential usefulness of numbers in describing data (Morse, 1991) and highlighting similarities and differences (Maxwell, 2010).

The choice of methods was very much driven by the nature of the problem and the data available with which to answer it (see Table 4-1), an inherently pragmatic (Creswell, 2012) approach. In phase 1 coding and narrative analysis typical of qualitative studies is paired with simple statistics in order to better describe the data (Morse's (1991) QUAL + quant approach). Phase 2 initially adopts a more variable orientated (Ragin, 1989) approach, measuring success in reconciling the two agendas.

Table 4-1 provides a summary of the main features of the design.

Table 4-1 Summary of research design

Phase	Objective		Methodology	Literature	Data Collection	Data types	Sampling	Analysis	Validity and replicability requirements	Contribution
Phase 1 - Exploratory	1	Demonstrate the existence of interaction by locating, describing and categorising instances of interaction in real building design processes, comparing the empirical findings to theoretical interaction types.	Inductive / Constructivism	CCA literature for existing understanding of interaction effects and typologies. Comparison of adaptability and low carbon principles to identify possible overlaps.	Documentary, supplemented with semi-structured interviews.	Publically available documents describing the case study designs and the process through which they were developed, supplemented with semi-structured interviews.	All interactions noted in the published data and interviews (where available) of the cases within the phase 2 purposeful sample.	Content analysis to identify interaction. Qualitative coding and thick description to formulate interaction types.	Coding manual.	Description of interaction effects between adaptability and low carbon in construction design.
	2	Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.		Design process studies. CCA literature for existing combination strategies between low carbon and climate change adaptation.				Qualitative coding, memo writing and thick description.		Identification of design strategies addressing both adaptation and mitigation (creation of reference examples)
	3	Identify important factors in the selection of approach for each identified interaction, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.		Work on factors influencing adaptability, low carbon and sustainability.				Comprehensive-Inductive approach to identifying conditions. Inductive element to use interactions identified by content analysis as a focus and then apply narrative and open coding techniques to identify conditions. Construction of concept definitions (memo making).	Coding manual. Constant comparison to ensure consistent application of codes.	Lists of factors influential in construction design interaction processes.
Phase 2 - Comparative Analysis	4	Operationalize the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successful in reconciling low carbon and adaptability principles.	Deductive / Realism / Critical Realism	Carbon and adaptability measurement literatures. Built environment measurement theory papers - e.g. DQI, work on quality measurement. General measurement theory.		Energy Performance Certificates, BREEAM and other sustainability ratings. Planning application drawings. References within the documents to adaptability and low carbon tactics.	Purposive sampling of cases likely to demonstrate interaction, comparable to one another but sufficiently diverse to explore interaction effects. Convenience sampling within this population.	Quantitative using existing indicators of adaptability and low carbon design. Benchmarking of data and graphical representation of cases relative to one another.	Explicit presentation of indicators and the data used to apply them.	Definition of reconciliation and proposal of indicator. Benchmarking of adaptability indicators.
	5	By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, propose causal pathways to successful reconciliation of adaptable and low carbon design.		CCA literature for existing understanding of interaction effects and typologies. Comparison of adaptability and low carbon principles to identify possible overlaps. Work on factors influencing adaptability, low carbon and sustainability.		Coded data and narrative description developed from phase 1. Conditions from objective 03 and outcomes from objective 04.		Qualitative Comparative Analysis (QCA). Interpretation of the results using qualitative techniques (coding, memo making, process tracing).	Check minimisation in Excel - known issues with fsQCA errors	Pathways to successful energy efficient, adaptable design.

4.3 SAMPLING

4.3.1 GENERALISING BETWEEN PHASES

As this study is what Cresswell and Plano Clark (2011) describe as exploratory sequential, in that the results of the qualitative first phase are used to inform the second phase, it is necessary for the initial exploratory ("revelatory" in Yin's (2003) terms) cases to have a valid relationship to the QCA sample. This ensures the theory developed in the initial phase is applicable to the QCA phase – that is, it must be possible to generalise from one to the other. There are multiple ways in which this could be achieved: Jordan et al. (2011) use a panel of 'experts', defined by their familiarity with the phenomena at hand; Schaffer-Boudet (2010) undertakes two detailed case studies of examples of her focus area drawing on an theoretical framework built using relevant existing theory. An obvious choice is to employ the same cases for both exploratory and QCA phases. There is nothing within the QCA literature to prevent this, a number of researchers use the same cases for conceptual framework refinement and later QCA (e.g. Boudet, 2010). It does not however entirely solve the problem of generalising from one phase to another – if we term the cases in the exploratory phase A1, A2…An and those of the latter QCA as B1,B2,…Bn it can be noted that while A1 generalises to B1 (in that they are the same case) there is no explicit reason why A1 should relate to B2. It is only possible to understand if A1 is sufficiently similar to B2 after some analysis has been completed. Employing random selection criteria to choose instances from each of the cases would inevitably have guaranteed generalizability, but is flawed in that it was highly unlikely that every instance of interaction could be observed. This makes the true population unknowable with the methods and resources available and prevents application of a random sampling approach.

The solution adopted was to maximise the chance of generalizability by using the same cases for both, accepting that a return to the case selection would be necessary following the specification of a conceptual area in which to operate. This is in no way unusual for a comparative study ("*the point to remember is that revisions of one's cross-case research design is entirely normal and perhaps to be expected*" (Seawright & Gerring, 2008)), and indeed is actively courted by QCA where case selection is "*tentative and iterative*"(Berg-Schlosser & de Meur, 2009), an incomplete process where cases may be added to, and removed from, the analysis at any point on the basis of the case evidence. Many critics (de Meur & Rihoux, 2004) see this as cheating – allowing users to manipulate results by removing problem cases. However, in the same way other researchers justify the inclusion of cases at the outset of their study all exclusions are justified (see 4.4.3) and in accordance with good QCA practice (Berg-Schlosser & de Meur, 2009) data relating to these cases is presented so others could repeat the results with the initial sample if desired.

4.3.2 CASE SELECTION

To maximise the chances of observing interaction and attempts at reconciliation, cases were first limited to projects with explicit design intent for adaptability and low carbon design. Cases were then selected purposefully with the intention to create a sample sufficiently homogeneous to allow sensible comparison, while demonstrating sufficient diversity (in outcome and the conditions of interest) to allow a thorough understanding of the conditions in which a given outcome does and does not occur. This led to a number of additional criteria:

- Projects were all to be located within the UK. This limits generalisation, in that the UK is unique in choosing to base its legislation on a carbon metric while the majority of other European countries utilize an energy metric (Wilford and Ramos, 2009). The use of a region with such overt legislative reference to carbon does however sit well with the studies aims, of examining design in a low carbon context.
- Projects should have been undertaken in the recent past, reflecting interest in contrasts between the current manifestations of the adaptability and low carbon perspectives.
- Projects needed to be large and complex enough to involve a number of different stakeholders in design, in order to maximise the chances of different views of sustainability within a single case.
- A high likelihood of gaining sufficient access to develop detailed case studies.
- The cases needed to be sufficiently different from one another along theoretically important lines (Jordan, Gross, et al., 2011). Diversity is required for QCA studies to be robust and comes from both the inclusion of negative cases (i.e. instances where reconciliation was not successful) and different configurational arrangements (i.e. a diverse range of cases). Ensuring diversity was complicated by the inductive nature of the study where the relevant lines along which cases should vary could not be specified in advance, therefore the study sought cases that varied along lines known to typically influence sustainable outcomes more generally such as typology and client commitment.

Various case groupings were considered and evaluated for compatibility with the above outlined criteria – appendix 4A presents the evaluation.

As a result it was decided to sample from the Technology Strategy Board (TSB) competition cases. This set included a range of project sizes and types, a mixture of new build and refurbishments, client types and procurement approaches and the projects were undertaken by different combinations of designers. This would, it was hoped, provide the diversity required in a QCA study. The cases were required to demonstrate their low carbon intentions in order to qualify for the competition, and were provided with monies to undertake adaptation studies. While the focus was predominantly adaptation for climate change, preliminary investigations suggested a range of adaptable features compatible with other types of adaptable design were included. Appendix 4B contains a list of all cases in the TSB competition.

4.3.3 DETERMINING THE SAMPLE SIZE

Having selected a group of cases, it was then necessary to establish how many would be required for robust analysis. A defining characteristic of QCA is its applicability to 'medium N' studies (Jordan, Gross, et al., 2011; Ragin, 1989), "*a number considered by most social scientists to be too few for the application of commonly used multivariate statistical techniques (e.g., multiple regression) but too many for in-depth, case- oriented analysis*" (Ragin et al., 2003). As a lower bound Rizova (2011) suggest four cases, Ragin et al. (2003) five. Others (Berg-Schlosser & de Meur, 2009; Fiss, 2007) opt for ten. At the upper end recommendations of 40 (Berg-Schlosser & de Meur, 2009) and 50 cases (Ragin et al. 2003; Fiss, 2007) are typical, although a small number of studies (e.g. Greckhamer et al., 2007) have been published with much larger samples.

Between 4 and 50 cases is a particularly wide scope and therefore to infer standard practice, the sample sizes of existing studies were reviewed (see appendix 4C – previously reported in Grinnell et al., 2013). This revealed (Figure 4-1) that in practice, samples of between 10 and 20 were most common, although one outlier study (not shown) consisted of over 2000 cases. This result is in-keeping with Schneider and Wagemann's (2012) comment that "*if the number of cases is very small, say below ten, then QCA loses most if its comparative advantage to traditional case studies*". The upper bound is likely to reflect the number of cases that can be examined without losing the data familiarity required for thoughtful analysis.

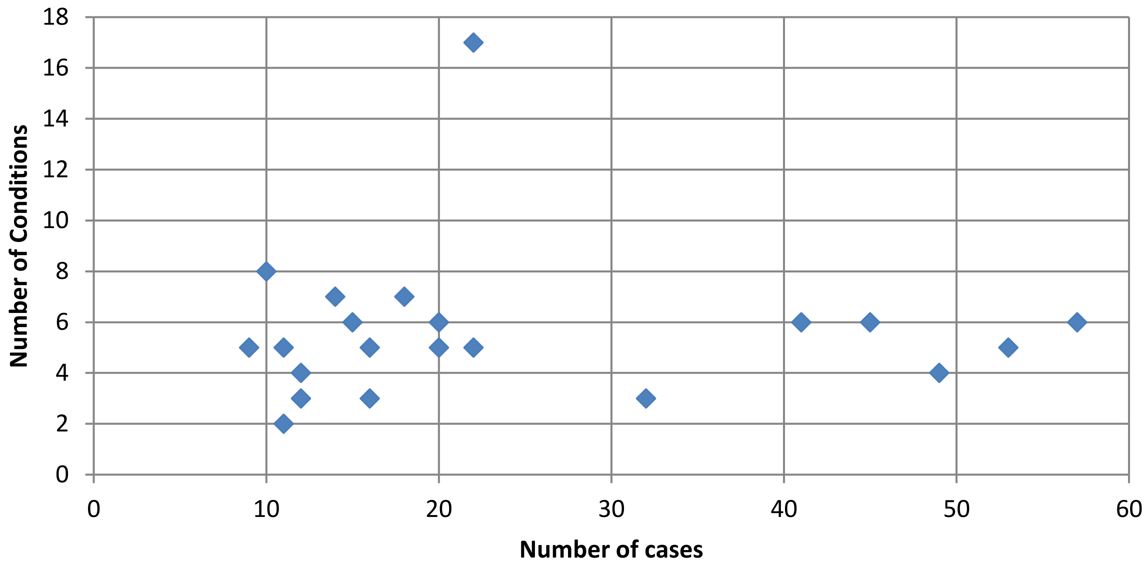


Figure 4-1 Sample of size and number of conditions considered (for a list of studies plotted, see appendix 4C)

On the basis of the review it was decided that circa 20 cases would be appropriate. This is consistent with the QCA studies examined and should provide for sufficient diversity. It also allowed for some cases to be excluded during the case definition refinement process by the inclusion of a considerable 'buffer' in data collection activities – given sufficient diversity, as little as 10 cases would be permissible. To select cases masterplans and projects that made use of multiple, single family dwellings (houses) were first excluded, as both concentrated on spatial scales distinct from others in the sample. Then, due to the delayed reporting of many of the studies, selection proceeded in the order the cases were published (convenience sampling (Bryman, 2012a)). The basic characteristics of the cases are described in Table 4-2.

In all, 25 cases were selected. This number reflects two cases that included multiple buildings (case 06 included three schools, case 38 a domestic and non-domestic building). Case 06C was dismissed as it consisted solely of minor refurbishment work without a significant element of design. Case 38B was not pursued due to there being insufficient evidence available to form a robust case study.

Table 4-2 TSB cases selected for study – basic information

Project No.	Project Name	Location	Building type	Value	Project type
01	Admiral Insurance Headquarters	Cardiff	Office (HQ)	£25,000,000	new build
04	British Trimmings Extra Care Home	Leek	Assisted living residential home	£10,020,000	new build
06A	Wyre Forest Primary Schools: Offmore Primary	Worcestershire	Primary school	£20,000,000	new build
06B	Wyre Forest Primary Schools: Offmore Primary	Worcestershire	Primary school		new build
07	Harris Academy	Purley	Secondary school	£20,000,000	new build
09	Technical Hub @ EBI	Hinxton, nr Cambridge	Office / laboratory	£23,000,000	new build
10	Edge Lane - Time Project	Liverpool	Mental health facility	£22,000,000	new build
11	St Loyes Extra Care building	Exeter	Assisted living residential home	£6,000,000	new build
14	London School of Tropical Medicine	Keppel Street	Higher Education	£10,000,000	refurbishment
16	University of the Arts London (UAL) King's Cross campus	London	Higher Education	£120,000,000	new build
17	Oxford University Press offices	Oxford	Office	£11,000,000	mixed
19	University of Greenwich - Stockwell St.	Greenwich, London	Higher Education	£60,000,000	new build
20	Church View	Doncaster	Office	£6,500,000	refurbishment
21	Great Ormond Street Hospital (Phase 2B)	London	Hospital	£45,000,000	mixed
23	Trowbridge County Hall	Trowbridge, Wiltshire	Library / Office	£25,000,000	refurbishment
24	University of Sheffield Engineering Graduate School	Sheffield	Higher education	£12,000,000	new build
25	Ebbw Vale 11-16 phase school	Ebbw Vale, Wales	Secondary school	£27,000,000	new build
31	The Cooperative Head Office (1 Angel Square)	Manchester	Office (HQ)	£100,000,000	new build
35	Environment and Sustainability Institute	Penryn, Cornwall	Higher Education	£11,640,000	new build
38A	Site J, New England Quarter	Brighton	Residential flats	£25,000,000	new build
46	Hinguar Primary School	Shoeburyness, Essex	Primary school	£5,200,000	new build
47	Westbrook primary school	Hounslow, London	Primary school	£8,600,000	new build
48	London Bridge Station	London	Rail station	£35,000,000	refurbishment

4.4 DATA COLLECTION

4.4.1 OVERVIEW OF THE APPROACH TO DATA COLLECTION

QCA as an approach makes no allegiance to a particular data collection technique, and both qualitative and quantitative evidence is admissible (Blackman et al., 2013; Rihoux, 2006). The emphasis is instead placed on a data collection approach that allows for the required 'closeness' with the cases (Rihoux & Lobe, 2011) and the "*practical requirement ..to be able to transform these data into categories or numbers*" (Berg-Schlosser et al., 2009). In common with case studies employing an experimental replication logic (i.e. the type outlined by the likes of Yin (2003) and Eisenhardt (1989)) "*multiple sources of evidence must usually be 'crossed*" (Rihoux & Lobe, 2011) in order to gain a full understanding of each case.

Yin (2009) suggests six potential sources of information for case studies: documentation, archival records, interviews, direct observation, participant observation and physical artefacts. Observation was ruled out because:

- The selected cases were already some considerable way into the design process, with some under construction and others occupied (see section 4.3 for a justification case selection).
- The multiple case study approach meant it would have been impractical to observe every case in any great detail. Observations would have been restricted to a very small portion of each case's design process (say, a design team meeting).

Examination of the case buildings (Yin's physical artefacts) was seriously considered. Design structure matrix (DSM) methods had been used by some to 'measure' adaptability (Schmidt et al., 2011; Schmidt, Vibæk, et al., 2014) and could potentially be used to understand if low carbon design affected the interconnectedness of a building's components (and thus reduce its adaptability by some measures – 2.3.3.3). However, DSMs were known to be extremely labour intensive to construct and the results difficult to interpret. They are also limited to exploring technical compatibility, whereas this study was equally interested in socially derived interaction effects.

This left interviews and documentation. In light of what can reasonably be achieved by a single researcher in a restricted period of time, the decision was made to focus on documentary evidence with interview evidence treated a supplementary. This approach is a reversal of many construction management case studies where it is more usual for documents to take a supporting role (see, for example, Moncaster (2012)), if they are used at all: In an examination of 107 papers published in the journal Construction Management and Economics Dainty (2008) finds less than 15% using documentary evidence. Instead there is an "*apparent reliance of qualitative construction management research on open-ended interviewing*" (Dainty, 2008).

Documents were prioritised as their collection is much less obtrusive and time consuming for participants than other forms of evidence (Bryman, 2012b) and pragmatically, with recent moves to digitise planning applications and the selection of cases for which a large number of detailed reports had been produced and published, documents were highly accessible.

Data was collected for each case in turn, as intensively as possible. This allowed case reports to be written and reflected upon, outcomes assessed in context and coding networks expanded or simplified if necessary. A progressive approach also ensured a manageable workload. Documentary evidence was generally collected first (a desk study) prior to approaching interviewees. This allowed for a more focussed interview, see 4.4.4. The general process for each case is depicted in Figure 4-2.

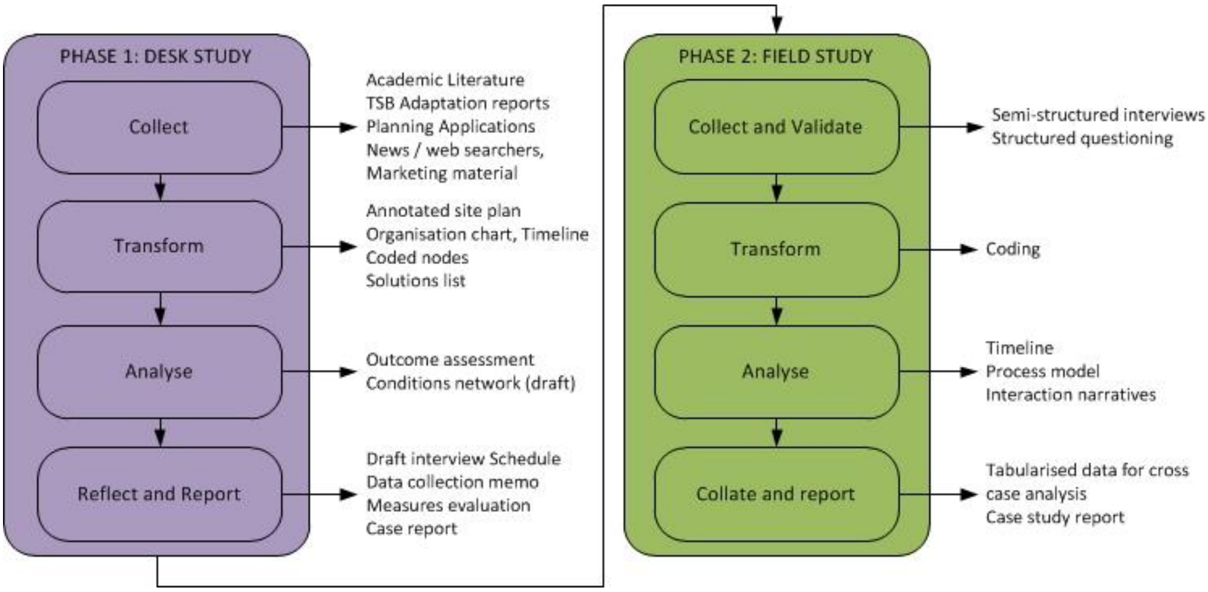


Figure 4-2 Data collection, transformation and analysis process for a single case.

4.4.2 DOCUMENTARY EVIDENCE

Table 4-3 provides an overview of the different types of documents consulted (for full listings and source see appendix 4D). These documents can be classified into two basic types, public and private (Gidley, 2012; Scott, 1990). Public documents are generally available, while access to private documents is restricted to specific organisations and/or individuals. This study predominately collected public documents[8], from multiple sources. This means almost all documentation was intended for publication and therefore portrays what Gidley (2012) describes as a "*frontstage*"

[8] A small number of private documentation was offered by interviewees and thus recorded and analysed. Documentation obtained from the 'private' arena is clearly marked as such in appendix 4D

identity – the view the authors wished us to see. Backstage, where "*conflicts, contradictions and ambiguities are more often expressed*" (Gidley, 2012) is inaccessible and so in some ways the choice of evidence is expected to limit the amount of conflict between adaptability and low carbon ideas than might have occurred.

In total 3391 individual documents were collected and retained for further inspection, of which 1078 were considered to contain information of relevance to the study and underwent further analysis. A summary of the number of documents obtained for each case is presented in Table 4-4.

Table 4-3 Desk Study Data Sources

Data type	Source
Planning applications (Design and Access Statement, Energy Statements, plans).	Local authority planning databases[9]: see appendix 4D for a detailed list.
Design 4 Future Climate Change reports and appendices	Connect platform (registration required): https://connect.innovateuk.org/web/design-for-future-climate
Media (newspaper and magazine articles, press releases)	Keyword search of the NEXIS database (www.lexisnexis.com/uk/nexis). Key word searches were manually sorted for relevancy once the results were deemed specific enough to have reduced the record count to a manageable number (<150).
Design team project profiles	Company webpages (see appendix 4D for a detailed list of sources)
General project information, timescales, etc.	Development websites (larger projects only) A simple search of primary design team members (architect, services engineer, structural engineer, environmental design if any) and client corporate websites.
Online media articles, references to awards, research articles and dissemination presentations.	Google Keyword Search (www.google.co.uk), limited to the first five pages of results.
EPC and DEC certifications	National EPC database (www.ndepcregister.com)
BREEAM final and interim ratings, case studies[10]	BREEAM Live website (www.greenbooklive.com/search/scheme.jsp?id=202)
Project location context	Googlemaps (https://maps.google.co.uk/)

[9] A limited number of local authorities do not maintain planning documentation online: case 25's application was obtained by contacting planning departments directly.
[10] Case 48 London Bridge is registered under the CEEQUAL scheme, data was obtained from the CEEQUAL website (www.ceequal.com).

Table 4-4 Summary of the number of documents collected for analysis ('collect') and retained for analysis ('coded')

Case		TSB		Planning		Other		Total		TSB Report	EPC	BREEAM / CSH	Design & Access Statement
		Collect	Coded	Collect	Coded	Collect	Coded	Collect	Coded				
1	Admiral HQ	2	2	34	4	22	20	61	28	x	x	x	x
4	British Trimmings Extra Care	22	17	73	14	7	4	103	34	x	x	x	x
6.1	Wyre Forest Schools - Offmore Primary	4	2	24	6	6	2	39	14	x	x	x	x
6.2	Wyre Forest Schools - St Catherine's	4	2	31	8	7	2	47	17	x	x	-	x
7	Harris Academy, Purley	22	11	95	22	2	2	125	41	x	x	x	x
9	Technical Hub @ EBI	36	16	116	21	9	8	162	46	x	x	x	x
10	TIME Project - Edge Lane	33	15	171	32	16	15	220	62	x	-	x	x
11	Extra Care 4 Exeter / St Loyes	21	15	59	28	21	19	101	62	x	-	-	x
14	London School of Hygiene and Tropical Medicine	14	9	26	0	19	10	61	20	x	-	-	-
16	Central St Martin's (Nanotechnology)	11	9	153	39	10	6	191	65	x	x	x	x
17	Oxford University Press	8	6	47	14	5	4	60	24	x	-	x	x
19	University of Greenwich, Stockwell Street	18	12	112	15	16	11	146	38	x	x	x	x
20	Church View	15	11	91	16	2	2	110	30	x	x	-	x
21	Great Ormond Street Hospital	7	3	65	18	12	9	84	30	x	-	x	x
23	Trowbrige County Hall	10	7	134	16	11	9	157	33	x	x	x	x
24	University of Sheffield Engineering Graduate School	27	9	33	10	14	4	75	24	x	x	x	x
25	Ebbw Vale 11-16 Phase School	7	4	18	2	15	10	40	16	x	x	x	x
31	The Co-Operative HQ	7	4	78	11	25	21	112	38	x	x	x	x
35	Environment and Sustainability Institute	15	13	114	42	10	6	141	63	x	x	x	x
38.1	Site J, New England Quarter (residential)	32	13	192	36	14	15	238	62	x	-	x	x
38.2	Site J, New England Quarter (non-domestic)	26	12	196	35	14	15	236	60	x	x	-	x
46	Hinguar Primary School	12	10	100	16	14	12	129	40	x	-	x	x
47	Westbrook Primary School	20	6	102	10	11	8	133	24	x	-	-	x
48	London Bridge Station	19	6	548	173	10	2	577	181	x	-	-	x
Totals		416	227	2612	588	306	225	3391	1078	100%	58%	62%	88%

4.4.3 COVERAGE AND DATA QUALITY

One of the inherent drawbacks of using documentary data is the inability to control what exists, and what does not. While this is in itself an interesting facet of the cases that often says something about them (why do some cases prepare LZC feasibility reports for planning while others do not? Why did case 47 write at length about issues concerning the envelope while other cases overlook the issue entirely?), it is also problematic for a study that seeks understanding by comparison across a number of cases. This section is a brief attempt to clarify what data is considered 'missing', why it is missing and the perceived effect on the study. It is concerned mostly with the documents found to be most useful: EPCs, TSB reports and planning documentation.

All cases had competed TSB final reports. While the reports had been written to a common specification (Technology Strategy Board, 2011) they were of varying detail – some included large quantities of information including project drawings, others only brief descriptions. Where organisations had been responsible for multiple projects in the programme there was often evidence of 'copy and paste' between the reports (e.g. 21, 47 and 48), although this was not always the case where project teams differed (e.g. cases 17 and 19).

Cases 11 and 14 were at too early a stage to have submitted planning applications. Case 14 is unlikely to result in a full planning application due to the nature of the works (refurbishment) and the fact that its client chose not to progress the project. While this project forms an excellent case study of the difficulties of refurbishing and retrofitting an occupied non domestic building, as the study developed it became clear it was not progressed far enough to constitute 'design' contemporary with the other cases and as such the case was excluded from further analysis following the exploratory phase. Case 11 was included in an outline planning application for the wider site in which it sits, which was retrieved and provided the planning context for the scheme. This project had progressed further than case 14, with the TSB report clearly evidencing conceptual design and was therefore retained for analysis.

Other planning applications varied in detail and content; smaller developments were exempt from some of the more onerous requirements and local authorities had differing requirements for producing energy and/or sustainability statements, with some not requiring them and others making them mandatory. This variability was generally incorporated into the analysis, as to varying extents planning could be seen to influence the design. Missing sustainability statements were most problematic when counting low carbon tactics (see 5.2.1), where schemes with the documents had an obvious advantage. In a bid to counter this, only the strategies the documents explicitly listed as installed were included; approaches referenced but uncorroborated by other evidence were excluded.

EPC certificates were only available for completed buildings. Cases 10, 11, 14, 17 and 20 were stalled for various reasons and therefore did not submit certificates. While the cases could have been excluded from the analysis, this biased the sample towards successful cases. Instead, and in line with Yin's (2003) advice that multiple data sources will normally need to be consulted to gain a full picture of a case, other documents were consulted to 'patch' the missing information. For example, cases 10 and 11 had strong sustainability goals that linked to anticipated EPC scores.

4.4.4 SUPPLEMENTARY INTERVIEWS

To supplement the documentary evidence and to some extent validate its interpretation interviews with a person involved in the project were pursued. A long-list of potential interviewees was developed from individuals and organisations noted in the amassed documents. This list was then refined to a short list of one interviewee per case. Interviewees were selected based on their perceived usefulness to the study – strategic, purposeful sampling (Bryman, 2008). Of the 30 individuals (a mix of clients, architects and TSB project leads) contacted for interview, 12 participated, 2 declined and 16 failed to respond to multiple invitations. Although it was not possible to arrange interviews for all cases, over 80% of the cases were covered -

Table 4-5.

All interviewees were provided with an information sheet containing the project outline (appendix 4E) in their invitation to participate, together with information on their right to withdrawn from the study at any time by contacting the investigator. All interviewees were required to sign a consent form prior to participation (appendix 4F), as required by university guidelines. Interview data has been anonymised insofar as possible, however all interviewees were aware that the cases were in the public domain and therefore would not be anonymised.

The interviews were semi-structured – using "*a list of questions or fairly specific topics to be covered…but the interviewee has a great deal of leeway in how to reply*" (Bryman, 2012a). This allowed each interview to be based the results of initial document analysis, while still maintaining the interviewees' ability to elaborate, disconfirm and incorporate new ideas. Although the specific set of questions varied from interview to interview, each followed a pre-set sequence:

1. A set of relatively straightforward questions about the interviewee and their relationship to the case. These questions both established the interviewee was who they were thought to be and allowed for a rapport to develop (Trinczek, 2009).
2. One or two questions focussed on generating new data – e.g. why is the building sustainable?
3. A series of questions designed to fill in perceived blanks in the documentary evidence, and others designed to gain additional detail and/or an alternative perspective on specific interactions noted in the documentary evidence.

Typically cross-case interviews would adopt similar questions to ensure cross case comparability (Bryman, 2012a). However, as the intention was not to compare the interview evidence between cases, but to validate the document analysis and fill in perceived gaps, it was seen as more important to tailor the questions to each case. Interview schedules can be found in appendix 4G.

All interviews were recorded and transcribed using a paid-for transcription service. Transcripts were checked for accuracy, resulting in minor corrections mostly of technical terms and names. The interviewer also kept notes during the interview as a backup and to record any relevant unspoken or drawn information.

The sequencing of the interview questions was intended to give the interviewee room to comment on interaction effects in sustainable design prior to mentioning the results of the documentary data to avoid what Bryman (2012a) terms "*leading*" the interviewee. However, it quickly became apparent that interaction was not something with which the interviewees were consciously concerned and it was often necessary vary the order and provide examples to illustrate the idea.

While the concurrent analysis of each project's documentary data was providing numerous instances of interaction, the interviewees found it extremely difficult to articulate examples of interaction, or muse on the possibilities of a somewhat abstract concept.

This was not an entirely surprising result, as Cross (2011) notes, "*Designers themselves are often not very good at explaining how they design…they talk exclusively about the outcomes, not the activities. They talk about the products of designing, rather than the process."* Overall this resulted in responses that were highly variable in their relevance to the study and depth of explanation. Due to the large differences in the quality and usefulness of the interview data, and the fact that for some cases it proved impossible to interview at all, omitting the interview data was considered. However, there had been considerable work by the researcher to undertake and subsequently transcribe the data resulting in a considerable familiarity with it. It was felt that, whether omitted or not, this familiarity would colour the analysis. It was therefore decided (in the interests of transparency) to include the data, albeit heavily caveated due to the inconsistencies.

Table 4-5 Number of interviews undertaken for each case

Case	Number of interviews	Notes
Admiral HQ	1	
British Trimmings Extra Care	0	
Offmore Primary (Wyre Forest Schools)	1	2 interviewees, interview covered case 6.1 and 6.2
St Catherine's Primary (Wyre Forest Schools)	1	2 interviewees, interview covered case 6.1 and 6.2
Harris Academy, Purley	0	
Technical Hub @ EBI	1	Interview also covered case 14.
Edge Lane	1	
St Loyes Extra Care	1	
London School of Hygiene and Tropical Medicine	1	Interview also covered case 09.
UAL Kings Cross Campus	2	Initial interview suggested contact with the second (snowball sampling)
Oxford University Press	1	Interview also covered case 19.
University of Greenwich, Stockwell Street	2	First of these interviews also covered case 17.
Church View	1	Interview also covered case 24.
Great Ormond Street Hospital	0	
Trowbrige County Hall	0	
University of Sheffield Engineering Graduate School	1	Interview also covered case 20.
Ebbw Vale School	0	
The Co-Operative HQ	2	
Environment and Sustainability Institute	0	No interview but some limited correspondence with researchers at Exeter University involved in the TSB project.
Site J, New England Quarter	1	Interviewee not involved in design of the building.
Hinguar Primary School	1	
Westbrook Primary School	0	
London Bridge Station	0	

4.5 ANALYSIS – PHASE 1

4.5.1 INTRODUCTION

Analysis within phase 1 of the study was concerned with objectives 01, 02 and 03. That is, identifying and classifying examples of interaction between adaptability and low carbon design and describing the ways in which teams reacted to it. Results for phase 1 can be found in chapter 5.

Having amassed a significant volume of material for each of the cases, the data was first condensed. A qualitative software tool, NVivo (QSR International Pty Ltd., 2012), was used for data management and retrieval. The use of NVivo as an interim recording mechanism, rather than the direct transposition of data to condition tables etc. enabled a return to information easily: node content could be extracted to Microsoft Word allowing for a further rounds of manual coding and database queries could be used to retrieve data with which to construct case vignettes or elicit key themes.

Data for each cases was examined and reduced to a more manageable form during the data collection phase by a process of exploratory coding, memo writing and simple case reports that summarised key information relating to the study's objectives. These notes were then used as a springboard for the analysis proper.

4.5.2 IDENTIFYING INTERACTION - CONTENT ANALYSIS

Content analysis was used to identify interaction between low carbon and adaptable design and begin to draw inferences about how often it occurred (contributing to objective 01). Content analysis is "*an approach to the analysis of documents and texts that seeks to quantify content…in a systematic and replicable manner*" (Bryman, 2012a). While it is usual for content analysis to work with multiple codes (requiring a codebook), this simple application used only one code – interaction.

To identify examples of interaction firstly the accumulated documentary data and interview transcripts were scoured for examples of low carbon and adaptable design interacting. NVivo nodes were used to record relevant data and facilitate simple retrieval of information filtered by case. Text segments were recorded as interaction whenever one agenda was linked in some way to the other.

Secondly, all references to low carbon and adaptability actions in the data were recorded. Adaptability actions were taken to include any references to facilitating later change in the building, in line with the definition adopted in chapter 2, and a broad definition of low carbon actions was adopted incorporating energy efficiency and embodied energy. Applying more general definitions ensured a range of case perspectives on the two concepts were included. With the exception of renewable energy sources, no attempt was made to subjectively interpret the motivation for design feature inclusion, restricting coding to those items explicitly identified by the cases as provision for either agenda. This is perhaps an overly cautious approach, but reflects a desire to let the cases speak for themselves.

An NVivo query was then constructed that returned all instances of 'low carbon' and 'adaptability' references coinciding. This duplicated many of the directly identified interactions but also generated a number of interactions that were not specifically highlighted by document authors. (A query based on adjacency of adaptability and low carbon segments was also trialled, but rejected due to high numbers of spurious results and repetition of existing data returned.)

Duplication was removed by compiling lists of the interactions generated by each method for each case, and then:

- Removing identical duplicates – this occurred where the same quote etc. had been coded,
- Manually grouping where several different sources referred to the same instance but in different ways.

This resulted in a final list of interaction instances that were numbered for reference purposes – the full list of interactions, the location of data relating to them and the allocated reference numbers are presented in section 4.3.2.

The results were analysed by counting the total number of interactions found across all the cases. General descriptive statistic techniques (averages, measures of spread) were then used to explore the results. Separating the cases into groups based on their value and the amount of low carbon or adaptability techniques observed allowed for some further simple correlation analysis to explore if these variables might be related to the amount of interaction observed.

4.5.3 DESCRIBING INTERACTION TYPES AND STRATEGIES – QUALITATIVE CODING

In order to better understand the types of interaction observed (objective 01) and the strategies case actors adopted for dealing with them (objective 02), the interaction text segments identified during the content analysis above were subjected to a traditional qualitative analysis – i.e. a process based around coding (Creswell, 2009). All interactions were first considered individually, pertinent terms highlighted and notes made, Figure 4-3 and Figure 4-4. To focus the analysis "*case study questions*" Yin (2009) were asked of each interaction:

- How are the low carbon and adaptable agendas related to each other?
- Is the interaction positive, negative or neutral?
- Is one agenda portrayed as dominant over the other?

- What key words or phrases are used to describe how the agendas are related?
- What verbs are used to describe how the interaction is resolved?

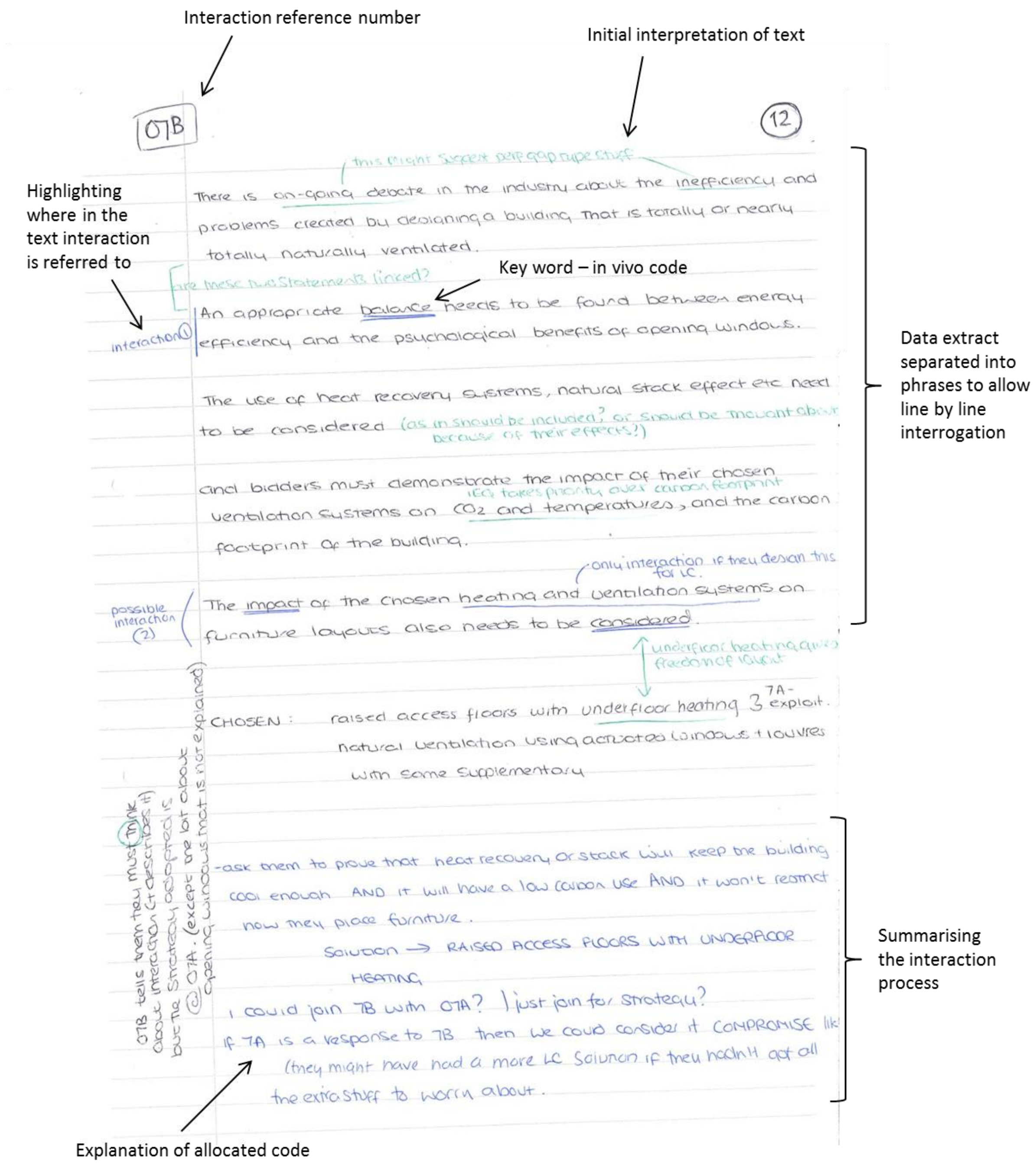


Figure 4-3 Example of initial interaction type and strategy coding

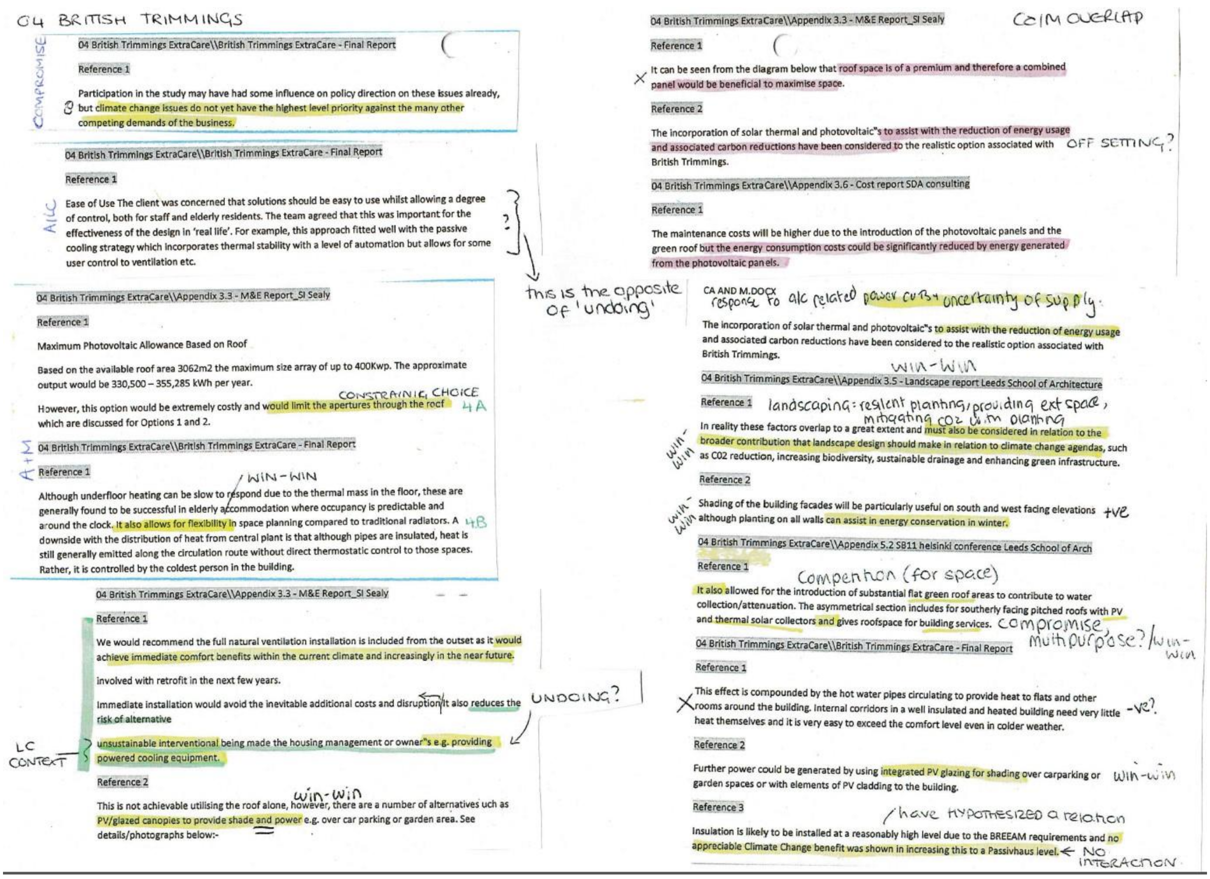


Figure 4-4 Interactions showing notes and highlighting

These initial notes were then used to collate similar interactions, and begin to form tentative groupings through a process of reflection, review and refinement (as described by Rapley (2011) in his pragmatic "*fundamentals*" of qualitative research):

- Similar codes were identified. Initial codes frequently used wording taken directly from the data ('in-vivo' codes) resulting in synonyms that could be combined to a single code; other codes required a more careful consideration of content to ascertain repetition of a general theme or idea.
- For each code all interactions were grouped and examined for coherency – did everything allocated to a particular label 'fit' together? Incoherent codes were re-examined to identify the source of the differences and split apart to make new codes.

Initially sketches (Figure 4-5) using the interaction reference numbers (see 4.5.2) were made to facilitate this. However, this required constant reference back to the interactions themselves to ensure nuances of the data were not becoming dissolved and so an alternative was adopted. This used cut-outs of the interaction text and accompanying hand annotations (photocopies of the original marked up data sheets at a reduced size) pinned to large sheets of brown paper – Figure 4-6.

The pinned data could be repositioned as required and the backing paper used to draw links and circle tentative groupings.

Interrogation of the groupings continued, challenging each interaction's inclusion or exclusion, until a point was reached where it was felt the labels applied were sufficiently abstract as to constitute theoretically useful categories without misrepresenting the detail of the qualitative data they represented. In Rapley's (2011) terms, the codes moved from "*verbatim, descriptive labels to more conceptual, abstract and analytical labels*".

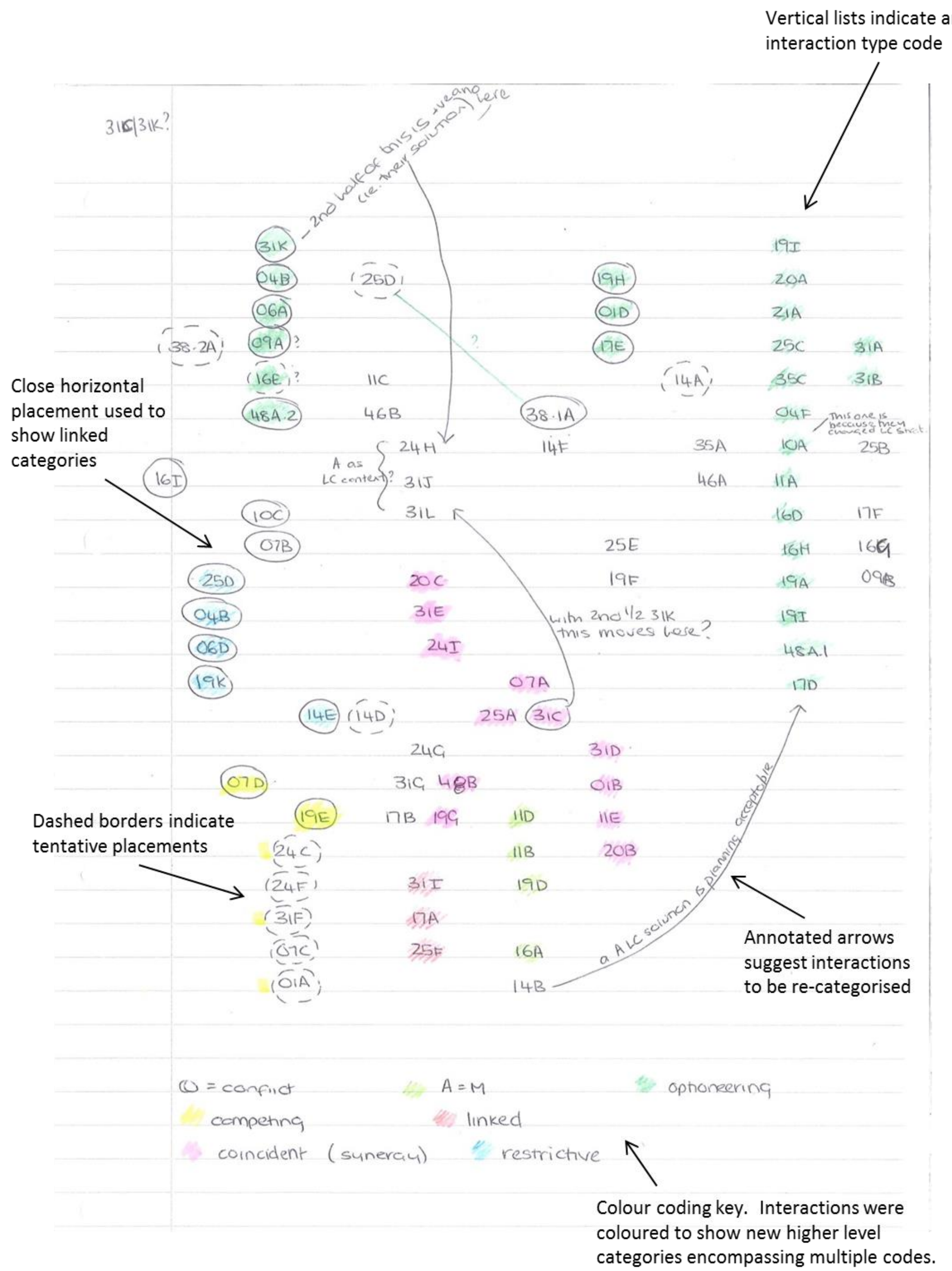


Figure 4-5 Example of code refining sketches (showing interaction types), with explanatory label

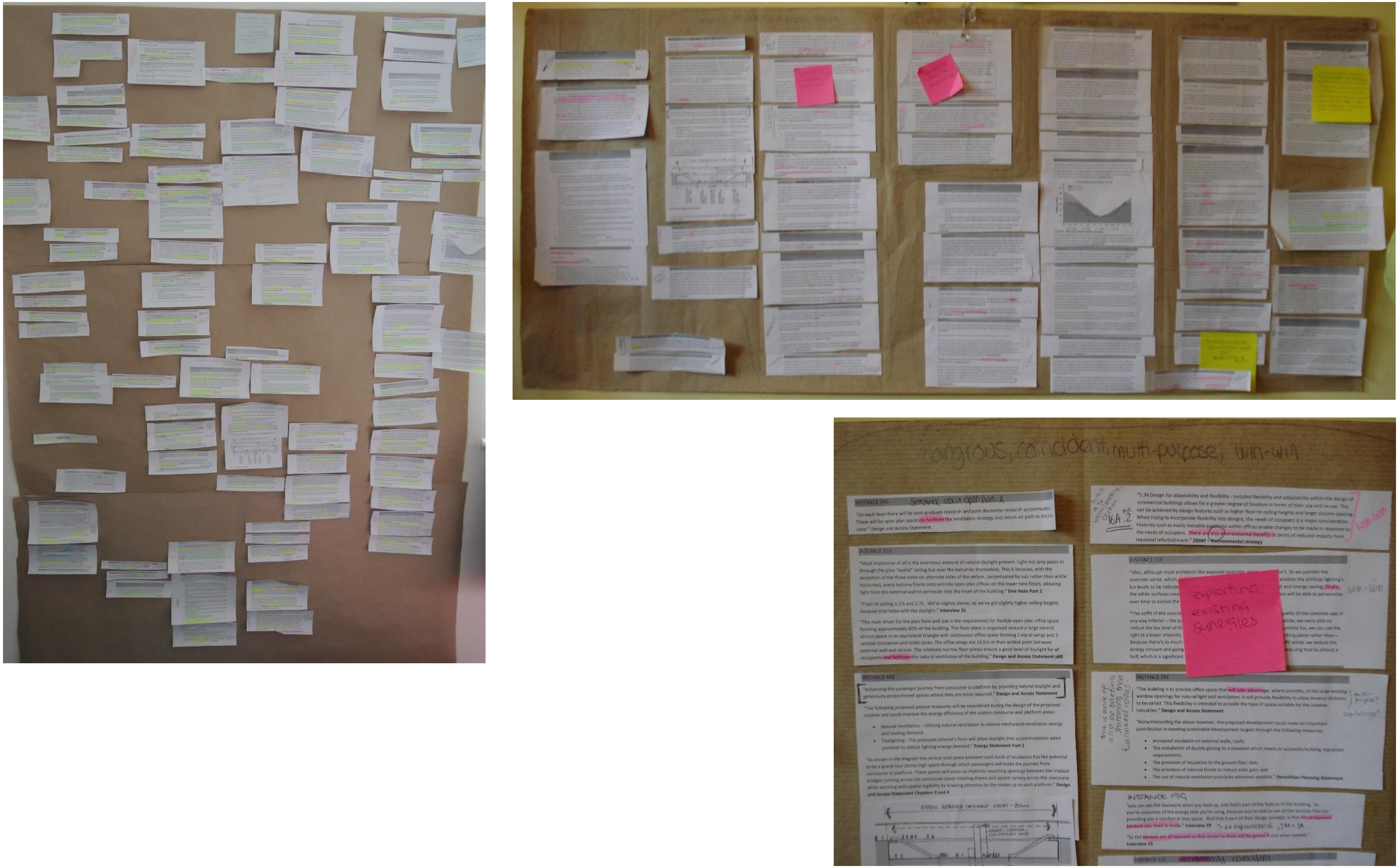


Figure 4-6 Photographs showing various stages of coding using brown paper layouts

4.5.4 UNDERSTANDING INTERACTION STRATEGIES – NARRATIVE ANALAYSIS

For the purpose of complexity reduction QCA relies on the identification of "conditions" that influence the outcome. Conditions are analogous to variables in quantitative research or concepts in qualitative. Yamasaki and Rihoux (2009) list several ways that conditions might be identified: comprehensive, perspective, significance (statistical), second look, conjectural and inductive. Perspective, second look and conjunctural approaches rely on substantial existing theory in the area to be studied and were dismissed on the basis of an absence of a coherent theory of interaction effects. Instead a comprehensive-inductive approach (Yamasaki and Rihoux 2009) to condition selection was adopted. This draws on the literature, while allowing for the latter addition of conditions drawn from the cases themselves.

The comprehensive element requires a thorough search of the existing literature (see section 3.4). This generated a preliminary list of codes generated from conditions known to influence adaptability, low carbon and sustainable design. This list was used to create a preliminary node tree in NVivo which were then used during the data collection and exploration phase (see 4.5.1) to begin to code the data and separate out relevant ideas. While new conditions/nodes were added as their importance became apparent, beginning with an initial listing provided a more structured start and for this reason is often advised (e.g. by Miles & Huberman, 1994) for exploratory qualitative research. For the inductive element, the identification of strategies (see 4.5.3) generated a number of hints towards likely conditions. This was then augmented by drafting short 'stories' for each interaction (a narrative type approach). Initially focussed on the data segments, the NVivo database allowed a return to the data in context where this was helpful to telling the 'story'.

In keeping with good qualitative research practice (Bryman, 2012a), coding memos describing each of the conditions were drafted and redrafted as the codes were refined in a similar process to that outlined above (see 4.5.3). Further, to ensure the findings were consistent within cases and interaction/strategy types (and therefore valid conditions for the selection of each strategy) as the coding developed the interactions and their associated conditions were sorted by case and by interaction type and compared. Any contradictory findings were used to refine the analysis. This eventually resulted in a long list of potential conditions for interaction strategy selection (see appendix 5A).

4.6 ANALYSIS – PHASE 2 (QCA)

4.6.1 INTRODUCTION TO THE PHASE 2 ANALYSIS

The steps involved in QCA as an analysis method are shown in Figure 4-5. The sections that follow summarise the main requirements of each stage and how they were applied to this study. Note this section deals with QCA as a method, rather than a wider research approach as described by Rihoux and Lobe (2011).

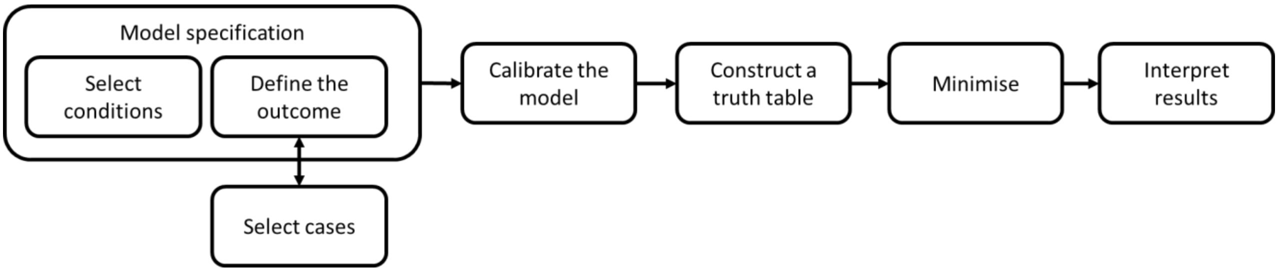


Figure 4-7 Summary of key stages in the QCA analytical method

Note following the exploratory phase there is something of a theoretical leap required in order to progress to the next phase and begin selecting conditions for input into the QCA stage. The exploratory stage establishes the types of interaction occurring, the strategies adopted to deal with it and the conditions under which those strategies are adopted. Phase 2 is intended to determine the conditions under which successful reconciliation (at a project level) occurs. It must therefore be assumed, in order to process, that the conditions influencing strategy selection will ultimately influence reconciliation in the fully designed solution. This assumption is not considered untenable, but is obviously untested.

4.6.2 SELECTING CONDITIONS FOR THE MODEL

Returning to Figure 4-1, almost all the QCA studies in the survey limited themselves to between four and six conditions. However, the first phase analysis (4.5.4) had produced a considerably longer list of codes, highlighting a limitation of QCA. While it is necessary to sample for as much of the diversity existing in a population as possible (Schneider and Wagemann, 2012), this diversity expands exponentially as the number of conditions included in the analysis increases: four conditions can be combined in 16 (2^4) ways, six conditions in 64 (2^6) ways. Beyond circa 10 conditions the 'logic space' (number of possible combinations of conditions) becomes so large as to render any increase in the number of cases meaningless (Jordan, Gross, et al., 2011). It was therefore necessary to reduce the long list to something more manageable.

QCA researchers have produced a number of techniques for reducing the number of conditions to more manageable levels including Schneider and Wagemann's (2006) formalised MSMD (most-similar, most-different) method and Yamasaki and Rihoux's (2009) iterative process of "*many preliminary tests*". The problem of too many conditions is by no means unique to QCA however (Rihoux, 2003), and therefore "*old fashioned techniques*" (Coverdill & Finlay, 1995) of qualitative analysis are equally effective in establishing what is useful, what could be merged and what it is possible to ignore. Having already evaluated the conditions in relation to the relevant literature, the analyst opted first to reduce the list by removing any factors deemed highly specific. Conditions likely to prove trivial (Schneider & Wagemann, 2012), in that they described the successful cases rather than contributed to the outcome, were also excluded. Those remaining were then condensed by grouping similar factors into 'super variables'. However, the number of conditions was still greater than the generally opted for a maximum of 6 conditions. It was therefore necessary to follow Yamasaki and Rihoux's (2009) example and run multiple tests, using the results to evaluate the usefulness of the various combinations of conditions. Conditions that were of limited usefulness is separating successful and unsuccessful cases (identified by the fact they rarely appeared in minimal formulae) were ultimately removed.

4.6.3 MEASURING THE OUTCOME - ASSESSING RECONCILLIATION SUCCESS

Understanding how the sustainable agendas are reconciled meant assessing which of the cases had successfully reconciled the two agendas (OB03), and which had not. As discussed in chapter 2, substantial literatures exist for both low carbon and adaptable design that attempt to define and measure their individual success. There is however only limited, indirect reference to measures that consider both adaptability and low carbon design success (e.g. Preservation Green Lab, 2011). Other studies of competing design agendas (e.g. Edum-Fotwe et al., 2004) tend towards congruency in goals as their typical indicator. Therefore, in the absence of alternatives, this approach has been adopted and the successful reconciliation of the agendas is defined as the co-achievement of both agendas goals. This ultimately allowed for each element to be assessed separately, and the results combined into an indicator of reconciliation.

Various indicators for both low carbon and adaptability concepts were described in chapter 2. To choose the most appropriate, each was evaluated against a combination of typical measurement best practice for reliability and validity as well as more pragmatic requirements. Six primary criteria were used:

- Good correspondence between the indicator and the concept itself - a basic requirement of construct validity (Bryman, 2012a). This meant that any low carbon indicator should exclude unregulated loads for example.

- Applicable to all cases in the sample: able to assess both designs and completed buildings and not restricted to a particular typology.
- Published in sufficient detail to allow reliable replication. This ruled out several of the adaptability measures such as Multiconsult (Larssen & Bjørberg, n.d.) that were published only in part.
- Workable. Due to the number of cases, the measures needed to be simple to apply and generate results quickly.
- Make use of data that was accessible with the selected means of data collection. This favoured measures that were widely reported by the cases such as EPC asset ratings and eliminated several of the more involved adaptability assessment types.
- Equally applicable to buildings outside the sample - external validity, allowing for generalisation of the results where appropriate (Bryman, 2012a).

In addition indicators with existing benchmarks (or datasets with which to compare results) were preferred as this simplified the calibration process (see 4.6.4). Table 4-6 presents a summary of the assessment of the various evaluation tools identified in chapter 2 against these criteria. Full details are provided in appendix 4H.

Table 4-6 Summary evaluation of various low carbon and adaptability evaluation tools

	Evaluation name	Source	1 – Correspondence	2 – Applicability	3 – Replicable	4 - Workable	5 - Availability	6 – External validity	7 - Benchmarking
Adaptability	AdaptSTAR	Conejos (2013)	✓	✓	✓	✓	✓	✓	✓
	n/a (Characteristics based)	Schmidt (2014)	✓	✓	✓	✓	✓	✓	✓
	n/a (Tactic count based)	Schmidt (2014)	✓	✓	✓	✓	✓	✓	✓
	Transformation meter	Geraedts and de Vrij (2004)	X	x	✓	X	X	✓	X
	Use comparator	Kincaid (2002)	X	✓	✓	✓	X	✓	✓
	FlexD (Flexibility Degree)	Saari and Heikkila (2008)	✓	X	✓	X	X	✓	X
	Flexibility degree	Cowee and Schwehr (2009)	✓	✓	✓	X	X	✓	X
	Building Adaptability Assessment (BAS)	March et al. (2012)	✓	✓	✓	✓	✓	✓	✓
Low Carbon	Metered energy use	n/a	X	X	✓	X	X	✓	✓
	Energy Performance Certificates	EPC website	✓	✓	✓	✓	Most	✓	✓
	Display Energy Certificates	EPC website	X	X	✓	✓	X	✓	✓
	BREEAM ENE01	Building Research Establishment (2014)	✓	✓	✓	✓	✓	✓	✓
	LEED Energy and Atmosphere credits		X	✓	✓	✓	X	✓	✓
	Code for Sustainable Homes	DCLG (2010b)	✓	X	✓	✓	X	✓	✓

4.6.3.1 *LOW CARBON EVALUATION*

At the outset of the study, based on Table 4-6, it was envisaged that BREEAM 2011's ENE01 credit would be the preferred low carbon indicator, offering a means to quantify the carbon performance of each building in a manner consistent with the definition adopted in section 2.2.3 and also a benchmark that would be meaningful to others. However, a number of problems with this approach quickly became apparent. Firstly the vast majority of the case projects had registered under the 2008 version of the scheme and employed the old methodology based on a building's asset rating. This meant applying the 2011 approach would be measuring low carbon in a different way to how the cases understood it, and may have undermined the validity of the measure. Secondly, it proved extremely difficult to obtain the required information for calculating the ENE01 score for more than a handful of cases.

It was therefore decided to use EPC asset ratings (ARs) for scoring and BREEAM 2008 ENE01 credit minimum requirements as calibration points. BREEAM categories are particularly helpful for calibration as they have meaningful statements of achievement attached to them:

- *Outstanding: Less than top 1% of UK new non-domestic buildings (innovator)*
- *Excellent: Top 10% of UK new non-domestic buildings (best practice)*
- *Very Good: Top 25% of UK new non-domestic buildings (advanced good practice)*
- *Good: Top 50% of UK new non-domestic buildings (intermediate good practice)*
- *Pass: Top 75% of UK new non-domestic buildings (standard good practice)* (BRE Global, 2011)

The excellent category corresponded well with the adopted definition, which clearly requires its low carbon buildings to perform better than average. While new and refurbished buildings are subject to different variants of BREEAM and therefore slightly different targets, the decision was taken to score all buildings using the new build criteria. This reflects the significant nature of the refurbishment changes being made by cases in the sample.

Asset ratings were collected as described above, section 4.4. Where available statements of low carbon achievement and other reported low carbon measures were also recorded as a check (testing what Bryman (2012a) refers to as "*convergent validity*"). Asset rating results that deviated significantly from other case evidence would highlight potentially erroneous results. In the event, several of the projects were not completed sufficiently quickly to publish their EPCs and this additional information proved invaluable in enabling qualitative assessment (see 5.2).

4.6.3.2 *ADAPTABILITY EVALUATION*

Selecting an adaptability measure was more difficult; unlike the low carbon arena few of these measures can be considered mature or well used (see 2.3.3). It was therefore decided to use several assessment approaches and compare results. The benefits of adopting a multiple measure approach are twofold: it would highlight any measures producing unusual or incongruous results but also allow for calibration (see 4.6.4) of the scales relative to one another. This has not previously been attempted in the adaptability field, where the tendency has been to invent new measures rather than reuse existing ones. While the results would not be statistically generalizable due to the nature of the sample, there would be a valuable contribution made in understanding how a score on one measure relates to scores in the others.

Four methods were selected: Conejos's (2013) AdaptSTAR, March et al.'s (2012) Building Adaptability Score (BAS) and the two unnamed techniques described by Schmidt (2014), hereafter referred to as the CAR and tactic methods. It was also decided to measure each case's alignment with the 65 characteristics of adaptable buildings identified within the literature (see 2.3.3.3 and figure 2-8). In order to do this each of the characteristics were allocated scoring criteria based on adaptability guidance (see appendix 4I). (In some instances this was more specific than others – floor loadings sometimes had numerical values attached for instance, while a building being 'well designed' was often mentioned but poorly defined.) Where possible, phrasing that required a yes/no answer was adopted in an attempt to minimise the amount interpretation required. Each characteristic was allotted a maximum of 1 point if achieved. To create the compliance measure raw scores were simply summed. The scoring matrix can be found in appendix 6B.

Various alterations that might have increased the compliance measure's accuracy were considered. Criteria that occurred more frequently in the literature could have been afforded greater weight for example. However, it was felt this was likely to bias the scale towards characteristics that were common building features. Measures that have greater weight of empirical evidence would be a more appropriate basis on which to weight criteria, for example Manewa (2012) gives a robust defence of storey height, while Wilkinson and Reed (2012) specify a range of characteristics associated with the reuse of a large statistically generalizable sample (albeit of Australian buildings). However, there was little evidence to suggest how much difference these characteristics might make and so no basis on which to establish accurate weightings.

Each case was scored using the instructions provided or method outlined above. Because the adaptability measures tended to require more qualitative judgement than the low carbon indicator, care was taken to ensure these judgements were made consistently over time by recording them and comparing across cases multiple times. Corrections were made as necessary.

Once scoring was complete an internal reliability test was performed on the adaptability compliance assessment in order to better understand the degree to which the literature's description of adaptability is coherent and homogenous. (The adaptSTAR and BAS methods have previously been tested (see Conejos (2013) and Wilkinson and Reed (2011)) and were therefore not retested. Schmidt (2014) describes the CAR method as multi-dimensional and therefore it was not seen as appropriate to test for internal validity across the whole measure.) Internal reliability is the degree to which a scale's items can be seen to measure the same thing – it is an assessment of the coherency of a measure (DeVellis, 1991). Various methods of establishing internal reliability are available; Cronbach's alpha was selected for this study as it is a more robust measure than the simpler split halves test on which it is based (Field, 2013).

Results were then compared across the various measures. As all of the measures should be measuring adaptability, results should co-vary. Co-variance is the degree to which changes in variable X result in a similar change in another variable Y (Field, 2013). This was initially explored visually using scatterplots – correlated measures should produce all points in a straight line or curve. A correlation coefficient, Spearman's ρ, was also calculated for all adaptability indicator pairings. Spearman's ρ calculates the amount of agreement between the two variable in the rank order of the data points (Field, 2013), and was considered more appropriate for the adaptability measures than the more powerful Pearson's r due to the ordinal nature of the data. Any techniques that failed to co-vary with the majority of the other measures were dismissed.

Having determined which of the measures appeared to be reliable indicators, results for each approach were benchmarked to determine an appropriate adaptable design cut off point. Where possible results were compared to cases scored by others using a combination histograms and descriptive statistics (averages and measures of spread). Given most of the buildings previously tested tend to be examples of adaptable design, this gave an indication as to whether cases in this study were more or less adaptable; more adaptable cases could be placed firmly in the adaptable design set according to a given measure.

However, due to very limited number of existing cases against which to benchmark it was decided to score an additional two 'calibration' cases of known adaptability. One adaptable case and one unadaptable building were selected to represent opposite ends of each scale. The adaptable case selected was a large shopping centre previously studied in detail by the author. It had successfully undergone numerous changes early in its life. The author had access to various plans and a good working knowledge of the building which made applying each of the assessments relatively straightforward. For the unadaptable case Birmingham Central Library was chosen. A relatively young institutional building, it has been abandoned in favour of a more modern, flexible structure. The building is set to be demolished in 2015 as "*in its current form the Central Library [is] unsuitable for many alternative uses.*"(Argent LLP, 2014).

All measures of adaptability should be able to distinguish between the two benchmarking cases: assessments that did not were unlikely to be valid measures of adaptability. Also because the cases were of known adaptability, all cases scoring above the 'adaptable' case should be adaptable, and all those scoring below the unadaptable library building should be un-adaptable. Some cases sat between the two benchmarks, creating a number of borderline cases which required some further justification before being allocated to one set or another – see 6.5.9.1.

4.6.4 CALIBRATION

Once the final model was established, conditions were calibrated. Calibration uses "*theoretical knowledge and empirical evidence*" (Schneider & Wagemann, 2012) to relate an observation to an observed standard. This allows researchers to apply meaningful labels to cases (Ragin, 2008). While traditional quantitative measurement typically describes by comparison (X is more than Y, X is less than average etc.), calibration allows us to say what X being, say 10, means (Ragin, 2008). Where calibration results in only two categories, it may be referred to as dichotomisation.

For example, suppose two buildings were scored for design quality. Building A scores 80 and building B 40. Building A clearly has a higher score than building B. Comparing building A and building B to a large sample of other building scores, we might be able to go further and say that building A has an above average score and building B a below average score. We cannot however say that either building is an example of good design without calibrating the scores. That is, defining what score defines the tipping point from average design to good design. (QCA assumes categories are asymmetrical (Ragin, 2006), so for example not being tall would not automatically make a person short. Instead QCA theorists are encourages to calibrate so each condition is either present or absent – tall or not tall.)

QCA has come under sustained attack for this process which is seen as artificially truncating the diversity of a sample (Vaisey 2009) and being prone to manipulation. To illustrate how dichotomisation truncates data Field (2013) uses the example of test scores:

"Imagine there are four people: Peter, Birgit, Jip and Kiki. We measure how much they know about Star Wars as a percentage and get Jip (100%), Kiki (60%), Peter (40%) and Birgit (0%). If we split these four people at the median (50%) then we're saying that Jip and Kiki are the same (they get a score of 1 = fanatic) and Peter and Birgit are the same (they both get a score of 0 = not a fanatic). In reality, Kiki and Peter are the most similar of the four people, but they have been put in different groups. So median splits change the original information quite dramatically…" (Field, 2013)

For Field (2013) and others (DeCoster et al., 2009; MacCallum et al., 2002) dichotomisation is a "*statistical procedure*" (DeCoster et al., 2009) resulting in a loss of information[11]. This has two implications for their statistical tests: they will have less power (for samples of a similar size, they are less likely to spot an effect than the same test applied to the continuous variable (an increase in type II error) and effect sizes will be smaller (DeCoster et al., 2009; Field, 2013; MacCallum et al., 2002). For these authors, all variation is equally relevant. However, the argument made by QCA proponents has been that there exists a qualitative difference between some scores, and not others (Ragin, 1989, 2008).

Continuing the example above, let us say that the test has a pass score of 50%. Jip and Kiki will pass, Peter and Birgit will not. Whether this difference, or the differences in the scores themselves, is of interest will depend on the research question posed. If we are interested in whether scores on the star wars test are related to the amount of sci-fi films a person watches, then maintaining a continuous variable makes sense as we would be exploring covariance. If however we would like to know whether *passing* the star wars test improves our likelihood of getting a marshalling job at a sci-fi convention, 'truncating' the data is arguably more appropriate. Thus QCA proponents argue it is not necessarily splitting the data which is problematic, it is splitting the data unthinkingly (Ragin, 2008; Rihoux, 2006). QCA researchers are therefore urged to "*look at the cases and ask whether this difference…is a relevant and meaningful difference with respect to the underlying concept*" (Ragin, 2008).

If we accept that for some concepts, dichotomisation can be theoretically useful, how should the cut off points be determined? At what point does someone cease to be short, and at what point to they become tall? This leads to the second most prevalent argument against calibration, that it is open

[11] Field (2013) and DeCoster et al. (2009) are both concerned with a specific type of dichotomisation – median splits. This form always segregates the data at the median value, and is typically used where a researcher wants to understand differences between high and low scoring groups but the data indicates no obvious break point. It is important to note that despite genuine reservations about its appropriateness in all but a minority of situations, median splits are still frequently observed in published studies (DeCoster et al., 2009).

to manipulation. Prior (2003) illustrates the point using the example of a scale designed to measure mental illness:

"It is possible, for example, to select a different cut-off point. Moving the point, to say, 10 would increase the prevalence of mental illness in the community. Moving the point to 18 would decrease it. So we can have as much or as little mental illness in the community as we want." (Prior, 2003)

Setting aside that this is not solely an issue for QCA (Prior is writing about social science measurement generally rather than critiquing QCA specifically), QCA counters that, as cut off points should be theoretically informed (Ragin, 2008; Rihoux & de Meur, 2008; Schneider & Wagemann, 2010) there is a relatively limited range within which the cut-off point can be legitimately placed (Schneider & Wagemann, 2012). Further, as QCA requires calibration to be fully justified calibration is much more transparent process than many traditional measurement approaches. This is particularly appealing to a built environment application where many concepts still lack consensus in definition and metric (e.g. value, design quality), ensuring studies make a contribution to the debate on appropriate metrics through an explicit presentation and justification of the approach adopted.

The third criticism is that dichotomisation imposes an arbitrary boundary. Crisp sets (those described above, where someone has either passed the test or not) have an obvious limitation; not everything can be described in terms of dichotomies. Taking the first example above, it would be difficult to describe building A as good design with a score of 10, but not good design with a score of 11. For many categories, there is a slow progression from being in to being out of the set, with no well-defined crossover point. While many variables can be dichotomized straightforwardly when we are dealing with the presence or absence of some phenomenon (Rihoux, 2003), for others the approach is arguably inappropriate. It is partly for this reason that fuzzy set QCA (fsQCA) (Ragin, 2002) was developed, using fuzzy set theory to permit partial set membership.

Despite the improvements made with fsQCA criticism remains and it is considered that an alternative response to the complexity of fuzzy sets is more appealing: any method of qualitative analysis necessitates some form of reduction, and crisp set QCA (csQCA) does this in a way that is compatible with people's general methods of making sense of the social world they inhabit (categorisation) and manner that is transparent rather than developed through an opaque analytical process. Therefore for the purposes of this methodological 'experiment', csQCA calibration was selected on the basis that it is considered the most easily interpreted (Schneider & Wagemann, 2010) and can be accomplished with the smallest case set (Gross and Garvin, 2010). Should the either/or dichotomy requirement of csQCA have proven to be too limiting, additional thresholds could readily be introduced using the case data to undertake fsQCA (Rihoux et al., 2009 p169).

It should be noted that while the arguments above are based mostly on calibration of measured variables, reflecting the fact a large proportion of criticism of the process originates with quantitative researchers, qualitative ideas are admissible (Berg-Schlosser et al., 2009). The primary requirement is that the outcome and variables should represent categories – for example we might describe a set of organisational cases as main contractors, or building cases as offices. This feature was fully exploited when calibrating conditions for the study, some of which were unsuitable for a numeric indicator approach.

4.6.5 THE TRUTH TABLE AND CONTRADICTION SOLVING

Having specified and calibrated the model, the next step in applying QCA as a technique is to construct a truth table. Schneider and Wagemann (2012) describe truth tables as "*the indispensable tool for QCA*". They list all possible combinations of the selected conditions (all possible 'truths') and record the number of times each combination was observed in the data. For example, suppose a situation with two conditions, A and B. There are four possible combinations: ab, AB, aB and Ab - Table 4-7. (For a brief explanation of Boolean notation, see appendix 4J).

Table 4-7 Example truth table

A	B	Frequency	Outcome
a	b	2	1
A	B	3	0
a	B	1	1
A	b	2	0

Truth tables can be generated manually, as the above example, but this becomes time consuming and prone to error as the number of conditions (and therefore combinations) increases (Schneider & Wagemann, 2010). It is more usual for QCA software to be used. Two packages were used for this study - fsQCA (Ragin & Davey, 2014) and TOSMANA (Lasse, 2011). Both have the core QCA features of truth table generation and minimisation, but allow different levels of user specification, present results differently and have some distinct additional features (TOSMANA for example can generate Venn diagrams while fsQCA cannot). Using both therefore allowed for a more refined analysis as well as a limited comparison of their usefulness (see chapter 8).

While it is generally stated as good practice to supply the entire truth table (Schneider & Wagemann, 2010), this is rarely seen in published work due to space limitations. Instead authors typically reproduce only those lines of the table recorded in the data (e.g. Javernick-Will et al. (2012) or Stokke (2007)). As a compromise solution and to avoid unwieldy tables in the bulk of the text, short form tables are included in the main body of this thesis with full tables supplied in the appendices.

Prior to minimising the truth table was checked for quality as recommended by Jordan et al. (2011). Previous test runs of the fsQCA software had demonstrated that on occasion erroneous truth table rows were generated. Multiple runs were therefore conducted as well as a manual check of the truth table against the data. A reasonable balance of successful and unsuccessful outcomes had been obtained and around 28% of the logic space included at least one case suggesting it was sufficiently diverse along the selected lines.

The table was then examined for coherency. Software developed for csQCA does not permit contradictory configurations (Ragin & Amoroso, 2011), that is, configurations for which the outcome is both present in some cases and absent in others. There are various techniques available to eliminate contradictory row (Schneider & Wagemann, 2012):

- Adding a condition to the truth table (expand the model)
- Redefining the case population (excluding one or more cases)
- Revisit the definition, conceptualisation and/or measurement of the conditions or outcome (refine the model)

Essentially, csQCA treats contradictions as errors with the base model and the process of removing them as a process of refinement. This prevents the inclusion of unique or deviant cases and has led to criticism of the method as overly deterministic (Mahoney, 2008). Such criticism can be overcome either by introducing a probabilistic element (e.g. certain forms of fsQCA) or extracting these cases from the truth table and instead analysing as an isolated case study.

4.6.6 MINIMISATION

QCA has developed three ways in which a truth table can be minimised creating three forms of solution: complex, intermediate and parsimonious (Schneider & Wagemann, 2010). Complex solutions are derived using only those configurations for which data exists. While this makes it the least controversial approach, restriction to only the observed cases tends towards merely describing the data (Rihoux, 2003), particularly where the logic space is underpopulated. The result is overly long Boolean equations that offer little insight. The parsimonious solution produces the simplest recipes. It does this by allowing the software to assume outcome values for those configurations about which nothing is known (hypothetical cases termed "*logical remainders*" (Jordan, Gross, et al., 2011)), an approach that has been widely criticised as it allows "*the researcher to cheat, ... to introduce cases that do not exist, some of which could be empirically absurd*" (Rihoux, 2003).

The intermediate solution is the mostly widely recommended (Ragin, 2008; Schneider & Wagemann, 2012). It allows the user to simplify by including some assumed cases in the minimisation, but only those for which "*both the empirical evidence at hand and existing theoretical knowledge*" (Schneider & Wagemann, 2012) suggest it should lead to the outcome. These cases are termed "*easy counterfactuals*" (Ragin, 2008). Difficult counterfactuals (that is those for which there is no theoretical, only empirical support) are generally excluded on the basis they are more difficult to justify. While in theory the intermediate solution would require a researcher to undertake many "*thought experiments*" (Ragin, 2008) to determine how a range of cases might turn out, this would be extremely time consuming. In practice, it is common to use the directional expectations formed when selecting conditions to simplify the complex solution (Ragin, 2008; C. Q. Schneider & Wagemann, 2012). As this application of the QCA is somewhat experimental, both approaches were applied (see 7.2.4) to ensure a thorough understanding of the results.

In practice, and because it is relatively simple to do so when using software for the minimisation process, most researchers compute all three solutions – an approach frequently referred to as the "*standard analysis*" (Schneider & Wagemann, 2012) and the one adopted by this study.

Whichever method is selected, minimisation provides one or more Boolean equations ("*recipes*" (Ragin, 1989)) that describe the conditions required for the outcome. The possibility of multiple recipes is a key feature of QCA, allowing different routes to the same outcome (Rihoux & Lobe, 2011).

Two quality tests for QCA results are available, consistency and coverage. Consistency "*is the degree to which a set relation has been approximated, that is, the degree to which the evidence is consistent with the argument that a set relation exists*" (Ragin, 2008). It describes the number of cases included in the recipe obtaining the outcome as a percentage of all cases included in that configuration. Recipes with low consistency values are unlikely to valid results.

$$Consistency = \frac{\sum cases\ in\ configuration\ where\ outcome\ is\ present}{\sum cases\ in\ configuration}$$

Coverage describes how much of the data set is explained by a given recipe – high coverage values indicate a recipe explains the outcome for a large percentage of the sample population. Two types of coverage are usually reported – raw and unique. Raw coverage is calculated using all cases in the sample, unique using only those cases not described by other recipes:

$$Coverage = \frac{\sum cases\ explained\ by\ recipe}{total\ number\ of\ cases}$$

Both types of coverage are reported. However, recipes with low coverage were not automatically discounted; as Ragin (2008) notes, such cases may have high theoretically usefulness of novelty or describe a distinct subset of cases which cannot be explained by other means.

4.6.7 INTERPRETING THE QCA RECIPES

Despite 'qualitative' claims (Ragin, 1989, 2008), many published QCA studies (particularly in the macro comparative sciences) are quantitative examples where statistics would have been used if the sample were larger and there is limited, post-hoc reference to case data. See, for example Blake and Adolino (2001) and Greckhamer et al. (2007). Studies in other disciplines demonstrate attempts at more qualitative investigations where an understanding of the mechanisms and process at work is as important as the minimal equations obtained. Here a mixed methods approach is often employed, whereby QCA is augmented with traditional qualitative analysis: thematic coding, narrative construction and mapping activities. Examples include Marx and van Hootegem's (2007) inclusion of a within-case qualitative analysis to address "*How do the configurations of variables generate the presence or absence of RSIW [their outcome of interest]?*" and Kahwati et al.'s (2011) "*thematic analysis of site interview data*" to elaborate on the quite abstract conditions they find linked to the outcome, enabling their findings to be better related to reality by the practitioners they hope to influence.

This requirement to resort other qualitative techniques demonstrates QCA's failure to overcome the black box problem - "*logical methods ...do not, in themselves, provide an account of the actual processes involved"* (Goldthorpe, 1997). While Rihoux (2003) offers convincing arguments that "*opening up the black box of process is not one of the goals of the QCA technique*" and instead "*shows the researcher on which key spots in the black box to point the flashlight*" (Rihoux, 2003), this does not avoid the fact that QCA offers little guidance as to how to proceed in the identification of mechanisms that link conditions together to produce the outcome. QCA claims to be a systematic technique for qualitative analysis (Rihoux, 2006) are therefore perhaps somewhat overstated.

In the absence of more nuanced instructions the study follows the example of others (Coverdill & Finlay, 1995; Kahwati et al., 2011; Marx & van Hootegem, 2007), and uses qualitative analysis to interpret the recipes in the context of each of the cases. Applying the resulting recipes to each case, the analyst first challenged whether the result 'made sense' – did it seem plausible? Were all the conditions present in the case? Was there anything significant that appeared to be missing? Did all the cases covered by a particular recipe seem to fit as a group? Once this was established, data recorded in Nvivo and notes made during data collection were reviewed in an effort to establish how the identified combinations of causes might have influenced sustainable outcomes – see 7.4.

4.7 CHAPTER CONCLUSION

This chapter has provided an overview of the research methodology (summarised in Table 4-1) and also introduced a relatively novel research approach, qualitative comparative analysis. The following chapters present the results of applying the methods outlined above. Chapter 5 presents the results of phase 1 of the study – describing interaction and the ways in which the case actors dealt with it. Chapter 6 assesses the degree to which the cases were successful reconciling the current low carbon and adaptable sustainability agendas while chapter 7 brings the results of the previous two together to form and test a simple model of interaction. Chapter 8 reflects on the results, before 9 presents the overall conclusions of the study.

5 INTERACTIONS

5.1 INTRODUCTION

This chapter presents the results of the largely interpretive, inductive phase of the study, addressing objectives OB01, OB02 and in part OB03. Section 5.2 presents the results of a simple content analysis. It reveals interaction occurring in 23 case study design processes, adding weight to chapters 1 and 3's theoretical case for interaction between adaptability and low carbon principles. Section 5.3 considers each interaction qualitatively as a discrete event. This allows the recorded interactions to be grouped and categorised, providing the foundation of an evidenced based typology that can be compared to theoretical interaction types in other fields. Lastly, section 5.4 locates the interactions within their individual case contexts to understand how project actors engaged with interaction.

5.2 EVIDENCE OF INTERACTION

Interaction between adaptability and low carbon ideas has been hypothesized and assumed, but not proven (see section 3.3). This first section therefore presents results demonstrating interaction empirically and makes some limited remarks as to its prevalence in the selected sample.

5.2.1 FINDING INTERACTION

Content analysis was used to locate occurrences of interaction within the case evidence, see section 4.5.2. Initial coding generated 149 coded segments ('references' using NVivo terminology) [12]. A further 85 references were generated using a coding query that returned overlap in 'adaptability' and 'low carbon' coding schemes. As described in section 4.5.2 this data set was then subjected to a second reading to remove obvious duplication, coding errors and interactions deemed out of scope. This process of consolidation resulted in an initial long list of 121 observations, appendix 5A.

Results were graphed in the order they were coded as a simple check for coding bias, for instance the coder becoming more sensitised to interactions as coding proceeded. The results, Figure 5-1 demonstrated no obvious pattern or trend although it was apparent a number of cases had very few observations. These cases were briefly returned to, ensuring the lack of interaction was a genuine feature of the data available and not the result of superficial coding.

[12] Coding activities also recorded references to interaction between low carbon principles and climate change adaptation measures (483). Largely deemed out of scope, where the CCA tactic could be considered adaptability in the more general sense and were installed these were included in the initial long list.

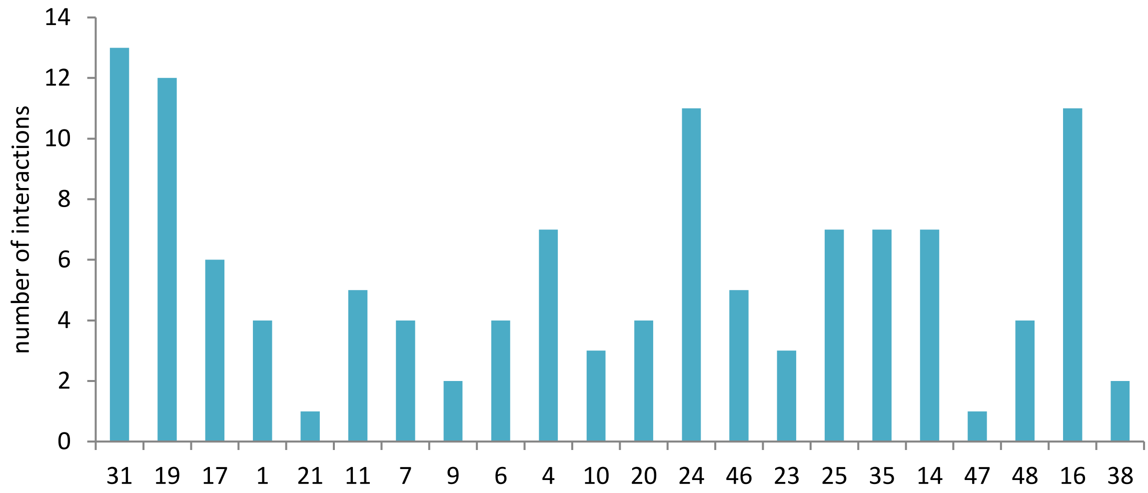


Figure 5-1 Number of interactions arising from evidence (documentary and interview) coding by case, cases arranged chronologically in order of coding from left to right

Following this check, all interaction observations were tabulated and the low carbon and adaptable elements identified – see appendix 5A. This highlighted a number of instances where no adaptable or low carbon principle could be clearly identified in the data, often the result of 'reading between the lines' during coding. For example in the text below "*right-sized*" had been understood as a deliberate absence of flexible over-sizing:

> *"The building has been designed to incorporate the best low energy, high performance systems which are 'right-sized', using thermal mass and night cooling to deliver the desired level of temperature control without mechanical cooling." Case 16, interaction 16F*

These interactions were removed. This is perhaps an overly cautious approach, but ensures all of the interactions were clearly perceived as such by the cases (reflecting a desire to let the cases speak for themselves) and avoids the inclusion of spurious and irrelevant data.

Six interactions were merged following a more detailed comparison. Several interactions were removed because it was felt on further reflection that they lay outside the study's scope. Most notable of these exclusions were the removal of climate change adaptation (CCA) and low carbon interactions where the CCA action could not be linked to more general change provision. Details of all removals from the long list (including justifications for removal) are given in appendix 5B.

The refinement process identified 86 unique examples of low carbon and adaptable design interaction, summarised in Table 5-1. The complete data segments are located in appendix 5C. 64 interactions emerged from the documentary analysis while a further 22 were located within the interview data. Figure 5-2 shows the distribution of interactions across the cases.

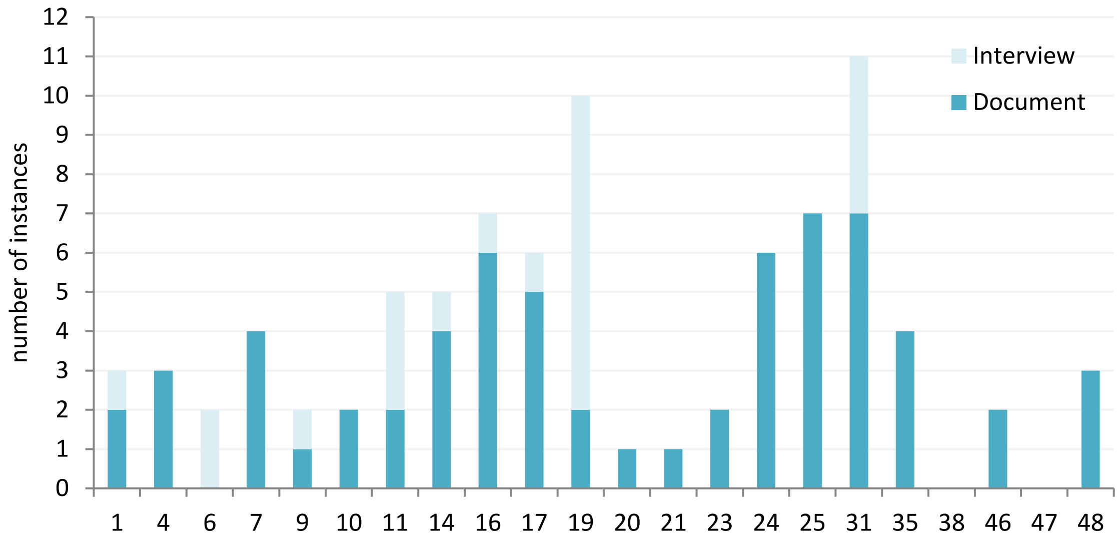


Figure 5-2 Interactions recorded for each case study

5.2.2 DISTRIBUTION OF INTERACTION ACROSS THE CASES

All cases with the exception of Westbrook Primary School (case 47) and the two New England Quarter Site J buildings (case 38) demonstrate evidence of interaction between adaptability and low carbon design intent, with a mean of 3.9 observations per case.

Considering the case profiles for Westbrook Primary and Site J there is little to set them apart from the other cases where interaction was found. Case 47 lies beneath the Heathrow flight path, raising the importance of acoustic design, although other schools (e.g. case 25) suffered similar issues. Case 38 contains the only true residential block, but is in essence similar to the extra care buildings (case 04 and 11). On reflection the lack of interaction for cases 37 and 47 (although plausibly reflecting an absence of interaction) likely reflects inadequacies in the case data. These deficiencies are described in section 4.4.3.

Within the cases where interaction was identified there is variability in the extent to which the interaction is apparent; some cases have only one example and others multiple. This is illustrated by the boxplot (Figure 5-3) below.

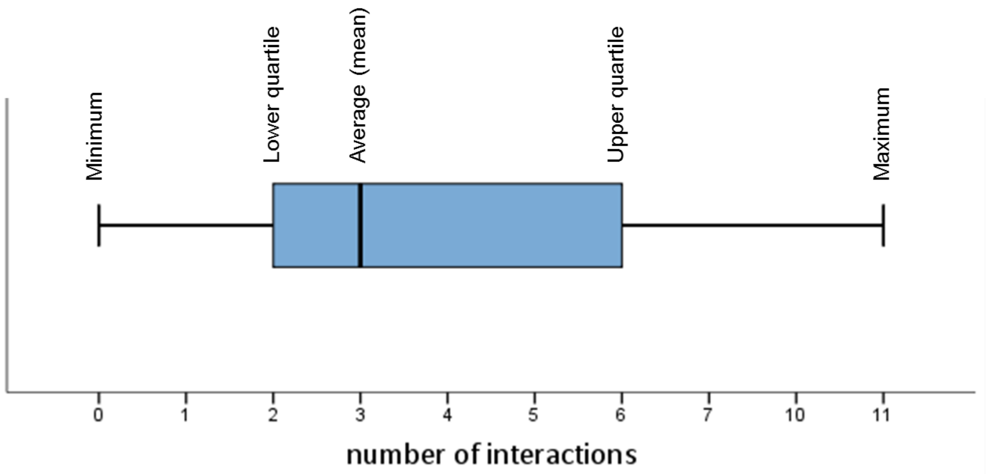


Figure 5-3 Boxplot showing variability in total interactions recorded per case

Some variation is to be expected, with the cases varying significantly in scope and complexity. However, as Figure 5-4 shows, larger projects (measured by value) were not consistently associated with larger interaction numbers.

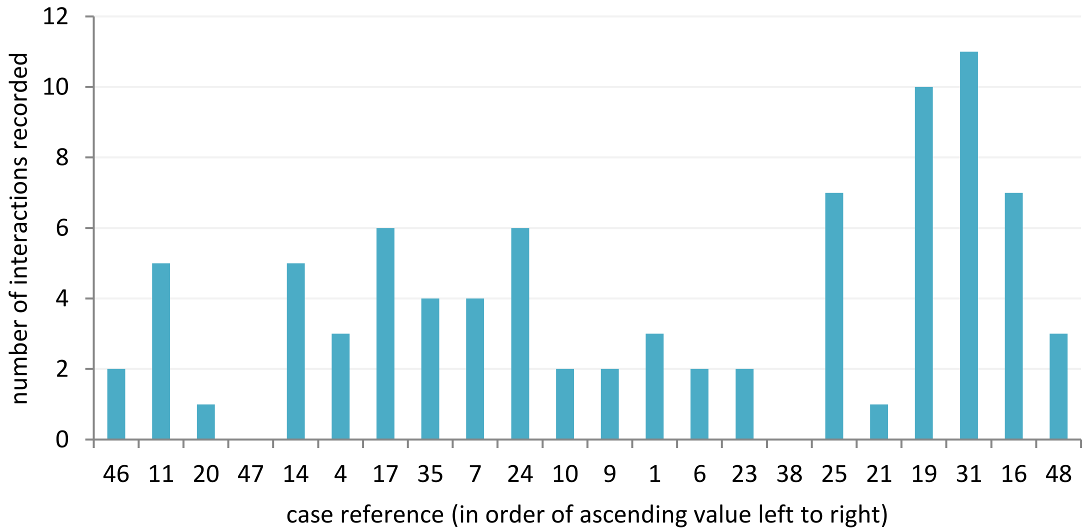


Figure 5-4 Recorded interactions per case, shown with cases ordered by value (project values are located in table 4-2)

Instead, the amount of interaction recorded appears to be related ($p < 0.01$, $r = 0.65$) to the number of low carbon actions ('tactics' – see appendix 5D) pursued by each case, Figure 5-5. (Adaptability ($p<0.05$, $r = 0.5$) showed only a weak relationship – see appendix 5D.) This is an intuitive finding where cases attempting to implement more low carbon ideas have a greater opportunity to encounter interaction.

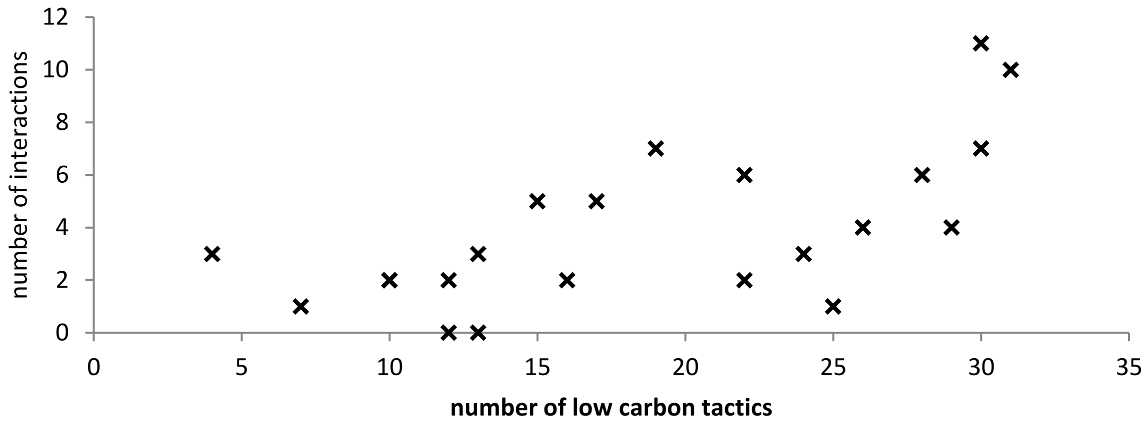


Figure 5-5 Relationship between case low carbon actions and number of recorded interactions

Despite the results above, some variation undoubtedly reflects the varying quality and quantity of information available for analysis. Variability in the availability of interview data is a particular concern; cases with interviews produced a mean of 4.8 interactions per case, those without only 2.7. Statistically, the sample is too small (N = 21) to draw significant conclusions about the difference in the two means (independent t-test $t(20) = -1.70$, $\rho = .104$, see appendix 5E). However, qualitatively it is likely that those cases with interviews have a greater depth of information. Interestingly, comparing cases where a person actively involved in the design was interviewed to those where a person primarily involved in the CCA study was consulted (Figure 5-6) there is very little difference in the median count; a slight upward skew to the designer interview group suggesting only a small beneficial effect.

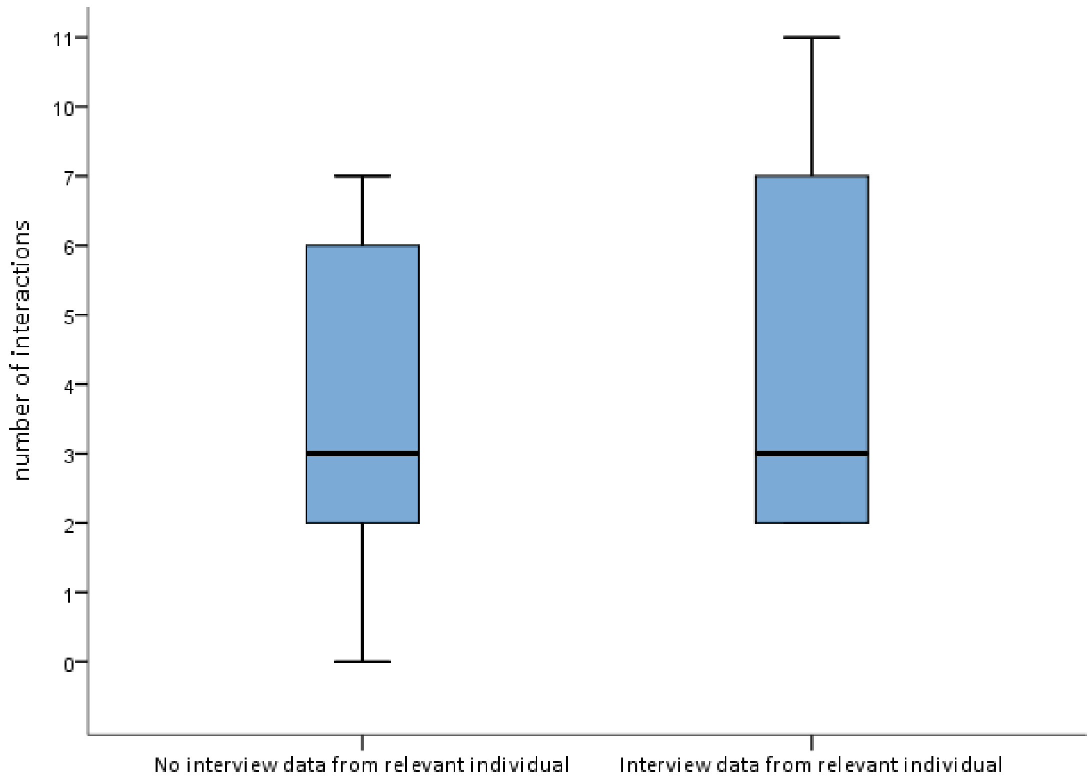


Figure 5-6 Boxplots illustrating differences in interaction counts between cases where an individual involved in the design was available for interview and the remainder of the sample

As described in chapter 4, it was never intended that the study would uncover all interaction occurring, only interaction the cases were willing and able to articulate in documentary evidence and discussion. As a result the data is limited in its completeness and it would be irresponsible to comment on differences in the prevalence of interaction between the cases as it is obvious some cases were given more licence to articulate than others. The data is nonetheless sufficient to demonstrate the occurrence of interaction between adaptability and low carbon ideas in the practice of building design as per the requirements of objective 1.

Table 5-1 List of identified interactions

Case	Interaction	Description
1	01A	Green policy based on delivering low energy buildings that can be adapted to different workplace requirements
1	01B	BREEAM sub-metering requirements allow monitoring of energy use should the building be divided into separate tenancies.
1	01D	HVAC ensures building will remain comfortable in a changing climate, but will increase energy use.
4	04B	Full roof coverage with PV panels would restrict ability to provide roof penetrations.
4	04F	Roof will be designed to allow retrofitting of PV panels at a later date.
4	04G	Recommendation to install improved natural ventilation to prevent occupiers retrofitting energy consuming air conditioning in response to climate change.
6	06A	Occupants cover windows with artwork to reduce glare and solar gain resulting in increased energy use for lighting.
6	06D	Earth tubes reduce energy use but require later work to 'build round them'
7	07A	Raised access flooring for flexibility and energy efficient displacement ventilation.
7	07B	Heating and ventilation systems chosen for energy efficiency can potentially restrict furniture arrangements.
7	07C	Educational buildings are expected to maintain a comfortable environment without compromising flexibility of the space or unreasonable energy consumption
7	07D	Designers stated that mitigating against climate change traditionally took priority over adapting buildings to climate change
9	09A	Building is designed for high visitor numbers making it impossible to guarantee use of energy efficient equipment and a need to design equipment gains for the worst case.
9	09B	Recommendation for modular boilers to allow decommissioning with climate change predicted increases in temperature.
10	10A	Provision in structural design for retrofitting of PV panels or a green roof.
10	10C	Openable windows included for patient benefit despite contradicting low carbon air tightness and heat recovery strategy.
11	11A	Buildings orientated and designed to allow later upgrade with renewable technologies.
11	11B	Buildings to be demolished rather than reused due to being unadaptable and incapable of meeting CSH Level 3.
11	11C	Natural ventilation chimneys puncture building fabric, impacting on air tightness making windows the preferred ventilation option.

Case	Interaction	Description
11	11D	Clear spanning offices, with good cross ventilation and thermal envelope will be easiest to reuse.
11	11E	Simple PassivHaus M&E design also provides easy access to frequently replaced items.
14	14A	Light wells for day lighting in-filled to provide additional accommodation/
14	14B	Listed status of building restricts ability to adapt. Adaptable solutions might allow retrofitting of low carbon solutions with limited impact on heritage asset.
14	14D	Structural soffits exposed for thermal mass, floor slabs isolated from thermal mass by installation of a raised access floor.
14	14E	Exposed soffits for thermal mass impose a sustainable aesthetic that might not be appropriate for all spaces and will restrict client decoration choices.
14	14G	Multiple HVAC connections to theatre to allow for reduced output when space is divided.
16	16A.1	Design for disassembly and long life reducing through life carbon emissions (embodied energy)
16	16A.2	Reduced environmental impact of repeated refurbishment where buildings are designed to adapt.
16	16D	Design CHP system to be compatible with bio-fuel ahead of its widespread availability.
16	16E	Exposed structural mass reduces cooling requirements and is compatible with a base build only route.
16	16G	Modular, progressively installed CHP
16	16H	Ability to retrofit PV and other renewable technologies
16	16J	Shell and core decision separating design decisions (particularly relating to BMS controlled systems) resulting in less efficient operation of the building.
17	17A	Adaptability listed within features of the design included to achieve energy efficient and sustainable scheme
17	17B	Atrium included to provide adaptable space and increase daylight / natural ventilation
17	17C	Air conditioning (A/C) designed with sufficient capacity for differing climates, meaning design effort is focussed on reducing the need to use the A/C and reducing the accompanying energy requirement.
17	17D	Provision for retrofitting a low carbon cooling solution (discouraging a less sustainable solution to overheating in future)
17	17E	Roof loading allowances and knock out panels to allow retrofitting of energy consuming cooling plant if required.

Case	Interaction	Description
17	17F	Recommendation for modular boilers to allow decommissioning with climate change predicted increases in temperature.
19	19A	Scheme designed to allow retrofitted connection to any future district heating system.
19	19D	Reducing energy use reduces carbon allowance payments and makes a building more viable in the long term.
19	19E	Pursuing TSB climate change study BREEAM innovation credit in lieu of a more expensive embodied energy reduction credit.
19	19F	Mixed mode HVAC providing a low energy solution that allows for user intervention locally.
19	19G	Visible ductwork providing easy access and knowledge of the energy being consumed by the building.
19	19H	Reinforced roof slab to permit retrofitting of additional cooling plant if required in future, which would increase the buildings energy use.
19	19I	Roof loading allowance for retrofitting PV panels that are currently not permitted due to planning conditions.
19	19J	Single taps to wash hand basins to allow switch to cold water only (saving water heating energy).
19	19K	Desire for natural ventilation removing the ability to have a café at ground floor level.
19	19L	Standard low energy lighting and services module throughout the building, restricts the use of high powered computers outside designated areas.
20	20A	Provision to retrofit solar panels post completion.
21	21A	Dual fuel CHP system (gas and biofuel) to allow switch to a lower carbon fuel should it become viable.
23	23B	Air tight floor plenum for low energy, efficient ventilation displacement. Restricted access under flooring for maintenance access and grilles placed within fixed furniture for aesthetic reasons.
23	23C	ETFE roof highly insulating (reducing heat loss and associated energy use) and adaptable to external climate via variable solar shading.
24	24C	Requirements for natural ventilation having "significant implication" for façade design, floor to floor heights and plan depth coupled with a requirement to align floor to floor heights with existing adjacent building for departmental flexibility.
24	24F	Fully naturally ventilated solution compromised client brief for a flexible scheme fully linked with the adjacent existing building.
24	24G	Open plan spaces used to facilitate natural ventilation.

Case	Interaction	Description
24	24H	Labs designed to function as naturally ventilated (reducing energy use now) with provision for mechanical ventilation if required for future lab uses.
24	24I	Concrete frame selected for flexibility and thermal mass properties.
24	24K	District heating system can be easily scaled to provide more or less heat.
25	25A	Fully accessible floor void providing adaptable floor plan, accessible services and low energy displacement ventilation solution.
25	25B	Adding additional buildings to an existing CHP plant will increase its operating efficiency.
25	25C	Energy centre includes space for additional low carbon generation technologies, e.g. a fuel cell.
25	25D	Openable windows provided for occupant local adjustment and as part of a low energy ventilation strategy.
25	25E	Mixed mode ventilation allowing for passive ventilation (low energy) in the current climate and a move to more mechanical ventilation and comfort cooling in future if required.
25	25F	Low carbon and adaptability both included as aspects of "environmental sustainability"
25	25G	Central energy centre provides low carbon power and is more easily scaled for any future expansion and kept current than multiple plant sites.
31	31A	Dual fuel CHP system (gas and Biofuel) to allow a switch to gas if subsequent occupier cannot obtain biofuel reliably.
31	31B	Building designed to "plug-in" to future low carbon energy solutions such as district heat.
31	31C/K	Deliberate choice to prevent occupiers opening windows and influencing the energy efficient ventilation strategy.
31	31D	Smart grid - adapts local power supply (lighting, small power) to reflect occupancy. Performative building, allowing for hot desking and more flexible use of spaces. Reduces energy use by turning off power in areas not currently occupied.
31	31E	Concrete soffits painted white to allow a reduction in lux and associated energy saving. Also perceived as providing "a blank canvas which the workers will be able to personalise".
31	31F	Building described as achieving a balance of sustainability and space flexibility.
31	31G	Larger floor to ceiling heights and narrow floor plan creating an adaptable (divisible) floor plan that also allows daylight to penetrate reducing the need for artificial lighting.

Case	Interaction	Description
31	31I	Long life, fit for purpose (adaptable) building reducing total embodied carbon emissions through reduced need for demolition and rebuild.
31	31J	Low energy displacement and stack ventilation strategy designed to work in multiple letting scenarios (single tenant, multiple tenants).
31	31L	CO2 sensors and smart grid planned on a 3x3m grid to ensure if internal partitions replanned they remain effective at minimising energy use.
31	31M	Decision not to automate blinds and allow local user control, despite the potential for blinds to be left down/up at inappropriate times and affect the building's low energy HVAC strategy.
35	35A	Portrayal of wind turbines (low carbon renewable technology) as difficult to retrofit.
35	35C	Buildings designed to allow retrofitting of renewables such as PV.
35	35D	GSHPs restrict choice of internal heating systems to low temperature type.
35	35E	Community heating scheme (centralised CHP) provides low carbon energy and improved ability to upgrade in future if required (only one system need be replaced).
46	46A	Not possible to retrofit GSHPs due to the high cost and disruption to the site involved.
46	46B	Adjustable solar shading to allow solar gains in winter (heating benefit) but exclude in summer.
48	48A.1	Centralised, energy efficient plant removing retailer fit-outs which are potentially inefficient. Central plant is also compatible with later connection to a local district heating network.
48	48A.2	Base build in retailer fit out areas maximises retailer flexibility but minimises client control over energy consuming items such as lighting.
48	48B	Large spaces provide adaptable, legible spaces. Large spaces also used to ensure the natural ventilation scheme is effective.

5.3 DESCRIPTION OF INTERACTION OBSERVED

5.3.1 INTRODUCTION

Chapter 3 described the limited, speculative attempts to define how adaptability, low carbon and other aspects of sustainability might interact. There have been no attempts to describe the phenomena in the practice of building design. Thus, having identified interaction occurring within the case study designs, this section describes those interactions addressing the question: *what does interaction look like in a building design context*?

The answer is presented as an evidenced typology of interaction (summarised in Figure 5-7) that can be compared to the simple conceptual models of interaction referenced in chapter 3. This section therefore, with the preceding section 5.2, fulfils the date requirements of objective 01:

> *OB01: Demonstrate the empirical existence of interaction by locating, describing and categorising interaction in real building design process, comparing the empirical findings to theoretically extant interaction types.*

The remainder of this chapter will use the 86 interactions as the primary unit of analysis, i.e. there are 86 'cases' of interaction, with the projects providing the context for several interactions. To avoid confusion however, the term case will be used exclusively for reference to the projects.

5.3.2 TYPES OF INTERACTION

The analysis was conducted as described in section 4.5.3 of chapter 4. Each interaction's classification (type) is given in Table 5-2. Broadly in line with the macro, policy level interaction typologies described in section 3.3 three primary types were identified (Figure 5-7):

- Negative interaction whereby the agendas are detrimental to each other in some way (5.3.3);
- Neutral interaction having neither positive nor negative impacts on either agenda (5.3.4).
- Positive interaction which is beneficial to a least one of the agendas and has no negative consequences for the other (see 5.3.5);

An additional type, modification (see 5.3.6) reflects differences between interactions posing problems and providing opportunities during design and other interactions having future consequences. It encapsulates both positive and negative interactions, occurring where the benefit / dis-benefit occurs at some future point in time.

These types can be further broken down into a number of sub-types (black text Figure 5-7), which elaborate on how the high level types interaction manifested themselves in a construction design context.

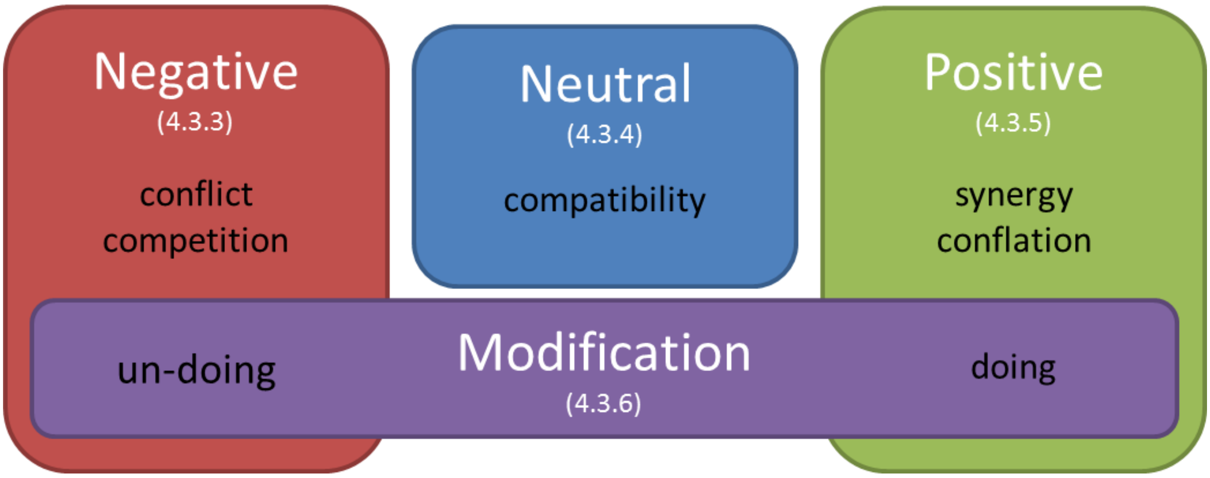


Figure 5-7 Types of interaction (section references in brackets)

Each sub-type is described in the following sections, grouped using the four primary classes of negative, positive and neutral interaction. Numbers in square brackets refer to observed frequencies.[13]

[13] It was felt the actual counts offered greater transparency than terms such as 'some', 'many' or 'most' (aligning with Maxwell's (2010) view that numbers can be advantageous to qualitative research), although caution should be applied in interpreting the frequencies, given the variability in data quality discussed above.

Table 5-2 Interaction type classifications and project interaction strategy

Case	Reference	Interaction type	Interaction strategy
1	01A	Conflict	Prioritise
1	01B	Synergy	Exploit - win-win
1	01D	Conflict	Mitigate
4	04B	Conflict	Compromise
4	04F	Modification - doing	Retrofit
4	04G	Modification - undoing	Control
6	06A	Modification - undoing	None
6	06D	Conflict	Avoid
7	07A	Synergy	Exploit - multi-purpose
7	07B	Conflict	Compromise
7	07C	Conflict	Compromise
7	07D	Competing	Prioritise
9	09A	Modification - undoing	Permissive
9	09B	Modification - doing	Future proof
10	10A	Modification - doing	Retrofit
10	10C	Conflict	Prioritise
11	11A	Modification - doing	Hedge
11	11B	Synergy	None
11	11C	Synergy	None
11	11D	Conflated	None
11	11E	Synergy	None
14	14A	Modification - undoing	None
14	14B	Synergy	Exploit – facilitate
14	14D	Conflict	Compromise
14	14E	Conflict	Prioritise
14	14G	Compatible	Design for Compatibility
16	16A.1	Conflated	Exploit - Co-opt
16	16A.2	Synergy	Exploit - win-win
16	16D	Modification - doing	Hedge
16	16E	Modification - undoing	Permissive
16	16G	Compatible	Design for Compatibility
16	16H	Modification - doing	Retrofit
16	16J	Conflict	None
17	17A	Compatible	None
17	17B	Synergy	Exploit - multi-purpose
17	17C	Conflict	Mitigate
17	17D	Modification - doing	Retrofit
17	17E	Modification - undoing	Hedge
17	17F	Modification - doing	Future proof
19	19A	Modification - doing	Retrofit
19	19D	Conflated	Exploit - Co-opt
19	19E	Competing	None
19	19F	Synergy	Exploit - win-win
19	19G	Synergy	None
19	19H	Modification - undoing	Hedge

Case	Reference	Interaction type	Interaction strategy
19	19I	Modification - doing	Retrofit
19	19J	Modification - doing	Retrofit
19	19K	Conflict	Prioritise
19	19L	Conflict	Compromise[14]
20	20A	Modification - doing	Retrofit
21	21A	Modification - doing	Hedge
23	23B	Conflict	Prioritise
23	23C	Synergy	Exploit - multi-purpose
24	24C	Conflict	Compromise
24	24F	Conflict	Prioritise
24	24G	Synergy	Exploit - facilitation
24	24H	Compatible	Design for Compatibility
24	24I	Synergy	Exploit - multi-purpose
24	24K	Compatible	Design for Compatibility
25	25A	Synergy	Exploit - multi-purpose
25	25B[15]	Synergy	Exploit – facilitate
25	25C	Modification - doing	Retrofit
25	25D	Conflict	Mitigate
25	25E	Conflict	Compromise
25	25F	Conflated	None
25	25G	Synergy	Exploit - win-win

Case	Reference	Interaction type	Interaction strategy
31	31A	Modification - undoing	Hedge
31	31B	Modification - doing	Hedge
31	31C	Modification - undoing	Control
31	31D	Compatible	Design for Compatibility
31	31E	Synergy	Exploit - win-win
31	31F	Conflict	Compromise
31	31G	Synergy	Exploit - facilitation
31	31I	Conflated	None
31	31J	Compatible	Design for Compatibility
31	31L	Compatible	Design for Compatibility
31	31M	Modification - undoing	Permissive
35	35A		(anti-retrofit)
35	35C	Modification - doing	Retrofit
35	35D	Conflict	Avoid
35	35E	Modification - doing	Hedge
46	46A	Conflict	None
46	46B	Synergy	Exploit - Co-opt
48	48A.1	Modification - doing	Retrofit
48	48A.2	Modification - undoing	Permissive
48	48B	Synergy	None

[14] 19L can also be considered an example of control.

[15] 25B can also be considered a compatible/ Design for Compatibility pair.

5.3.3 NEGATIVE INTERACTIONS

Negative interaction, posing problems for design, occurred in two forms – conflict and competition. Conflict manifests as the opposition of adaptability and low carbon design principles – to incorporate adaptability would require something counter to the basic principles of low carbon design and vice versa. Competition, in contrast, has no direct opposition between the ideologies of the two approaches, and instead occurs because of a need to share resources – funding, design time, physical space. Examples of conflicting adaptable and low carbon design within the data include:

- Allowing occupants local control of spaces by providing openable windows was frequently (07B, 10C, 25D, 31C) in conflict with energy efficiency, compromising air tightness and the effectiveness of heat recovery;
- A sustainable aesthetic dictated the internal finish of spaces and could be counter to client wishes (14E);
- Earth tubes (06D) and PV panels (04B) were both noted as low carbon technology that could be physically in the way of later change;
- Oversizing plant to accommodate a degree of flexibility runs counter to the principle of sizing precisely for efficiency (01D, 17C);
- Separating base build and subsequent fit out, a key adaptability principle, caused problems at 16J where rushed commissioning struggled to marry the resulting inconsistent systems;
- Flexible, generic space was difficult to reconcile with low energy HVAC systems (19L, 31C)
- GSHPs dictated the use of low temperature heating systems for the duration of their life (35D)[16];
- Connectivity and viable floor plans can conflict with plan depths most suited to natural ventilation (24F)[16].

Conflict was characterised by a tension in some design parameter (for example 23B and 10C describe a trade-off between adaptability and airtightness), or by one agenda imposing on the other (24C, 07B). The data contains several examples of direct conflict (e.g. 23B, 14D), but conflict was also implied by the term "*whilst*" (01A, 07C, 24C). Where a requirement existed to incorporate both agendas *whilst* suggested they may not be congruent, and effort was required for reconciliation. Employed by clients *whilst* served as a warning (07B, 07C, 24C), used by supply side agents it reassured (e.g. 01A were keen to reassure customers a green strategy would not detriment the provision of "*space that can be simply adapted*").

[16] Note both these items also have contrary synergisms – e.g. low temperature heat installed as underfloor heating offered greater space planning possibilities than traditional radiators.

In contrast to conflict's see-saw like relationship between the agendas, competing casts them engaged in a tug of war, with incremental gains in one detrimental to the other. Whilst it is feasible that competition could arise through restrictions to other shared project resources (e.g. 07D might be an allusion to competition for design resource) competing was the least frequently observed of all the interaction types [2/86] and could only be explicitly linked to finite funding (19E). It is unlikely the paucity of evidence for competition is truly reflective of its prevalence in the cases, but rather an unwillingness to publish sensitive commercial decisions or be seen to concede sustainable design on budgetary grounds given that many of these documents were produced to demonstrate compliance with planning policy. Indeed there are descriptions of situations in which competition seems likely to have occurred, but for which it is impossible to be certain due to a lack of specific description: cases 25 and 46 describe value engineering (cost cutting) efforts that removed low carbon additions to the design (renewables being a particular target) but retained adaptable features, such as moveable walls for example.

5.3.4 NEUTRAL INTERACTION

Compatibility is a neutral interaction that has neither positive nor negative connotations for either agenda. Whereas no interaction (coexistence) has the agendas distinct and separate from one another, with compatibility (24H, 24K, 31D, 31J, 31L) the agendas coincide, often physically occupying the same spaces. There is no synergism, no beneficial effect from one agenda to the other. Rather, compatible interaction has the agendas working around one another. Compatibility has distinct connotations of conflict (particularly in an "undoing" sense, see below) avoided:

"*those glass screens can be slotted in, slotted out and the environmental strategy still works*" (31J)

While co-existence (no interaction) arises effortlessly from each agenda's disinterestedness in the other, compatible interaction suggests that if a particular approach had not been taken, conflict would have occurred.

5.3.5 POSITIVE INTERACTION

Positive interaction in the data was of two types, synergy and conflation.

Synergistic interactions occurred where the agendas were supportive - engaging in activities related to one would benefit the other. Terms associated with synergy include "*in addition*", "*not only*" (31E), "*also*" (16A.2), "*as well as*" (17B), "*and*" (07A, 17B, 25A) (used to describe tactics and technologies contributing to both agendas) and "*facilitate*" (24G, 31G) (describing how one agenda aided the other).

Twenty of the recorded interactions describe technologies or design approaches contributing to both adaptable and low carbon goals:

- Open plan spaces (24G, 31G) provided flexibility in furniture layout and spatial activity but also created clear air paths required for successful natural ventilation.
- Raised access floors were considered compatible with both flexible space planning and energy efficient displacement ventilation or underfloor heating (07A, 25A).
- Sub-metering and zoned controls (01B) allowed the building to be easily divided for sub-letting but also provided the ability to monitor energy use and switch off equipment in areas not in use.
- White painted surfaces (31E) created "*a blank canvas which workers will be able to personalise*" but also reflect light sufficiently to reduce lux levels and consequent lighting energy use.
- Exposed ductwork (19G) made services easily accessible and was expected to increase occupant awareness of energy consumption.
- A concrete frame (24I) created flexible obstruction free floor plates and acts as a thermal sink to smooth heating and cooling energy peaks.
- Good daylighting gave greater freedom of space use (17B) and reduced lighting requirements (17B, 31G and 48B)
- Performative architecture – using adaptability to deliver the low carbon strategy (46B)

Conflation occurred where one agenda was described exclusively in the other's terms. Conflated agendas give the impression that adaptability *is* a low carbon strategy, or low carbon buildings are, by their very nature, adaptable. Within the case study data, where adaptability was conflated with the low carbon agenda it was via the concept of embodied energy (16A.1, 31I). This is a logical extension of work in the embodied energy and adaptability fields that makes strong links between the two (e.g. Durmisevic, 2006; Pinder et al., 2013; Preservation Green Lab, 2011; Russell & Moffatt, 2001). Low carbon principles were conflated with adaptability in the manner of a prerequisite – it would not be desirable to adapt energy intensive buildings (11D, 19D). Conflation might be viewed as agenda creep, with some aspects of sustainability coming to be understood and justified by reference to other more accepted or palatable aspects.

5.3.6 MODIFICATION - DOING AND UNDOING

Despite UK legislation specifically excluding the effects of changing context by the use of standard assumptions and the omission of unregulated loads (Cheshire & Menezes, 2013), many of the projects reflected on the impact adaptability and change might have on the as-designed low carbon strategy. These reflections gave rise to the modification group of interactions, whereby adaptability permits the user to alter the building in a way which affects the low carbon design strategy for good or ill. Modification can be considered interaction offset in time – both agendas can be designed without interference from the other, but when the building is operational and the adaptability is made use of, a conflict or benefit arises. This is in contrast to the interactions described above that outline conflict and synergy during design. This means that these interactions were distinctly different to the types outlined above, which are concrete, in that they are hypothetical.

Construed as both a positive interaction ('doing' - improving the low carbon performance of the building) and a negative one ('undoing', whereby adaptability permits alteration counter to the logic of the low carbon strategy), modification is associated with scenario thinking, 'what if?' type analyses (24H, 31C, 31J), speculation on future occupant behaviour (06A, 09A) and consideration of the possible effects adaptability might have (16E, 35E, 48A.2). Interactions were categorised as modification where the interaction was predicted rather than encountered by the cases and where there was some projection of the building beyond an as-designed static representation.

Undoing arose from a consideration of what could be done to the building counter to the design intent, how adaptability could be misused. Misuse was seen as arising from three sources:

- occupant behaviour (06A, 09A, 31M)
- tenants fit-out choices (04G, 16E, 48A.2)
- long term owner behaviour (17E, 19H, 31A).

There are notable omissions in undoing: occupants frequently do 'bad' things to their buildings, such as drilling cables through airtight walls and infilling atria (14A), which were overlooked. Instead the projects chose to concentrate on change they had been explicitly asked to design for or was a requisite part of their building's typology (e.g. adding air conditioning at 24, partitioning the floor plate at 31), and occupant behaviours.

Typical examples of 'doing' interactions include:

- Orientation (11A, 16H) and roof loading allowances (04F, 10A, 16H, 19I, 20A) for photovoltaics or solar thermal panels;
- Installing modular plant to maintain optimal operating efficiencies through times of change (09B, 17F, 16G);
- Allocating space for later low carbon technologies (16H, 19A, 25C); and
- Installing biofuel capable boilers in anticipation of availability (16D, 21A).

There were also a range of more imaginative links, such as 19J's single tap basins.

The same interaction could frequently be construed as both doing and undoing, e.g. case 31 considers occupant control of windows as likely to lead to inefficiency (31M) while case 46 describes this "user control" as a central part of its adopted low carbon strategy (46B). Both are examples of occupant control being used to modify the low carbon design, but the cases hold different beliefs about the effect this interaction would have on the strategy. Interactions were categorised based on how the case chose to present the effect – as beneficial or counterproductive.

5.3.7 RELATIVE FREQUENCY OF INTERACTION TYPES

As noted above numerical comparison between the cases are somewhat suspect given the variable quality of the data. However, because there is no reason to suggest interactions were systematically removed or included across the sample it is felt some broad comment on the prevalence of each type across the set can be made (Table 5-3). This is presented with the additional caveat that several of the categories demonstrate strong overlap – undoing and conflict differ only in whether the problem was considered one of design or occupancy by the teams, while compatibility arises solely from the teams managing perceived conflict for example.

Table 5-3 Interaction type counts

Type	Sub-type	Count (N= 86)
Positive	Conflated	5
	Synergy	20
Modification	Doing	19
	Undoing	11
Negative	Compatible	8
	Conflict	20
	Competing	2

Negative interaction types [23/86] were less frequently observed than positive types [25/86]. This is a rather marginal difference given the source of the material – it was surprising to find the cases portraying problematic interaction in publicly available documents. A possible explanation is that negative interaction was as useful as the positive form in constructing arguments for planning, e.g. interaction was clearly being used as a persuasion tool at 35D where there is a strong desire (by the developer and planners) to install a wind turbine despite local opposition:

"In order to ensure the necessary structural support for the turbine as part of the construction of the building, planning permission is needed. Otherwise, the cost of installing the roof mounted turbines would increase sharply if they were retrofitted." (Wind turbine application, planning statement p3)

Conflict [20] and synergy [20] are the most frequently observed sub-types, although modification-doing [19] has a very similar level of occurrence. Because the difference between doing and undoing is largely one of perception the relative preference for doing [19/86 versus 11/86 undoing] may suggest a tendency by the designers to be optimistic in their predictions of occupant behaviour.

5.4 INTERACTION STRATEGIES

5.4.1 INTRODUCTION

Having established that interaction occurred in the cases, this section explores how the project teams managed it by reducing negative impacts, capitalising on positives or avoiding interaction entirely. These management actions are termed interaction strategies, and form the output for objective 2:

OB02: Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.

In developing the categories interactions with different intent were separated, the analysis concerning itself more with what the teams were trying to achieve than the outcome of their actions. However, mention is made throughout where strategies bear strong similarities in outcome. Outcomes will be dealt with more thoroughly in chapter 6.

This section of the chapter also begins to consider the likely motivations for different choices of strategy given similar interaction, in line with research objective 03:

OB03: Identify important factors in the section of approach for each identified instance, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.

Details of the narrative approach used to identify factors can be found in section 4.5.4.

5.4.3 OBSERVED INTERACTION STRATEGIES

The strategies were arrived at as described in chapter 4. Strategy classifications for each interaction are given in Table 5-2. Not all interactions were able to be allocated; some because of a lack of overt strategy (see section 5.4.3.1, below). These interactions are marked in Table 5-2.

Twelve strategies were identified, each associated with an interaction type, Table 5-4.

Table 5-4 Interaction strategies

Interaction type	Strategy
Conflict	• Avoidance • Compromise • Prioritisation • Mitigation
Synergy	• Exploitation
Modification	• Control • Permissiveness • Reconciliation • Retrofitting • Future-proofing • Hedging

Competition type interaction is not shown in the table due to very limited data [2 occurrences]. One of these was identified retrospectively (see 5.4.3.1) and is recorded as no strategy. The second competition interaction was solved using a prioritisation strategy (5.4.3.6). Conflation has a larger number of interactions recorded [5], but due to the nature of these interactions as a statement of fact many were not associated with a particular interaction strategy (see 5.4.3.1). The remaining conflation strategies are discussed in section 5.4.4 as they have a high similarity with those of synergy.

5.4.3.1 *NO STRATEGY*

Thirteen interactions are recorded as demonstrating no strategy (marked 'none' in Table 5-2). These arise for a number of reasons:

- The text segments describe interaction with no corresponding description of how that interaction was managed (17A, 25F, 31I).
- Incidental interaction, where interaction seemingly went unnoticed by the cases. This required a feature to be explicitly, but separately, described as meeting some aim of both agendas (19G, 48B).
- Interaction noted after the building had been completed (14A, 16J, 19E and 46A).

Data for the latter arises almost solely as a result of interviewee reflection[17]: retrospectively interviewees identified adaptability or low carbon design decisions which had later consequences as a result of interaction. All of the examples are negative type interactions but given the limited data available from which to infer, there is no reason why synergistic interactions might not be similarly overlooked only to be later exploited by owners and occupants.

With respect to design interactions passing unseen, two cases describe aspects of their building having both adaptable and low carbon qualities yet make no obvious connection between the two. Interviewee 19 articulates the exposed services of the building as central to an energy efficiency design concept – "*you can see the ductwork when you look up…So you're conscious of the energy you're using*", but elsewhere is insistent the "*services are all exposed so that access to them will be gained if and when needed*". There is also a duality to the decision making that is also evident in 48B's grand spaces, where the narrative is one of separate decisions for adaptability and low carbon ideals that happened (from the perspective of an external observer) to coincide. This effect could be labelled as good design – good daylighting, generous proportions: these are the natural overlaps in the two agendas.

Case 11 is a peculiar example of incidental interaction. Given the design team's preoccupation with low carbon design ("*when we set up twenty years ago we specifically wanted to design low energy buildings*" Interview 11) it seemed odd that no prioritisation actions (see 5.4.3.6) were found in the data. In fact very few interactions were located in the documentary evidence and it was only when prompted during interview that low carbon decisions impacting on adaptability were identified:

> *"Interviewer [referencing earlier talk about the unadaptable Victorian pool building]: Is that because they have learnt on the old pool that that's difficult to do?*
>
> *Interviewee 11: No, erm…possibly but it's mainly us learning from the German example of laying things out nicely and having access to them and you know."*

On reflection case 11's low carbon interpretation of sustainability led to a situation in which it was designed exclusively for low carbon operation. Case 11 displays minimal interaction strategies because its designers pursue so extreme a variety of prioritisation that adaptability is never considered, any interaction evident is entirely accidental.

[17] The exception being case 14, an existing building where the design was able to reflect on previous use.

5.4.3.3 *DEALING WITH CONFLICT*

Four approaches to dealing with conflict were identified: prioritise, compromise, mitigate and avoid:

- Avoiders selected an alternative piece of technology or design tactic for which there was either no interaction (06D) or a more synergistic combination (35D), making use of the fact that whether conflict arises or not was dependent on the particular adaptability / low carbon combination.
- Compromisers approached conflict as an optimisation problem, a need to "*balance*" (31F) competing ideas. Often described as an iterative back and forth process characterised by a series of moves and counter moves towards a "*pragmatic*" (24C) solution, compromise manifests as a juggling of design priorities. Inherent in compromise is that the solution will be in some way compromised, it will be sub-optimal from the perspective of a single agenda.
- Mitigaters allowed one agenda to prevail, but sought to limit its detrimental effect through the addition of otherwise unnecessary design features.
- Prioritisers chose to deal with conflict by allowing one agenda to hold supremacy over the other. This resulted in the inclusion of low carbon aspects that restrict future change (19K, 07D) or adaptability that is "*counter to the concept and science*" (10C) of low carbon design.

5.4.3.4 *AVOIDANCE*

Avoidance was the least used [2/86] of the conflict strategies, possibly because project teams chose not to articulate dismissed alternatives unless they were required to do so (e.g. interaction 35D is found within a low zero carbon feasibility report complied for BREEAM credit which explicitly requires a discussion of "*all technologies appropriate to the site and energy demand of the development…[and] reasons for excluding other technologies*" (BRE Global, 2011)). The avoidance strategies that were observed were reactions to restricting low carbon technologies i.e. those that required large amounts of space or imposed restrictions on the systems they could be connected to. These were rejected in favour of more change compatible alternatives. (Where these alternatives resulted in the selection of a less suitable solution a blurring with compromise strategies occurs, as a sub-optimal choice selected was made marry the agendas.) No examples of avoiding adaptability were observed.

Understanding why avoidance was pursued is difficult because of the limited number of avoidance strategies observed, although obviously to be practical a viable alternative must be available. Based on the two examples (both of which are very similar and thus offer limited scope to examine variation) two plausible causation factors are identifiable: Firstly both avoidance examples concern renewables. Comparing a number of information sources for each case, avoidance was a side effect of a desire to avoid installing expensive LZC technologies where other, cheaper alternatives were available. Current renewables practice tends towards requiring the designer to rule out, rather than select for inclusion, LZC technologies (e.g. BREEAM's Ene04 credit). Thus design teams constructed arguments dismissing costly and unwanted technologies, making reference to a number of reasons for non-suitability including reductions in adaptability (e.g. see 35D's stacked argument). Essentially, having made a decision not to install on cost grounds conflict with adaptability is noted to strengthen the argument against installation rather than record the decision making process (reflecting the documents use as an instrument of persuasion - see 4.4.2).

Secondly the two examples of avoidance both occur within cases commissioned by clients likely to retain a long term hold and expect to expand – case 06 are rebuilds of existing schools currently operating in part out of temporary classrooms to manage demand bulges (Case 06.1 Planning Statement, p5), while case 35 is a campus development with vague, but long term, expansion plans (Case 35 Design and access statement, p25). Other cases with no long term interest in accommodating expansion made no reference to adaptability in dismissing unsuitable renewables (e.g. 16H).

5.4.3.5 *COMPROMISE*

Compromise was one of the more frequently used strategies [8/86] and was generally framed as an unfortunate necessity, only case 31 seeming to promote it. Two compromise tactics were evident within the data. Firstly where a solution could be pared back or partially installed, as with the photovoltaics at 04B, the teams were presented with an obvious opportunity to compromise. Exposing only some thermal mass elements (14D) and limiting the areas to which cooling is provided (19L) are similar examples. Secondly, project teams were able to specify limits within which both agendas must perform, e.g. 07C describes the need to provide adaptable spaces without "*unreasonable*" energy consumption. The particular tactic chosen was specific to the aspects involved – modular and distributed technologies lent themselves to reduction tactics for example.

Where compromise was adopted as a design strategy, a strong reason for the designer to pursue a balance of adaptability and low carbon design ideas was required. This included strong client briefs for adaptable, energy efficient buildings or typologies where such a brief was implied – schools for instance should be "*flexible … without unreasonable energy consumption*" (07C). Many clients (07B, 31F and 24C, 07C both in part) recognised the conflict in their requirements and challenged design teams to propose acceptable compromises, although in some instances design teams were able to propose alternative strategies for conflict management: 07B's pessimistic view of a harmonious ventilation system is responded to by 07A's synergistic solution of "*raised access floor with underfloor heating providing enhanced flexibility, energy efficiency and comfort*" for example.

Compromise was often difficult to disentangle from prioritisation (5.4.3.6): whilst true compromise resulted in a sub-optimal solution from both adaptability and low carbon perspectives, compromisers could in some instances be seen to favour one agenda over the other (e.g. 24C), choosing to present one agenda as core to the design problem, with the other agenda operating as a design constraint. This meant one agenda was tackled first (albeit with the constraint in mind) and the latter then optimised within the selected solution. Similarly where an agenda was prioritised within some limit, it could be considered a compromise strategy.

5.4.3.6 *PRIORITISATION*

While in some cases prioritisation resulted from exhausting other options (there were no alternatives available and compromise was impractical or resulted in too poor a solution, e.g. 24F) the majority of prioritising was a deliberate decision to optimise one agenda to the detriment of the other. These prioritisers made no attempt to design around the problem by avoidance, compromise or redesigning for compatibility. Examples such as these cast prioritisation as a means 'solve' the interaction design problem by imposing additional criteria, constructing arguments for why one agenda is more important and cannot be sacrificed in aid of the other: 23B belittles the importance of adaptability ("*it's a small consideration*") and describes the prioritisation process as "*justified…by the excellent performance [of the low carbon approach]*" for example.

Prioritising resulted from a mix of factors, some beliefs of what a given building should look like or incorporate, and others tightly related to the specific context the prioritisation decision was made within. Examples of the former include typologies where adaptability or energy efficient design was expected (01A, 10C), and traditional design practices that emphasised a particular agenda (e.g. 07D). The latter were much more varied, in line with the variety of prioritisation decisions observed and included location (14E, 19K), planning constraints (19K), client brief (24F) and visual impact (14E, 23B) amongst others. The importance of specific issues meant that the cases were by no means consistent in prioritising one agenda over the other; for example interactions 31C and 31M share a case context but adopt very different approaches due to differences in the costs of low carbon prioritisation.

5.4.3.8 *MITIGATION*

Mitigation prioritises one agenda but attempts to reduce the detrimental impact on the other by installing additional features:

> *"Things are designed with so much bunce in them it's going to be a long time before say the climate change is going to have an impact where 'oh my god, add these systems'. I think the key seems to be mitigating the impact from an energy point of view." (17C)*

Mitigation was only observed as attempts to decarbonise adaptable buildings, no examples of re-introducing flexibility into low carbon designs were observed. This might suggest adaptability to be a more fundamental design component than low carbon design with its obvious potential for bolt-on solutions ('green bling'). Yet, perhaps because of the early stage at which the cases were observed, the limited mitigation strategies[18] available for analysis [3] shied away from renewables in favour of more low tech solutions (17C's thermal mass) and better informed occupants (25D's indicator panel). Thus mitigation in the data is associated with passive design and in particular a desire for passive design in buildings where a totally passive solution was impractical (e.g. case 01 and 17 are intensively occupied offices which are cooling dominated).

5.4.4 STRATEGIES FOR SYNERGY AND CONFLATION – EXPLOITATION

In comparison to conflict, synergy (and conflation where a strategy was adopted) have a much narrower range of strategies, perhaps because there was less of a need to manage something that did not pose a problem. The strategies that were identified are best described as a family of three tactics used to exploit synergies and deliver improved performance over what might otherwise be obtained:

- **Win-wins** describe a buy-one-get-one-free mentality: technology X "not only" (31E) does this, it does that too, approach Y does this "as well as" (17B) that. Win-wins are included for one desired agenda, but have ancillary benefits.
- **Multi-purpose solutions** are specifically selected to meet the goals of both agendas: that a particular design decision embodies aspects of both agendas is a requirement for its selection. Multi-purpose decisions tended to relate to major elements – frame (24I), floors (07A, 25A), ventilation schemes (07A, 25A, 19F) and roofs (23C).

[18] While there are few examples within the limited scope of this analysis, within the un-used CCA data mitigation was more prolific – e.g. some of those teams resorting to retrofitted mechanical cooling chose to 'offset' the resulting carbon emissions with renewable technologies.

- **Facilitation** ‘piggybacks’ one approach on the other: teams described an agenda “increasing its potential” (17B) or being used “to facilitate” (24G). Facilitation aides the second agenda rather than outright replaces the need to design for it. Facilitation tended to be related to general principles - open plan layouts (24G) and good day-lighting (31G) that are considered helpful in creating both adaptable and low carbon spaces.

Exploitation is a deliberate mobilisation of synergy for some ends. Examples of synergy that did not demonstrate this deliberateness, but instead a serendipitous overlap in the agendas (e.g. 01B, 48B) were considered examples of no strategy and are discussed above (5.4.3.1).

From a causal perspective facilitation largely followed from the principles of good design, similar to incidental synergy (5.4.3.1). Win-wins seem likely to have been more post-rationalised success than actively pursued strategy in many cases (see for example 31E), noted because of planning policy or similar requirements suggesting adaptability and low carbon design to be related. Assessment schemes such as BREEAM are also implicated (01A) in the pursuit of win-wins, inciting the cases to install synergistic features beyond what they might normally have considered.

Understanding the motivation for multipurpose solutions was problematic, cases tended to portray their selections as the obvious culmination of a logical decision making process (24I) rather than the product of specific factors. The multi-disciplinary nature of these solutions (raised access floors as spatial and services solution, concrete frame as structural support and HVAC component) do however suggest coordinated teams and/or more complex designs were important.

5.4.5 STRATEGIES FOR MODIFICATION – PREVENT, ALLOW, ENCOURAGE

When faced with the prospect of adaptability permitting owners and occupants to influence how well the low carbon aspects of a design worked, the cases adopted a number of strategies:

- Designing change out to preserve the low carbon strategy (control)
- Designing so that change could occur without detriment to the strategy (reconciliation)
- Accept the possibility of change on the low carbon strategy (permissive)
- Making change part of the low carbon strategy (retrofit, future-proof)

A further strategy, facilitated un-doing, embraces change similar to retrofit but does so in a manner counter to low carbon thinking: facilitated un-doing actively encourages users and future owners to alter the building in ways counter to the low carbon agenda. There are specific circumstances surrounding its application that are expanded upon below.

In general the approaches adopted can be considered attempts to prevent change (control), allow change (reconciliation, permissive) and encourage change (retrofit, futureproof and facilitated-undoing).

5.4.5.1 *CONTROL*

Those adopting control type strategies described adjustable change as akin to granting a licence for inefficiency ("*people will go home and leave the windows open*" 31C), presenting owners with the opportunity to make "*unsustainable [energy using] interventions*" (04G). Thus control strategies attempt to dissuade or prevent future tampering with the 'as-designed', idealised low carbon solution. This restriction of adaptability in favour of reducing energy use makes control a form of low carbon prioritising (see 5.4.3.6).

Some aspects were more amendable to control than others; while 31C/K were able to completely remove the ability of occupants to compromise the envelope's air tightness and the effectiveness of heat recovery by sealing the facade, 04G could only attempt to avert the possibility by pre-installing the 'better' choice. Others tried to control through the imposition of rules of the user:

"*But what we've said to the School of Architecture is, if you can keep your high powered up that end, because they do need some of that. And then the rest of it's designed for thin clients…*" Interview 19

This example at 19L provides a direct contrast to 09A (a permissive interaction – see 5.4.5.2), who choose to design to a worst case scenario with regard to computing heat generation because "*if you are turning up as a visiting researcher you would use the machine that you've got and I don't think we could stop you.*" (09A). The decision making at 19L has an amount of calculated risk involved: there is an expected move towards more efficient computing, Greenwich will occupy the building themselves with a consequent improved ability to police the decision, and there is some over-provision beyond the expected need ("*whether they all get turned on, on day one, who knows?*" Interview 19), but ultimately 19L is more trusting of its user than 09A.

There are two likely candidates for the motivations surrounding the pursuit of control strategies. Firstly the desire to control and prevent occupants 'damaging' a building is an existing theme within the adaptability literature (e.g. Till, 2013), where architects' 'preciousness' towards their designs creates barriers to adaptability. Preciousness in the adaptability literature is normally confined to the building aesthetic, and there is no prior evidence of this in relation to energy efficiency design. There is also the option that control is an attempt to improve reliability of energy use predictions. For example case 31's pursuit of a control strategy appears to, at least in part, have been motivated by a contractual requirement to deliver a DEC A building and a consequent nervousness to leave too much "down to the owner occupiers" (31C).

In terms of the ability to implement a control strategy, typology was important – large, office type environments were more accepting of HVAC control than residential settings, which tended to adopt a stance of prioritising adaptability to the detriment of the low carbon strategy (e.g. 10C). Similarly buildings with complex approaches to their low carbon strategy were seemingly more likely to remove control from the user, although 25D bucks this trend by attempting to better inform users with a mitigation strategy. This is perhaps a trust issue, with designers more willing to trust occupants adopting a permissive strategy (see 5.4.5.2). There is also evidence that (as for avoidance) control was sometimes pursued for reasons ancillary to the interaction itself – at 31C for example noise and pollution from the nearby ring road preclude a more user engaging natural ventilation strategy.

5.4.5.2 *PERMISSIVENESS*

Permissiveness evidenced as either an unwillingness to dictate how the building might be fitted-out and occupied (48A.1, 6E), or a sense of futility in trying to dictate (09A). Non-imposers were often willing to "*recommend*" (16E) that certain things were done, but felt they were "*unable to dictate*" (48.2A) and thus excused themselves from the responsibility of providing or guaranteeing aspects of the low carbon design felt to be owned by others. Along with retrofit (5.4.5.4) and future-proof (5.4.5.5) strategies, permissiveness provides an option to undertake low carbon actions, imparting a responsibility on the owner / occupant to act responsibly.

Non imposition of two sorts was evident in the data – low carbon base builds (16E, 48.2A) demonstrating indifference to the fit-out aspects of the building perceived as the remit of others, and designing energy consuming systems for a worst case scenario (09A). Similarly to control strategies, there was limited consistency in the adoption of the strategy with case 48 both removing control of plant installations from tenants (48A.1) while simultaneously divesting themselves of responsibility for lighting efficiency (48A.2).

Non-imposition was almost exclusively the preserve of developments designed to be tenanted (either at completion or some future point). These shell-and-core developments allowed tenant choice, but also provided a means for developers to absolve themselves of the detailed aspects of low carbon design – presenting themselves as powerless to control tenants:

> *"Network Rail is unable to dictate the lighting solutions and requirements for unknown future tenants" Interaction 48A.2*

This non-imposition is inherent to speculative building and allowed for in both UK building regulations (Part L paragraphs 4.25 and 4.26) and BREEAM.

The exception to the developer rule is case 31, presenting an oddity in that it both adopts a control strategy elsewhere (31C), and is intended (at least initially) to be solely occupied by the Cooperative group. The Cooperative Group is a 'green' client ("*The ethical sustainable thing is what the Co-operative Movement is all about*", Interview case 31), determined to operate the building in an efficient manner ("*the client is so acutely focussed on cost in use of this building that there will be staff training, there will be all sorts of protocols*" Interview case 31). This seems to have fostered a sense of security in the designers that the adaptability would not be misused where it was police-able.

5.4.5.3 *RECONCILIATION*

Reconciliation is a conscious design decision to ensure the two agendas are compatible; it implies the deliberate selection of adaptability and low carbon tactics to enable the agendas to operate un-hindered. There is an emphasis on interaction management as a design activity, with the examples uncovered describing how the building "*has been designed*" (31D) to avoid interaction. Those engaging in compatible design described accommodating adaptability within the low carbon philosophy ("*we had to design the building anticipating*" (31J), "*the building needed to be designed so that, if in the future…*" (31J), as well as ensuring adaptability would not be limited by the strategy adopted (24H).

Reconciliation is similar to compromise in requiring a strong commitment to maintaining both adaptability and low carbon principles within the design. What pushed teams to design for compatibility rather than compromise was the presence of specific requirements for adaptability – known change. For example the cooperative group's brief for case 31 was clear on the need for sub-letting provision:

> *"they had some physical constraints within the brief that the floor plates ideally should be no less than 20,000 sq ft because that gives them a big floor plate, but it can also be sub-divided. They wanted maximum flexibility in terms of sub-division at a later date to future-proof the design." Interview 31*

And it was possible for this requirement to be specified quite explicitly:

> *"…this building is in Manchester, so if you can design a building that's flexible enough to accommodate the smallest requirement, i.e. three or 5,000 sq ft, but could also give ten or*

fifteen or twenty, everything up to thirty, then you've covered all your bases and that provides an immense amount of resilience in the design" Interview 31

This precision delimited the problem sufficiently to allow the team to demonstrate how the ventilation system would operate both with open floor plates and sub-let enclosed compartments (31J), something that might not have been possible with a more open brief and a multiplicity of scenarios. Essentially known change allowed designers to consider a particular, limited, range of scenarios of building configurations when conceiving the design solution and thus demonstrate compatibility.

Reconciliation did not occur in cases where compromise was driven by planners or designers; a strong client commitment (evident at both case 31 and 24) was important. The timeliness of this commitment similarly appeared central to the adoption of a compatibility approach over one of compromise or prioritisation, perhaps because clients input into how the building would be operated was required early on for the detail of compatibility scenarios to be worked out. The problems with commissioning identified within interaction 16J for instance seemingly arise from a necessary dislocation of developer driven base build and a later client led fit out.

5.4.5.4 *RETROFITTING*

Retrofitters added adaptive capacity to their designs allowing the addition of renewable technologies at some future date, providing the means to increase the energy performance beyond the 'as-designed'. Retrofit strategies are therefore strongly aligned to 'doing' interpretations of modification type interaction. Retrofitters make the building more adaptable as they exclusively employ adaptability techniques: increased loading allowances (04F, 10A, 19I), extra connection points (19I) and extra service distribution (17D).

Building regulations, planning and BREEAM all assess as-designed performance therefore retrofitters had to ensure their buildings met minimum compliance criteria before pursuing the strategy. The cases employed passive design principles to do this, choosing either to prioritise passive design from the outset (16H) or after value-engineering (VE) out active elements (10A). Items to be retrofitted were predominantly renewables, perhaps because they are easily retrofitted (and, as 'bolt on' solutions, easily removed in VE exercises) but also because they were expensive: adaptability was cheaper than incorporating them at the outset. Thus retrofitting was used to push low carbon costs out of the capital budget by postponing them.

The rationale for postponement required a desire for low carbon design coupled with obstacles preventing immediate installation. The desire could be client driven (as a case 19), design driven (10A, 17D) or the result of planning policy (16H, 19A, 20A, 35C, 48A.1). Barriers were most frequently financial although there was evidence of other constraints – case 19 is restricted by statutory agencies (19I) and the protected view of St Paul's cathedral (19A) for instance. Financial barriers were of two types: a limited capital budget with which to deliver the project or an unwillingness to pay for expensive, non-essential additions. The former tended to include aspirational clients or design teams paired with limited capital budgets (04F, 10A) or funding cuts and the resultant value engineering exercises (25C) - the school projects in particular suffered heavily as the result of upheaval in BSF funding circa 2010. The latter were developers, reluctant to commission expensive renewables they would not benefit from. This situation is commonly termed the 'principle agent' problem (3.4.3) and presents a known barrier to the inclusion of non-essential items that deliver savings to occupiers over the long term. What had not been identified prior to this study is the use of adaptability to provide a low cost alternative to the immediate installation of low carbon technologies.

5.4.5.5 *FUTURE-PROOFING*

Retrofit seeks to enrol the building's owner in an incremental low carbon strategy, whereby the building is designed to be added to in a manner which would improve its low carbon performance. Future-proofing, in contrast, casts contextual change as a potential threat to the low carbon ideal unless the building is sufficiently able to adapt. Future-proofers mobilise adaptability to ensure the building continues to run efficiently. Adaptability for future-proofers is a means of ensuring the building can respond to a changing climate (09B, 17F) or occupancy (09A) in a way that maintains the status quo – there is no attempt to improve carbon performance beyond the as – designed:

> *"…buildings may not need as large a boiler capacity in the future. For the EBI2 building, it might be worth considering modular units of smaller sized boilers, which when not required, could be switched off so that ones that are operating will continue to run at optimal efficiencies." (Interaction 09B)*

This means future-proofers are concerned with changes perceived as known and unavoidable. Future proofers were the exclusive preserve of CCA strategists (who take increases in temperature as given), and were primarily suggested for buildings with long term ownership by a risk adverse client.

5.4.5.7 *FACILITATED UNDOING*

Facilitated undoing was observed only as a product of the climate adaptation studies. It is included in the main analysis as both of these projects (cases 17 and 19) were able to convince their clients to install, in contrast to the majority of other suggestions made by these teams and others across the D4FC programme. It may be significant that both cases were undertaken by the same lead consultant.

Facilitated un-doing is the deliberate provision of adaptability to enable or simplify later installation of energy consuming equipment, or 'undoing' of the low carbon strategy. Within the data this manifests only as additional loading capacity for cost effective and non-disruptive retrofitting of additional cooling plant, although other techniques are feasible. Facilitated un-doing actions look very much like those of retrofitters (5.4.5.4), the difference is entirely one of intent; the access, load allowances and additional connection points for renewables retrofit are likely to be equally beneficial should an owner decide to install less saintly equipment.

Interestingly none of the systems, such as raised access flooring (cases 01, 07, 17, 23, 24, 31) or over provision of service connection points (19, 24) designed to assist in the re-planning and expansion of building services were linked by any of the cases to facilitated undoing. This is despite examples such as cases 19 demonstrating a clear understanding such tactics would be used to increase the amount of power-using equipment within the building:

> *"Why did we do that? We did that because you never have enough power and data in a building for your use in 20 years' time." Interview 19*

In the discussion surrounding this statement there is no indication such increases might be undesirable from a low carbon point of view; instead there is an almost inevitability to the expansion, an unstoppable change that the adaptability merely orders:

> *"So rather than having someone tack on horrible services in the future, we just made the provision for them to easily run it, now a little bit bigger, so that they stick to the design principle. The building doesn't look old and tired when someone runs a cable up the wall in their own bulldog clip fashion." Interview 19*

Why did the two teams feel this un-doing was justified? Both buildings are mixed mode and already incorporated cooling equipment, meaning adaptability provides an extension to the existing provision rather than an outright addition. Thus it might have been seen that the building failed in future whereas other buildings with no cooling equipment resorted to overheating 'management' options. Both buildings were commissioned by clients who intend to occupy them for some considerable length of time (OUP has been at their current site for some 180 years - OUP Design and Access Statement), and have been subjected to the difficulties with adapting their existing buildings to accommodate change (*"in a World Heritage site you can't move a wall. The footprint is what it is and there are lots of secular rooms. Some of them are nice big open spaces, but lots of them are secular rooms ..."* Interview 19; OUP Design and Access Statement, p6). Thus these clients might have been more susceptible to simple measures that could aid future improvements.

5.4.5.8 *HEDGING*

Hedging is a risk management strategy. Hedgers talk about "*later*" and "*in future*", with interaction arrived at through a deliberate mashing of adaptability and low carbon design ideas to avoid locking the building into a particular low carbon path. Key hedging tactics include the provision of adaptable LZC technologies (predominately CHP in the examined sample), designing the development to be amenable to the addition of new expensive or unproven technologies. This means that, unlike retrofit and facilitated un-doing, whose general adaptability provisions may in fact find themselves used for different purposes (e.g. using PV roof load allowances to install a green roof) hedging does not significantly increase the building's general adaptability.

Somewhat surprisingly, there were a large number of interactions arising from this use of adaptability to manage risk. While a number of authors have commented on the use of adaptability to reduce the costs of likely change later as a motivating reason for its use (Ball, 2002; Ellison & Sayce, 2007), there was no evidence to suggest this might be extended to reducing the risk associated with new technologies, although it is perhaps an obvious extension. Construction is a notoriously innovation adverse industry, reticent to adopt new, unproven ideas. This is evident in the cases themselves[19] and seems, at least in part, responsible for some of the hedging employed: Low carbon design was undergoing a tumultuous period of legislative uncertainty, fluctuating energy costs and rapid decreases in the cost of low carbon technologies as the market matured. Developers waited impatiently for finalisation of changes to the building regulations fixing carbon reduction targets, a concrete definition of 'zero carbon' and the permissibility of allowable solutions. In this context hedging was prevalent amongst commercially minded developers of large sites, whose construction period would span a number of years. Developers sought to minimise the risk of uplifts in renewables requirements (11A) and for those with a long term hold, minimise the risk of relying

[19] "*there was one design team meeting where he [the client] said, "The design ethos of this building is pragmatic innovation," … there should be nothing that's untried and tested on this building. This building wasn't to be a testing ground or a mule for some new technologies that were being developed. We were to use technologies which we know work and we know they've been used before.*" Interview 31

on a single energy source that might not in future deliver the best savings (31B, 35E). Hedging was used both to ensure a building was saleable and to allow a phased development some openness to new (potentially more cost effective) low carbon solutions that might become available over the masterplan programme.

Hedging was prevalent in the larger London based cases, which were subject to GLA requirements for district heating and promises of the imminent availability of a reliable bio-fuel supply. These cases were able to demonstrate significant savings in carbon emissions using biofuel, but were reluctant to rely on the GLA's promised security of supply, hedging with the installation of multi-fuel CHP (16D, 21A). 'Exemplar' cases 16 and 25, where planners expected the incorporation of cutting edge elements the developers were uncomfortable with, were also punctuated with examples of hedging (16D, 25C).

5.4.6 FREQUENCY OF INTERACTION STRATEGIES AND THEIR RELATIONSHIP TO INTERACTION TYPE

Table 5-5 summaries the number of times each strategy was observed, split by interaction type. As the strategies overlap to varying degrees (as noted in the text above), the table should be interpreted with caution and only general remarks are made.

Table 5-5 Frequency of interaction strategies split by interaction type

		Interaction Type						
Interaction Strategy	**Frequency**	Conflated	Synergy	Compatible	Conflict	Competing	Doing	Undoing
Avoid	2	0	0	0	2	0	0	0
Prioritise	7	0	0	0	6	1	0	0
Compromise	8	0	0	0	8	0	0	0
Mitigate	3	0	0	0	3	0	0	0
Exploit	17	2	15	0	0	0	0	0
Control	2	0	0	0	0	0	0	2
Permissive	4	0	0	0	0	0	0	4
Reconciliation	7	0	0	7	0	0	0	0
Retrofit	11	0	0	0	0	0	11	0
Future proof	2	0	0	0	0	0	2	0
Facilitated un-doing	2	0	0	0	0	0	0	2
Hedge	6	0	0	0	0	0	5	1
None	13	3	5	1	1	1	1	1
Total		5	20	8	20	2	19	10

The table reveals that, as might be expected, different types of interaction generated different strategies. What is also apparent reading vertically from Table 5-5 is that there were different approaches to dealing with a given interaction type (conflict can be addressed in multiple ways for instance). In choosing between type relevant strategies situational factors were important, as described above. These situational factors meant that, as each interaction had a different local decision context, the cases were not consistent in their choice of strategy and adopted a pick and mix of approaches, Figure 5-8.

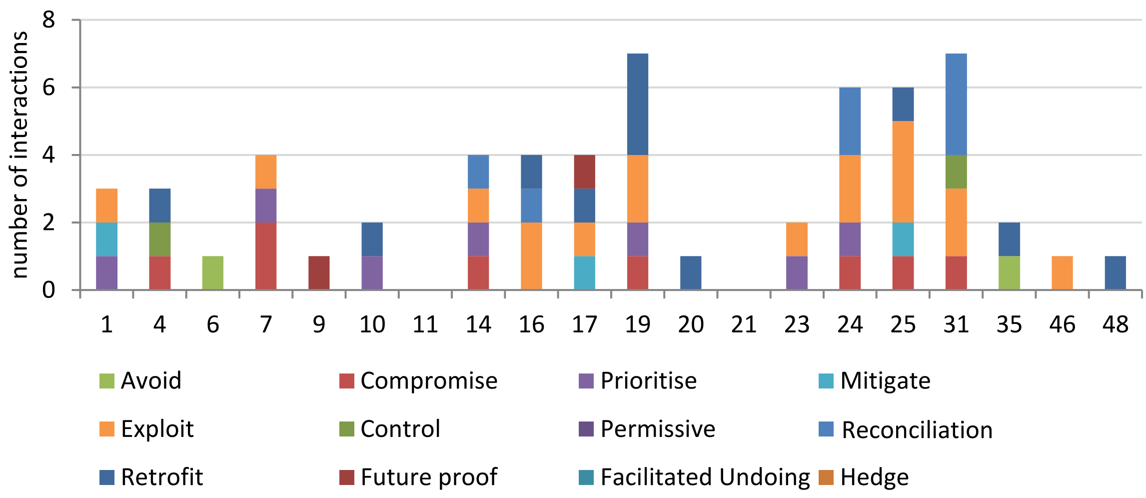


Figure 5-8 Bar chart illustrating the variation in interaction strategy choice within each case

5.5 CHAPTER CONCLUSION

This chapter has identified interaction between two sustainability principles, adaptability and low carbon, occurring in 20 case study building design processes. 83 interaction examples were uncovered, describable using seven interaction 'types'. These seven types can be broadly placed into one of four broader categories - positive, negative, neutral and modification interaction. Together the seven types and four subsuming categories form an empirical typology (specific to the cases studied) describing interaction in building design. The chapter has also demonstrated how each interaction type was associated with a number of interaction management strategies, selected by the cases depending on the particular requirements of their project situation and their understanding of what would, or should work best.

The findings of the chapter are summarised in Figure 5-9.

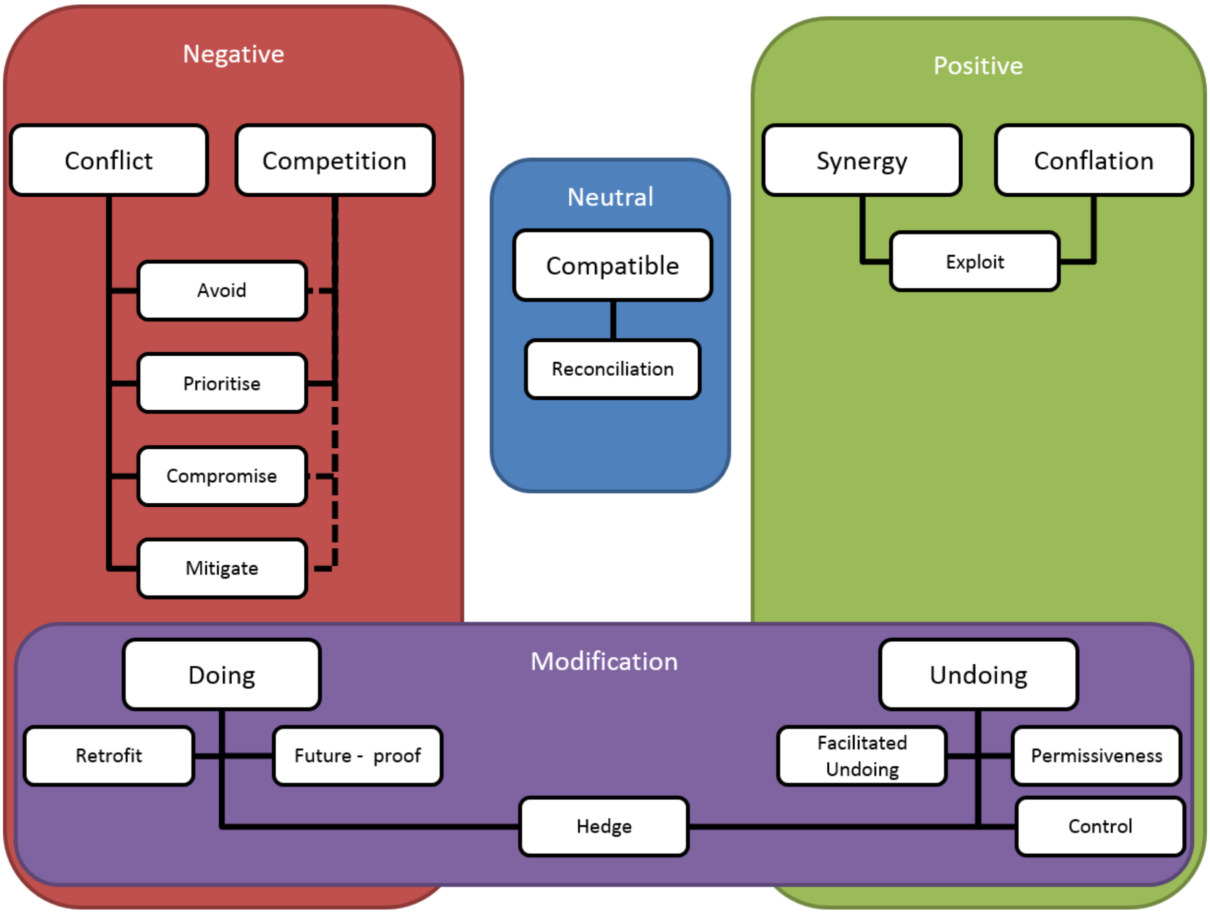


Figure 5-9 Types of interaction and associated strategies (dotted lines indicated hypothesized links)

6 SUSTAINABLE OUTCOMES / RECONCILIATION

6.1 INTRODUCTION

Chapters 1 and 3 have argued the many diverse and seemingly unrelated sustainable building agendas are not as easily integrated as much of the construction literature assumes. Rather, holistic sustainability requires effort – it is necessary to reconcile the requirements into a coherent 'sustainable' design. To better understand the possibility of reconciling different sustainability ideals, this chapter considers how successful the 23 case studies were in producing simultaneously adaptable and energy efficient designs. This will be achieved by addressing objective four:

> *OB04: Operationalize the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successful in reconciling low carbon and adaptability principles.*

The cases will be assessed using the method outlined in chapter 4, where reconciliation was defined as success in achieving best practice adaptable and low carbon design simultaneously.

Successfulness will be measured by assessing adaptability and low carbon success separately and combining the result – see method, section 4.6.3. Case 14 will not be assessed for reasons outlined in section 4.4.3. All buildings will be assessed as designed, rather than as built or occupied, because of this study's interest in how sustainability is defined during design. Results of the low carbon assessment are presented first, section 6.2, followed by adaptability results in section 6.3. Results are combined in section 6.4 to determine each case's successfulness in reconciling adaptable and low carbon design requirements.

6.2 LOW CARBON

6.2.1 INTRODUCTION

Low carbon buildings were defined in chapter 2 as:

> *"Buildings which are designed to use significantly less regulated energy and emit less carbon than current industry standards in their typical operation"*

The chapter also discussed a range of indicators of carbon performance currently in use. Of these indicators, the energy performance certificate (EPC) asset rating (AR) (or for domestic buildings the Environmental Impact Rating (EIR)) was identified as the most practical means of assessing each case (see section 4.6.3.1). However, a variety of data was collected relating to the low carbon outcome because it was unknown what data would be available. This data is summarised in Table 6-2.

As expected, the information available varied depending on the progress of the project (completed projects having more data than those that stalled post planning), the size of the scheme and to a lesser extent the availability of interview evidence. Primarily the cases chose to describe low carbon aspirations and compliance using BREEAM classifications and percentage improvements to Part L of the building regulations. Some cases provided estimated EPC asset ratings and a limited number also gave kWh/m2.yr and/or kgCO2/m2.yr figures to comply with local planning submission requirements. The majority of the cases had asset rating or similar data available and presented their interpretation of low carbon ideas in a manner compatible with the EPC asset rating.

The following sections describe how the data was interpreted to allocate each case to the low carbon / not low carbon sets. Residential and non-residential buildings are assessed separately as they are subject to different regulations (Part L1 and Part L2 respectively). The descriptions are further split into those cases where quantitative evidence was available and those where a qualitative judgement was made, see Table 6-1. Qualitative judgements where cases lacked EPC certificates or other comparable quantitative information.

Table 6-1 Case outcome results – chapter location map

	Quantitative evidence	Qualitative evidence
Domestic buildings	Section 5.2.2.1 04 – British Trimmings Extracare 38 - Site J / SuperB	Section 5.2.2.2 11 – St Loyes Extra Care
Non domestic buildings	Section 5.2.3.1 01 – Admiral HQ 06 – Wyre Forest Schools 07 – Harris Academy 09 – Technical Hub @ EBI 10 – Edge Lane 16 – University of Arts London, KX 17 – Oxford University Press 19 – Stockwell St 20 – Church View 23 – Trowbridge Council Hub 24 – Sheffield Graduate School 25 – Ebbw Vale School 31 – Cooperative HQ 35 – ESI 46 – Hinguar School 47 – Westbrook Primary	Section 5.2.3.2 21 – Great Ormond Street 48 – London Bridge Station

Table 6-2 Summary of low carbon outcome data

	Case Name	Asset Rating (estimates in brackets)		BER or DER ($kgCO2/m^2$)	BREEAM score	BREEAM Rating	CSH Score	CSH Level	Planning Conditions
1	Admiral Insurance Headquarters	34	B	14.15	-	Excellent	n/a	n/a	BREEAM Excellent, minimum of 6 Ene01 credits
4	British Trimmings Extra Care Home (Daisy Haye)	86-90	B	-	n/a	n/a	-	3	None.
6.1	Wyre Forest Schools Offmore Primary	41	B	20.55	73.80%	Excellent	n/a	n/a	BREEAM Very Good
6.2	Wyre Forest Schools St Catherine's Primary	50	B	26.66	NC	NC	n/a	n/a	BREEAM Very Good
7	Harris Academy	40	B	22.62	61.65% / 71.2%	Very Good / Excellent	n/a	n/a	BREEAM Excellent, 10% of regulated and unregulated carbon emissions to be offset using renewables
9	Technical Hub @ EBI	36	B	19.3	73.69%	Excellent	n/a	n/a	Outline application: Energy audit and energy statement (detailing the influence of the energy audit)
10	Edge Lane - Time Project	(21)	(A)	(29.0)	78.57%	Excellent	n/a	n/a	Renewable Energy Statement included in decision notice documents (BREEAM Excellent and NHS targets)
11	St Loyes Extra Care Scheme	-	-	-	NC	NC	NC	NC	Outline application: 25% improvement in carbon emissions using low carbon or renewable technology
14	London School of Tropical Medicine	-	-	-	-	-	n/a	n/a	Case excluded - see section 4.4.3.
16	University of the Arts London Kings Cross Campus	65	C	26.58	59%	Very Good	n/a	n/a	BREEAM Very Good. S106 5% better than Part L and connection to CCHP.
17	Oxford University Press offices	≥ 40	(B+)	-	-	-	n/a	n/a	Application withdrawn by council. BREEAM Excellent target.
19	University of Greenwich - Stockwell St.	35	B	13.18	75.63%	Excellent	n/a	n/a	BREEAM Excellent
20	Church View	-*	-	-	-	-	n/a	n/a	None. "Planning requirements for 15% renewable provision" stated in TSB report but not included in planning conditions.

	Case Name	Asset Rating (estimates in brackets)		BER or DER ($kgCO_2/m^2$)	BREEAM score	BREEAM Rating	CSH Score	CSH Level	Planning Conditions
21	Great Ormond Street Hospital (Phase 2B)	-	-	-	-	-	n/a	n/a	S106 NEAT Excellent. S106 includes Energy Demand Assessment and NEAT assessment.
23	Trowbridge County Hall	39	B	26.34	70.60%	Excellent	n/a	n/a	None
24	University of Sheffield Engineering Graduate School	32	B	17.64	-	-	n/a	n/a	BREEAM Very Good
25	11-16 phase school (Ebbw Vale)	26	B	9.65	72.84%	Excellent	n/a	n/a	Information not available.
31	The Cooperative Head Office	-58	A+	-29.38	92.25%	Outstanding	n/a	n/a	BREEAM Outstanding
35	Environment and Sustainability Institute	23	A	14.06	91.57%	Outstanding	n/a	n/a	None
38.1	Site J, New England Quarter (Super B)	-	-	-	-	-	72.1-73.8	4	Code Level 4. Installation of "sustainable measures" (904sqm of PV, ASHPs)
46	Hinguar Primary School	27	B	19.51	58.48%	Very Good	n/a	n/a	10% building energy delivered by renewables
47	Westbrook primary	(25)	(A)	8.9	-	-	n/a	n/a	Approval of on-site renewable energy generation scheme.
48	London Bridge Station	-	-	36.1	NC	NC	n/a	n/a	CEEQUAL Excellent (96.9%)

Estimates shown in brackets, dashes indicate missing data.

NC = not certified; project was not submitted for BREEAM / CSH assessment.

n/a = non-domestic projects for which the Code for Sustainable Homes (CSH) is not applicable.

* Case 20 has an EPC certificate (asset rating = 85) but it is dated March 2009, coinciding with the sale of the building to the developer and precedes the design work that this study is concerned with.

6.2.2 DOMESTIC BUILDING OUTCOMES

6.2.2.1 *DOMESTIC CASES WITH EPC OR SUBSTITUTABLE EVIDENCE*

Case 04's flats are rated B for environmental impact, with EIRs ranging from 86 to 90 (reflecting different sizes, aspects and configurations). Figure 6-1 illustrates the assessed EIR for case 04 with respect to all domestic, new construction EPCs lodged between 2008 (when EPCs first became mandatory) and 2014.

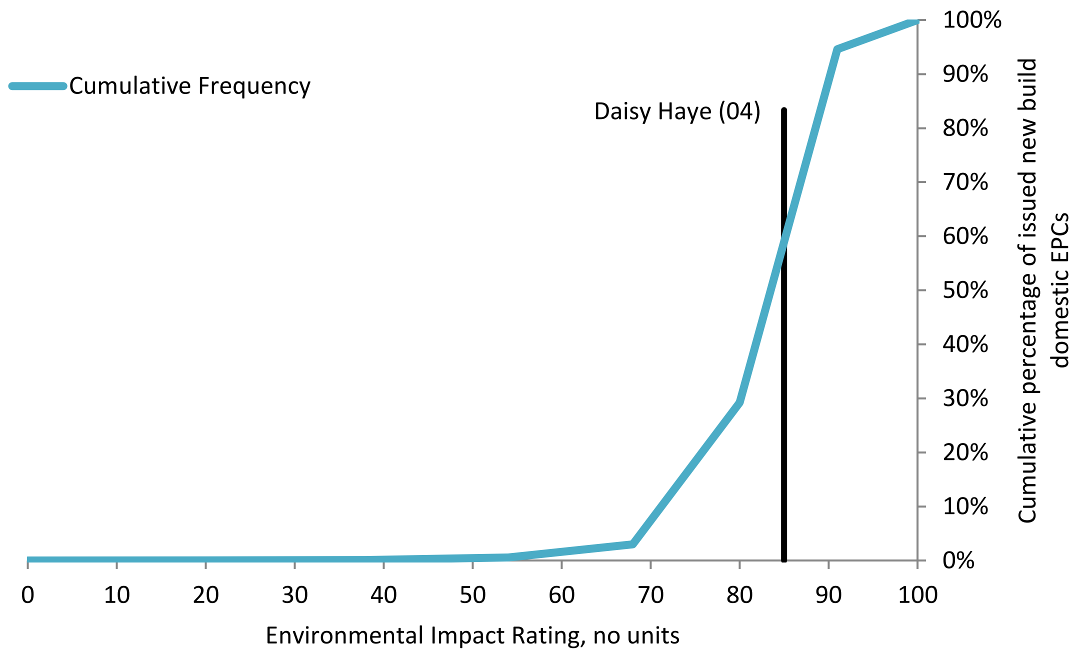


Figure 6-1 Daisy Haye (Case 04) Environmental Impact Rating compared to national EPC data for new domestic buildings (Department for Communities and Local Government, 2015d)**.**

The figure shows case 04's performance is by no means exceptional - 60% of new domestic buildings since 2008 have attained the same or better impact rating. Designed to the Code for Sustainable Homes level 3 (Case 04, Report to the Resources Overview & Scrutiny Panel), the intent was to meet legal requirements "*without the need for expensive renewable technology*" (Case 04, Report to the Resources Overview & Scrutiny Panel). The building is compliant with current legislation but does not exceed it and is allocated to the not low carbon set.

Case 38.1 (Site J SuperB) has yet to submit EPCs to the national register. Submission of Code for Sustainable Homes (CSH) details were however a condition of planning and reveal the flats obtained an ENE 1 (dwelling emission rate) score of 3/10 and an ENE02 (fabric energy efficiency) score of 7.1/9. This indicates the flats have a good level of insulation and meet the relevant standard for a code level 4 building. An ENE01 score of 3 is equivalent to a 25-35% improvement over Part L2A (Department for Communities and Local Government, 2010b); this building therefore exceeds the requirements of 2010 legislation and betters the 6% aggregate improvement that will be required by the 2013 redraft. Case 38.1 is therefore allocated to the low carbon set, despite being considerably less efficient than the now abandoned zero carbon target for homes.

6.2.2.2 *DOMESTIC CASES WITHOUT EPC EVIDENCE*

Case 11 is assessed qualitatively as no data suitable for estimating an EIR rating is available. This is relatively straightforward as Case 11 is designed to achieve Passive House standards. Passivhaus is a "l*ow energy design concept*" (Building Research Establishment, 2011), requiring buildings to consume less than 120 kWh/m^2 of primary energy per year. The standard is widely perceived as an exemplar of low carbon design (McLeod et al., 2013).

The primary complication with case 11's low carbon outcome is the economic feasibility of the scheme – double aspect, passivhaus design added significant costs:

> *"Incorporating the Passivhaus requirements … was approximately £216,000 or an additional £4,320 per flat when compared to 2010 building regulations" D4FC Report, p52*

As funding for the scheme has yet to be secured, there is little way of knowing if the scheme design is affordable and will be realised in its present form. The architect however describes Exeter City Council as "*committed to building it*" (Interview 11) and therefore in the absence of more concrete data undermining the scheme's cost plan, case 11 is allocated to the low carbon set.

6.2.3 NON DOMESTIC BUILDING OUTCOMES

6.2.3.1 *NON-DOMESTIC BUILDINGS WITH EPC OR SUBSTITUTABLE EVIDENCE*

Thirteen of the non-domestic cases lodged EPCs on the national database following completion of construction work. Figure 6-4 illustrates the asset ratings of these buildings with respect to all non-domestic EPCs lodged between 2008 and 2014. (Note EPC data for new and existing non-domestic buildings is aggregated prior to publication so a proportion of the statistic will to relate to buildings constructed well before energy efficiency was made mandatory.)

Of the remaining cases three provided estimated asset ratings. Numerous studies have sought to understand the links between as designed performance and actual performance (see, for example Bordass et al., 2001; Oreszczyn & Lowe, 2010; Sunikka-Blank & Galvin, 2012), however to date, no work has explicitly considered how EPC values predicted early in design might relate to the finalised certificate. Anecdotally, many of the cases reported a watering down of low carbon proposals due to budget cuts and value engineering:

"there was a major overhaul of the design in a value engineering exercise. This resulted in the omission of many [low carbon] elements and the redesign of others." (Case 25, D4FC report, p59)

However these claims contradict guidance arguing early incorporation of low carbon ideas prevents their removal by designing them into the scheme rather than 'bolting on' (HM Government, 2013; Kershaw & Simm, 2014). To understand how reliable the estimated ratings might be, data for all cases (n = 5) where both predicted asset ratings and lodged EPC certificates are available were plotted, Figure 6-2. Data accompanying the chart is given in Table 6-3.

Table 6-3 Actual and estimated asset rating for cases with both values

Case	Estimated asset rating	Actual asset rating
Admiral HQ	39	34
Harris Academy	33	40
Ebbw Vale School	37	26
Hinguar School	30	27
Greenwich	37	35
Sheffield	30-37	32

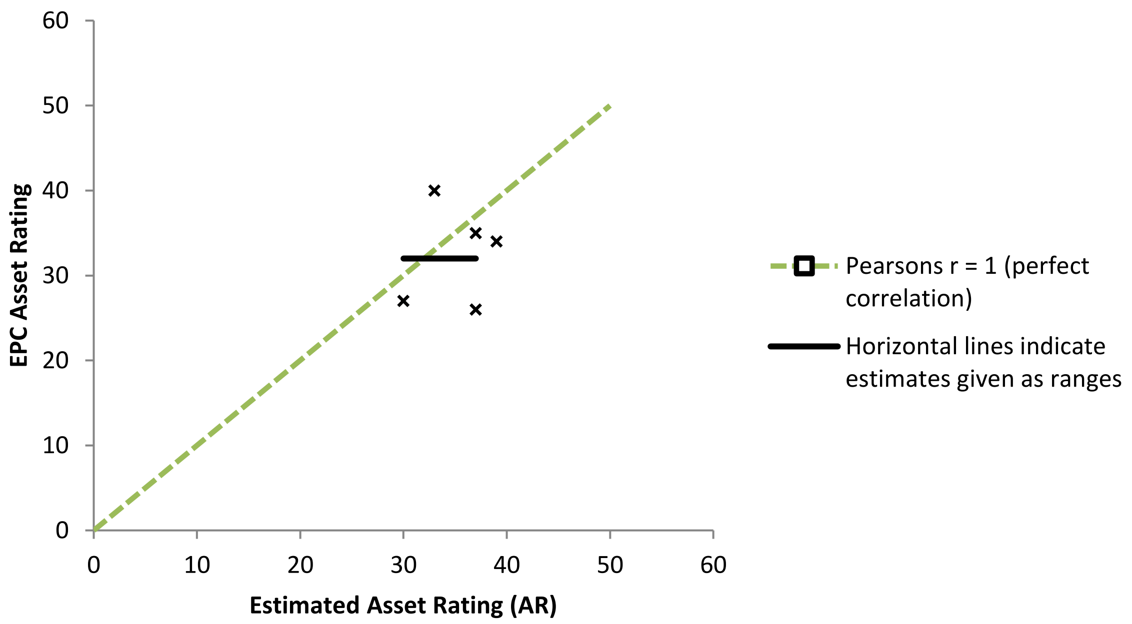


Figure 6-2 Scatter graph showing relationship between estimated asset ratings and EPC asset ratings

The scatter graph shows the relationship between case estimates and finalised EPCs. If the cases were perfect estimators we would expect perfect correlation (*r* = 1) and all points would lie on the dashed line shown. Points below the line indicate underestimation and above it over estimation. Any correlation would indicate estimated values could be used to predict actual values, while a random scatter would indicate no relationship between estimated and actual values.

Statistical measures of correlation are inappropriate as the sample is very small (N=6) and unrepresentative of the wider case population (only completed buildings are included, which may have been less affected by changes to legislation or lengthy design process for example). However, all points lie close to the line indicating only small changes in asset rating from planning to construction stages for the cases where data is available. One interpretation of this result is that changes during construction had minimal impact on the asset rating achieved, in agreement with low carbon design guidance (Kershaw & Simm, 2014) suggesting early action is imperative. However, because none of the cases were followed between planning and construction it is impossible to substantiate without further investigation.

Overall the scatter graph suggests reasonable agreement between estimated and final EPC asset ratings and in the absence of evidence to the contrary it has been assumed planning estimates provide a reasonable approximation of the asset rating. Estimates have therefore been used where a firm EPC is unavailable (i.e. cases 01, 10 and 47).

Cases 17 and 20 provide no estimates of EPC performance, but do specify BREEAM Excellent performance. As BREEAM 2008 Excellent ratings require a minimum asset rating (Building Research Establishment, 2008a, 2008b), it is possible to derive a lower bound for each building's estimated performance: as a new build case 17 requires an AR of 40 of better, case 20 is a refurbishment and requires an AR of 47 or better. For case 20 it seems unlikely a significantly better AR is achievable – located in a conservation area the building was "*difficult to upgrade to meet higher environmental standards*" (Case 20 CCA report, p6) and the BREEAM Excellent target itself is described as an "*aspiration*" (ARUP Sustainability Measures Note). Case 17 has been shelved following a re-evaluation of space needs by the client, but it seems likely that these aspirations were feasible given they were to be enforced as planning conditions.

Figure 6-3 summaries asset rating data for all non-domestic cases with information available.

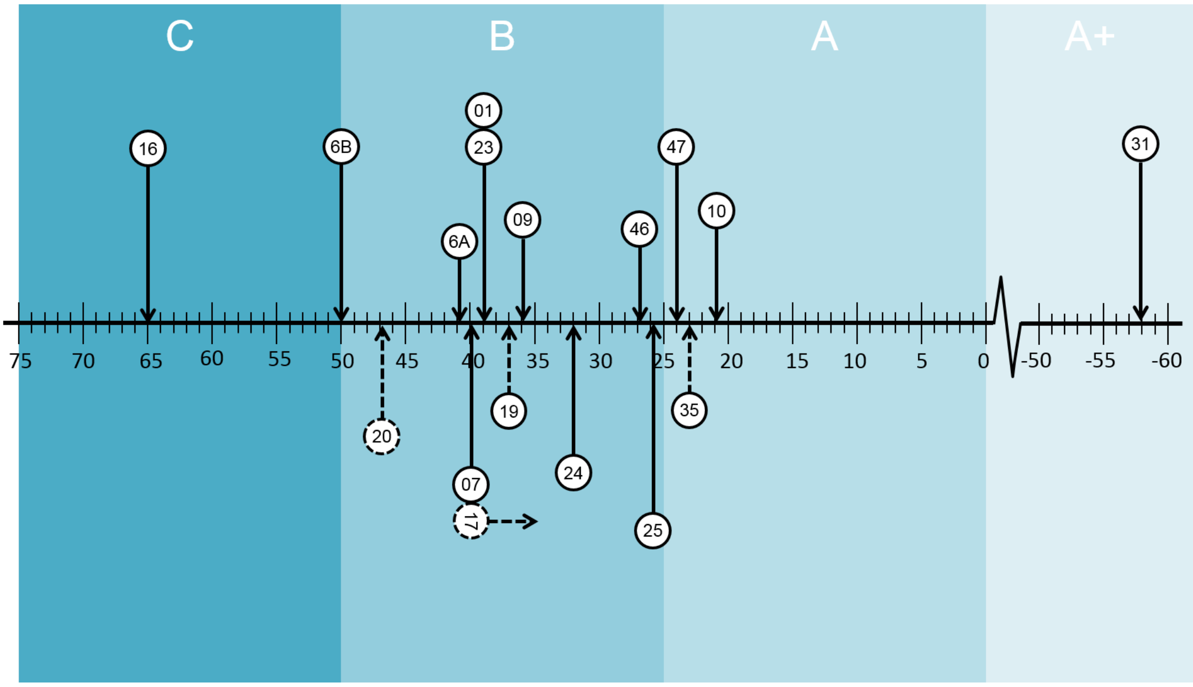


Figure 6-3 Non-domestic case asset ratings (dotted lines indicate estimates)

Asset ratings range from -58 to +65. Case 31's negative asset rating (-58) indicates it is designed to generate sufficient renewable electricity to meet all of its regulated needs and supply some energy back to the grid. Less than 1% of domestic buildings have achieved scores of less than 0 and received A+ ratings. Other buildings scoring highly are cases 10 (Edge Lane) and 35 (ESI) which both obtain asset ratings high enough to qualify for a BREEAM outstanding rating (described by the scheme as representing "*exemplary practice in the design and construction of new buildings in the UK*" (BRE Global, 2011)). Ebbw Vale school narrowly misses the outstanding criteria, with an asset rating of 26. The majority of the buildings cluster within the A and B ratings (ARs of between 0 and 50), with only UAL (case 16) being C rated. Case 16 performs significantly worse than other cases, most of which lie within the top 5% of non-domestic EPCs (see Figure 6-4 and Figure 6-5)

Applying the low carbon outcome criteria selected in chapter 3, 13 cases (see Table 6-4) achieve the requirements for BREEAM Excellent performance (AR ≥ 40 for new buildings) and are described as low carbon for the purposes of this study. The large number of buildings achieving low carbon status is unsurprising when considering the origin of the sample: as projects funded by the Technology Strategy Board's D4FC programme all were required to demonstrate "*low impact goals aimed at a recognised standard such as BREEAM 'excellent' or 'very good'*" (Technology Strategy Board, 2011).

Offmore Primary (case 06A) is excluded using the BREEAM criteria, but, with an asset rating of 41 has very similar ratings to both Harris (AR = 40) and Trowbridge county hall (AR = 39). The division between these cases as low carbon and not low carbon therefore seems rather arbitrary. This is a product of the adopted crisp set QCA method, a decision that was justified in chapter 4. Offmore Primary could be moved into the low carbon set on the basis of its closeness to the other results. However, both Harris Academy and Trowbridge included significant reuse of an existing building, Offmore Primary is an entirely new build structure. While chapter 4 described the decision to score refurbishments and new buildings using the same criteria, in this instance it seems a relevant consideration as it is the new build performing less well. Given refurbishments are often expected to be less energy efficient than new buildings (e.g. Ball, 1999; Boardman, 2007), Offmore Primary's score appears unambitious relative to other primary schools in the case set (cases 46 and 47). On the basis of this evidence, Offmore Primary was not moved to the low carbon outcome set.

Table 6-4 Low carbon outcome for non-domestic projects with EPC data available

	Case	Asset Rating (estimates in brackets)		BREEAM Excellent (≥40)	BREEAM Outstanding (≥ 25)
1	Admiral Insurance Headquarters	34	B	✓	X
6.1	Wyre Forest Schools – Offmore Primary	41	B	X	X
6.2	Wyre Forest Schools - St Catherine's Primary	50	B	X	X
7	Harris Academy	40	B	✓	X
9	Technical Hub @ EBI	36	B	✓	X
10	Edge Lane - Time Project	(21)	(A)	✓	✓
16	University of the Arts London Kings Cross Campus	65	C	X	X
17	Oxford University Press	(≥ 40)	(B+)	✓	X
19	University of Greenwich - Stockwell St.	35	B	✓	X
20	Church View	(≥ 47)	(B)	X	X
23	Trowbridge County Hall	39	B	✓	X
24	University of Sheffield Engineering Graduate School	32	B	✓	X
25	Ebbw Vale 11-16 phase school	26	B	✓	X
31	The Cooperative Head Office	-58	A+	✓	✓
35	Environment and Sustainability Institute	23	A	✓	✓
46	Hinguar Primary School	27	B	✓	X
47	Westbrook primary	(25)	(A)	✓	X

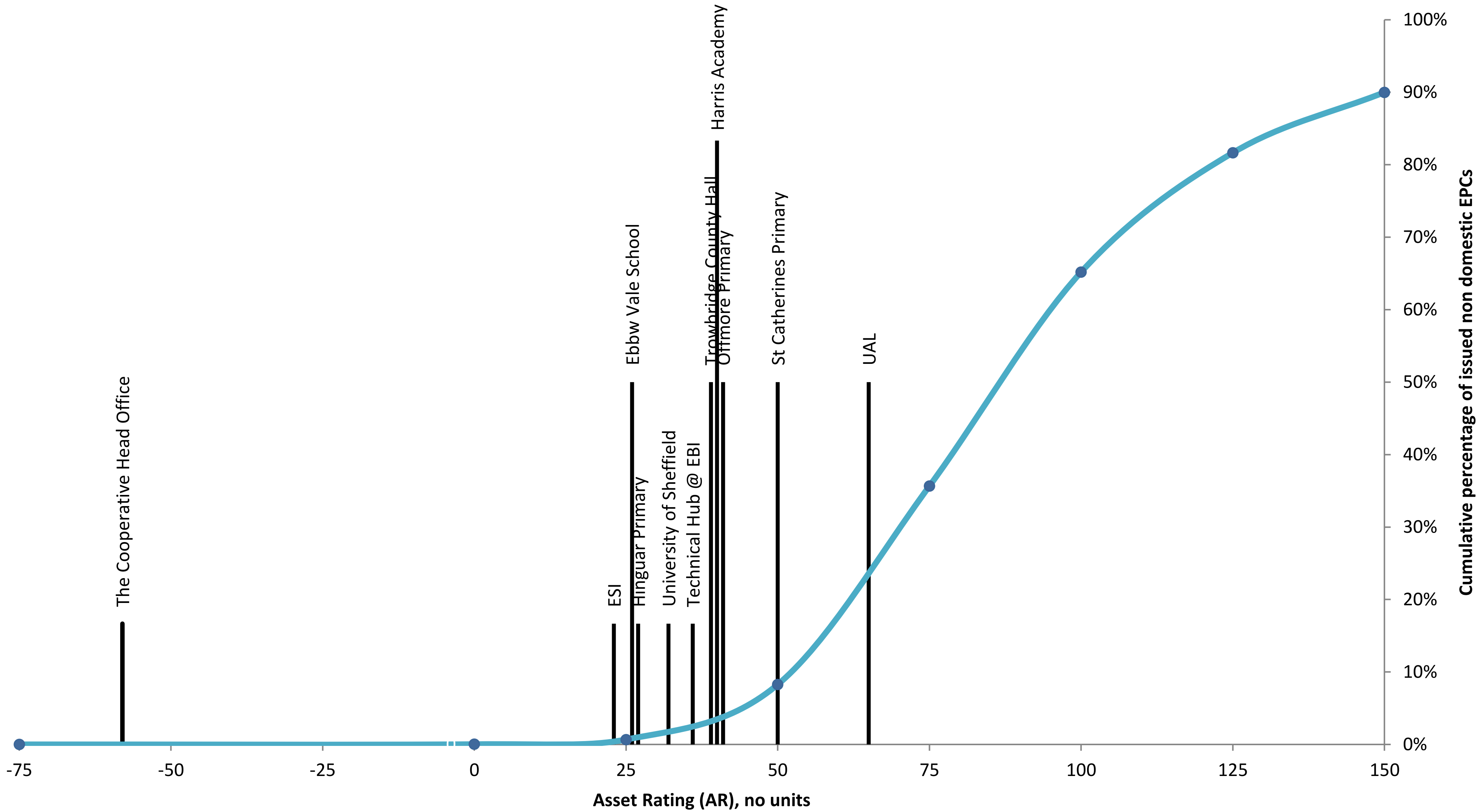


Figure 6-4 Asset ratings for cases with firm EPCs compared to all non-domestic EPCs issued between 2008 and 2014

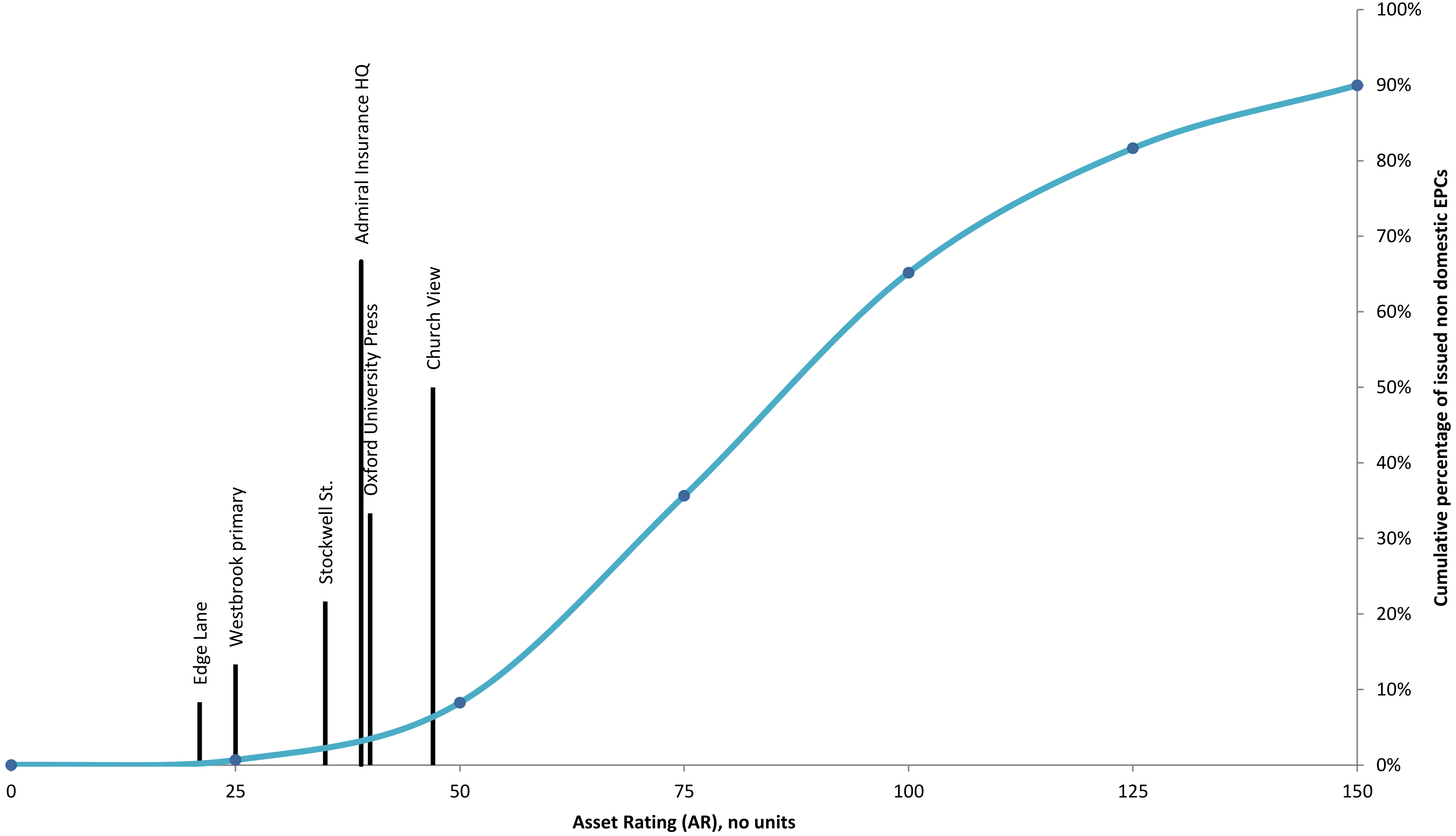


Figure 6-5 Asset ratings for cases with estimated EPCs compared to all non-domestic EPCs issued between 2008 and 2014

6.2.3.2 *NON-DOMESTIC CASES WITHOUT EPC EVIDENCE*

No quantitative data suitable for estimating an asset rating is available for cases 21 or 48. These cases are assessed qualitatively. Case 21 is not allocated to the low carbon set on the basis that:

- Despite the local authority's preference for a BREEAM assessment, the Trust successfully petitioned for rating using NEAT (NHS Environmental Assessment Tool). NEAT was superseded by the more onerous BREEAM Healthcare in July 2008 (6 months after the planning permission was granted) because NEAT "*had not been updated since its creation [in 2002]."* and *"NEAT was a self assessment tool, therefore there was not a quality control procedure at the end of the assessment."* (BRE Global, 2013)
- BRE assessors expressed low confidence in the Trust's commitment to deliver the required 60% of NEAT energy credits: "*Currently the energy and management related submission is weak. For energy we would expect key assumptions fundamental to achieving the energy targets to have been included and these to be driving the design and pushing integrated solutions. The documentation provided suggests a piecemeal approach which potentially is a project risk. … In our experience when NEAT assessments are undertaken on completed buildings the scoring is consistently lower than aspiration NEAT scores taken before the design is fully worked up.*" (Case 21, BRE NEAT Assessment)
- The recently completed connecting building (The Morgan Stanley Clinical Building) has not been BREEAM rated suggesting the trust retained use of the NEAT tool despite it being now considerably outdated. The building is DEC F (137) rated.
- The application relies heavily on biofuel powered CHP to deliver GLA renewables targets but "*at current prices bio-fuels are unlikely to be considered as a feasible option*" (Case 21, Opportunity Appraisal Report)

Overall there is no evidence to suggest Great Ormond Street Hospital's phase 2B design to be 'low carbon' beyond Part L 2010 compliance.

As case 48 is, at least partly, a piece of infrastructure it is registered with the CEEQUAL sustainability assessment scheme rather than BREEAM. Reliance on CEEQUAL for the low carbon outcome is problematic for a number of reasons:

- While the station achieved a score of 96.9% (rated excellent) at design stage, suggesting the majority of the energy and carbon credits were obtained, CEEQUAL's evidence procedure has greater flexibility than BREEAM. Applicants must demonstrate "*evidence of appropriate measures having been incorporated to reduce energy consumption in use*" (CEEQUAL, 2010).

22 credits are available but there is no guidance in the assessment manual as to how these credits might be allocated and what constitutes 'appropriate' appears subject to the assessor's discretion.

- CEEQUAL does not impose minimum energy performance requirements for rating and it is possible for several of the carbon related credits to be 'scoped out'.
- CEEQUAL's interpretation of energy performance is broader than Part L and includes the energy used (and carbon produced) during construction and demolition.

These issues make it impossible to compare CEEQUAL and BREEAM directly or estimate an EPC for the CEEQUAL score. Other evidence must therefore be used.

It is obvious from planning application and publicity material that case 48 relies heavily on reductions in travel related emissions for its low carbon claims:

> *"This increased capacity of the station will result in estimated savings of 24 million kg of C02 per annum resulting from the modal shift from the provision of new and improved rail services. This is equivalent to the carbon dioxide emissions of ten typical office buildings of a similar size to that of the Shard." (Case 48, Sustainability Statement Appendix 3)*

However, while rail travel may reduce carbon emissions associated with the use of private cars, these emissions are not governed by the building regulations and thus do not contribute to this study's definition of a low carbon outcome. For building related emissions a detailed energy statement accompanies the planning application to satisfy the requirements of The London Plan. This document describes how the building will be predominantly naturally ventilated with no heating or cooling provided to the open air environment. Air conditioning will be provided to the retail areas, although the imposition of centralised servicing ensures a degree of energy efficiency. The building therefore incorporates a range of features typical of 'low carbon' buildings. However, despite these admiral design features the document also describes an energy efficiency target of only 5-10% improvement over Part L2A 2010, missing the 25% improvement required by the London Plan because "*technical constraints exist that prevent the fulfilment of this target with the use of on-site technologies*" (Case 48, Directions 2011-09-01, p24). Further, although the SBEM method from which the BER is derived is designed to compare similar buildings only (Department for Communities and Local Government, 2010a) and the station is of a very different building type, the predicted Building Emission Rate (BER) of 36.1 $kgC0_2/m^2$ is much higher than any of the other buildings in the case set (see Table 6-2). Thus, in the absence of information placing the design for London Bridge

Station firmly within the adopted low carbon criteria, the decision was taken to exclude it from the low carbon set.

6.2.4 COLLATED CLASSIFICATIONS FOR LOW CARBON OUTCOME

Finalised classifications for all case buildings are shown in Table 6-5. 15 cases meet the criteria for best practice energy performance using BREEAM 2008 criteria and are classed as 'low carbon'.

Table 6-5 Low carbon case outcomes

Case	Low Carbon
01 Admiral HQ	✓
04 British Trimmings (Daisy Haye)	X
6.1 Offmore Primary	X
6.2 St Catherine's Primary	X
07 Harris Academy Purley	✓
09 Technical Hub @ EBI	✓
10 Edge Lane	✓
11 St Loyes Extra Care	✓
14 London School of Hygiene and Tropical Medicine	n/a
16 University of the Arts London, Kings Cross Campus	X
17 Oxford University Press (OUP)	✓
19 Greenwich University, Stockwell Street	✓
20 Church View	X
21 Great Ormond Street Hospital (GOSH) Phase 2B	X
23 Trowbridge County Hall	✓
24 Sheffield Engineering Graduate School	✓
25 Ebbw Vale 11-16 Phase School	✓
31 Cooperative HQ	✓
35 Environment and Sustainability Institute	✓
38 Site J SuperB	✓
46 Hinguar Primary	✓
47 Westbrook Primary	✓
48 London Bridge Station Redevelopment (LBSR)	X

6.3 ADAPTABILITY

6.3.1 INTRODUCTION

Chapter 2 discussed the limited consensus in conceptually defining adaptability as a concept resulting in an assortment of indicators in use. No measure has been widely used and as such the approach adopted (described in chapter 4) employs multiple independent indicators. Cases that score highly across a range of indicators will be considered more adaptable than those with consistently low scores. This approach is also advantageous in allowing some commentary on the usefulness of the various adaptability measurement techniques for research applications. The selected measures are:

1. Building Adaptability Score (BAS) (March et al., 2012)
2. AdaptSTAR (Conejos, 2013)
3. Tactic counts (Schmidt, 2014)
4. Adaptability characteristics (CARs) (Schmidt, 2014)
5. Expert Opinion

In addition compliance with existing conceptualisations of adaptability will be measured using the scale developed in section 4.6.3.2. Two benchmarking cases of known performance are scored using BAS, AdaptSTAR and the literature compliance scale (see 4.3.6.2). This is intended to provide an indication of 'not adaptable' and 'adaptable' scores for these methods that have not been calibrated and/or have minimal existing cases for comparison.

6.3.2 BUILDING ASSESSMENT SCORE (BAS)

March et al.'s (2012)'s BAS method consists of 10 items. Despite March et al. (2012) providing little explanation, almost all items relate to well defined physical characteristics making the method straightforward to apply. Only two criteria were considered ambiguous, site boundaries and hostile factors. Site boundaries is defined as the degree of attachment to other buildings following reference to Wilkinson and Reed (2011), who describe the data set on which the BAS method is based. The hostile factors criteria is clear in its meaning, but allocates scores on the basis of 'mild' and 'extreme' which are not defined. In the absence of better information a scoring mechanism was assumed: mild as loud traffic noise from adjacent main roads or similar, extreme for case 46 due to its location within the flood plain and case 47 as it is located directly beneath Heathrow airport's flight path. Scores for each building were calculated as described by March et al. (2012):

$$BAS = VW \times TW$$

Where TW is the type weighting (component score between 0 and 1) and VW is a weighting factor. Scoring, weightings and results for each case are shown in Table 6-7.

Results range from 0.392 to 0.529. The two test cases generate unexpected scores, the shopping centre achieving a higher score (BAS=0.418) than the library (BAS=0.411). The difference is due to building age; celebrating its 40th birthday in 2014 the library scores substantially higher than the relatively new shopping centre. The library is however very near the upper boundary; altering the building age parameter to match the year of the library's scheduled demolition (2016) pushes the building into the next category and generates an lower BAS score (0.403) than the shopping centre. This demonstrates a high level of sensitivity in the BAS method to individual parameters.

March et al.'s two case studies score 0.376 (case A) and 0.421 (case B). Due to March et al.'s case selection procedure these should represent extreme values (one case adaptable and the other not). It is unclear from the descriptions provided which case occupies which position, although it seems reasonable to assume Case A to be the less adaptable. None of the case study buildings described here score less than Case A and as such none can be conclusively described as not adaptable using the BAS method. Case B's score is described as "*marginally higher than Case A*" by March et al. but there are no other indications to how the scores should be interpreted.

6.3.3 ADAPTSTAR

The AdaptSTAR method (Conejos, 2013) consists of 26 items measured using a Likert type scale. AdaptSTAR was simple to understand and use although more time consuming than the BAS method, largely due to it being longer. Conejos provides good descriptions of all 26 items (Conejos, 2013, p116-120) which were referred to frequently while scoring the cases to ensure consistency with the original scoring method. Most difficult was ensuring the Likert scale was consistently and objectively applied across the cases – it was very easy for the meaning to drift. To combat this effect each scale item was checked after completing the case by case assessment and inconsistencies rectified. Keeping notes as to why a specific score had been allocated was helpful in this respect.

Conejos does not supply numerical meanings for the scale's statements, but these were relatively simple to ascertain from the case score sheets supplied:

- Strongly disagree = 1
- Disagree = 2
- Neutral = 3
- Agree = 4
- Strongly agree = 5

This is the normal method of scoring a Likert scale (DeVellis, 1991), but has the effect that the minimum possible AdaptSTAR rating is 20. (Adopting an alternative numeric starting point and/or increment for the scale would not have affected the method's ability to distinguish between cases, but would have rendered direct comparisons with Conejos's cases invalid.) Conejos (Conejos, 2013) refers to the weighted scores as percentages - somewhat misleading given the non-zero start point. Further because of the limited lower bound achieving an 'unrated' AdaptSTAR score would be rather difficult; 'disagreeing' with all statements in the rating scheme (score of 40) would award a building '2 stars'.

Table 6-8 shows weighted scores for all cases, the scoring sheets themselves are located in appendix 6A. Scores for the cases ranged from 86.50 to 57.42, representing the adaptable (SC) and non-adaptable (BCL) cases respectively. The method is therefore able to differentiate between the two calibration cases. As expected few cases achieved low scores; only one case (BCL) is rated at less than 3*. Star ratings for each case are given in Table 6-6.

Table 6-6 Star Ratings for all cases

Star Rating	Cases achieving rating
Unrated	No cases
*	No cases
**	Birmingham Central Library (54.72)%
***	Case 04 British Trimmings Extra Care (Daisy Haye) (58.27%)
	Case 38.2 New England Quarter Site J Non domestic (60.68%)
	Case 14 London School of Hygiene and Tropical Medicine (61.48%)
	Case 11 St Loyes Extra Care (62.15%)
	Case 20 Church View (63.56%)
	Case 09 Technical Hub @ EBI (64.83%)
	Case 38.1 New England Quarter Site J Residential (SuperB) (66.27%)
	Case 6.2 St Catherine's' Primary (66.47%)
	Case 6.1 Offmore Primary (66.68%)
	Case 35 Environment and Sustainability Institute (66.69%)
	Case 17 Oxford University Press (OUP) (67.04%)
	Case 07 Harris Academy (68.10%)
	Case 21 Great Ormond Street Hospital (GOSH) Phase 2B (68.52%)
	Case 47 Westbrook Primary School (69.31%)
	Case 10 Edge Lane (69.69%)
****	Case 46 Hinguar Primary School (71.71%)
	Case 23 Trowbridge County Hall (72.27%)
	Case 01 Admiral HQ (72.69%)
	Case 25 Ebbw Vale 11-16 Phase School (72.75%)
	Case 24 Sheffield Engineering Graduate School (74.57%)
	Case 48 London Bridge Station Redevelopment (LBSR) (75.79%)
	Case 19 Greenwich Stockwell Street (76.82%)
	Case 16 UAL Kings Cross (79.39%)
	Case 31 Cooperative HQ (83.99%)
*****	Shopping Centre (86.50%)

Table 6-7 March et al. (March et al., 2012) assessment results

Physical building characteristic	Scoring	Weighting	Case 01	Case 04	Case 6.1	Case 6.2	Case 07	Case 09	Case 10	Case 11	Case 14	Case 16	Case 17	Case 19	Case 20	Case 21	Case 23	Case 24	Case 25	Case 31	Case 35	Case 38.1	Case 38.2	Case 46	Case 47	Case 48	Shopping Centre	BCL
Date of construction	0 - 18 years = 0.1 19 - 41 years = 1 42 - 156 years = 0.3 157+ = 0	0.053	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0	0.3	0.1	0.3		0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	1
Type of construction	Steel / concrete = 0.08 Other = 0.92	0.058	0.08	0.92	0.92	0.92	0.08	0.08	0.92	0.08	0.08	0.08	0.08	0.08	0.92	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.92	0.08	0.08
Height of building (storeys)	6 or less = 1 7 - 20 = 0.2 21 - 45 = 0.4 46+ = 0.1	0.023	0.2	1	1	1	1	1	1	1	1	1	1	1	1	0.2	1	0.2	1	0.2	1	0.2	0.2	1	1	1	0.2	0.2
Floor size	Small (<700m2) = 0.5 Large = 1	0.117	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plan shape	Deep plan = 1 Irregular = 0.8 Narrow frontage = 0.6 Wide plan = 0.4 Curved = 0.2	0.127	1	0.8	0.4	0.8	1	1	0.4	0.2	1	1	0.8	1	0.8	0.8	1	1	0.8	0.8	0.8	0.4	0.4	1	0.8	0.8	1	0.8
Service core location	Central = 1 Dual locations = 0.5 Other = 0.1	0.073	1	0.1	0.5	0.5	0.1	0.5	1	0.1	0.1	0.1	0.5	0.1	0.1	0.5	0.1	0.5	0.1	0.1	0.1	0.5	0.1	0.1	0.5	0.1	0.1	0.1
Site boundaries	None = 1 Bounded on 2 sides = 0.8 Bounded on 1 side = 0.6 Bounded on 3 sides = 0.4 Bounded on all sides = 0.2	0.079	1	1	1	1	1	1	1	1	0.6	0.6	0.8	1	1	0.2	1	0.8	1	1	1	0.6	0.6	1	1	0.6	0.6	0.6
Access to building	Access all sides = 1 Street and side access = 0.8 Street and rear access = 0.6 Street only = 0.4	0.03	1	0.8	0.8	0.4	0.8	0.4	0.4	0.8	0.8	0.8	0.4	0.8	1	0.4	1	0.8	0.4	0.8	0.6	0.8	0.8	1	0.4	0.8	1	1
Building width (M)	20m = 0.1 20.01 - 40m = 0.5 40.01 - 60m = 1 60.01 - 201.25 = 0.5	0.062	1	0.1	0.5	0.5	1	0.5	0.5	1	1	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5	1	0.5	1	1	1	0.5	0.5	0.5
Hostile factors	None = 1 Mild = 0.6 Extreme = 0.2	0.044	0.6	1	1	1	1	1	0.6	1	0.6	0.6	1	0.6	1	1	1	0.6	1	1	1	0.6	0.6	0.2	0.2	1	1	1
Total score			0.529	0.461	0.464	0.444	0.493	0.479	0.471	0.392	0.455	0.408	0.449	0.445	0.502	0.367	0.479	0.471	0.425	0.418	0.462	0.348	0.349	0.464	0.450	0.449	0.418	0.441

Table 6-8 AdaptSTAR (Conejos, 2013) assessment results

How do you judge the following statements for the above building/facility?	Weight	Case 01	Case 04	Case 6.1	Case 6.2	Case 07	Case 09	Case 10	Case 11	Case 14	Case 16	Case 17	Case 19	Case 20	Case 21	Case 23	Case 24	Case 25	Case 31	Case 35	Case 38.1	Case 38.2	Case 46	Case 47	Case 48	SD2
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.	5.58	4.46	4.46	2.23	2.23	3.35	3.35	5.58	2.23	4.46	2.23	1.12	4.46	3.35	3.35	3.35	3.35	2.23	5.58	3.35	2.23	2.23	4.46	2.23	4.46	4.46
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.	5.33	4.26	3.20	4.26	4.26	4.26	3.20	2.13	4.26	5.33	4.26	4.26	5.33	4.26	3.20	5.33	4.26	4.26	5.33	4.26	4.26	4.26	4.26	4.26	4.26	5.33
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.	5.17	4.14	3.10	4.14	4.14	3.10	4.14	4.14	4.14	1.03	4.14	4.14	4.14	2.07	4.14	4.14	4.14	3.10	4.14	4.14	4.14	4.14	4.14	4.14	3.10	4.14
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	4.47	3.58	1.79	0.89	0.89	1.79	1.79	2.68	0.89	4.47	4.47	3.58	3.58	2.68	4.47	1.79	3.58	1.79	4.47	0.89	3.58	3.58	0.89	1.79	4.47	3.58
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.	4.52	3.62	2.71	2.71	1.81	2.71	1.81	3.62	1.81	3.62	4.52	2.71	3.62	3.62	3.62	3.62	2.71	2.71	4.52	2.71	3.62	2.71	2.71	3.62	4.52	3.62
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.	4.41	1.76	2.65	1.76	2.65	2.65	3.53	2.65	2.65	3.53	3.53	1.76	2.65	3.53	1.76	3.53	2.65	3.53	3.53	3.53	1.76	1.76	1.76	1.76	3.53	3.53
The building's interior layout exhibits strong versatility for alternative arrangements without significant disruption or conversion cost.	3.42	3.42	1.37	1.37	2.05	2.05	2.05	1.37	0.68	1.37	2.74	2.74	2.74	2.74	2.05	2.74	2.74	2.74	3.42	2.74	1.37	2.74	3.42	2.74	1.37	3.42
The building has significant components or systems that support disassembly and subsequent relocation or reuse.	2.96	1.18	1.18	1.18	1.18	1.18	1.18	1.18	0.59	1.18	1.18	1.78	2.37	1.18	1.18	1.18	1.78	1.18	1.18	1.18	1.78	1.18	1.18	1.18	1.18	2.37
The building has sufficient internal open space and/or atria that provide opportunity for spatial and structural transformations.	3.00	1.20	2.40	2.40	2.40	2.40	2.40	3.00	2.40	0.60	3.00	2.40	2.40	2.40	1.20	2.40	2.40	3.00	3.00	2.40	1.20	1.20	3.00	2.40	2.40	3.00
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.	3.03	3.03	1.21	1.82	1.82	1.82	1.82	1.21	1.21	0.00	2.42	1.82	1.82	1.82	2.42	2.42	2.42	2.42	2.42	1.82	1.82	1.21	1.82	1.82	1.82	3.03
The building provides easy access to concealed ducts, service corridors and plant room space for effective horizontal and vertical circulation of services.	2.82	1.69	1.13	0.56	1.69	2.26	1.13	1.69	1.69	1.13	2.26	2.26	2.26	2.26	1.69	1.69	2.26	2.26	1.69	0.00	1.13	1.13	2.26	1.69	1.69	2.82
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.	2.8	1.12	1.12	2.24	1.68	1.68	1.68	1.68	2.24	2.24	1.68	1.12	1.68	2.24	1.68	1.68	1.12	1.68	2.24	0.00	1.68	1.68	1.68	1.68	2.24	2.24
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.	2.54	2.03	0.51	2.03	1.52	2.03	1.02	1.02	1.02	1.02	1.52	2.03	2.54	1.52	1.52	2.03	2.03	2.03	2.03	2.03	2.03	1.52	2.03	1.52	2.03	1.52
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.	2.49	1.99	1.99	1.99	1.99	1.99	1.99	2.49	2.49	1.00	1.99	1.99	1.99	1.49	1.49	1.99	1.99	1.99	2.49	2.49	1.99	1.99	1.99	1.99	1.49	1.49
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.	2.67	1.60	1.60	2.67	2.67	2.14	1.60	2.14	2.14	1.07	1.60	1.60	1.60	2.14	1.60	1.60	2.14	2.14	1.60	2.14	1.60	1.60	2.14	1.07	2.14	2.14
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.	2.31	2.31	1.39	2.31	1.39	1.39	1.85	2.31	2.31	0.46	1.39	1.39	1.85	0.92	0.92	1.85	1.85	1.85	2.31	2.31	1.39	0.92	1.85	1.85	1.39	1.85
The building supports efficient operational and maintenance practices including effective building management and control systems.	2.04	1.63	1.22	1.63	1.63	1.63	1.63	1.22	1.63	0.82	1.22	1.63	1.22	0.82	1.63	1.22	1.63	1.63	2.04	1.22	1.22	1.63	1.63	1.22	1.22	2.04
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.	4.69	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	4.69	4.69	2.81	2.81	2.81	1.88	3.75	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	3.75	2.81
The building has high architectural merit including pleasing aesthetics and compatibility with its surrounding streetscape.	5.04	3.02	2.02	3.02	3.02	3.02	3.02	3.02	2.02	4.03	5.04	4.03	4.03	4.03	4.03	3.02	4.03	3.02	2.02	3.02	3.02	3.02	3.02	4.03	4.03	4.03
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.	4.64	2.78	3.71	3.71	3.71	4.64	1.86	3.71	3.71	2.78	3.71	0.93	3.71	3.71	3.71	4.64	3.71	3.71	2.78	1.86	1.86	0.93	3.71	3.71	3.71	4.64
The building displays a high standard of construction and finish consistent with current market expectations.	4.36	4.36	1.74	2.62	2.62	2.62	3.49	2.62	2.62	2.62	3.49	3.49	3.49	1.74	3.49	2.62	3.49	3.49	4.36	3.49	3.49	3.49	3.49	3.49	3.49	4.36
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.	4.65	4.65	4.65	4.65	4.65	3.72	4.65	4.65	4.65	3.72	3.72	4.65	4.65	3.72	3.72	3.72	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	3.72	4.65
The building offers an enhanced workplace environment that provides appropriate user comfort, IAQ and environmental health and safety.	4.26	3.41	2.56	3.41	3.41	2.56	3.41	3.41	3.41	1.70	3.41	4.26	3.41	1.70	4.26	3.41	3.41	3.41	4.26	3.41	3.41	3.41	2.56	3.41	3.41	4.26
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.	4.05	1.62	1.62	3.24	3.24	2.43	2.43	3.24	2.43	1.62	2.43	2.43	3.24	2.43	1.62	2.43	2.43	3.24	3.24	3.24	3.24	1.62	3.24	3.24	1.62	2.43
The building displays a high level of community interest and political support for its future care and preservation.	4.35	2.61	2.61	2.61	2.61	3.48	2.61	2.61	2.61	3.48	4.35	2.61	2.61	1.74	3.48	2.61	2.61	3.48	3.48	2.61	2.61	1.74	3.48	2.61	4.35	4.35
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.	4.39	4.39	3.51	4.39	4.39	4.39	4.39	3.51	3.51	3.51	4.39	3.51	2.63	2.63	4.39	3.51	4.39	4.39	4.39	4.39	4.39	3.51	3.51	4.39	4.39	4.39
Total		**72.69**	**58.27**	**66.68**	**66.47**	**68.10**	**64.83**	**69.69**	**62.15**	**61.48**	**79.39**	**67.04**	**76.82**	**63.56**	**68.52**	**72.27**	**74.57**	**72.75**	**83.99**	**66.69**	**66.27**	**60.68**	**71.71**	**69.31**	**75.79**	**86.50**

6.3.4 LITERATURE COMPLIANCE

A method for measuring compliance with literature views of what an 'adaptable building' should include was developed in chapter 4. All case study buildings, including the two benchmarking cases, were assessed. Due to its large size the scoring matrix is located in appendix 6B. Justifications for the scoring of each element were recorded in an accompanying table, appendix 6B.

Following scoring a number of changes were made to the scale. Fire and storage space criteria were omitted due to difficulties in scoring when applied to insufficiently developed designs (approximately RIBA stage D). Zoning was omitted as scoring did not vary across the cases: requirements for zoned services in building regulations (HM Government, 2013) meant all of the buildings demonstrated zoning to some degree and all cases scored 1. It was therefore also omitted. (Durability also demonstrated limited variation but this is believed to reflect the case sample (consisting largely of owner-occupiers keen to reduce maintenance costs) rather than a deficiency in the scoring and the item was retained.) Height proved problematic. The literature largely indicates buildings should not be tall, and following the guidance of March et al. (2012) an initial threshold of 6 storeys was set as the break point for tall/not tall. This however divided the cases into odd groupings, with otherwise high scoring tall buildings penalised for constructing to a height in-keeping with their surroundings, while relatively awkward squat buildings benefited. To further investigate a correlation analysis between height (measured in no. of storeys) and the AdaptSTAR method was undertaken, demonstrating no significant relationship (Figure 6-6).

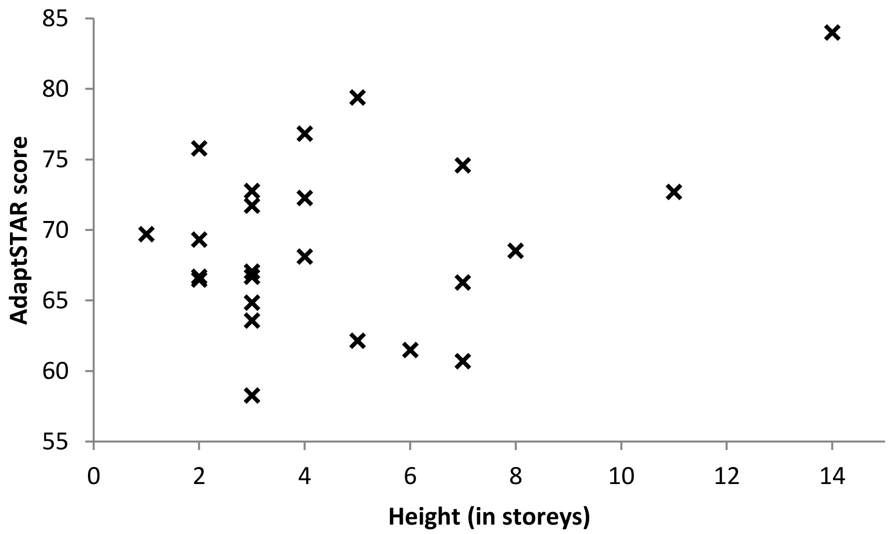


Figure 6-6 Scattergraph showing no relationship between height and AdaptSTAR

The apparent randomness is likely due to complexity in the adaptability – height relationship: March et al.'s (2012) scoring pattern for height is not regular – buildings between 0 and 6 storeys receive the highest score, followed by those between 21-45 storeys suggesting the relationship between height and adaptability is more complex than the idea of shorter buildings being more adaptable. Other commentators have similarly suggested it is not so much the height itself, as the height in relation to a building's location – low rise buildings in high density areas are more likely to be redeveloped given the potential to increase the value of the built asset (Wilkinson & Reed, 2011). This complexity led to the exclusion of building height from the final scale.

Finalised total scores for the compliance scale, in rank order, are shown in Table 6-9.

Table 6-9 Finalised adaptability literature scale results

Case	Score	Rank
Co-op HQ	43.0	1
Admiral HQ	41.0	2
Shopping Centre	40.8	3
CSM	40.6	4
ESI	33.8	5
Greenwich	33.6	6
Offmore Primary	33.0	7
St Catherine's	33.0	7
Hinguar Primary	32.6	9
Westbrook Primary	32.4	10
Harris Academy	31.6	11
OUP	31.6	11
Sheffield Grad School	31.4	13
Church View	30.6	14
Technical Hub @ EBI	29.8	15
Ebbw Vale	29.6	16
Birmingham Library	29.6	16
Trowbridge	27.6	18
Edge Lane	25.8	19
GOSH	24.6	20
NEQ Site J (Resi)	24.2	21
NEQ Site J (NonDom)	23.4	22
London Bridge (LBSR)	23.0	23
LSHTM	20.6	24
British Trimmings	20.0	25
Extracare4Exeter	18.0	26

6.3.4.1.1 Internal reliability

As the scale was developed specifically for this study and has not been trialled elsewhere, it was tested for internal reliability. The final scale exhibits a Cronbach's α of 0.79 (Table 6-10) which is within deVellis's (1991) 0.7-0.8 range for "*respectable*" and above Bryman and Cramer's (2011) "*rule* *of thumb*" 0.7. This suggests the scale has reasonable internal reliability. However there are limitations to the usefulness of the α measure. Firstly larger scales will have greater values of α than smaller ones due to the nature of the calculation (DeVellis, 1991; Field, 2013). The scale outlined here has 49 items which artificially boosts its alpha score. Secondly, a large number of items fail to meet Field's (2013) criteria that all scale items should correlate with the overall scale result - higher individual criteria scores should be associated with the higher scoring cases. The small number of negatively correlated cases are also problematic, suggesting criteria are included that produce less adaptable buildings. One explanation for the weak and negative correlations is that the scale reflects the confusion and contradictory guidance in the adaptability literature used to develop the scale, where different types of adaptability have different requirements (see section 2.3.3.3). However, the scale has been applied to only a small number of cases (N=26) that have not been randomly sampled from a population of buildings and further testing would be required to assess the scales reliability and validate the results. For example it is noticeable that residential buildings all obtained relatively low scores. This may reflect the adaptability literature's preference for non-domestic building qualities (e.g. Kincaid, 2002) or indicate a bias in the scale towards non-domestic typologies.

Table 6-10 Cronbach alpha calculation table

Criteria (N = 49)	Item-Total Correlation	Cronbach α if Item Deleted
Good access to public transport	0.147	0.791
Good access to main (A roads and motorways) roads	0.189	0.789
Space for parking	0.094	0.792
Central location	0.008	0.796
Not located in a mono-planning district	0.119	0.791
No nearby hostile factors	0.158	0.790
No of sides accessible by vehicle	-0.004	0.795
Attached to other buildings	0.066	0.793
Room for expansion within site boundary	0.115	0.792
Single occupier	0.546	0.778
Storey heights	0.394	0.785
External wall to external wall / atrium depth of 13.5 - 15m	0.148	0.791
Regular shape, limited curves	0.414	0.782
Good access to natural light throughout	0.242	0.787
Shell and core or other unfinished space	0.322	0.785
Evidence of use of standard components	0.176	0.790
Durable structure and substructure	0.106	0.791
Office loading or above	0.498	0.781
Evidence of foundations being oversized	0.033	0.794
Regular	0.350	0.784
Span ≥ 6m	0.311	0.785
Framed construction	0.387	0.784
Standard / repeated pattern to external facade	0.214	0.788
Use of a planning grid in positioning services and partitions	0.192	0.789
Evenness of service outlets	0.534	0.779
Services not embedded in structure	0.222	0.788
Accessible horizontal service zone	0.426	0.784
Penetrable slab	-0.046	0.796
Generous vertical riser provision	0.151	0.791
Plant located in an accessible location	0.313	0.785
Exposed components	0.368	0.783
Oversized distribution	0.597	0.775
Oversized or additional plant	0.158	0.790
Extra connection points	0.253	0.787
Hub and spoke arrangement of spaces	0.072	0.793
Open plan spaces	0.569	0.776
Non-load bearing internal walls	0.493	0.780
Moveable walls	0.238	0.788
Circulation large enough to be used as space / no hallways	0.500	0.778
Provision of space above minimum required, "elbow room"	0.159	0.790
Rooms demonstrate reasonable standardisation in sizing	0.134	0.791
Generic finish and / or fittings	0.191	0.789
Number of core groupings	0.126	0.792
Number of openings	0.380	0.784
At least one oversize entrance	0.267	0.787
Main entrance space central to the plan	0.079	0.793
Provision for additional openings	-0.001	0.793
Occupants capable of furniture arrangement (not fixed)	0.395	0.782
Provision of extra space	0.174	0.790

6.3.5 TACTIC METHOD (SCHMIDT, 2014)

Schmidt (2014) examines 25 cases and records the number of adaptability actions (‘tactics’) each pursues, using this as a proxy measure for adaptability. To apply the method adaptability tactics (actions intended to improve the case buildings’ adaptability) were recorded and counted for each case (appendix 6C), Figure 6-7. Tactic counts were not undertaken for the two calibration cases due to the onerous data collection requirements and the availability of comparison cases in Schmidt’ data.

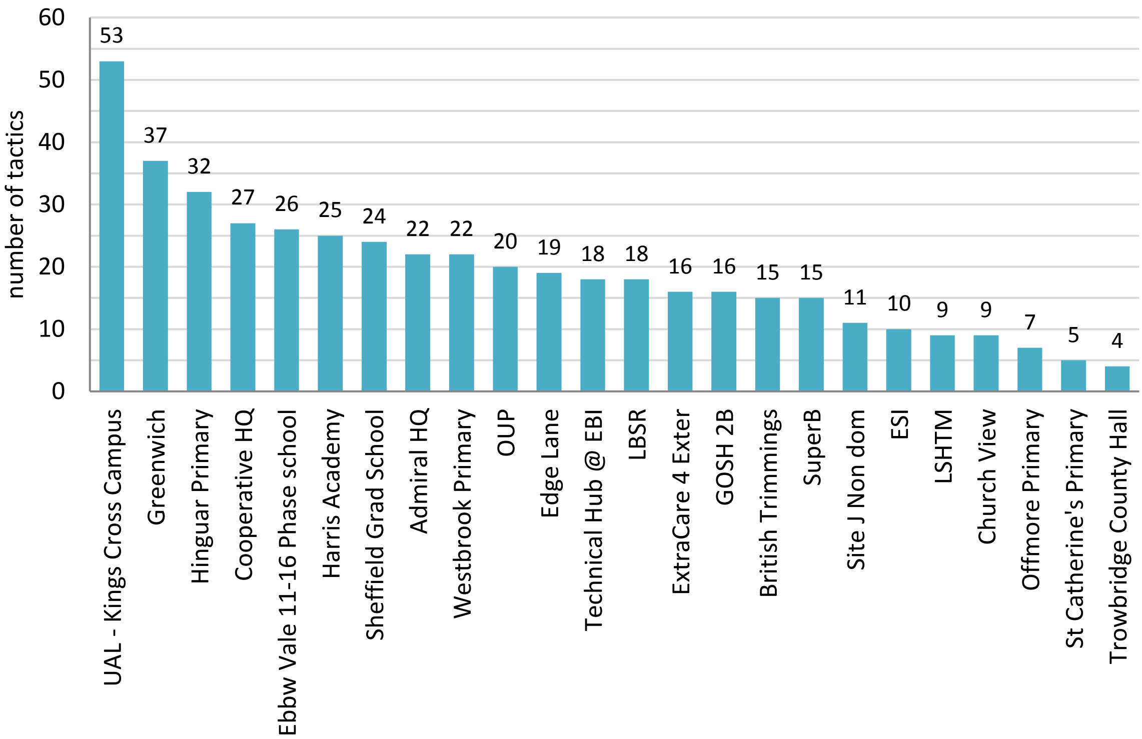


Figure 6-7 Chart showing total counted tactics per case study

The number of recorded tactics varies from 4 (case 23) to 53 (case 16). (Case 16 has considerably more tactics than any other case and is considered an outlier; as such the analysis draws comparisons with and without its inclusion.) Some of this variation is accounted for by case size – splitting the cases into two equal groups the larger half has on average 22 tactics per case while the smaller only 16. Standardising tactics counts by averaging over the floor area (i.e. measuring tactic counts per m^2) was considered but unfairly penalises larger buildings: assuming a finite pool of adaptability tactics exists, and decreasing gains as more are installed, a tactic ‘ceiling’ would be expected beyond which any linear tactic/size relationship would cease.

Table 6-11 compares the counts with Schmidt (Schmidt, 2014), who provides similar data for two sets of cases with “*explicit intent to design for adaptability*”. No comparison with Schmidt’s (2014) B sample is made due to significant differences in depth of analysis.

Table 6-11 Comparison of case counts to Schmidt's (2014) samples A and C

	N	Mean	Median	Max	Min	Standard Deviation
A cases	15	19.3	17	35	12	5.9
C cases	10	11.3	13	17	2	4.2
Interaction cases	24	19.2	18	53	4	10.8
Interaction cases (case 16 outlier removed)	23	17.7	18	37	4	8.4

Cases generated an average of 19.2 tactics per case, slightly lower than Schmidt's (2014) 'A' sample (19.7) but more than the C sample (11.3). Schmidt (2014) describes the C sample as "*exploratory*" having less depth of analysis than the "*primary*" A sample which may account for the lower sample C mean. Because of this variation in case depth across sets (but not within them), comparisons of the standard deviation are more helpful. Both Schmidt's samples generate relatively small values (sample A, $\sigma = 5.9$; sample B $\sigma = 4.2$) as might be expected of samples selected specifically as examples of adaptable design. In contrast, the interaction cases have a much higher standard deviation ($\sigma = 10.8$) which persists even when excluding the outlier case 16 ($\sigma = 8.4$). There is therefore more variability in the interaction cases with respect to adaptability than either of Schmidt's samples. Assuming, as primary case studies, that sample A and the interaction cases were examined in similar depth (as signified by the similar means), the larger variation of the latter suggests some of the cases to be more adaptable than those of Schmidt and some less.

6.3.6 SCHMIDT'S (2014) CHARACTERISTIC (CAR) EVALUATION

Schmidt (2014) describes a method for evaluating building adaptability based on compliance with 6 adaptability 'types' (see 2.3.1). These types can be considered dimensions of adaptability. Each type comprises between 1 and 4 primary characteristics and between 5 and 41 secondary characteristics. Schmidt (2014) applies two tests in the evaluation:

1. Cases should demonstrate all primary characteristics associated with an adaptability type.
2. Cases should demonstrate more than 60% of the total primary and secondary characteristics associated with an adaptability type.

All case adaptability tactics were coded using Schmidt's (2014) list of 60 adaptability characteristics (CARs). To ensure consistency with Schmidt (2014), the coded tactics list was validated by Schmidt. The validation process consisted of a number of iterations whereby both the initial coding and the coding schema were challenged and revised. For alterations to the coding schema see Schmidt (Schmidt, 2014). Finalised tactic-characteristic pairs are given in appendix 6C.

Outcomes for the tests are shown in Table 6-12. 14 cases meet the primary criteria for adjustable, 10 the primary characteristics of scalable, 4 refittable and 1 convertible. No cases meet the primary criteria for versatility, which was unexpected: open plan offices are traditionally associated with versatility (a change of spatial layout) and there are a number in the sample (01, 09, 17, 23, 31). This is likely because of a requirement to demonstrate 'moveable stuff' (furniture), something the cases were either at too early a stage to make detailed reference to or were unconcerned with due to the base build only remit (e.g. cases 01 and 31).

Table 6-12 Results of CAR assessment (highlighted cells indicate compliant values)

			key					Total				
	Case Name	Total CARs	Adjustable	Versatile	Refitable	Convertible	Scalable	Adjustable	Versatile	Refittable	Convertible	Scalable
1	Admiral HQ	18	0	2	1	3	2	33%	40%	25%	33%	21%
4	British Trimmings	11	0	2	1	2	1	33%	23%	31%	18%	21%
6.1	Offmore Primary	7	0	0	0	0	1	0%	10%	6%	11%	21%
6.2	St Catherine's Primary	5	0	0	0	0	2	0%	7%	6%	9%	29%
7	Harris Academy	24	1	3	1	1	1	50%	57%	31%	38%	43%
9	Technical Hub @ EBI	16	1	2	1	1	1	33%	33%	19%	22%	21%
10	Edge Lane	15	1	0	1	1	2	33%	27%	25%	22%	21%
11	Extra Care 4 Exeter	12	1	1	0	0	1	17%	20%	6%	22%	14%
14	LSHTM	8	1	2	0	0	1	50%	20%	13%	11%	7%
16	UAL - Kings X Campus	35	1	3	2	4	2	100%	83%	44%	58%	57%
17	OUP	13	1	1	2	2	2	50%	33%	19%	20%	21%
19	Greenwich	20	1	3	2	1	1	67%	43%	38%	31%	36%
20	Church View	9	0	0	0	2	1	17%	10%	19%	16%	14%
21	GOSH 2B	17	1	2	0	2	1	33%	43%	19%	31%	36%
23	Trowbridge County Hall	3	1	1	0	0	0	17%	10%	0%	4%	0%
24	Sheffield Grad School	21	1	3	1	2	2	50%	47%	19%	36%	29%
25	Ebbw Vale School	19	1	3	1	1	1	50%	47%	19%	31%	21%
31	Cooperative HQ	23	1	2	2	2	2	67%	57%	44%	31%	50%
35	ESI	11	0	0	1	2	1	0%	17%	25%	18%	14%
38.1	SuperB	14	0	2	1	0	1	33%	23%	19%	24%	21%
38.2	Site J Non domestic	15	0	3	0	1	1	17%	30%	13%	29%	21%
46	Hinguar Primary	22	1	2	1	1	2	67%	53%	19%	38%	29%
47	Westbrook Primary	15	0	3	0	1	2	50%	40%	6%	27%	21%
48	LBSR	14	0	0	1	1	2	17%	20%	19%	24%	14%

Unlike the AdaptaSTAR or BAS methods, this approach relied on the cases reporting adaptable features. To produce a more balanced view of the characteristics demonstrated by each case, relevant evidence was used to assess each building design and score 'missing' CARs. This also standardises the approach with that of Schmidt (who does not rely solely on case reports) and allows for comparison. The resulting CAR coding summary is located in appendix 6D. Table 6-13 shows the results of Schmidt's tests applied to this revised data.

Table 6-13 Results of revised CAR assessment (highlighted cells indicate compliant values)

			Primary CARs					Total CARs				
	Case Name	**Total CARs**	Adjustable (1)	Versatile (3)	Refittable (2)	Convertible (4)	Scalable (2)	Adjustable	Versatile	Refittable	Convertible	Scalable
1	Admiral HQ	39	0	2	1	4	2	67%	67%	56%	69%	64%
4	British Trimmings	24	0	3	1	2	1	67%	53%	50%	38%	43%
6.1	Offmore Primary	18	0	1	0	2	1	17%	33%	13%	33%	50%
6.2	St Catherine's Primary	16	0	1	0	2	2	17%	27%	13%	31%	50%
7	Harris Academy	32	1	3	1	2	1	67%	73%	44%	53%	43%
9	Technical Hub @ EBI	36	1	2	1	3	1	67%	70%	50%	56%	71%
10	Edge Lane	25	1	1	1	1	2	33%	40%	38%	38%	21%
11	ExtraCare 4 Exeter	28	1	2	0	1	1	50%	47%	19%	53%	29%
14	LSHTM	20	1	2	0	1	1	50%	30%	19%	38%	36%
16	UAL - Kings X Campus	44	1	3	2	4	2	100%	83%	50%	80%	79%
17	OUP	28	1	2	2	3	2	100%	63%	38%	40%	50%
19	Greenwich	39	1	3	2	1	2	100%	67%	63%	62%	71%
20	Church View	24	0	2	0	3	1	33%	37%	31%	47%	29%
21	GOSH 2B	25	1	2	0	2	1	50%	53%	38%	44%	57%
23	Trowbridge County Hall	19	1	1	0	1	0	33%	33%	13%	33%	14%
24	Sheffield Grad School	35	1	3	1	4	2	67%	77%	25%	62%	50%
25	Ebbw Vale School	29	1	3	1	2	1	50%	70%	38%	51%	29%
31	Cooperative HQ	39	1	3	2	4	2	83%	77%	63%	64%	71%
35	ESI	20	0	0	1	4	1	0%	33%	38%	33%	36%
38.1	SuperB	25	0	2	1	1	1	50%	33%	31%	47%	50%
38.2	Site J Non dom	27	0	3	0	3	1	17%	43%	19%	56%	50%
46	Hinguar Primary	33	1	2	1	2	2	67%	70%	38%	56%	43%
47	Westbrook Primary	30	0	3	0	3	2	50%	70%	13%	58%	50%
48	LBSR	35	0	1	1	2	2	33%	57%	44%	62%	43%

With the revised approach the number of characteristics per case ranges from 16 to 44, with an average of 29 per case. Schmidt (2014) obtains a similar range (17 to 41) for his sample A but a slightly higher mean (30.5). This suggests Schmidt's sample is marginally more adaptable than the interaction sample. Only one case fulfils the primary criteria for all 5 adaptability types, with five cases failing to meet the criteria for any of the types. In contrast all of Schmidt's buildings meet the criteria for at least one type. Using the high percentage (>60%) of relevant CARs test less cases meet the criteria for at least one of the types. This reflects Schmidt's findings (4 of Schmidt's cases fail to meet the criteria for any types using the percentage test). However, more cases are able to demonstrate compliance with convertibility using this test. As for the primary CAR test, Case 16 performs well. Cases 19 (Greenwich Stockwell Street) and 31 (Cooperative HQ) have marginally better results. Case 01 (Admiral HQ) performs considerably better using this test.

Schmidt (2014) makes no suggestions as to how the types might be combined into a single measure of adaptability. In the absence of a suggested method the number of types achieved using each test were summed for each case and used to indicate an adaptability score. The number of CARs achieved was also recorded. Results are summarised in Table 14.

Table 14 Results of Schmidt's CAR test

Case		Number of primary CARs	Primary types	Secondary types	Total CARs
1	Admiral HQ	9	2	4	39
4	British Trimmings	7	1	1	24
6A	Offmore Primary	4	0	0	18
6B	St Catherine's Primary	5	1	0	16
7	Harris Academy	8	2	2	32
9	Technical Hub @ EBI	8	1	3	36
10	Edge Lane	6	2	0	25
11	ExtraCare 4 Exeter	5	1	0	28
14	LSHTM	5	1	0	20
16	UAL	12	5	4	44
17	OUP	10	3	2	28
19	Greenwich	9	4	5	39
20	Church View	6	0	0	24
21	GOSH 2B	6	1	0	25
23	Trowbridge County Hall	3	1	0	19
24	Sheffield Grad School	11	4	3	35
25	Ebbw Vale School	8	2	1	29
31	Cooperative HQ	12	5	5	39
35	ESI	6	1	0	20
38A	SuperB	5	0	0	25
38B	Site J Non domestic	7	1	0	27
46	Hinguar Primary	8	2	2	33
47	Westbrook Primary	8	2	1	30
48	LBSR	6	1	1	35

6.3.7 EXPERT ASSESSMENT

Expert 1 was provided with a typical floor plan, elevation and section, a photograph or visualisation of the building and a short description of the building type, size, location and key adaptable features. Using this information the expert was asked to complete two tasks:

- Rank the cases in order of least to most adaptable
- Separate the cases into two groups – adaptable and not adaptable.

The manner in which these tasks were completed was left open to the expert. In the event the expert adopted a makeshift scoring system:

> *"It was an incredibly crude scoring system as a way of helping me make sure I wasn't completely being biased based on buildings that I liked … what I did was simply give 1 point for every positive aspect I could identify related to adaptability from the drawings/notes from our discussion. I don't think I gave any 'penalty' points for negative aspects, it was simply a total of positive points" (Expert 1, email dated Feb 2014)*

Using this scoring system the expert allocated cases to three primary classes: good, so-so and not good. The expert further classified these groups by the use of + and – qualifiers (good+ being better than good- for example). There is a lack of direct correspondence between the expert's scoring system and case classification in some instances; for example the so-so(+) classified Edge Lane (case 10) scores more highly than the good (-) Greenwich Stockwell Street development (case 19). After consulting with the expert the classifications are the preferred ordering method and as such the results, shown in table 6-15, are ranked first by category.

Table 6-15 Expert 1 assessment of case adaptability result

Case	Case Name	Classification	Score
Case 16	University of the Arts London (UAL) Kings Cross Campus	good (++)	17
Case 24	Sheffield Engineering Graduate School	good (+)	12
Case 46	Hinguar Primary School	good	7
Case 20	Church View	good (-)	7
Case 31	Cooperative Headquarters	good (-)	7
Case 19	Greenwich University Stockwell Street	good (-)	6
Case 47	Westbrook Primary School	so-so (+)	9
Case 10	Edge Lane	so-so (+)	8
Case 25	Ebbw Vale 11-16 School	so-so (+)	6
Case 17	Oxford University Press (OUP)	so-so (+)	5
Case 07	Harris Academy	so-so (-)	7
Case 04	British Trimmings Extra Care	so-so (-)	6
Case 01	Admiral headquarters	so-so (-)	5
Case 09	Technical Hub @ EBI	so-so (-)	4
Case 35	Environment and Sustainability Institute (ESI)	so-so (-)	4
Case 48	London Bridge Train Station	so-so (-)	4
Case 38.1	Site J non-domestic	so-so (+)	2
Case 23	Trowbridge County Hall	not good (+)	2
Case 11	Extra Care 4 Exeter	not good	3
Case 21	Great Ormond Street Hospital (GOSH) 2B	not good	3
Case 38.1	SuperB (site J residential)	not good	3
Case 06.1	Offmore Primary	not good	2
Case 06.2	St Catherine's Primary	not good	2
Case 14	London School of Hygiene and Tropical Medicine (LSHTM)	not good	2

6.3.8 COMPARISON OF ADAPTABILITY ASSESSMENT TECHNIQUES

This section briefly compares the different adaptability measures and considers the degree of agreement between them. This is primarily a check on convergent validity of the measures for the population of 24 designs - if all six measures outlined above are valid measures of adaptability, we would expect them to co-vary. However, comparing the assessment methods also presents an opportunity to better understand how the measures relate, something which is rarely done with adaptability measures (see section 2.3.3.5).

Scatter plots, Table 6-17, indicate positive correlation between some of the measures. None of the scatter plots suggest any strong non-linear relationships and so a linear correlation method was appropriate (Field, 2013). All of the scales were treated as producing ordinal level data – capable of ranking or ordering the cases with respect to adaptability but with no certainty that the difference between scores is constant. As such a non-parametric test of correlation, Spearman's ρ, was selected. This is perhaps overly conservative; several texts (Bryman & Cramer, 2011; Field, 2013) note the application of parametric texts to ordinal data "*is a matter for some debate*" (Bryman &

Cramer, 2011). However data for most of the methods also violates the assumption of normality (see histograms, appendix 6E) which for the relatively small samples being used justifies the use of the less powerful test. Correlations coefficients between each of the assessment methods were computed using SPSS, Table 6-16.

As was expected, the variety of measures described by Schmidt (2014) show a high degree of consistency with one another and the expert assessment. AdaptSTAR also indicates a good level of agreement in the rank order of the cases with all measures except BAS, and is the only metric to correlate with literature interpretations of adaptability (as measured by the literature compliance metric). BAS shows little consistency with the other measures. BAS's developers assumed that buildings undergoing change more often are more adaptable (Wilkinson & Reed, 2011). This lead to the inclusion of a number of scale items that seem more linked to the likelihood of change being attractive, than the ease of change occurring; building age is a typical example. The failure of the BAS method to correlate with other methods does not conclusively prove the method inaccurate or misleading – both the AdaptSTAR and Schmidt methods could be at fault. However, both these methods correlate, albeit weakly, with the literature comparison making it more plausible these methods are superior.

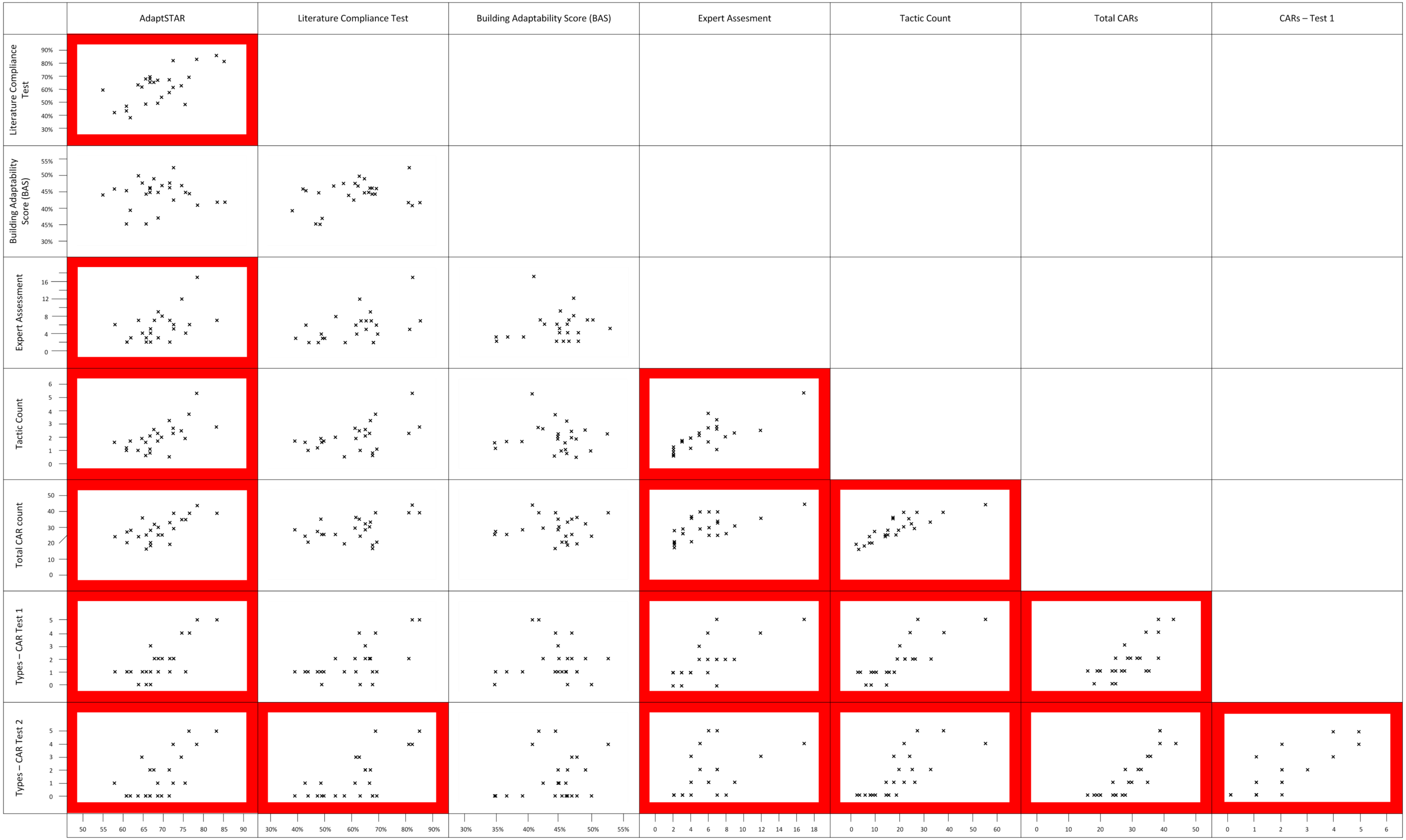
Overall the measures demonstrate an unexpectedly high level of agreement in the rank order of the cases –that statistically significant correlations for the population examined were found at all is somewhat surprising given the lack of consensus in the literature (see 2.3.3).

Table 6-16 Correlation coefficients (Spearman's ρ) for all numeric adaptability measures – shaded cells indicate significant (p>0.01) strong correlations (ρ>0.55)

Spearman's rho		AdaptSTAR	Generic Assessment	BAS	Expert 1	Tactic Count	CARs Count	Primary CARs (Test 1)	Secondary CARs (Test 2)
AdaptSTAR	Correlation Coefficient	1.000	.591**	-.015	.570**	.687**	.640**	.705**	.624**
	Sig. (2-tailed)		.001	.940	.004	.000	.001	.000	.001
	N	26	26	26	24	24	24	24	24
Generic Assessment	Correlation Coefficient	.591**	1.000	.165	.462*	.407*	.353	.496*	.534**
	Sig. (2-tailed)	.001		.421	.023	.048	.091	.014	.007
	N	26	26	26	24	24	24	24	24
BAS	Correlation Coefficient	-.015	.165	1.000	.189	-.067	-.028	-.009	.148
	Sig. (2-tailed)	.940	.421		.377	.754	.897	.968	.491
	N	26	26	26	24	24	24	24	24
Expert 1	Correlation Coefficient	.570**	.462*	.189	1.000	.731**	.630**	.729**	.666**
	Sig. (2-tailed)	.004	.023	.377		.000	.001	.000	.000
	N	24	24	24	24	24	24	24	24
Tactic counts	Correlation Coefficient	.687**	.407*	-.067	.731**	1.000	.883**	.858**	.833**
	Sig. (2-tailed)	.000	.048	.754	.000		.000	.000	.000
	N	24	24	24	24	24	24	24	24
CARs Count	Correlation Coefficient	.640**	.353	-.028	.630**	.883**	1.000	.722**	.882**
	Sig. (2-tailed)	.001	.091	.897	.001	.000		.000	.000
	N	24	24	24	24	24	24	24	24
Primary CARs (Test 1)	Correlation Coefficient	.705**	.496*	-.009	.729**	.858**	.722**	1.000	.790**
	Sig. (2-tailed)	.000	.014	.968	.000	.000	.000		.000
	N	24	24	24	24	24	24	24	24
Secondary CARs (Test 2)	Correlation Coefficient	.624**	.534**	.148	.666**	.833**	.882**	.790**	1.000
	Sig. (2-tailed)	.001	.007	.491	.000	.000	.000	.000	
	N	24	24	24	24	24	24	24	24

**Correlation significant at the 0.01 level (2-tailed).
*Correlation significant at the 0.05 level (2-tailed).

Table 6-17 Scatterplots illustrating relationships between different adaptability metrics (plots highlighted in red indicate correlation coefficients (ρ) of 0.6 or greater, significant at the p>0.01 level)



6.3.9 ADAPTABILITY OUTCOME SCORING

On the basis of the correlational analysis (6.3.8) the BAS assessment was deemed unreliable and discounted. Various methods were experimented with for combining the remaining adaptability measures. Summing scores gave metrics with a larger range (e.g. AdaptSTAR) a greater influence than those with simpler scoring approaches (e.g. the CAR method). Converting all scores to percentages and averaging was considered but produced very flat results with all cases clustered together. This not only failed to differentiate the cases but also obscured the very high, low and sometimes inconsistent scores the cases achieved across the indicators. Average rank was similarly dismissed as it levelled potentially important variation across the cases.

Instead, it was decided to score each case as adaptable/not adaptable using each metric individually. Set allocations could then be determined by combining total adaptable / not adaptable results with the degree of consensus across the metrics. This approach required each metric to be individually calibrated. As noted in chapter 3, no a-priori cut-off for 'adaptable' was specified for any of the methods due to the limited data against which to benchmark. Calibration points were therefore set using a combination of the two benchmarking cases (see section 4.6.3.2), previous work, case knowledge and as last resort the distribution of the data. This later method was not preferred as it relies on the case sample, which cannot be considered representative of a wider population.

The two calibration cases (BCL and SD) score within the range of case scores for the literature metric and these are used as benchmarks defining adaptable / not adaptable points. Cases scoring higher than the SD case (i.e. ≥ 40.8 / 82%) are classed as adaptable, while cases scoring lower than BCL (≥ 29.6 / 59%) as not adaptable. This allocates 11 cases to either set, with 12 cases unallocated.

For AdaptSTAR the calibration cases fall at extreme ends of the scores obtained – suggesting either all the buildings are adaptable or perhaps more likely the selection of extreme cases for benchmarks fails to differentiate between more mundane examples. Conejos' star ratings cannot be used as they have little meaning – the star rating boundaries are rather arbitrarily placed and it is not known how a 1* building relates to a wider population of buildings. Instead cases were compared to Conejo's 12 award winning "*successful reuse conversions*" (Conejos, 2013), Figure 6-8. All case study designs achieve scores greater than Conejos's least adaptable case, the Mint Coining Factory, suggesting all of the designs (with the exception of unadaptable benchmark, BCL) could be considered to some extent adaptable with respect to reuse potential.

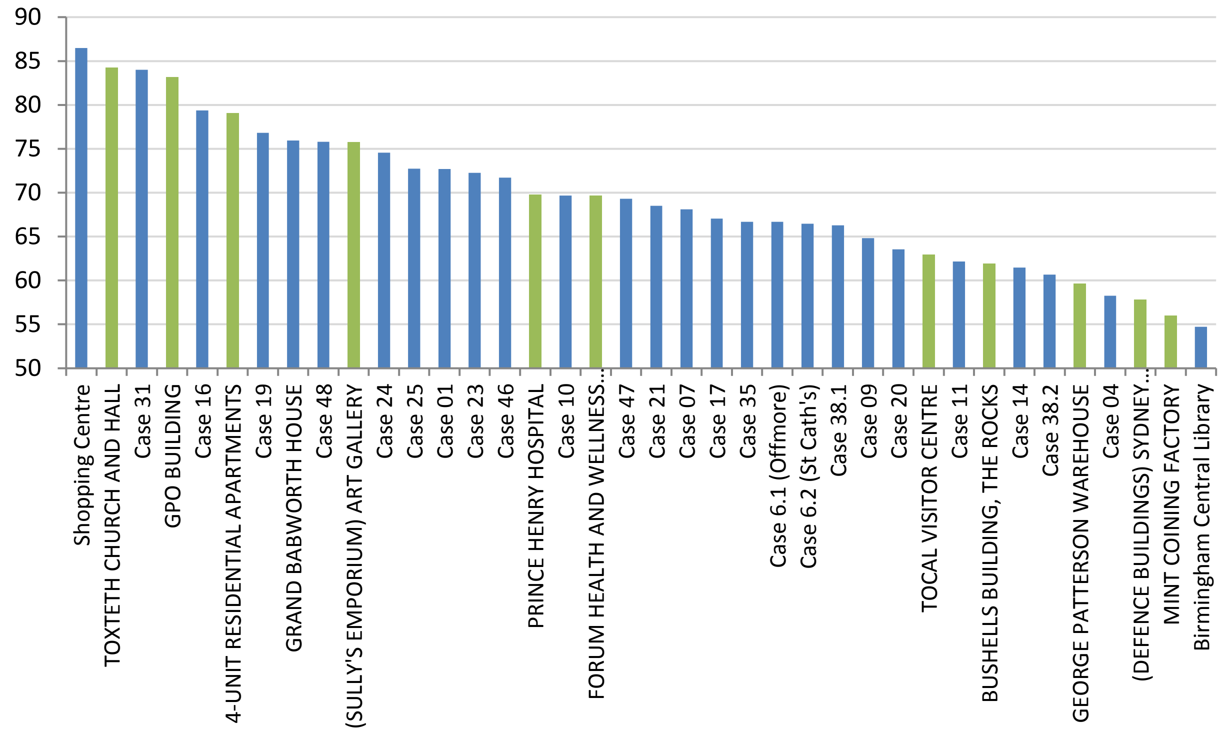


Figure 6-8 Bar chart showing AdaptSTAR scores for cases studies (blue) and Conejos (2013) cases (green)

Neither benchmarking case was scored using the tactic count method due to the onerous data collection requirements. Schmidt (2014) provides comparison values for his case set (see section 6.3.5), but there is no other information with which to benchmark the cases. Figure 6-9 shows the spread of total tactics per case, demonstrating a reasonably normal type distribution with no obvious break points other than between the bulk of the data and the outlier case 16. As a last resort, a median split was therefore adopted. This results in tactic count being the most inclusive of the adaptability metrics (11/23 cases allocated to the adaptable set).

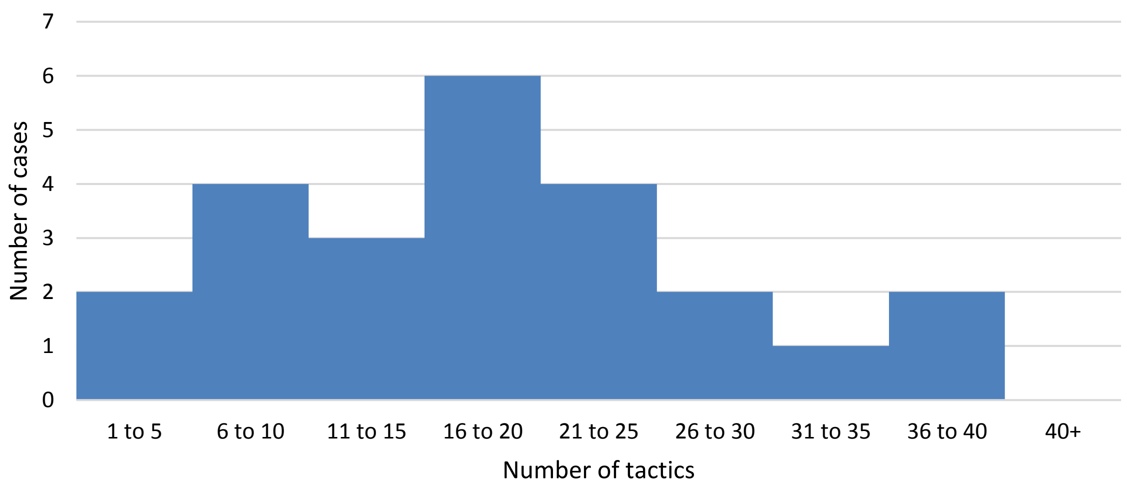


Figure 6-9 Histogram showing tactic frequency for the TSB cases

Interpreting the results of Schmidt's tests is difficult; as Schmidt notes the yes/no criteria for achievement of a CAR provides "*no indication to what extent a characteristic has been embedded*" and "*this lack of clarity can provide a false sense of achievement*" (Schmidt, 2014). Taking 'reversible' as an example, one component being "reversible" arguably does not make the building itself reversible. However, a number of cases score zero in Schmidt's (2014) CAR tests and it seems reasonable to presume (as no lower score is possible) these cases not adaptable. Similarly, cases scoring five (the maximum possible) were labelled as adaptable. This left a large portion of the scale's range creating 'middling' cases that belonged to neither set, and so the decision was made to also allocate those cases scoring 1 to the not adaptable set and those scoring 4 to the adaptable set. This is in line with Schmidt's (Schmidt, 2014) treatment of results.

The expert marked cases good, so-so and not good. Good cases are presumed adaptable, not-good cases as unadaptable. No presumption on the meaning of so-so cases is made initially, although the +/- weighting the expert applied to the so-so cases was referred to for the eight 'swing' cases, see below.

Results of applying these calibration points are shown in Table 6-18, red indicates 'not adaptable', green 'adaptable' outcomes. Cases with two or more 'adaptable' outcomes and no red 'not adaptable' marks were allocated to the adaptable set. Cases with two or more not adaptable outcomes and no green marks were allocated to the not adaptable set, see Table 6-18.

6.3.9.1 *SWING CASES*

Eight cases generated conflicting results using the above cut-off points. These cases form the 'swing' cases, and required an element of judgement in scoring. Several approaches were considered. The first was to use a pattern matching approach (Hak & Dul, 2010), comparing the swing cases qualitatively to other cases in sample placed firmly in the adaptable and not adaptable sets. This method however largely confirmed that the cases were borderline adaptable – they displayed some adaptability characteristics but also had significant barriers to simple change. Fuzzy sets were considered, recognising the 'partial' success of the swing cases. However, much of the difficulty with scoring the swing cases is created by the lack of benchmark data – there is not an adequate understanding of what makes a building adaptable enough to separate those cases which are usefully adaptable and those which are not. Fuzzy sets still require an understanding of where the adaptable / not adaptable point lies. Fuzzy sets would therefore not solve the problem and the application of fuzzy sets would mask what is essentially a measurement problem.

An alternative was to concentrate on each case's consistency across the measures. Cases were allocated 1 point for a metric scoring them as adaptable, 0 for mediocre scores and -1 for low scoring metrics. Case scores using this approach are summarised in Table 6-18. All cases with positive scores (more cases describing them as adaptable than not) were allocated to the adaptability set, all those with negative scores to the not adaptable outcome set. Due to the rather arbitrary nature of this scoring mechanism these outcomes should be considered tentative and subject to revision during the QCA minimisation process (see chapter 6)

Table 6-18 Summary of adaptability assessment results (in descending order of total adaptable ratings)

Case	AdaptSTAR	Tactic Count	Primary CARs	60% CARs	Literature Compliance	Expert	+	-	Sum	Adaptable Outcome
16 University of the Arts London, Kings Cross	79% 🟢	53 🟢	5 🟢	4 🟢	83% 🟢	good (++) 🟢	6	0	6	1
31 Cooperative HQ	84% 🟢	27 🟢	5 🟢	5 🟢	86% 🟢	good (-) 🟢	6	0	6	1
19 Greenwich University, Stockwell Street	77% 🟢	37 🟢	4 🟢	5 🟢	69% ○	good (-) 🟢	5	0	5	1
01 Admiral HQ	73% 🟢	22 🟢	2 ○	4 🟢	82% 🟢	so-so (-) ○	4	0	4	1
24 Sheffield Engineering Graduate School	75% 🟢	24 🟢	4 🟢	3 ○	63% ○	good (+) 🟢	4	0	4	1
46 Hinguar Primary	72% 🟢	32 🟢	2 ○	2 ○	67% ○	good 🟢	3	0	3	1
25 Ebbw Vale 11-16 Phase School	73% 🟢	26 🟢	2 ○	1 🔴	61% ○	so-so (+) ○	2	1	1	1
07 Harris Academy Purley	68% ○	25 🟢	2 ○	2 ○	65% ○	so-so (-) ○	1	0	1	1
17 Oxford University Press (OUP)	67% 🔴	20 🟢	3 ○	2 ○	65% ○	so-so (+) ○	1	1	0	1
47 Westbrook Primary	69% ○	22 🟢	2 ○	1 🔴	67% ○	so-so (+) ○	1	1	0	1
10 Edge Lane	70% ○	19 🟢	2 ○	0 🔴	54% 🔴	so-so (+) ○	1	2	-1	0
48 London Bridge Station Redevelopment	76% 🟢	18 ○	1 🔴	1 🔴	48% 🔴	so-so (-) ○	1	3	-2	0
20 Church View	64% 🔴	9 🔴	0 🔴	0 🔴	63% ○	good (-) 🟢	1	4	-3	0
23 Trowbridge County Hall	72% 🟢	4 🔴	1 🔴	0 🔴	57% 🔴	not good (+) 🔴	1	5	-4	0
09 Technical Hub @ EBI	65% 🔴	18 ○	1 🔴	3 ○	62% ○	so-so (-) ○	0	2	-2	0
04 British Trimmings (Daisy Haye)	58% 🔴	15 ○	1 🔴	1 🔴	42% 🔴	so-so (-) ○	0	4	-4	0
21 Great Ormond Street Hospital Phase 2B	69% ○	16 ○	1 🔴	0 🔴	49% 🔴	not good 🔴	0	4	-4	0
35 Environment and Sustainability Institute	67% 🔴	10 🔴	1 🔴	0 🔴	70% ○	so-so (-) ○	0	4	-4	0
11 St Loyes Extra Care	62% 🔴	16 ○	1 🔴	0 🔴	38% 🔴	not good 🔴	0	5	-5	0
6.1 Offmore Primary	67% 🔴	7 🔴	0 🔴	0 🔴	68% ○	not good 🔴	0	5	-5	0
6.2 St Catherine's Primary	66% 🔴	5 🔴	1 🔴	0 🔴	68% ○	not good 🔴	0	5	-5	0
38 Site J SuperB	66% 🔴	15 ○	0 🔴	0 🔴	48% 🔴	not good 🔴	0	5	-5	0
14 London School of Hygiene and Tropical Medicine	61% 🔴	9 🔴	1 🔴	0 🔴	43% 🔴	not good 🔴	0	6	-6	0

6.4 RECONCILIATION OUTCOME

Table 6-19 summarises the low carbon and adaptability assessment results presented above. As stated in section 5.1 cases are deemed successful examples of low carbon adaptable design where they achieve the requirements of both adaptable and low carbon sustainable design. Reconciliation outcomes for all cases are as per the final column of Table 6-19.

Figure 6-10 visualises the reconciliation outcome of all cases. Top left are cases which would traditionally be labelled unsustainable – fulfilling the requirements of neither agenda. Bottom right are cases demonstrating holistically sustainable outcomes – both adaptable and low carbon. The top right segment shows adaptable cases not demonstrating low carbon best practice design; only case 16 was found to occupy this zone. Also demonstrated by Figure 6-10 is that more cases meet the requirements for the low carbon outcome than adaptability. This might reflect more difficult criteria for adaptability or the mandated status of low carbon design (see section 1.2) and the uplift in energy efficiency minimum standards following the introduction of Part L 2010.

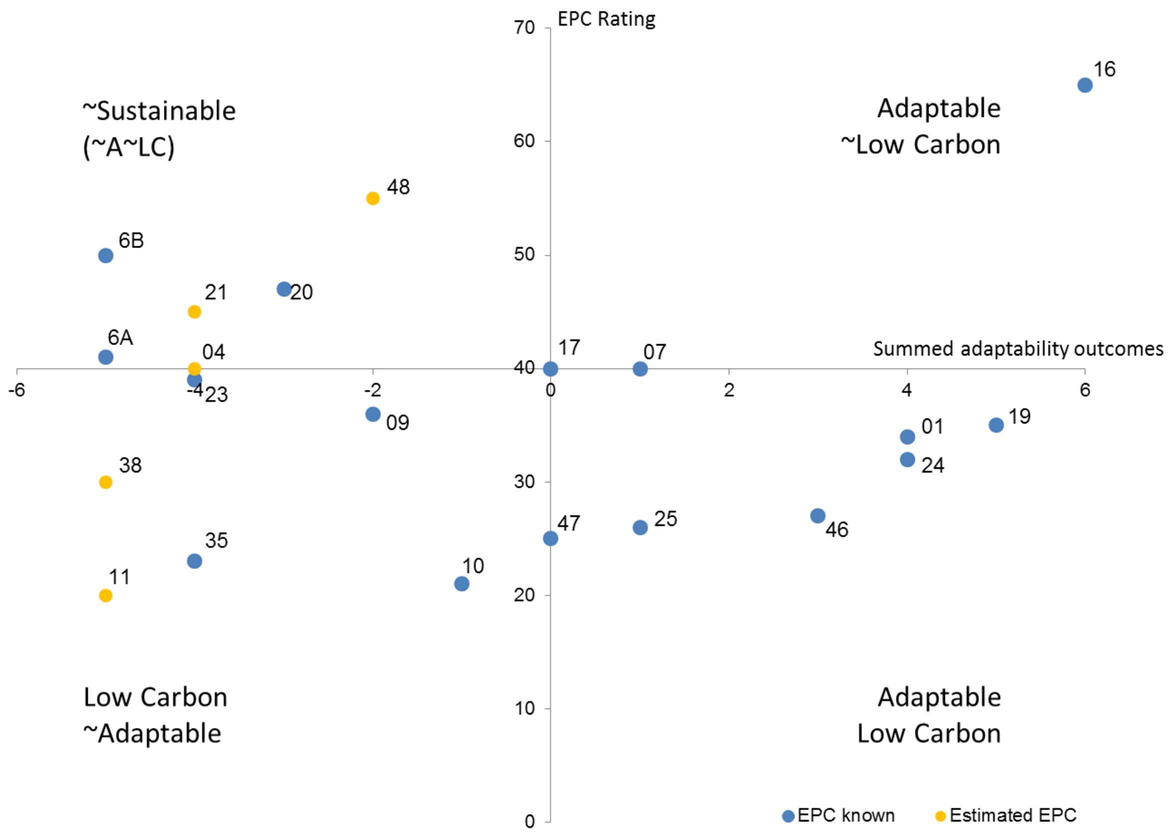


Figure 6-10 Graphical representation of case reconciliation outcomes (case 31 not shown, EPC = -58, summed adaptability outcomes = 6).

(Case 17 is plotted at its lowest possible EPC score (40); it is likely closer to the position of case 47.)

Table 6-19 Reconciliation outcome

Case	Low carbon best practice	Adaptability best practice	Reconciliation outcome
01 Admiral HQ	✓	✓	✓
04 British Trimmings (Daisy Haye)	x	x	x
6.1 Offmore Primary	x	x	x
6.2 St Catherine's Primary	x	x	x
07 Harris Academy Purley	✓	✓	✓
09 Technical Hub @ EBI	✓	x	x
10 Edge Lane	✓	x	x
11 St Loyes Extra Care	✓	x	x
14 London School of Hygiene and Tropical Medicine	-	x	-
16 University of the Arts London, KX Campus	x	✓	x
17 Oxford University Press (OUP)	✓	✓	✓
19 Greenwich University, Stockwell Street	✓	x	✓
20 Church View	x	x	x
21 Great Ormond Street Hospital	x	x	x
23 Trowbridge County Hall	✓	x	x
24 Sheffield Engineering Graduate School	✓	✓	✓
25 Ebbw Vale 11-16 Phase School	✓	✓	✓
31 Cooperative HQ	✓	✓	✓
35 Environment and Sustainability Institute	✓	x	x
38 Site J SuperB	✓	x	x
46 Hinguar Primary	✓	✓	✓
47 Westbrook Primary	✓	✓	✓
48 London Bridge Station Redevelopment	x	x	x

7 RECIPES FOR INTERACTION

7.1 INTRODUCTION

This chapter uses results from the previous two, which have examined the nature of interaction effects in design (chapter 5) and the possibility of producing reconciled design outcomes (chapter 6) to tackle the question: how does interaction affect sustainable outcomes?

Firstly conditions (being "*factor[s] which is used to explain the outcome*" (Schneider & Wagemann, 2012) affecting interaction decision making are identified and used to expand on the model of interaction between adaptability and low carbon design presented in section 5.5. The model is then compared to the cases (described as either reconciled design or not reconciled in chapter 6) systematically using qualitative comparative analysis (QCA). The intention is to produce a number of 'recipes' for reconciling the agendas, and complete objective 05:

> *By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, propose pathways to successful and unsuccessful reconciliation of adaptable and low carbon design. (Objective 05)*

The final part of the chapter (section 6.4) then interprets these recipes in light of the case evidence.

7.2 MODEL SPECIFICATION

7.2.1 IDENTIFYING FACTORS INFLUENCING THE CHOICE OF INTERACTION STRATEGY

Numerous factors influencing the choice of interaction strategy were identified in chapter 5 (see section 5.4) are summarised in Table 7-1. The intention is that these factors can be combined with the interaction types and strategies described in chapter 5 to form a preliminary model of interaction that can be refined using QCA. However, numerous factors were identified in chapter 5 and so to make the model more manageable similar ideas were grouped into 9 themes.

Table 7-1 Factors influencing the choice of interaction strategy sorted by theme

	THEME								
STRATEGY	**Adaptability push/pull**	**Low carbon push/pull**	**Planning and statutory bodies**	**Typology**	**Budget**	**Ownership**	**Trust**	**Technological**	**Other**
Avoid	Expected expansion				What is perceived as valuable	Long term ownership		Availability of alternatives	Available space
								LZC is expensive	BREEAM LZC technologies report
Compromise	Strong client brief for adaptable design	Strong client brief for low carbon design		Changeable, cheap to run typology				Availability of modular / distributed solutions	
		Client disinterestedness in sustainable design							
Prioritise	Strong adaptability brief	Strong low carbon brief	Planning constraints	Traditionally adaptable typology	Restricted resources – design time, funding			No alternatives	Location
				Beliefs about what the building should be				Visual impact	
Mitigate		Desire for a passive scheme		Intensively occupied buildings		Early owner involvement			
Exploit			Planning policy linkages						BREEAM requirements
									Multi-disciplinary teams
									Good design
									Legislation
Control				Non domestic v domestic norms		Owner occupier	Designer trust	Particular HVAC / LZC technology selected	Preciousness
							Performance gap liability	Design complexity	Beliefs about occupant behaviour
									Local environment
Permissive						Shell and core developments	Green, engaged client		Building regulation and BREEAM acceptance
						Tenanted buildings	Compliant occupants		
Reconcile	Specific adaptability requirements / scenarios	Low carbon brief				Ownership			
						Timely occupier involvement			
Retrofit		Client / designer desire for LZC demonstration	Statutory objection to LZC proposals		Funding cuts	Developers			
			Planning desire for LZC demonstration		Value engineering				
Future proof	Known / unavoidable change e.g. CCA					Long term ownership			
						Risk adverse owner			
Facilitated un-doing	Client experience of frustrated change					Long term ownership			
Hedge			GLA biofuel promises			Commercially minded developers		Risky, unproven technologies	Legislative uncertainty
								Rapidly reducing LZC costs	Prolonged build period (e.g. phased)
No strategy		Preoccupation with low carbon design				Late occupier involvement			

7.2.1.1 *THEME 1: ADAPTABILITY PUSH / PULL*

Factors in the adaptability requirements theme describe clients anticipating change and as a result requesting adaptable buildings. This link between expected change and adaptability demands is well established in the literature (Arge, 2005; Schmidt, 2014), however it was the nature of the adaptability requests which was important for interaction:

- Strong, unopposed adaptability briefs could override other considerations leading to prioritisation of adaptability at the expense of other options.
- Specific change requirements led to avoiding certain design combinations that prevented them, or deliberately selecting adaptable and low carbon solutions that worked well together (reconciling).
- Vague requests for adaptability led to compromising when coupled with an equally strong desire for low carbon design.

The difference between clients making specific demands and those who made more generic requests for flexible space was primarily in the type of change anticipated. Where change was predictable, clients stated specific scenarios and design teams were able to ensure these were accommodated. For example growing organisations (e.g. case 07, case 24 and case 17) commonly asked for expansion space:

> *"It will be necessary to identify where expansion is possible on a site master plan at an early stage to ensure the proposals do not limit or block future expansion." (Case 07, DQIs)*

Where experience suggested change would be necessary but in more unpredictable ways, requests for generic adaptability were more likely. For example based on experience of previous shifts in learning and care models, school and hospitals anticipated long term less predictable change:

> *"a healthcare building, by the time you've built it, it's already out of date…The models of care, the way care is delivered is evolving the whole time…" (Interview 10)*

Note the two types of request were not mutually exclusive. Case 46 for instance is designed as a series of flexible spaces but also incorporates a number of more specific requirements such as the ability to add classrooms and for the community to use the hall out of hours.

7.2.1.2 *THEME 2: LOW CARBON PUSH / PULL*

In the same way demands for adaptability were important in understanding interaction decisions, so too were low carbon aspirations. Low carbon aspirations were owned by primarily two stakeholder groups in the cases – the clients commissioning buildings and planning authorities imposing conditions on development (see planning theme below). The literature typically classes these two groups as demand pull and supply push (Adeyeye et al., 2007) and their effects on energy efficiency in isolation are well documented (Brennan & Cotgrave, 2014; Williams & Dair, 2007).

Two aspects of client aspiration were important in understanding interaction – the level of commitment to low carbon design and the client's vision of their low carbon building. Regarding the latter clients often had set views about what constitutes low carbon design: naturally ventilated, passive style buildings were requested by many:

> *"We went through all these scenarios and [the consulting engineer] did a lot of work in terms of simulation of different scenarios and we demonstrated to the clients that… If you want to have a building that consumes as little energy as possible, then I know it goes against your preconceptions about what you wanted, but actually, we can demonstrate that controlling the ventilation makes a more energy-efficient building." (Interview case 31)*

Other clients wanted to make a "*clear statement of environmental commitment*" (Case 35, Sustainability assessment) pushing teams towards the inclusion of LZC technologies. For example Case 21's natural ventilation flue "*expressed in the façade to demonstrate the Hospital's commitment to a green agenda*" (Case 21, Design and access statement). These client ideas influenced the low carbon solutions and approach adopted by the cases, which in turn limited the interaction options available – see theme 8, technology.

From a commitment perspective clients disinterested in green, energy efficient design were unlikely to support interaction decisions that favoured carbon reduction over other more valued aspects of the design (see also budget theme). Yet equally, an obsession with low energy design led to prioritisation at the expense of other aspects of sustainability (e.g. case 11). Producing the most balanced outcomes were clients with a clear commitment to low carbon design for operational reasons for whom energy efficiency was worth investing in, to a point. Where these clients owned and would maintain the building they also appeared more likely to be trusted (see theme 7).

7.2.1.3 *THEME 3: PLANNING AND STATUTORY BODIES*

There were many examples of environmental policies promoting low carbon, energy efficient design and the installation of renewable energy. In some cases planning obligations required designs to deliver best practice and set an example to others due to the local importance of a scheme:

> *"King's Cross Central has the potential to be an exemplar demonstration project" (Case 16, 2004P Delegated officer's report)*

"There is an aspiration for the Ebbw Vale Steel Works to be an exemplar of sustainable development" (Case 25, TSB Report)

These types of planning conditions created an impetus for low carbon prioritisation, although many cases chose to hedge their way out of the more onerous requirements (e.g. case 16). In contrast planning policy had limited direct impact on adaptability. A small number of policies did make links between energy efficiency and long life, low waste developments. These linked policies provided opportunities for the cases to exploit interaction.

Planning and the various statutory agencies were most influential when they objected to design proposals – case 19's vision of a PV clad roof is stymied by Network Rail, Case 16's LED facade vetoed by English Heritage. By preventing the design teams from doing what they wanted this group are responsible for several applications of the retrofit strategy as design teams attempt to wait out the opposition:

"This is the absolute perfect roof to get PV on but we just couldn't get it for Network Rail's sake. So in the future if they did need it we have a water tap allocated to every roof. So that if we can get the Sedum off and panels on and they need cleaning or however it works then yeah, it might be a possibility." Interview case 19

7.2.1.4 *THEME 4: TYPOLOGY*

Typology essentially describes what a building is designed to do. It therefore influenced what clients expected from their buildings in terms of adaptability and low carbon design. For the commercial developments adaptability was strongly associated with the need to remain competitive and the practicalities of shell and core design for unknown tenants ("*Network Rail is unable to dictate the lighting solutions and requirements for unknown future tenants*" Case 48, Energy statement) leading to requests for adaptability addressing specific scenarios. In contrast the long term and less predictable nature of institutional ownership resulted in imprecise, over provision type requests:

"what we did do was ask them to design the infrastructure cabling, conduit trays, services risers. Things that would allow for double, point two, point three what we needed, because they need to be accessible in the future …" Interview case 19

From a low carbon point of view schools were keen to use the technologies as a learning opportunity ("*a visible example is a wind turbine, is felt to be of high educational benefit.*" Case 46, Southend New article) while commercial developers concentrated on improving brand image ("*any advice to help them to…enhance their eco brand has been well received*" Case 31, TSB report).

The design team's understanding of a particular typology was influential even where an explicit client brief was absent, with the teams using standard assumptions about how a particular type of building is designed and occupied to supplement other information and make decisions. For instance, commercial and institutional buildings had fundamentally different occupancy patterns and modes of use to the three residential case studies (04, 11 and 38). This strongly influenced HVAC strategies and energy efficiency approaches adopted by the cases and consequently the type of interaction encountered. To some extent it also limited the appropriate technological solutions to interaction problems. It is therefore expected that domestic and non-domestic properties would demonstrate different paths to sustainable outcomes although there is no strong indication either typology should be expected to perform better than the other.

In sum, typology affected interaction decisions by determining the desired mix of adaptability and low carbon design (influencing where interaction between the agendas was problematic or helpful) and limiting the relevant solutions for capitalising on good effects.

7.2.1.5 *THEME 5: BUDGET*

Available funding varied dramatically across the cases (table 4-2) reflecting differences in size, use and funding source. While some cases (e.g. 16, 19, 31 and 48) are large, apparently well-funded projects others were commissioned with "*severe budgetary constraints*" (Case 04, TSB factsheet). Funding is known to influence sustainable design (Häkkinen & Belloni, 2011; Morton et al., 2011; Williams & Dair, 2007). However, from an interaction perspective (and specific to the design period studied) changes to funding appeared most important. Funding cuts and associated 'value engineering' created an environment in which the agendas were required to compete. As noted in section 5.4.2 competition is associated with prioritisation, design teams choosing one agenda over the other. Other factors are required to explain why one factor prevailed over another – for instance the 'bolt on' nature of LZC technologies making them simple to remove, what was seen as valuable by the projects, the relative cost of the agendas.

7.2.1.6 *THEME 6: OWNERSHIP*

Ownership is a recurrent issue within both the adaptability (Arge, 2005) and low carbon (Peterman et al., 2012) literatures and was therefore unsurprisingly influential in interaction: different types of owners made different types of interaction decisions. Developers tended towards postponement techniques such as hedging and retrofitting, using cheap adaptability in place of more expensive or risky LZC technologies. These techniques put off low carbon gains at construction completion in favour of flexibility and thus are expected to create less balanced outcomes. Tenanted buildings chose permissiveness (reflecting an unwillingness to impose on tenants or accept liability for their actions) or failed to develop strategies at all – their dislocation from future tenant activities meaning they missed key future interfaces:

> *"we've provided them with solar reflective blinds, but that in an art college is contra to the way they want to operate 'cause they want light and so it's this big balance between actually, perhaps we should have provided opening windows, not a sealed environment." Interview 16A*

The behaviour of owner occupiers was more complicated. Early involvement by those understanding how the building would be used was linked to reconciliation in chapter 5. They were more likely to consider future use and thus asked for flexible spaces and reduced running costs. This led to a focus on particular forms of each agenda, limiting the interaction encountered. This may have benefited the cases by avoiding negative interaction, but would also have limited the ability to capitalise on synergies.

Overall the data suggests that owner occupiers were more likely to adopted strategies leading to reconciled outcomes than developers who chose to prioritise commercially more useful adaptability. This reflects the established low carbon literature's view that low carbon costs are difficult to pass on to tenants and buyers (Carbon Trust, 2009; Peterman et al., 2012; Rousseau, 2004) resulting in little incentive for developers to incorporate energy efficiency or adaptability they will not benefit from.

7.2.1.7 *THEME 7: TRUST*

The trust theme contains factors from two contrasting strategies – control and permissiveness. It concerns the design team's willingness to 'trust' occupants to manage the building in a low carbon way. Trusted occupants were given more licence to interact and alter their building's environment and thus improved adaptability at the user scale. Believing occupants would mismanage their surroundings was associated with control strategies and an unwillingness to let occupants adjust their environments:

> *"Really everything is just suspended and hung. So rather than having someone tack on horrible services in the future, we just made the provision for them to easily run it, now a little bit bigger, so that they stick to the design principle." Interview 19*

The adaptability literature does not discuss the issue of trust directly but Schneider and Till (2007) are concerned with the difference between architects "*prepared to let go*" (Habraken, 2008) and those who "*attempt to build in constraints intended to steer the user towards a 'good' result*" (Habraken, 2008). This idea of being able and willing to engage the user in a building's development has parallels with the trust theme, and is seen as promoting both adaptability and an occupant's satisfaction with their environment. From a low carbon perspective, building physics researchers have acknowledged a certain level of occupant control promotes user satisfaction (Leaman & Bordass, 2001), but also express concern over the possible implications of these actions (e.g. Coley et al., 2012). Whether a designer's trust in occupants was well placed or not, and thus whether control strategies would result in better, more predictable long term carbon performance is beyond the scope of this study: the standard practice (see 2.2.1) of excluding occupant effects would mean limited impact on the design outcomes measured in chapter 4. Therefore trust is only, from the perspective of this study, influential in promoting adaptability and is expected to have no effect on the low carbon element of the outcome.

7.2.1.8 *THEME 8: TECHNOLOGY*

Factors within the technology theme are concerned with the practical aspects of marrying two agendas. Some technologies (e.g. GSHPs) were simply incompatible, while others (e.g. sub-metering) were almost dual purpose. Off the peg compatible solutions were not always readily available or within reach of a project's budget and more innovative and unproven technologies were often incorporated cautiously, hedging against risks by opting for flexible choices (such as dual fuel CHP) or providing for their installation at a later date (a retrofitting strategy). Design decisions were therefore influenced by the solutions available to the teams as well as what the cases were familiar with and comfortable using.

The technological theme highlights the importance of the wider construction supply chain in the type of interaction encountered and how it was managed: the supply chain controlled whether viable, cost effective alternatives were available when conflict occurred (e.g. interaction 35D) or potential synergy identified. The supply chain was also implicated in how risky a particular approach was seen to be (through the provision or non-provision of warranties) and on occasion influenced clients in favour of particular solutions for non-project led reasons:

> *"The original design had a provision for a biomass boiler but it was decided to change that through a two stage tendering [contractor design] process." (Case 31)*

This theme is in line with the existing understanding within the separate adaptability (Douglas, 2006) and particularly low carbon (Hertin et al., 2003) literatures where the availability and enthusiasm of suppliers and constructors for particular technologies and approaches has long been known to influence uptake.

7.2.1.9 *THEME 9: OTHER FACTORS*

A number of factors identified in chapter 4 were not grouped into the themes above. These factors were of broadly three kinds:

1. Contextual issues such as legislation and BREEAM that were applicable to all cases.
2. Factors specific to the detail of a particular interaction e.g. the location of a component.
3. Factors ancillary but highly related to one or more of the themes described above.

The latter type includes ideas like risk, a prominent issue but one that intertwines with ownership, technology and budget themes and timing which is implied by ownership as owner occupiers are unlikely to enter the design process late and it was primarily their involvement timing is concerned with.

7.2.2 THE INITIAL MODEL

Two types of factor are apparent on the basis of the descriptions above: those determining the relative importance of adaptability and low carbon design to the project and those capable of modifying the balance by imposing barriers or presenting opportunities. The former are largely matters raised by each agenda's literature independently – anticipated change (Arge, 2005; Schmidt, 2014), a strong client commitment to low carbon design, ownership (Arge, 2005; Peterman et al., 2012) and planning requirements. These factors informed the sustainability brief – they determined if adaptable or low carbon design were to be pursued and in what mix. They were therefore highly influential in whether reconciliation of the agendas was pursued and in defining what successful reconciliation meant to a particular case. Modification type factors affected how interaction decisions were approached and reconciliation achieved. This group includes things such as what could be practically achieved (technology theme), what could be afforded (funding cuts - theme 5) and what was permitted (statutory objection –theme 3). These factors are for the most part additional constraints on the design problem, although some presented opportunities such as when design teams made reference to standard practice that benefited both agendas or a multi-skilled team used their expertise to find an integrated solution.

Using the eight themes and introducing two additional ideas (timing and legislation – see theme 9) identified above, and applying the idea that the factors within them can be thought of as of two types, an initial sketch model of conditions influencing interaction is presented, Figure 7-1.

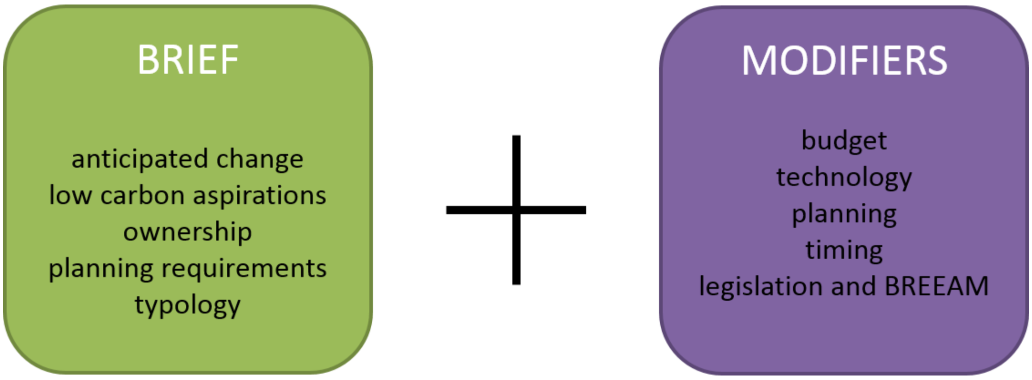


Figure 7-1 Initial model of interaction

This model requires a combination of briefing and modification conditions to produce the outcome. Furthermore, it is expected that multiple combinations of conditions indicated in the model will produce the outcome. This is because cases anticipated different types of change, requested different types of adaptability and thus encountered different types of interaction. The model therefore exhibits two of Berg-Schlosser et al.'s (2009) complexity scenarios – a combination of conditions generate the outcome and several different combinations may produce the same outcome – indicating QCA is a valid analysis approach.

7.2.3 SELECTING CONDITIONS FOR THE QCA MODEL

QCA, like many other methods, struggles to produce useful results when the number of variables exceeds six or seven (see 4.6.2). It was therefore necessary to reduce the number of variables by either combining or excluding (see section 4.6.2).

Firstly three contextual conditions were excluded. While important in differentiating between buildings built in different contexts, these are of little use in differentiating between the cases themselves. Excluded contextual factors include legislation, BREEAM and technology:

- All cases exist in the same 2008-2010 UK legislative framework[20], with differences between domestic and non-domestic regulations allowed for by the typology theme.
- BREEAM is implicated in a number of interaction management decisions. However, almost all cases chose to pursue a BREEAM or CSH rating (see table 6-2). Therefore while influential in framing the interaction decisions available to the cases, it is a contextual factor and omitted from the model.
- Technology was excluded as the cases are all concurrent in time and therefore had access to the same technology at similar levels of risk.

[20] There are small differences between English, Welsh and Scottish building regulations following devolution. However, only case 25 (located in south Wales) is located outside of England.

The second approach to reducing the number of conditions was to look at their anticipated effect. Each factor is associated with one or more interaction strategies and by considering the effect these have on the two agendas it is possible to postulate the effect of the factor. Strategy impacts deduced from descriptions in chapter 5 are shown in Table 7-2.

Table 7-2 Effect of interaction management strategy on adaptability and low carbon outcomes

Strategy	Description of effect on sustainability outcome	
	Design phase	Operation phase
Avoid	None, low carbon and adaptable design.	As design phase.
Compromise	Holistic but sub optimal adaptability and low carbon design.	As design phase.
Prioritise	Positive effect on adaptability or low carbon design depending on prioritisation choice. Negative effect on non-prioritised agenda.	As design phase.
Mitigate	Adaptability installed. Low carbon design compromised, but less than for prioritisation.	As design phase.
Exploit	Increased adaptability and improved carbon performance.	As design phase.
Control	Reduced adaptability. Greater control facilitates good operational performance.	As design phase.
Permissive	Tenant or occupant choice preserved. Missed opportunity to install energy efficient services.	Potential for tenant to install or not install low carbon features.
Reconcile	Neutral effect on adaptability and low carbon design, although implies both will be included.	Low carbon performance maintained post adaptation. Change unhindered by initial low carbon design choices.
Retrofit	Adaptability increased. Low carbon design limited to passive / efficiency approaches, missed opportunity for LZC energy generation.	Potentially allows occupants to install renewables and other carbon performance enhancement features.
Future-proof	Increased adaptability of HVAC systems and envelope. No effect on low carbon design.	Ability to maintain low carbon by replacing equipment etc.
Facilitate undoing	Increases the adaptability of the building. No effect on low carbon design.	Potentially allows occupants to install additional equipment detrimental to the building's carbon consumption.
Hedging	Installation of adaptable low carbon equipment.	Option to alter low carbon technologies to other more or less energy efficient choices.

All strategies affect the outcome; however the effect of the modification strategies is largely on the building in use. In-use effects were excluded from the outcome in chapter 6 and are therefore largely irrelevant for this study (although highly relevant for studies interested in performance in use, see section 9.4). In the short term, legislation prevents the complete replacement of low carbon design with adaptable alternatives (small negative effect of the low carbon outcome) and the additional adaptability gained would generally be expected to contribute only narrowly to a building's total adaptability (small positive effect on the adaptability outcome). This would suggest factors implicated in the modification strategies will be of limited use in explaining the case design outcomes assessed in chapter 6. However, many of the factors implicated in these strategies are also important in other strategy types. Thus, only factors associated solely with the modification strategies (GLA biofuel promises, unproven technologies, rapidly reducing LZC technology costs and legislative uncertainty) could be removed, and as these related primarily to the three conditions already omitted (technology and legislation), no further conditions were removed from the model.

Lastly, following Yamasaki and Rihoux's (2009) advice several early runs of the analysis were performed using various condition combinations. This showed typology was factored out of all QCA solution terms no matter which combination of model conditions were selected. This may reflect the non-domestic bias of the sample and others may wish to investigate further how influential typology is on adaptable/low carbon interaction. However, for the purposes of this study the theme was omitted.

This process reduced the number of themes in the model but several of those remaining (planning, low carbon commitment) contained multiple relevant dimensions. Therefore to simplify further, client aspirations for a particular form of low carbon design were omitted from the low carbon aspirations theme. These aspirations were implicated in only a very small number of the recorded interactions, and their effect was therefore unpredictable and would render interpretation unreliable. Planning aspirations for exemplar low carbon design were then merged with client low carbon aspirations (as the two have similar effects) leaving statutory consultee objections as a coherent condition. Timing was combined with ownership by choosing to differentiate between involved and uninvolved owner-occupiers.

The simplified model is shown in Figure 7-2.

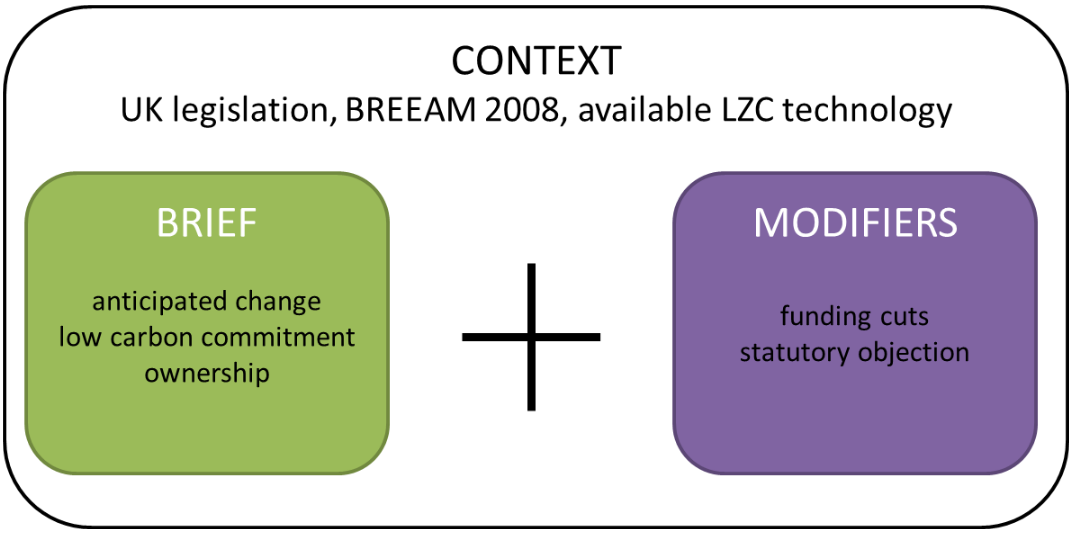


Figure 7-2 Simplified model of interaction

7.2.4 CALIBRATION

The model was calibrated (see 4.6.4) by selecting indicators and calibration points for each condition. Typically QCA studies rely on numerical indicators (e.g. Javernick-will et al., 2012), however qualitative interpretation has also been employed successfully (e.g. Forsythe, 2012). Qualitative indicators were employed for all conditions in this study, reflecting the nature of the conditions selected and a lack of existing reliable indicators. The decision was taken to code for trust rather than 'not trust' on the basis this was more significant in understanding the case interactions. Of ownership's three types, tenants and developers were grouped and a dichotomous split between this group and owner occupiers adopted. This reflects how the condition is generally conceived in the adaptability literature (Arge, 2005).

Calibration points were set using a combination of the established literature (existing theory) and case evidence (chapter 4 findings) in line with QCA best practice (Ragin, 2008). Literature expectations of the effect of each condition are taken from those identified in chapters 2 and 3. Case evidence is as described above, section 6.2.1. Where the two sources conflicted case evidence was preferred, relating directly to interaction effects whereas existing theory provides only an indication of the two sustainable design elements in isolation.

Presence, absence and expected effects for each condition are summarised in Table 7-3.

Table 7-3 List of conditions for QCA analysis including scoring criteria and anticipated effect

Condition	Variable name	Presence criteria (1)	Absence criteria (0)	Adaptability literature	Carbon literature	Case evidence	Anticipated effect
Adaptability requirements	CHANGE	Client requirements for adaptability	No requirements for adaptability	↑	-	Variable	↑
Low carbon commitment	CARBON	Client best practice design aspirations or planning requirements for exemplar low carbon / energy efficient design	Standard planning requirements for energy efficiency.	-	↑	Variable	↑
Ownership model	OWNERSHIP	Owner-occupied building with early client involvement	Developer owned building. Likely to be tenanted.	↑	↑	↑	↑
Funding restrictions	BUDGET	Evidence of extensive VE or other cost cutting during design	No evidence to suggest extensive VE or other cost cutting exercises took place during design	↓	↓	↓	↓
Statutory objections	STATOBJ	Statutory consultee (e.g. Environment Agency, English Heritage) opposition to adaptable / low carbon design elements.	No significant opposition from statutory consultees or planning officer during planning process.	-	↓	A ↑ LC ↓	↓
Trusting	TRUSTING	Evidence of designer trusting occupier or client behaviour associated with trust (e.g. a commitment to building management)	No evidence of trust between designer and occupant, or evidence suggesting occupants would have difficulty managing an involved low carbon strategy	-	-	A ↑ LC -	- or ↑

Notes

- Adaptability and low carbon literature expectations are taken from chapter 2. Where no expectation was identified this is indicated with a dash (-).
- ↑ Indicates a positive effect, ↓ indicates a negative effect. The anticipated effect column describes the predicated effect on the reconciled outcome.

7.3 QCA ANALYSIS

7.3.1 CREATING THE TRUTH TABLE

Each case was coded according to the rules listed in Table 7-3, with results summarised in Table 7-4. QCA software was used to convert this table to a truth table using the procedure outlined in section 4.6.5. Populated rows of the truth table are shown below, Table 7-5. The full truth table including configurations with no case evidence (of which there are 46) can be found in appendix 7A. Initial examination of the table shows one contradictory configuration (for notation see appendix 4I):

CHANGE*CARBON*OWNERSHIP*budget*statobj*trusting

This configuration relates to cases 24 (Sheffield Engineering Graduate School) and 35 (Environment and Sustainability Hub): while having the same configuration of conditions (i.e. being identical in QCA terms), these cases have different outcomes. There are several possible reasons for this: data entry errors, errors in coding such as misplaced dichotomisation points, an incorrectly specified model (e.g. too few conditions) or the possibility of genuine contradictory cases caused by the unpredictability of real data, "*because exceptions are almost always present*" (Ragin, 2008). Basic data input errors were first ruled out, before applying Schneider and Wagemann's (2012) approaches to resolving contradictory ('inconsistent') rows:

- Add a condition to the truth table (expand the model)
- Redefine the case population (exclude one or more cases)
- Revisit the definition, conceptualisation and/or measurement of the conditions or outcome (refine the model)

Adding a condition resolves contradictions by specifying why the contradictory cases are different. Obvious differences between case 24 and case 35 are that they are built in different locations (case 24 is an urban site, case 35 a rural campus) and case 35 is detached while case 24 is an extension. However, none of the distinguishing features showed evidence of affecting interaction within these two cases or others in the sample and this resolution method was dismissed. Excluding either case was ruled out as neither appears deviant from the case sample. Similarly neither case's outcome scoring was problematic – both sit outside the zone of adaptability ambiguity (see table 6-18) and both have firm EPCs providing the low carbon outcome component. Coding of conditions for both cases was therefore revisited.

The majority of codes revealed little to separate the two cases, with the exception of anticipated change. Case 24 had significantly more evidence for an adaptability brief than case 35, for which the majority of evidence originated in a masterplan of the surrounding campus. Case 35 showed little evidence of a specific brief for adaptability within the project itself and the decision was taken to recode the condition accordingly. This places it in line with the coding of case 09 (also part of a masterplan). Cases 16 and 31's coding remained unchanged as both had significant briefs for adaptability unrelated to their positions at the heart of the King's Cross and NOMA masterplans respectively.

Altering the anticipating change code produces the revised truth table shown below, Table 7-6. As before, non-populated rows are not shown but can be found in appendix 7A.

Table 7-4 Data table summarising condition coding for all cases

Case	Case name	Outcome	Anticipated change	Setting an example	Typology	Build type	Ownership model	Trust	HVAC	Budget	Statutory objection
01	Admiral HQ	1	1	0	1	1	1	1	0	0	0
04	British Trimmings Extra Care	0	0	0	0	1	1	1	1	1	0
6.1	Offmore Primary	0	0	0	1	1	1	0	1	0	0
6.2	St Catherine's Primary	0	0	0	1	1	1	0	1	0	0
07	Harris Academy	1	1	0	1	0	1	0	1	1	1
09	Technical Hub @ EBI	0	1	0	1	1	0	0	0	0	0
10	Edge Lane	0	0	0	0	1	1	1	1	0	0
11	St Loyes Extra Care Exeter	0	0	1	0	1	1	1	1	0	0
16	University of the Arts London, KX Campus	0	1	1	1	0	0	1	0	0	1
17	Oxford University Press	1	0	1	1	1	1	0	0	0	1
19	Greenwich University, Stockwell Street	1	1	1	1	1	1	0	0	0	1
20	Church View	0	0	0	1	0	0	0	1	1	1
21	Great Ormond Street Phase 2B	0	0	0	1	0	1	1	0	0	0
23	Trowbridge County Hall and Library	0	0	0	1	0	1	0	0	0	0
24	Sheffield Engineering Graduate School	1	1	1	1	1	1	0	0	0	0
25	Ebbw Vale 11-16 Phase School	1	0	1	1	1	1	0	0	1	0
31	Cooperative HQ	1	1	1	1	1	1	0	0	0	0
35	Environment and Sustainability Institute	0	1	1	1	1	1	0	0	0	0
38	Site J New England Quarter (SuperB)	0	0	0	0	1	1	0	1	0	0
46	Hinguar Primary School	1	1	1	1	1	1	0	1	1	1
47	Westbrook Primary School	1	0	1	1	1	1	0	1	0	1
48	London Bridge Station Redevelopment	0	0	0	1	0	1	0	1	0	1

- Orange cells indicate outcome coding with a lower degree of certainty ('swing' cases – see 6.3.9)
- Case 14 is omitted for reasons outlined in chapter 4.

Table 7-5 Truth Table

Anticipating Change	Setting an Example	Ownership	Budget	Statutory Objection	Trusting	No. of cases	Outcome	Consistency	Cases
0	0	1	0	0	0	3	0	0	Trowbridge (23) ,Edge Lane (10) ,GOSH (21)
0	0	1	0	0	1	2	0	0	Offmore Primary (6A), Site J Super B (38)
0	1	1	0	0	0	2	0	0	St Loyes (11)
0	0	0	1	1	1	1	0	0	Church View (20)
0	0	1	0	1	0	1	0	0	London Bridge Station (48)
0	0	1	1	0	0	1	0	0	British Trimmings (04)
0	0	1	1	0	1	1	0	0	St Catherine's Primary (6B)
1	0	0	0	0	0	1	0	0	Technical Hub@ EBI (09)
1	1	0	0	1	0	1	0	0	UAL (16)
0	1	1	0	1	0	1	1	1	OUP (17)
0	1	1	0	1	1	1	1	1	Westbrook Primary (47)
0	1	1	1	0	1	1	1	1	Ebbw Vale School (25)
1	0	1	0	0	0	1	1	1	Admiral HQ (01)
1	0	1	1	1	0	1	1	1	Harris Academy (07)
1	1	1	0	0	0	1	??	0.5	SEGS (24), ESI (35)
1	1	1	0	0	1	1	1	1	Cooperative HQ (31)
1	1	1	0	1	1	1	1	1	Stockwell Street (19)
1	1	1	1	1	1	1	1	1	Hinguar Primary (46)

Table 7-6 Revised truth table

Anticipating Change	Setting an Example	Ownership	Budget	Statutory Objection	Trusting	No. of cases	Outcome	Consistency	Cases
0	0	1	0	0	0	3	0	0	Trowbridge (23) ,Edge Lane (10) ,GOSH (21)
0	0	1	0	0	1	2	0	0	Offmore Primary (6A), Site J Super B (38)
0	1	1	0	0	0	2	0	0	St Loyes (11) ,ESI (35)
0	0	0	1	1	1	1	0	0	Church View (20)
0	0	1	0	1	0	1	0	0	London Bridge Station (48)
0	0	1	1	0	0	1	0	0	British Trimmings (04)
0	0	1	1	0	1	1	0	0	St Catherine's Primary (6B)
1	0	0	0	0	0	1	0	0	Technical Hub@ EBI (09)
1	1	0	0	1	0	1	0	0	UAL (16)
0	1	1	0	1	0	1	1	1	OUP (17)
0	1	1	0	1	1	1	1	1	Westbrook Primary (47)
0	1	1	1	0	1	1	1	1	Ebbw Vale School (25)
1	0	1	0	0	0	1	1	1	Admiral HQ (01)
1	0	1	1	1	0	1	1	1	Harris Academy (07)
1	1	1	0	0	0	1	1	1	SEGS (24)
1	1	1	0	0	1	1	1	1	Cooperative HQ (31)
1	1	1	0	1	1	1	1	1	Stockwell Street (19)
1	1	1	1	1	1	1	1	1	Hinguar Primary (46)

This truth table has 46 un-populated rows, meaning 46 of the possible combinations of the model's 6 conditions are not demonstrated empirically in the data. These rows are termed 'logical remainders' in QCA and can arise due to an insufficiently large or representative sample or as a natural result of the phenomena being examined – some combinations being impossible or implausible in reality (Schneider & Wagemann, 2012). Using a six condition model produces 64 (2^n) possible combinations, therefore it was impossible 23 cases would cover all possibilities and some limited diversity was inevitable. This is typical of QCA studies, particularly in situations where the number of cases is practically limited (Ragin, 2008).

The sample is dominated by owner-occupiers, likely because, with a long term interest in their buildings, these clients were the most likely to engage with the D4FC programme. As a result, a large number of logical remainders incorporate ¬ownership. Thus any conclusions relating to ownership are likely to be tentative and limited in their applicability. ¬Budget also has a larger number of cases than its opposite. This is perhaps more representative of non-sample building designs than ownership, as many buildings do not face severe funding shortfalls during their development however this remains problematic from a QCA perspective as the technique requires diversity rather than representativeness (Berg-Schlosser & de Meur, 2009).

7.3.2 NECESSITY

Following the advice of Schneider and Wagemann (2012) the truth table was examined for necessary conditions. (Identifying necessary conditions prior to minimisation prevents the use of inconsistent logical remainders, see Schneider and Wagemann (2012)). Necessary conditions are those without which the outcome cannot occur. They are located by first considering all cases for which the outcome is 1, table 7-7. Conditions necessary for the outcome should be present (shown shaded in the table) for all positive outcome cases / rows.

Table 7-7 Truth table extract showing necessary condition analysis

Anticipating Change	Setting an Example	Ownership	Budget	Statutory Objection	Trusting	Cases
0	1	1	0	1	0	OUP (17)
0	1	1	0	1	1	Westbrook Primary (47)
0	1	1	1	0	1	Ebbw Vale School (25)
1	0	1	0	0	0	Admiral HQ (01)
1	0	1	1	1	0	Harris Academy (07)
1	1	1	0	0	0	SEGS (24)
1	1	1	0	0	1	Cooperative HQ (31)
1	1	1	0	1	1	Stockwell Street (19)
1	1	1	1	1	1	Hinguar Primary (46)

An unexpected finding is that neither a strong commitment to adaptability (resulting from anticipated change) nor aspirational low carbon design ideas are necessary for a holistic outcome. Instead only ownership meets the requirements for a necessary condition (Figure 7-3 – showing all success cases within the ownership area of the Venn diagram). However, this result should be interpreted with a degree of caution: the high number (83%) of ownership cases in the sample increases the likelihood the condition is trivial. Trivial conditions are "*strongly present in most cases, whether or not these cases display the outcome*" (Ragin, 2008) and describe the sample rather than reflect a genuine requirement for the outcome. For example both adaptability and low carbon literatures strongly suggest the importance of ownership, as these clients are more likely to value and benefit from long term savings (Arge, 2005; Rousseau, 2004; Schmidt, 2014). Ownership might therefore be seen as a pre-requisite for clients requesting adaptability and/or low carbon design rather than an important factor in successful outcomes, i.e. it establishes a space in which interaction may take place, but tells us little about interaction. However, ownership is implicated in the effects of several interaction themes (Table 7-1). It is also influential in understanding why, despite having aspirations for both adaptability and low carbon design, cases 09 and case 16 fail to fully reconcile the agendas. For both these cases creating HVAC systems that could meet the demands of a variety of occupiers overruled a more energy efficient approach:

> *"part of that facility is visiting researchers will turn up with whatever equipment they're using. So there's an element to which you can say, 'Our policy is that everybody uses energy star computers that are really low energy,' but if you turned up as a visiting researcher you would use the machine that you've got and I don't think we could stop you." Interview case 9*

Therefore on the basis of the case evidence, ownership is understood as important in understanding interaction decisions and is treated as a necessary condition for the remainder of the analysis.

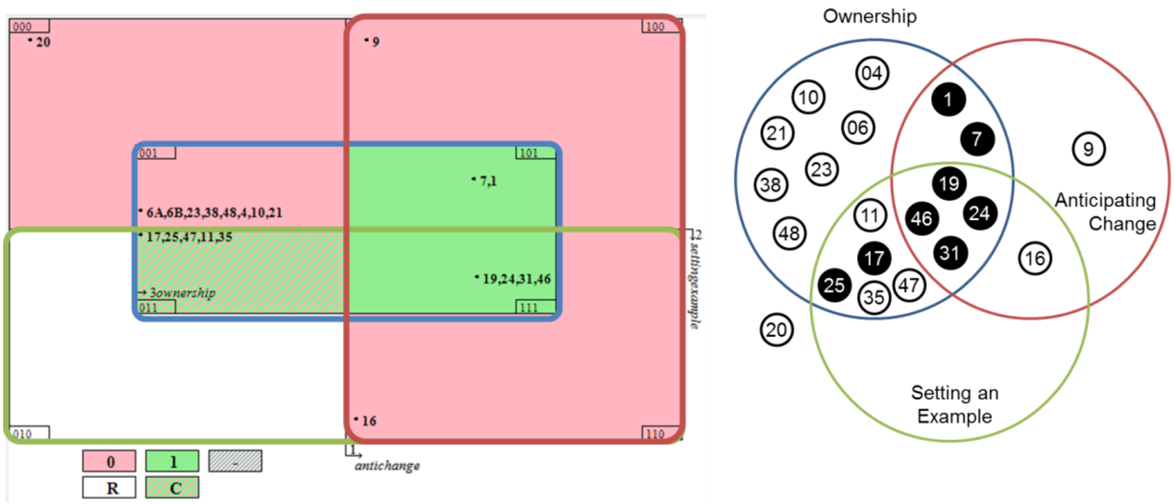


Figure 7-3 Venn diagram illustrating necessity (TOMANA output shown left, traditional representation shown right)

Note: numbers in the figure above are case references, success cases are shown shaded green / black.

7.3.3 MINIMISATION

The next step was to perform an enhanced standard analysis (Schneider & Wagemann, 2012) producing complex, parsimonious and intermediate solutions. Due to the use of csQCA and the lack of inconsistent rows in the amended truth table consistency values for all solution terms are 1 and are not repeated below.

7.3.3.1 *COMPLEX SOLUTION*

Table 7-8 shows the complex solution, consisting of six terms. The first three terms cover cases firmly within the outcome set (01, 24, 19, 31 and 46) while the latter three describe those more tentatively included (07, 17, 25 and 47). The last two terms contain all six conditions, indicating they describe only a single configuration. This is reflected in the coverage values (see 4.6.4) for each term, which are low. While low coverage is not in itself an indicator of theoretical usefulness (Schneider & Wagemann, 2012), the complex solution contains multiple conditions, is difficult to interpret and largely describes the cases rather than demonstrating meaningful similarities and differences that might be useful in developing new theory.

Table 7-8 Complex solution

ID	Solution terms	Cases	Coverage (raw)
C1	**change*ownership*¬budget*¬statobj*¬trusting**	24, 1	0.2
C2	**change*carbon*ownership*¬budget*trusting**	19, 31	0.2
C3	**change*carbon*ownership*statobj*trusting**	19, 46	0.2
C4	**¬change*carbon*ownership*¬budget*statobj**	17, 47	0.2
C5	**change*¬carbon*ownership*budget*statobj*¬trusting**	7	0.1
C6	**¬change*carbon*ownership*budget*¬statobj*trusting**	25	0.1

7.3.3.2 *PARSIMONIOUS SOLUTION*

In order to simplify the solution it is necessary to assume outcomes for a selection of logical remainders (configurations about which nothing is known empirically). 21 assumptions (table 7-11[21]) are necessary to produce the simplest or 'parsimonious solution', shown in Table 7-9.

Table 7-9 Parsimonious solution

	ID	Term 1 (P1)		Term 2 (P2)		Term 3 (P3)
	A	change*ownership	+	carbon*budget	+	¬change*carbon*statobj
	B	change*ownership	+	carbon*budget	+	carbon*ownership*statobj
	C	change*ownership	+	carbon*trusting	+	¬change*carbon*statobj
	D	change*ownership	+	carbon*trusting	+	carbon*ownership*statobj
Cases		01, 07, 19, 24, 31, 46		25, 46 (A/B)		17, 19, 46, 47 (B/D)
Raw coverage		0.67		0.11(A/B)		0.44(B/D)
Unique coverage		0.44		0.22(A/B)		0.22(B/D)

The table indicates multiple possible solutions due to the presence of prime implicants (logically equivalent alternatives). Examination of the options shows that both P2 and P3 terms contain options without the necessary condition ownership. This indicates the software made "*untenable*" assumptions (Schneider & Wagemann, 2012) to minimise the data. Disregarding these assumptions (01-08 in table 7-11) eliminates options A and B and has the effect of adding ownership into both solutions for term P2:

(B) (change*ownership) + (carbon*ownership*budget) + (carbon*ownership*statobj)

(D) (change*ownership) + (carbon*ownership*trust) + (carbon*ownership*statobj)

[21] Assumptions were produced using TOSMANA as fsQCA does not include this function.

Both solution terms appear sensible in relation to the results of chapter 4: option B is linked to a retrofit strategy that increases the adaptability of low carbon builds, option D to permissiveness and a user sponsored, adjustable low carbon strategy. Considering those cases the solution term explains (cases 25 and 46), funding restrictions were detrimental to case 25's sustainability plans (see 7.4.3) but less so to case 46's ("*the client was very good, they didn't just say, 'We've got less money now, let's make it all cheap.'*" Interview 46). Overall the reconciled outcome seems to stem from the nature of the buildings (flexible learning spaces) and the client and design team's desire to produce an energy efficient building as cheaply as possible. This led to outcomes with elements of both solution options (cheap solutions also tended to be those that were user operated) and suggests both cases are examples of exploiting synergies in the agendas.

Relating the solutions to existing knowledge, TRUST is expected to contribute to the outcome or have a neutral effect, BUDGET to negatively impact on it (see Table 7-3). This suggests option D should be preferred and this is to some extent backed by the QCA analysis – Option D requires a greater number of assumptions regarding unobserved configurations, Table 7-10.

Table 7-10 Assumptions required to produce solution terms P2B and P2D

	CHANGE	CARBON	OWNERSHIP	BUDGET	STATOBJ	TRUST	Assumed outcome
B	0	1	1	1	1	1	1
	1	1	1	1	0	1	1
	0	1	1	1	0	0	1
	0	1	1	1	1	0	1
	1	1	1	1	1	0	1
	1	1	1	1	0	0	1
D	0	1	1	1	1	1	1
	1	1	1	1	0	1	1
	0	1	1	0	0	1	1

Table 7-11 Simplifying assumptions used to produce the parsimonious solution

ID	CHANGE	CARBON	OWNERSHIP	BUDGET	STATOBJ	TRUST	Assumed outcome
01	0	1	0	0	0	1	1
02	0	1	0	0	1	1	1
03	0	1	0	1	0	1	1
04	0	1	0	1	1	1	1
05	1	1	0	0	0	1	1
06	1	1	0	0	1	1	1
07	1	1	0	1	0	1	1
08	1	1	0	1	1	1	1
09	0	1	1	0	0	1	1
10	0	1	1	1	1	0	1
11	0	1	1	1	1	1	1
12	1	0	1	0	0	1	1
13	1	0	1	0	1	0	1
14	1	0	1	0	1	1	1
15	1	0	1	1	0	0	1
16	1	0	1	1	0	1	1
17	1	0	1	1	1	1	1
18	1	1	1	0	1	0	1
19	1	1	1	1	0	0	1
20	1	1	1	1	0	1	1
21	1	1	1	1	1	0	1

7.3.3.3 *THE INTERMEDIATE SOLUTION*

As noted above, in order to obtain the parsimonious solution the software makes a number of assumptions (Table 7-11). Having discounted assumptions 01-08 on the basis they contract the belief of ownership as a necessary condition, the remaining assumptions fall into three groups:

- Assumptions 09 – 11, eliminate CHANGE from terms P2 and P3.
- Assumptions 12-17 produce solution term P1, by removing the CARBON term i.e. they suggest a strong low carbon commitment is not required for the outcome.

- Assumptions 18-21 include the expected combination of CHANGE and CARBON and OWNERSHIP but with the addition of planning or funding barriers typically understood to hinder adoption of low carbon and adaptable design.

Many of these assumptions are difficult counterfactuals, meaning they contradict theoretical predictions of what might be expected based on existing knowledge of adaptability and low carbon design as separate activities. While legitimate for generating the most parsimonious solution, difficult counterfactuals are problematic from a theoretical perspective and should not be used without good reason. Restricting the analysis to only easy counterfactuals - those assumptions in line with theoretical predictions (as per Table 7-3) gives the intermediate solution, Table 7-12.

Table 7-12 Intermediate solution

ID	Solution term	Cases	Raw coverage	Unique coverage
I1	**change*ownership**	01, 07, 19, 24, 31, 46	0.67	0.56
I2	**carbon*ownership*¬budget*statobj**	17, 19, 47	0.33	0.22
I3	**carbon*ownership*budget*¬statobj*trusting**	25	0.11	0.11

The first term (I1) is identical to the parsimonious solution term P1, indicating P1 is in line with existing theoretical predictions of the effects of individual conditions. Terms I2 and I3 however differ. Term I2 expands the parsimonious solution term P3 (carbon*ownership*statobj) with the addition of ¬budget. This makes intuitive sense –in order to build in resilience to the restrictions placed upon them the cases needed sufficient funding available. Term I3 combines options A/B and C/D from the parsimonious solution, adding an additional term, ¬statobj. This solution has a very low coverage value, explaining only case 25.

Overall the intermediate solution is preferred due to its improved I2 term. It will therefore be the subject of the interpretation in the following sections, although reference will be made to the parsimonious solution where appropriate.

7.4 INTERPRETATION

7.4.1 SOLUTION TERM 1: OWNERSHIP AND ANTICIPATED CHANGE

Solution terms P1 / I1 have a high coverage value (0.67) and explain all cases (01, 19, 24, 31, 46) that might be described as 'fully in' the outcome set (see section 6.4), Figure 7-4. This strongly suggests they describe the most favourable conditions for reconciled design.

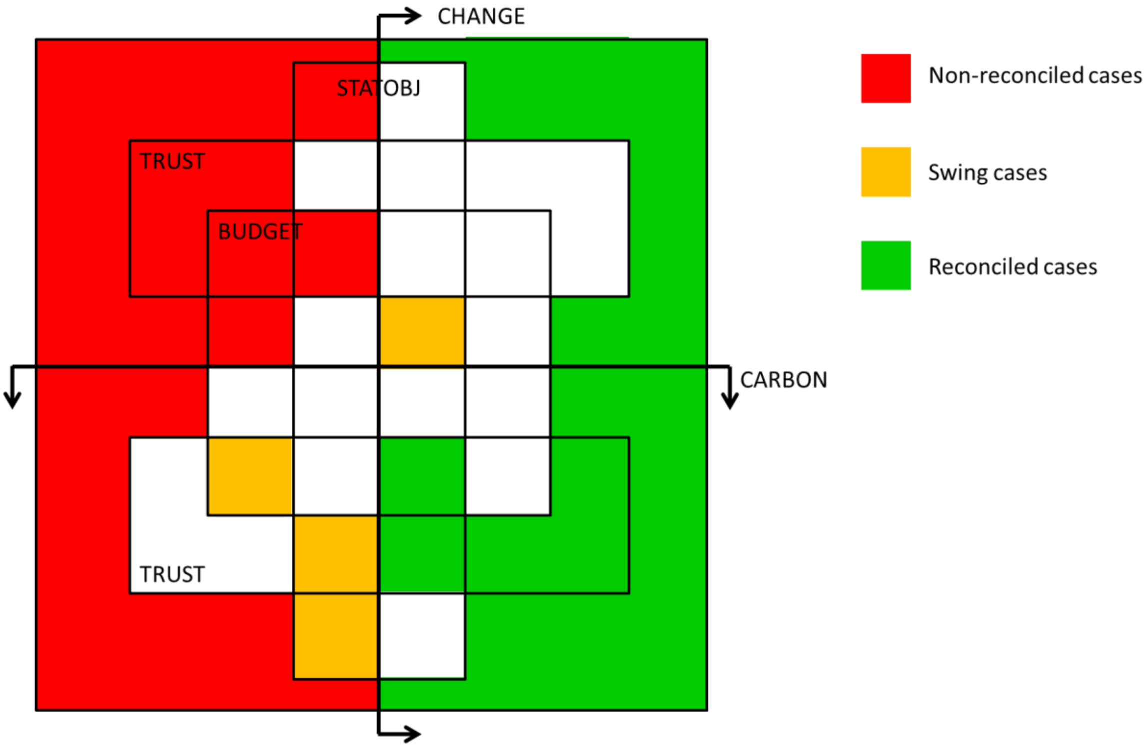


Figure 7-4 Venn diagram illustrating intermediate and parsimonious solutions (¬ownership cases excluded)

The solutions indicate anticipated change and ownership are sufficient for the outcome, without a strong commitment to low carbon design. They therefore rely on the conclusion of the necessary analysis that a strong commitment to low carbon design is not required for the outcome. This finding is counter to the literature's understanding of low carbon design drivers. However, the result is perhaps less deviant from theoretical knowledge than it may appear. Firstly, all the cases had a baseline commitment to produce low carbon buildings (see 4.3.2). While for a number of cases this commitment appears to have been somewhat dampened by later funding cuts and other barriers, most cases retained their low carbon briefs. The low carbon condition distinguishes between those cases with clients, planners and design teams actively pursuing an exemplar, low carbon building and others who were less ambitious. The absence of the low carbon code therefore does not signify a complete disinterestedness in low carbon design. Further, there are two cases demonstrating the outcome that are not coded as CARBON: Admiral HQ (case 01) and Harris Academy (case 07). These cases demonstrate that reconciled design is possible without a strong low carbon commitment.

What this solution therefore tells us is that there does not need to be a strong, conspicuous commitment to low carbon design to reconcile the agendas. But that some element of trying to design for both elements is important. This is an expected result in line with the existing understanding of sustainable design and is also obvious in many of these cases' descriptions of what they were trying to achieve.

The lack of negative outcomes associated with the anticipated requirements/low carbon aspirations pairing highlights the importance of a commitment to multiple sustainability ideals. This might be seen as supporting the existing literature's assumption of easily reconciled agendas (section 1.3); however the evidence presented in chapter 4 counters this, demonstrating the need for conflict management strategies and thoughtful compatible solutions.

7.4.2 SOLUTION TERM 2: LOW CARBON ASPIRATIONS, OWNERSHIP AND PLANNING OBJECTIONS WITHOUT FUNDING RESTRICTIONS

The second solution term describes three cases. Two (cases 17 and 47) are explained only by this configuration, while case 19 is also explained by solution term 1 (due to overlaps in the two solution spaces). Coverage is middling, although this solution is not associated with the theoretically expected combination of anticipated change and low carbon aspirations, suggesting a higher likelihood of theoretical novelty. Considering the solution term, low carbon aspirations are an expected requirement for the outcome (see theme 2 above). There is however nothing (with the possible exception of the ownership ¬budget combination) that the literature suggests would produce adaptable design. The addition of planning objections that are usually understood as posing barriers for sustainable design (Häkkinen & Belloni, 2011) are also problematic from an interpretation perspective.

The interaction analysis (section 5.4.4.4) found a strong link between planning objection and the use of adaptability to provide the objected to element later (retrofitting):

> *"you're building the structure now, reinforce it now [to accommodate PV] and then you can deal with the planners in 2040." (Interview case 19)*

This reinforces the importance of the ¬budget condition in term I2 and suggests cases 17, 19 and 47 are successful due to retrofitting and similar activities replacing the adaptability requirements driver. Reflecting on the case evidence, this seems reasonable for cases 17 and 19 where a number of retrofitting and similar type future proofing actions were noted. Case 47's evidence is less aligned with a retrofitting interpretation but this reflects the lack of interaction recorded (see 5.4.5). It is also evident from the case data that budget was a barrier to retrofitting:

> *"But with such tight financial constraints the Healthcare Trust won't pay for that to happen with the possibility that it might be needed." (Interview case 10)*

However, it seems unlikely that a small number of retrofitting actions would substantially increase a building's adaptability. An alternative, more general, interpretation is one of frustrated low carbon ambitions. Comparing cases 17, 19 and 47 to cases to case 11 and 35 (which have a similar configuration of conditions but no planning objection) we see cases with strong low carbon ambitions. There is an argument that, with no restraining barriers, these cases' low carbon ambitions took precedence over other elements of the sustainability brief deemed less important:

> *"when we set up twenty years ago we specifically wanted to design low energy buildings … basically I haven't designed any other buildings for my whole professional career only buildings that are low energy and ecological and healthy." (Interview 11)*

While appealing, this solution is largely speculative: it is not contradicted by the case evidence, but is unsupported other than through comparison. Instead the case evidence suggests adaptability was driven by space constraints – case 17 is physically restricted by a small, awkward plot and case 47's maximum floor area is limited by schools design guidance and limited funds. These restrictions lead both cases to use adaptability to get the most from the available space:

> *"The school were keen to explore the possibility of creating more innovative and flexible teaching space than could be accommodated in banks of single classrooms and it was suggested that the specialist areas could be added to the circulation zones in each wing to create shared spaces between the clusters." (Design and Access Statement, Case 47)*

Overall there is no strong evidence of interaction within case 47 and limited evidence (when interactions relating to CCA have been discounted) within case 17. Without this evidence it is impossible to understand which of the above proposed explanations is more plausible or confirm if interaction effects were important to the outcome at all.

7.4.3 SOLUTION TERM 3: LOW CARBON ASPIRATIONS, TRUSTED OCCUPIERS AND OWNERSHIP WITH FUNDING CUTS BUT NO PLANNING OBJECTIONS

As noted above solution term I3 relates only to case 25. It is identical to the complex solution term C5, containing five of a possible six conditions. It is therefore largely descriptive. As for solution term 2, this configuration excludes anticipated change with adaptability presumably arising from the low carbon aspirations / trusted occupiers combination. Trust was clearly important – following funding cuts, the design team trusted the school to continue to 'finish' the building sustainably when funds allowed:

> *"As the initial brief was downgraded to fit the revised budget after the financial review for the masterplan, opportunities for capturing adaptation measures for climate change were eliminated. It is also hoped that … some of the suggestions will be retrofitted in the future." Case 25, TSB Report*

However, again similar to solution term 2, the low carbon aspirations/trusted occupiers combination seems an unlikely candidate to fully explain the building's reconciled outcome. There is an argument for the importance of budget (funding restrictions) in combination with ¬statobj (absence of objection during planning) - case 25's stringent outline planning conditions were influential in ensuring low carbon elements remained after funding changes. However, planning support for low carbon design is incorporated into the low carbon aspirations condition (see above). ¬statobj therefore seems rather redundant and indeed is omitted from the parsimonious solution (P2).

On the basis of the case evidence, it is the design team's commitment to the original sustainability brief and their desire to build a long term solution despite funding changes that seem most important to the outcome. This suggests overall the parsimonious solution P2A/B (carbon* ownership*budget) is the most plausible if incomplete explanation. However, there is insufficient case evidence to fully support this more general solution and it is at least partially at odds with the evidence presented by case 46 (which would be covered by a more general solution - see 7.3.3, parsimonious solution).

7.5 CHAPTER CONCLUSION

The results of this chapter have confirmed the importance of a long term interest in a building for sustainable design (ownership as a necessary condition), and challenged the idea that a strong client commitment to low carbon or adaptable design is essential to reconciled design. But, disappointingly, the QCA analysis does not appear to have resulted in a set of theoretically useful explanatory paths to reconciled design, rather a series of descriptions. This is in part due to the difficulty in interpreting the recipes without resorting to examining the agendas independently or relying heavily on the understanding gained in chapter 5. However, even with this taken into consideration the recipes remain more descriptive than explanative.

For those cases described by solution term 1 it is possible to infer what led to the reconciled outcome – pursuit of reconciled design options, compromise where necessary and exploitation of synergies wherever possible. These cases anticipated conflict and dealt with it in the best way possible. This suggests the decision in this research to use factors that influenced interaction decision making rather than involve the interaction strategies themselves in the model is, at least in part, responsible for the disjointed solutions obtained. However, this approach was adopted as it is difficult to determine to which approach a project should be ascribed, given that all projects adopted a pick-and-mix of strategies (5.4.5). Counting strategies would have been impractical as this study could not uncover every interaction occurring and in any case some interaction decisions are likely to have been more important in determining the outcome than others. A more detailed understanding of interaction processes was therefore required before embarking on the QCA, but this rather presupposes that one knows the answer before specifying the analysis. This suggests QCA's applicability is limited to areas with a good level of existing theory or studies that are able to return to a qualitative phase to explore and understand the results (see for example Marx and van Hootegem, 2007).

There is also the issue that, while this study chose to define success as the co-achievement of both agendas (an idealised holistic outcome), many of the cases did not. Case decision making demonstrates a variety of different 'versions' of sustainability with different combinations of adaptability and low carbon design to suit the owner, the building type and its context. This shows practioners are embracing Guy and Farmer's (2001) vision of sustainable building "*adapted to, and grounded within, particular local ecological conditions*", but means the measured outcome was somewhat detached from the case's decision making. More useful results may have been obtained had the study limited itself to cases pursuing a particular interpretation, or segmented the analysis.

8 DISCUSSION

8.1 INTRODUCTION

This chapter considers the findings of the previous three chapters (5, 6 and 7) in the context of existing theory described in chapters 1 and 2 and 3. Chapter 1 described the two separate treatments of sustainability in the construction management literature – as a holistic yet vaguely defined concept and as a series of diverse discourses with claims to it. Traditionally research has focussed on either understanding these individual discourses as distinct fields of inquiry, or defining the slippery idea of a sustainable building in totality. It was argued there has been little work focussed on understanding how the components are assembled into a coherent sustainable building. This is a significant oversight: better understanding how the facets interact, and how this interaction can be managed and exploited, would increase our understanding of the implementation of sustainable design and its impact on the built environment. Thus, the thesis borrows from the ideas of social interactionism (and the idea that sustainability is constructed by actors through their interactions with each other and their environment), but is primarily concerned with how this negotiated definition is influenced by interaction, manifested in the decisions actors make and the resulting design outcomes. Chapters 5, 6 and 7 presented results intended to compare observed interactions between adaptability and low carbon design (two separate sustainability discourses) with existing theoretical descriptions of interaction (chapter 3) from non-construction fields with the intention of extending that theory to construction design.

Looking first at how this study's results relate to existing theoretical descriptions of interaction (section 8.2), the chapter then discusses the implications of interaction for adaptability and low carbon as distinct ideas (section 8.3) as well as the wider literature covering sustainable design implementation (section 8.4). The latter part of the chapter (section 0) reflects on the study's use of QCA, presenting an honest opinion of its usefulness for construction-type problems. This section of the chapter therefore addresses objective 06:

> *OB06: Conduct a method experiment to assess the usefulness of Qualitative Comparative Analysis (QCA) as a research tool for problems of a socio-technical type within a built environment context*

8.2 WHAT DO THE RESULTS TELL US ABOUT INTERACTION EFFECTS IN BUILDINGS?

8.2.1 INTERACTION TYPES

The interaction types identified in section 5.3 (Figure 8-1) demonstrate broad agreement with the theoretical expectations of synergy, conflict and trade-offs described in chapter 3.

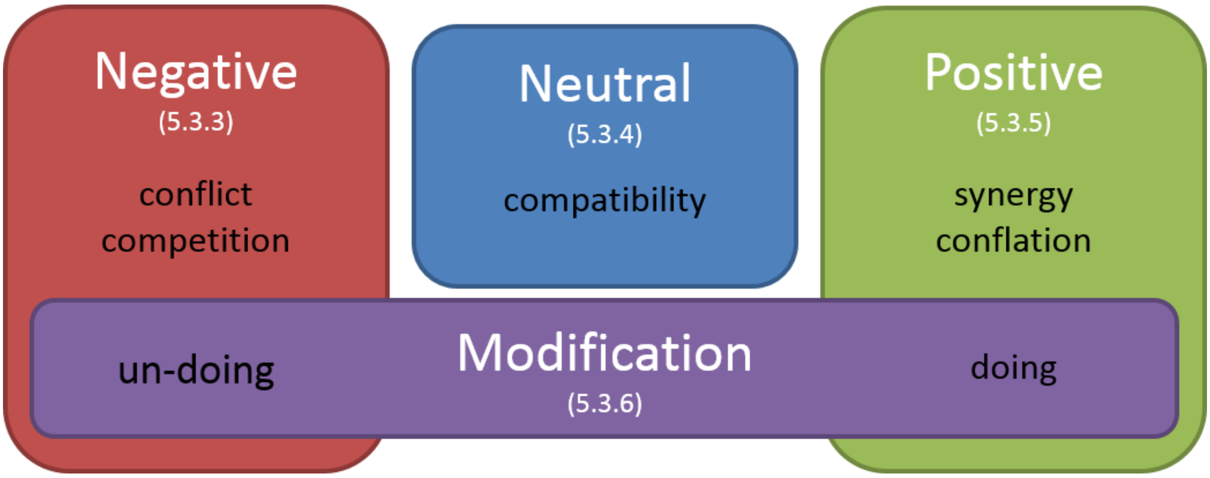


Figure 8-1 Types of interaction identified in chapter 4 (section references shown in brackets)

The two types of negative interaction observed, conflict and competition, are well described in policy research (e.g. Klein et al., 2007; Leinert et al., 2013; Ürge-Vorsatz & Herrero, 2012). However, there have been only limited descriptions of these phenomena in buildings (McEvoy et al., 2006; Williams & Dair, 2007) and therefore the findings provide a valuable source of empirical examples. Both short term conflicts (over design and built form) suggested in section 3.3 were observed, but also other issues caused by adaptability's desire to separate components and the space demands of low carbon renewable technologies (see 5.3.3).

Positive interaction was also predicted (see 3.3) and as a result section 3.2.3 was able to suggest a number of possible long term synergies in the two approaches goals. In the short term however, few synergies were immediately obvious. Despite this, the cases were able to find numerous helpful overlaps in the two principles (see 5.3.5). Furthermore, the findings demonstrate an additional type of positive interaction (conflation – see 5.3.5) that is overlooked by other sources. Conflation has potentially important consequences for how adaptability is understood and positioned in relation to sustainability - see 8.3.2.1 below.

Neutral interaction was not explicitly discussed in chapter 3, however the assumption of many implementation studies of easily integrated agendas (see 1.4) would suggest simple coexistence. While this was obviously often the case, there were also examples of an apparently forced neutrality in the data. These compatible (section 5.3.4) interactions gave the impression of conflict avoided, of an uneasy truce and provide evidence of the potential for conflict type interaction within the cases. That compatibility is not noted in the policy literature likely reflects the timing of the study, which looked at actions already taken. In contrast policy work tends to focus on the effects of possible future actions (e.g. Ürge-Vorsatz & Herrero, 2012).

Modification type interaction (5.3.6) bears a good resemblance to the IPPC's (Klein et al., 2007) differentiation between "*trade-offs and synergies*" in decisions made now and "*actions that have consequences*" later. However, rather than the typical portrayal of these later effects as "*unintended consequences*" (Davies & Oreszczyn, 2012), the identification of doing and un-doing (see 5.3.6) suggests the case teams were aware of the potential for future conflict and synergy as a result of their choices. This is an interesting finding given construction has long faced criticism for its short term vision with limited thought for a building might be operated and maintained (Way et al., 2009). The short term focus has to some extent been exasperated in low carbon design by legislation that specifically excludes future change or unique operation (see section 2.2). It was therefore an unexpected finding that design teams should be so frequently (see 5.3.7) considering the often very long term effects of their design decisions. Had they not, no modification type interaction would have been uncovered. (Note while a large amount of modification was found, the teams were limited in what they chose to speculate on - see 5.4.4 and 8.3.1.2 below). The teams consideration of modification effects also suggests that, as the IPCC (Nobel et al., 2014) propose, long term conflict is not just the result of "*badly planned*" action, but can also occur through "*deliberate decisions*" based on wider considerations. (This is not to suggest that unintended side-effects of design decisions will not occur later. In fact, that the cases were required to speculate on future events to such a degree suggests that at least some of their guesses will have been incorrect and as a result their decisions may or may not have been appropriate.)

Overall the results are sufficient to demonstrate the existence of interaction effects between sustainable design agendas, and that the general theoretical understanding of interaction effects at policy level appears sound when applied to the examples of construction design studied. It is perhaps worth noting however, that while the above descriptions and much of the literature described in section 3.3 portrays interaction as something encountered (where particular combinations will always yield a particular interaction effect), often the type was dependent on the particular aims, concerns and framing of the case actors concerned. This meant different cases drew different conclusions about similar combinations of adaptability and low carbon technologies. For example, while interactions 07A and 25A consider the benefits of raised access flooring for small power flexibility and low carbon displacement ventilation, 14D notes that this effectively isolates the thermal mass of the floor slab from the room and would conflict with any low carbon strategy reliant upon it. There are also examples of interactions emphasising design beliefs more than scientific fact; for example it is arguable if 19G's use of exposed services to encourage sustainable energy use will have a significant effect on consumption. Similarly 24I's insistence on a concrete frame for adaptability and thermal mass somewhat sidesteps existing guidance (Braham et al., 2001) suggesting the frame's mass is relatively insignificant. Both of these points would suggest the appearance of synergy and conflict is a matter of what the cases were trying to achieve and how they chose to promote their decisions.

8.2.2 INTERACTION STRATEGIES

Despite a lack of guidance or examples (section 3.3) the cases were often doing what scholars expected them to – capitalising on synergy (see 5.4.3) and avoiding conflict (5.4.2.3). There was perhaps less avoidance than suggested by existing work, but this may reflect avoidance being less frequently recorded by the cases than other interaction strategies (see 5.4.2.3).

In respect of synergy, win-wins between adaptability and low carbon actions were identified by the teams, similar to those identified in other fields (such as those identified by McEvoy et al. (2006) for climate change, see also section 3.3). However, this approach frequently appeared more post rationalised justification than considered choice and therefore it is arguable whether these approaches provided significant overall benefit. In contrast, multi-purpose solutions (5.4.3) were often selected specifically because of the simple, effective solutions they provided. For negative interactions (and in contrast with existing theory – see section 3.3), trade-offs were the dominant approach reinforcing chapter 3's assertion that conflict is frequently unavoidable. While the need for trade-offs had previously been identified (McEvoy et al., 2006; Williams & Dair, 2007) the case studies demonstrated three different coping strategies – prioritisation, compromise and mitigation.

Considering first prioritisation (see 5.4.2.5), chapter 2's conclusion proposed the more prominent and measureable low carbon agenda was likely to dominate. Yet the converse was frequently the case, with adaptability being retained while low carbon additions were value engineered out. This seems at least partly because, unlike many of the adaptable features, renewables and energy efficiency measures were simple to remove (Kershaw & Simm, 2014) with minimal influence on the design (therefore minimising the costs of change). Adaptability also benefited from its status as a commercial as well as sustainable strategy - despite the adaptability and material reuse literatures creating convincing links to sustainable design (Bullen & Love, 2010; Durmisevic, 2006; Kendall & Teicher, 2000; Manewa et al., 2009), the primary driver for adaptability in many of the case buildings appears to have been a commercial or practical need to accommodate change quickly, easily and at minimal cost. In contrast low carbon design relied on a desire to minimise operating costs or pursue a sustainable strategy (Miller & Buys, 2008), neither of which were always an overriding priority.

Neither compromise nor mitigation approaches to managing conflict are well described by existing work in policy, and have been completely overlooked in relation to building design. Compromise capitalised on the ability of both adaptable and low carbon design principles to be applied to only parts of buildings or adopted in a less than perfect format. Sustainable ideas that require a more or-all-nothing approach would therefore be unlikely to benefit from (or be disadvantaged by) compromise type strategies. Mitigation arose from a desire to provide passively designed low carbon buildings in situations where other more fundamental design aspects prevented it. Passively designed buildings have tended to be the gold standard for low carbon approaches as they are based on changes to form that are cheap to maintain and long lasting (HM Government, 2013). That these cases were sometimes prevented from pursuing a passive strategy therefore has potential implications for the long term carbon performance of these buildings given owners are more able to remove (or fail to maintain) energy efficiency and renewable based elements of their buildings (see 3.3.3.2).

8.3 WHAT DO THE RESULTS TELL US ABOUT THE AGENDAS INDIVIDUALLY?

8.3.1 INTERACTION AND THE LOW CARBON LITERATURE

8.3.1.1 *THE IMPLICATIONS OF CHANGE FOR LOW CARBON DESIGNS*

Chapter 5 identified two interaction types (doing and undoing – see 5.3.6) which show the teams speculating on how adaptability and low carbon design decisions might affect each other in future. A number of these are concerned with the implications of enabling change using adaptability for any adopted low carbon strategy – would the change be helpful or harmful? This speculation, and the teams' responses to perceived issues arising from it, have a number of possible implications for the long term carbon performance of the case study buildings.

Firstly despite studies suggesting occupants make changes that hamper energy performance (Summerfield et al., 2010) (see also 3.2.3.2), there was considerably more doing than undoing observed (see section 5.3.6). This suggests a perhaps overly optimistic view of future user behaviour. Secondly, a number of the teams opted to restrict (or attempt to restrict) occupants ability to make detrimental changes. Chapter 5 noted similarities between this strategy and the idea of preciousness in the adaptability literature (see 5.4.4.1) whereby designers desire for perfect, static architecture conflicts with the ongoing evolution of most buildings. While this perspective offers helpful insights (see 5.4.4.1), there is also an alternative perspective; that control is a simplification for energy modelling purposes. Modern buildings are increasingly reliant on complex energy models (Donn et al., 2012), and these models require a variety of assumptions to be made regarding a building's operation. Control strategies might narrow the assumptions required and as a result produce more consistent results: the more imposing the control strategy adopted the less subject to occupant behaviours the low carbon strategy becomes, increasing its ability to be reliably modelled. This however, in the context of control strategies based on rules (which can be broken) is highly likely to result in significant disparities between modelled and actual performance (Carbon Trust, 2011; Cheshire & Menezes, 2013).

8.3.1.2 *THE EXTENT OF DESIGN RESPONSIBILITY*

As noted above (8.2.1), despite regulations that discourage speculation on future, non-conventional use (see section 2.2), the large number of modification type interactions recorded in the case documents suggests the teams were doing so anyway. The evidence shows the projects were happy to consider the impact of change they had been explicitly asked to design for, or was a requisite part of their building's typology on their low carbon strategies (e.g. partitioning the floor plate). There were also several examples of the teams considering the impact of occupant behaviour, in line with a growing trend to deliver more accurate energy consumption figures (e.g. Cheshire & Menezes, 2013) and in some of the cases a client expectation of a certain level energy performance in use (Case 31's design team had a contractual commitment to provide a DEC A rated building for example). Thus the boundaries of what it is reasonable to account for in design were being extended beyond what is typically required in the cases observed. However, there were however many notable exceptions: occupants frequently do 'bad' things to their buildings, such as drilling cables through airtight walls and infilling atria (e.g. interaction 14A), which were overlooked. Thus while design responsibilities were in some areas increasing (for the observed cases), maintaining low carbon strategies beyond basic changes included in the original brief was still regarded as a problem for the change undertaker.

8.3.1.3 *FUTURE-PROOFING*

Several of the modification strategies identified in chapter 5, and in particular retrofit (5.4.4.4), demonstrate the project teams 'putting off' installation of renewables due to difficulties with funding or planning objections. While the cases generally saw this approach as a positive or at least necessary measure and were able to meet or exceed legislative targets despite omitting low carbon design features, there is nonetheless possible merit in considering the implications of this choice.

A number of authors (Boardman, 2007; Summerfield et al., 2010) have argued that due to the pressing urgency for climate change mitigation action and the difficulties in ensuring owners upgrade their buildings following purchase (Summerfield et al., 2010), new buildings should be built to as high an energy efficiency standard as possible in the first instance, which the cases applying a retrofit strategy were clearly not. How damaging this is will depend on a number of factors. Firstly a number of the retrofit actions were made to avoid future risks in energy costs or taxes that, if forthcoming, may encourage more action than is noted by Summerfield et al. (2010) for example.

Existing evidence that energy costs are insignificant to may non-domestic users (Carbon Trust, 2011) would however suggest this is unlikely for the majority of the cases in the sample. Secondly, the size of the difference in performance as a result of omitting renewables is important. While renewables have been a government priority area to low carbon growth for some time (BIS, 2013), the contribution of small scale installations is relatively minor. Arguably the renewables would have made a relatively small contribution relative to savings possible by reducing energy consumption in the large, often intensively used buildings which make up much of the case sample.

The contrary argument is of course, that the cases were engaging in what Georgiadou, Hacking and Guthrie (2012) describe as "*uncertainty orientated future-proofing*" – providing low carbon buildings with sufficient adaptability to meet changing requirements of their occupants, climate and context. This perspective is bolstered by the fact that retrofitting is only associated with provision for later renewables. Energy efficiency and passive design measures were generally incorporated in the initial design, perhaps reflecting perceptions within the cases and the wider low carbon community (Carbon Trust, 2005) that energy efficient, passive design needs to be considered and incorporated early to be effective.

8.3.2 INTERACTION AND THE ADAPTABILITY LITERATURE

8.3.2.1 *CONFLATION AND AGENDA CREEP*

Adaptability was conflated with low carbon ideas by a small number of cases (5.3.5). Firstly, some attempted to sell adaptability to planners as an investment in embodied energy saving (generally in place of renewables or other energy saving measures). While on the one hand this might be viewed as helpful, promoting a more long term approach to energy design, there is also an inherent danger in asking sustainability measures to justify themselves in terms of carbon saved. Carbon is just one part of a larger environmental agenda, itself only one component of a sustainable society. By selecting carbon as a focus, the wider sustainable benefits of adaptable design such as retaining cultural heritage (Bullen & Love, 2010) and providing occupant choice (Kendall & Teicher, 2000) are potentially obscured. This is a cautionary note to those "*trying to sell a less sexy subject in a more popular packaging*" (Ürge-Vorsatz & Herrero, 2012).

Secondly, in a small number of cases energy efficiency was portrayed as a prerequisite to adaptable design: these cases thought it unlikely that anyone would want to retain and reuse an inefficient building. While Schmidt (2014) incorporates passive design principles in a list of basic adaptability strategies, previous work has largely overlooked its significance. The finding may suggest that, in addition to the low carbon agenda's impact on the design process (Zapata-Lancaster, 2013), it is also influencing how other sustainable agendas are defined.

8.3.2.2 *NEW OPPORTUNITIES FOR ADAPTABILITY*

All of the various modification strategies demonstrated a surprisingly amount of creativity in how adaptability could be used to increase opportunities for low carbon improvements in future. However, the use of adaptability as a low carbon technology risk management strategy (hedging – see 5.4.4.7) was perhaps its most unexpected application.

Adaptability has previously been supposed to provide risk reduction benefits, however these are generally via decreased vacancy periods (Ellison & Sayce, 2007; Russell & Moffatt, 2001; Schneider & Till, 2007). Williams and Dair (2007) have made passing reference to practitioners installing addition standard systems provided "*as a back-up*" in response to the perceived risks associated with 'untested' low carbon technologies (Kershaw & Simm, 2014) but overall this use of adaptability seems relatively unexplored. Yet it was surprisingly common among the cases studied, with risk conscious developers using it to avoid locking their buildings in to particular low carbon solutions that could prove unreliable, unavailable or more expensive than alternatives. The implications of this new link are unclear. On the one hand it provides an obvious opportunity for adaptability research to make new links with low carbon design barriers. On the other, it is a potentially damaging approach to low carbon design that allows developers to shirk responsibilities when they become too difficult or expensive.

8.3.2.3 *DEFINING ADAPTABILITY*

Chapter 2 discussed the conflicting interpretations of adaptable buildings (section 2.3.1) and the resultant difficulties in evaluating success (section 2.3.3). While a number of scholars had developed evaluation tools, few had been used on more than a handful of buildings. The results (chapter 6) show that, contrary to expectations, the selected adaptability evaluation tools were in reasonable agreement as to the rank order of the cases (see 6.3.8). Further, the majority were able to distinguish between the adaptable and unadaptable benchmark cases (see section 5.3.9). These results might suggest that adaptability is more coherent concept than previously thought. However, the diversity of guidance available (see Figure 2-8) would suggest otherwise. An alternative explanation is that the evaluations used may all have concentrated on areas of overlap in the literature and avoided including criteria that were potentially contradictory. Also, the majority of the adopted tools were of the criteria type (see 2.3.3.5). Applying a scenario, component connectivity of post occupancy evaluation approaches (see 2.3.3) may have produced differing results. Overall further work with a larger, randomised sample and a greater range of evaluation tool types would be necessary to understand how effective those used in this study were.

8.3.3 THE DIALOGUE BETWEEN ADAPTABILITY AND LOW CARBON DESIGN

Despite being very separate discourses (see chapter 2), and interviewees struggling to articulate how the principles might interact as a result (4.4.4), the study uncovered a range of examples of the two discourses interacting, to the extent that on occasion one might be used to justify the pursuit of the other (conflation – 5.3.5). For example, many of the basic principles of adaptability were seen by the case teams to facilitate low carbon passive design (see 5.3.5), or were used to provide innovative solutions to stifled low carbon goals (see retrofitting – 5.4.5.4). There were also notable theoretical crossovers – using the adaptability literatures portrayal of designers as controlling or permitting change (Schneider and Till, 2006) offers an alternative insight into low carbon design's occupancy problem (see 5.4.4.1).

This work therefore fundamentally challenges current research approaches to sustainable design that treat its disparate agendas as separate components to be simply assembled into a holistic sustainable building (see chapter 1). Instead the many interactions perceived and acted on by the design teams demonstrate that, at least in the case of adaptability and low carbon design, these discourses are far more interdependent than previously thought.

8.4 WHAT DOES INTERACTION TELL US ABOUT SUSTAINABILITY?

In the opening chapter, amongst the numerous competing ideas of a sustainable building was Guy's (2005) assertion that sustainable design was, ultimately, "*just good architecture*". While what exactly demonstrates good architecture is a matter of some debate (Dewulf & van Meel, 2004; Gann et al., 2003), there is evidence within the synergy strategies that some of the simpler but fundamental integration solutions employed by the teams are principles generally associated with good design – generous, unimpeded spaces , larger floor to ceiling heights, and good daylighting.

There is also evidence from the investigation's findings presented in sections 5.4 and 7.2 that many of the conditions influencing sustainable design's ability to integrate into a general project context are also important to understanding how successfully its different aspects are combined. For example, client commitment (themes 1 and 2 in section 7.2) is often viewed as imperative in successfully implementing sustainable design (Häkkinen & Belloni, 2011; Williams & Dair, 2007) as is theme 5, funding (Kershaw & Simm, 2014; Peterman et al., 2012). The potential of planning to promote and hinder (theme 3) is also evident (Williams & Dair, 2007). However, the particular focus on interaction between adaptability and low carbon was able to add some insightful details and unexpected differences. For example, whereas sustainable design generally considers the total funding element to be of primary concern, for the interaction examined here it was more often its late removal that proved problematic. The discussion in section 7.2 also shows that the type of commitment clients made to adaptability was as important, if not more so, than the commitment itself. The results also suggest a new issue – trust. While adaptability has toyed with the influence of designer's ability to "*let go*" (Habraken, 2008), both it and work on low carbon user acceptability have largely concentrated on user's ability to make changes, rather than designers willingness to permit them.

Overall, the findings emphasise the importance of interaction in potentially influencing sustainable outcomes. Almost all of the strategies are expected to have an influence on the outcome, either now or in future (table 7-2). It was however impossible to determine the case outcome by considering the interaction the cases encountered or the strategies pursued alone, firstly because this study has not uncovered every interaction occurring for each case (something unlikely to be feasible with any approach) so it is impossible to sum for the outcome, and secondly there is a distinct possibility that some strategies are more important in determining the outcome than others. For example compromise fulfils the full criteria of neither agenda, resulting in what priortisers might consider a defective building on both fronts.

These issues raise the interesting question, what is the most appropriate way to measure success when there are multiple objectives? Current approaches to evaluating sustainable design such as BREEAM allow users to mix and match issues (BRE, 2014), with the overall evaluation achieved through addition (occasionally after weighting the criteria). As a result, with the exception of some minimum requirements, designers are free to pursue any particular mix of credits, with the buildings being considered as sustainable as one another so long as the overall total is similar. In contrast this study adopted (see 4.6.3) co-achievement as its measure, requiring a reconciled, holistic interpretation of sustainability. Yet the case evidence, as well as the disappointing results of chapter 7, would suggest neither approach reflected the reality of how the cases understand sustainable design success. Generally they chose definitions that were personal to them and their case context. This presents an interesting conundrum – were the particular success definitions adopted by each of the cases the most suitable and sustainable? Or where they, as Cole (2005) and Hiete et al. (2011) suggest, subject to a certain amount of gaming by the design teams in order to achieve their sustainable outcomes with minimum effort? There is limited evidence of deliberate scheming by the case teams to score BREEAM points or meet planning targets without a genuine commitment to sustainable design. However, the teams did tend towards defining their outcomes in terms of the needs of its first user (their client) and its current context. Sustainability's concern with futurity may yet show this to be a flawed strategy.

8.5 REFLECTIONS ON THE USE OF QCA IN CONSTRUCTION RESEARCH

Early in the study's development, methodological discussions within the construction research community (Jordan, Gross, et al., 2011) suggested QCA's systematic procedures, ability to handle complex causality and multiple cases had potential utility for socio-technical problems of the type frequently encountered in building orientated research. The alleged benefits proved too tempting, and as a result this study was, at least in part, a method experiment: would QCA deliver on its multiple promises? This section reflects on the results of that experiment, from both a practical and methodological perspective. As a reflective piece, it is written largely in the first person.

8.5.1 QCA AS A QUALITITATIVE METHOD

Qualitative comparative analysis (QCA) has been described as an approach that "*starts by assuming causal complexity and then mounts an assault on that complexity*" (Ragin, 1989), providing a means to selectively reduce the complexity of case data enabling comparative analysis across a greater number of cases than might otherwise be possible in a way which is explicit and replicable (Jordan, Gross, et al., 2011). It is intended to capitalise on the benefits of case designs, while using a larger number of cases than would otherwise be possible (Ragin, 1989). However, there are a number of caveats to these claims.

Firstly, as discovered in chapter 3, the practicalities of the method mean that while a large number of conditions can be used to describe cases, the number of cases required to produce robust results increases exponentially (reflecting an increase in the number of possible combinations or "configurations" (Ragin, 2008) of the conditions). As a result QCA is typically limited to models containing only 5 or 6 conditions. This has two implications. While QCA is not the only method to suffer this limitation, it somewhat undermines the validity of QCA's assertions (Ragin, 2008; Rihoux & Lobe, 2011) of retained complexity. From a practical point of view this also means that, unless working deductively and able to select conditions on the basis of robust theoretical hypotheses, a considerable amount of work is required upfront in order to understand which conditions are relevant and valid influences over the outcome. Despite Amenta and Poulson's (1994) inclusion of inductive and comprehensive methods of condition selection, and Yamaski and Rihoux's (2009) insistence of the plausibility of inductive QCA, my experience would suggest QCA is not well suited to inductive research. (A point somewhat reinforced by the paucity of published QCA studies adopting such an approach). Instead, QCA's reliance on theory for narrowing the scope of its models suggests a need for either deductive research designs or an efficient method of specifying plausible conditions (such as Javernick-Will et al.'s (2012) use of a Delphi study) prior to embarking on the case data collection phase. Attempting to inductively derive relevant conditions from a full QCA sample is not advised.

QCA does provide robust, transparent and systematic procedures with which to compare cases once the initial data reduction is complete. Its Venn diagram representations proved particularly helpful in exploring how the cases could be grouped and its focus on necessary and sufficient conditions brings an often useful focus to the potentially laborious comparison process require to draw useful findings from multiple cases. The idea of contradictory configurations is also useful in encouraging researchers to challenge their initial models. It is also able to assimilate different evidence types through its emphasis on categories, lending it to a mixed methods approach. Thus, while QCA is not a panacea for data reduction and "*one cannot use QCA until quite a lot of thought and analysis has been completed*" (Coverdall and Finlay, 1995), it does provide a number of useful tools for data analysis and exploration.

Secondly, my experience of analysing the cases suggests that at least some of the rich detail of the cases was lost, as was the opportunity to single out particular pairs of cases to highlight contrasts. For example, a more qualitatively orientated research might ask why, given such similar set ups (owner occupiers with a long term interest, early involvement in the design, headquarter call centre typologies) case 01 and case 31 produce such different outcomes. What made case 31 special? Case 31 is perhaps the exemplar for reconciled design, yet its corresponding recipe (I1 – see 7.4.1) overlooks much of the detail a typical, yin-esque case researcher would consider essential. For instance the client's strong corporate social responsibility image and corresponding requirements for low carbon design, the low energy business case that made its BREEAM award winning design a reality. The commercial nature of the building and the cooperative's tradition of a Manchester presence (meaning the client expected to stay in the building for some time) also seem important yet overlooked. Overall, having been immersed in the rich detail of the case in order to generate conditions and identify interactions, I cannot help but feel the building is such an exemplar of reconciled design because of more complex reasons than the recipe suggests. While the analysis identified a number of important and relevant conditions, the rich, explanatory detail of the case evidence is lost in a simple result.

This leads to a general conclusion that, despite QCA's claims to retain qualitative depth, it is not the same sort of depth case study researchers are used too. Rather than QCA providing an alternative to experimental logic case studies, it is instead an additional tool. It provides different types of results to more orthodox case study approaches and users should be cognisant of the types of research outcomes would best answer there research questions before considering it.

8.5.2 USE OF QCA SOFTWARE

As a final note, it was felt useful to discuss the experiences with the specialist software used for QCA analyses. Two packages (fs/QCA and TOSMANA) were used in this study, initially out of curiosity to understand if one was preferable to the other and later largely out of necessity on realising the functionality of the two packages differed significantly. Both are able to import Microsoft Excel (.csv) files, generate truth tables and produce the complex and parsimonious solutions. TOSMANA is perhaps the better looking and user friendly of the two overall, although the process of generating solutions is less intuitive than in fs/QCA (which is not to suggest fs/QCA is straightforward, fs/QCA's manual concentrates heavily on the workings of QCA as a method rather than how to operationalise this in the software and it was not until a significant amount of time had been spent experimenting and consulting others that it became apparent how to use the package to its full potential). TOSMANA cannot generate the intermediate solution and therefore fs/QCA (or another of the available QCA packages) is required to perform a full standard analysis or enhanced standard analysis.

TOSMANA does however have a number of features that aid the interpretation of fs/QCA outputs:

- TOSMANA can generate graphical Venn diagram representations of the data and solution for up to five conditions. While these present no new information it is much more accessible.
- TOSMANA has an option to produce a list of assumptions made to obtain the complex solution, which fs/QCA does not. For an enhanced standard analysis as described by Schneider and Wagemann (2012) understanding these assumptions is vital, allowing erroneous assumptions to be excluded. While assumptions can be listed manually this is a time consuming process, prone to error where a large number of conditions are used.
- TOSMANA and fs/QCA treat prime implicants (logically equivalent solutions) differently. fs/QCA presents the user with a confusing display and requires the user to select a preferred solution before continuing to generate the result. TOSMANA, in contrast, generates all possible solutions. This latter method was simpler to understand and therefore more reliable choices were made. It was possible to compare the different solutions and select that which made the most sense. It is aids transparency – as all the solutions were generated these could be presented within the results and the selection procedure explicitly described.

Overall, neither piece of software is intuitive to use nor its results presented in a manner that makes them easy to interpret. Researchers familiar with Boolean algebra and the basics of combinations and permutations are likely to find they frequently need to resort to hand calculations to understand whether the software is producing the results expected.

8.6 CHAPTER CONCLUSION

This chapter has compared the findings of earlier results chapters with existing interaction theory presented in chapters 1, 2 and 3. This has demonstrated that, for interaction between adaptability and low carbon ideas at least, the theoretical descriptions provided by work in policy provide a useful framework for understanding. The interaction strategies presented in section 5.4 have demonstrated the achievability of researchers hoped for synergies, but also unveiled a considerable amount of conflict and unexpected approaches to managing it. Furthermore, by comparing the findings to expectations from both adaptability and low carbon's separate literatures (chapter 2), as well as the wider body of work concerned with sustainable design, this discussion chapter has been able to note a number of potentially interesting and unexpected consequences of interaction.

The next and final chapter summarises the findings of previous chapters and the most significant points emerging from the discussion above, using these to draw a number of conclusions.

9 CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

The intent of this study was to understand how building designers are reconciling the various facets of sustainability and the effect this has on the type of sustainability building designs embody. This was achieved by examining how interaction between two sustainability agendas, adaptability and low carbon, was managed within a selection of case studies and the outcome of those management actions. Having presented results to this effect in previous chapters, this chapter draws conclusions and evaluates the study's effectiveness in achieving its six objectives. Ultimately this chapter summarises the thesis's contribution to our theoretical understanding of sustainable design implementation.

9.2 FULFILMENT OF THE AIM AND OBJECTIVES

The aim of this thesis was to *understand how interaction between adaptability and low carbon sustainable design principles influences the process of sustainable design and its outcomes*. In order to achieve this chapter 3 identified six objectives.

9.2.1 OBJECTIVE 01

> *Demonstrate the existence of interaction by locating, describing and categorising examples of interaction in real building design processes, comparing the empirical findings to theoretical interaction types*

86 examples of interaction between adaptability and low carbon design principles were identified across 21 of the 23 building design cases examined. Two cases showed no evidence of interaction. Reflecting existing descriptions of interaction in other fields (see 3.2) the interactions could be broadly described using two dimensions – the type of effect and the timing of that effect, Figure 9-1.

		Interaction Effect		
Interaction timing		Positive	Neutral	Negative
	Design phase	Synergy Conflation	Coexistence (no interaction)	Conflict Competition
	Post design phase	Doing	Compatibility	Un-doing

Figure 9-1 Figure illustrating the two dimensions of interaction

However, as demonstrated by the descriptions and examples provided in chapter 4 these macro categories can be un-packed into seven sub-types. This extends the existing theoretical knowledge of interaction with empirical data.

9.2.2 OBJECTIVE 02

Distinguish approaches to the combination of adaptable and low carbon design principles by comparing designers' choices of technology and design tactics for individual buildings.

Few previous studies had examined how construction design teams might react to and manage interaction occurring during the design process (chapter 3). Chapter 5 therefore considered the actions surrounding each of the interactions noted in the cases. While some interaction appeared to have passed un-noticed by the teams, 11 types of interaction management strategy were identified. Some of these strategies sought to provide both adaptability and low carbon (e.g. reconciliation, compromise), others pursued one aspect at the expense of the other (e.g. prioritisation, control, permissiveness). Each case adopted a range of strategies depending on the particular circumstance.

9.2.3 OBJECTIVE 03

Identify important factors in the selection of approach for each identified interaction, in order to formulate a rationalised list of probable factors influential in the reconciliation of the two sustainability agendas.

Each agendas literature has ample commentary on factors influencing their adoption and implementation in building design. However, there had been no attempts to understand how these factors and others might influence attempts at reconciling adaptability and low carbon the two. Chapter 5 therefore looked within and across the examples of interaction observed to identify the conditions within which particular interaction strategies were pursued. A large range of factors were identified, which chapter 7 grouped into 8 themes: adaptability requirements, low carbon aspirations, planning and statutory issues, typology, budget, ownership, trust and technology. Many of these themes reflect factors previously identified by the sustainability literature as influential, although the focus on interaction was able to provide additional insight. For example while the importance of sufficient funding is often stressed, in the cases examined it was more often a late reduction in funding that was most influential.

Chapter 7 went on to suggest that the themes could be thought of as two types – briefing conditions which determined the relative importance of adaptability and low carbon design to a particular project and modifying conditions, were capable of altering the balance in favour of one agenda or the other. The modifying conditions can be usefully conceptualised as constraints and opportunities posed by the particular context of a given interaction.

9.2.4 OBJECTIVE 04

Operationalize the concept of reconciliation, allowing for an assessment of which cases are, and which are not, successful in reconciling low carbon and adaptability principles.

Chapter 6 considered how successful the case study designs were in reconciling the two relatively unrelated aspects of adaptability and energy efficiency. In line with the few similar studies available (e.g. Edum-Fotwe et al., 2004; Hiete et al., 2011) success was defined as a design embodying both principles to current standards.

Carbon performance of buildings has been a topic of considerable interest and therefore a range of well-established evaluation methods and benchmarking data were available. In contrast, difficulties defining adaptability have led to numerous assessment approaches and little consensus. The decision was therefore taken to use a number of assessments and combine the results. With the exception of the BAS method (March et al., 2012), the 6 adaptability evaluation tools demonstrated a surprising level of agreement in the rank order of the cases. As no studies had previously compared the results of these evaluation tools the results presented in chapter 5 also add to existing knowledge regarding how adaptability can be measured. (However the use of a non-random sample does limit their generalizability.)

Combining the results of the low carbon and adaptability evaluations evidenced a mix of outcomes – some cases successfully developed adaptable, low carbon designs while others managed neither, or only one of the agendas in isolation. More cases were successful in demonstrating low carbon design than adaptability reflecting the minimum energy efficiency requirements required by law.

9.2.5 OBJECTIVE 05

By describing cases as configurations of relevant conditions and undertaking a systematic comparison across these cases, propose pathways to successful reconciliation of adaptable and low carbon design.

Having established some cases were more successful than others in reconciling adaptability and low carbon design (chapter 6), and that the teams approach to reconciliation was contingent on a variety of factors (chapters 5 and 7) chapter 7 employed qualitative comparative analysis to describe each case using the identified factors and compare them systematically to eliminate superfluous factors. The result was three ‘recipes’ for reconciled design. The first and most straightforward of these is essentially *trying* – cases with an incentive to design for adaptability due to anticipated change and some low carbon impetuous (either from a client brief or planning requirement) almost always resulted in successful outcomes. This finding might be seen as validating the current approach by many within construction sustainability research of tackling aspects of sustainability individually. However, chapter 4 demonstrated a range of interaction and so this combination instead is likely to demonstrate the ingenuity of the design teams in managing negative interactions and capitalising on prospective synergies.

The second recipe proved difficult to justify when confronted with the more detailed case evidence, while the third largely described the case rather than provide theoretical insight. Two reasons for the disappointing QCA results were proposed – firstly that the cases often chose to define success in relation to their particular context rather than pursue the fully reconciled outcomes of chapter 6. More theoretically useful results might have been obtained by choosing to limit the QCA to cases with similar interpretations of success. Secondly, it seems likely that the interaction strategies were as influential as the conditions surrounding their use in determining outcomes requiring a much more complicated model than is possible with QCA.

9.2.6 OBJECTIVE 06

> *Conduct a method experiment to assess the usefulness of Qualitative Comparative Analysis (QCA) as a research tool for problems of a socio-technical type within a built environment context.*

Despite calls (Jordan, Gross, et al., 2011) to explore qualitative comparative analysis's usefulness within the construction management research community there have been only tentative attempts to apply it (Boudet et al., 2011; Gross & Garvin, 2011; Javernick-will et al., 2012) and limited critique. This study therefore sought to better understand the methods applicability and limitations in a construction orientated environment. The results were conflicting. On the one hand QCA provided a structured method to collect and reduce data, stressing the importance of understanding how concepts relate to existing theoretical and practical ideas. However there were also problems. QCA's claim to reduce the data required when using multiple cases to a manageable level is perhaps overstated. Considerable effort was required to condense the large number of documents examined into a manageable data set, extract conditions and assess outcomes. Further, despite several QCA texts suggesting the method can be used in an inductive manner (Amenta & Poulsen, 1994; Yamasaki & Rihoux, 2009), QCA's insistence on theory for specifying models and calibrating conditions makes this neither simple nor straightforward. Either a considerable commitment to an initial theory generating phase of research is required, or else it is perhaps best suited to combining and challenging existing theory rather than attempting to construct it.

9.3 CONCLUSIONS

As a result of the above findings, it can be concluded that:

1. There is interaction between the separate low carbon and adaptable approaches to sustainable design when pursued together.
2. That interaction can take a variety of forms (Figure 9-1), sometimes being perceived as helpful and at other times as problematic.
3. Despite this, it is possible to reconcile the two approaches using a range of interaction management strategies.

These conclusions emphasize the importance of understanding interaction between sustainable agendas as well as the with the wider design context. Theoretical work on interaction in policy fields was helpful in understanding the overall interaction landscape, but was not able to fully describe the range of interaction in building design or the ways in which the project teams approached it. It is also notable that while the conditions for adaptable, low carbon design are similar to those identified as influencing the implementation of sustainable design more generally, approaching the problem from an interaction perspective provided additional insight into why these conditions are important. The research has also demonstrated that while sustainable design may be "*increasingly narrowly interpreted as low operational carbon emissions*" (Moncaster, 2012), the cases often chose to prioritise adaptability.

- QCA provides an alternative, systematic approach for exploring socio-technical problems across multiple cases, but does not obviate the need for robust data processing procedures and qualitative description.

QCA was initially seen as a way of systematically and efficiently managing the inevitable data reduction process. However, the experience of applying it indicates QCA requires considerable 'up front' data processing and, in the case of an inductive approach (not well represented in existing studies), analysis too. The structured rules of QCA did however provide a methodical and transparent way in which to perform data reduction.

The method's emphasis on calibration and model specification was also beneficial in forcing the development of a thorough understanding of what was meant by adaptability and project success, and how these concepts might be best operationalized. While the QCA literature tends towards social concepts that come with pre-defined indicators, this experiment has demonstrated the plausibility of an involved metric creation stage (chapter 5) where measures are less well defined.

However, the method's claims to retain causal complexity of its cases was challenged by the requirement to reduce models to 6 conditions or less and the difficulty in explaining case outcomes without reference back to the more detailed case evidence.

9.4 LIMITATIONS

This study has a number of limitations that affect both the generalizability of its findings and what it was possible to achieve.

In order to limit the study's scope to a manageable level, only interaction effects between adaptability and low carbon design actions were considered. This has two implications. Firstly the findings are limited to commentary on interaction effects between adaptability and a narrowly defined low carbon agenda. There are some, very limited grounds to suggest the interaction effects between climate change mitigation and adaptation effects in buildings would follow similar patterns due to resonance with existing theoretical descriptions in this field (McEvoy et al., 2006; Williams et al., 2012) and climate adaptation's similarities to adaptability. However in general the interaction strategies identified are likely to be highly specific to the two agendas studied, particularly the idea of modification (see 5.3.6) and associated strategies (see 5.4.4) which emerge from adaptability's ability to change a building over time.

Secondly, the focus on interactions between only two aspects of sustainable design is an obvious simplification. In reality the teams were required to balance multiple competing views of sustainability with other aspects of design. Existing work on the driver of and barriers to sustainable design to some extent deals with conflict and synergy between traditional and sustainable design ideas (for example tensions between house builder's standard business models and the requirements of green design (Lees & Sexton, 2013)). However, as discussed in chapters 1 and 3, interaction effects between different aspects of sustainable design have received only minor attention.

This study also chose to focus on design due to suggestions this phase is critical to determining sustainable outcomes (Kershaw & Simm, 2014; Williams & Dair, 2007). However, it is unlikely that what is designed would ever perfectly reflect what is built. Amongst other actions, difficulties with enforcing low carbon regulations (Fischer & Guy, 2009; Peterman et al., 2012) and changes made by construction teams to improve buildability will all potentially alter outcomes. Others may therefore wish to explore how the decisions made during design are modified by the construction process.

Further, chapter 5 identified a number of strategies associated with modification designed to alter performance post-occupancy. Many of these strategies have implications for the long term carbon performance of the buildings, yet had little bearing on design stage evaluation detailed in chapter 6. However, the consequences of these actions are obviously of interest – did they have the intended effect? Was any effect to the benefit or detriment of either of the agendas? These questions point to a need for further work exploring the effects of the interaction decision making on the as-occupied buildings.

The case sample was a unique opportunity to reuse a significant amount of data generated as part of the TSB's £2 million investment in the Design for Future Climate Change programme. The TSBs selection procedure ensured a diverse range of building types, locations and teams as well as ensuring all the cases had pursued some variant of adaptability and low carbon design. However, it is precisely these features, which make the cases an attractive ready-made population from which to sample, that make the study's findings difficult to generalise. Projects are not typically awarded up to £100,000 to undertake climate change adaptation studies and only a small number annually will meet the TSB's entry requirements of a demonstrable commitment to low carbon design. Thus these projects are somewhat unique and this must be borne in mind when seeking to generalise the results to other similar buildings.

The study is also limited to understanding interaction between adaptability and low carbon design as these ideas were defined between approximately 2008 and 2010 when the design work was undertaken. Since then the UK has seen a progressive relaxing of its zero carbon buildings definition (McLeod et al., 2012) and associated targets (Treasury, 2015), as well as changes to the planning system designed to influence the attractiveness of reuse (see 3.2.3.1). Were the programme repeated today, we might expect different results.

Lastly, use of the reports produce for the TSB programme and planning applications has demonstrated the effectiveness a primarily documentary approach. However, as with any form of reported information there are limitations. While the document analysis adopts a realist perspective in that is the text has been used "*as evidence, as a representation of reality*" (Gidley, 2012), it is extremely unlikely that this recorded reality describes how the design process was experienced at the time. Instead processes are likely to have been considerably more 'messy', distributed across actors and time. What these descriptions do provide is an overview of the ways in which the cases were prepared to articulate interaction and their approaches to it.

9.5 CONTRIBUTION TO KNOWLEDGE

9.5.1 CONTRIBUTION TO THEORY

Exiting literature tends to view sustainable buildings as either a vaguely defined end goal or as a collection of approaches with claims to it (chapter 1). These has been little consideration of how these two views of sustainability are connected – how are the parts assembled into the whole? This thesis's main theoretical contribution was to begin to address this gap – developing our theoretical understanding of the implementation of sustainable design and this process's impact on sustainable outcomes. This thesis has made a theoretical contribution by improving our understanding of how sustainable design is implemented in construction. Despite existing work on implementation largely targeting individual aspects with limited concern for how easily they might be assimilated, this thesis has demonstrated that conflict and synergies exist between approaches and proven that reconciliation must be worked at.

The study provides empirical evidence of interaction between two separate sustainability discourses (chapter 4), which has allowed it to both demonstrate the applicability of existing interaction theory in the wider policy literature to a construction context and extend that theory to provide a more nuanced account of interaction effects in building design (5.3). It has demonstrated that, contrary to current thinking, interaction does not solely occur as a result of physical incompatibilities, but also as a result of perceived difficulties and indirect linkages such as funding constraints and client briefs (7.2).

The study also provides a novel contribution in describing the range of strategies employed by case actors to manage interaction (5.4). While there has been some speculation and limited calls for strategies expected to capitalise on beneficial interactions, this study provides the first detailed description of the strategies employed and their consequential effects on the relative balance of the two design principles examined. These descriptions further our understanding of the ways in which sustainable design is enacted by project teams, and represents a relatively isolated attempt to examine the process of building design rather than its outputs.

The thesis also provides a contribution to knowledge by challenging and developing the measurement of concepts relevant to a sustainable built environment. The review of measurement literature (chapter 2) and development of a low carbon metric (6.2) provide a direct contribution to the debate surrounding the definition of low and zero carbon buildings. Similarly, the work presented on adaptability measurement in chapters 2 and 6 represents a rare attempt to measure adaptability in new building, in addition to contributing significantly to adaptability measurement theory through the only known comparison of existing adaptability measures (6.3.8).

Lastly, this thesis makes a theoretical contribution to our understanding of the complex interplay of factors affecting the uptake of sustainable buildings. While existing literature portrays these concepts as external threats or incentives to sustainable design, this thesis has shown (section 3.4 and chapter 7) that they are also influential in determining the relative importance of different aspects of sustainability: different combinations will not only influence how sustainable a building is, but also the features that make it sustainable.

9.5.2 IMPLICATIONS FOR PRACTICE

This study provides practitioners with examples of interaction effects (chapter 5) and a range of strategies for managing them. This may allow more conscious decision making in the practice of sustainable design, and a greater ability to select strategies that will deliver project goals.

As an ancillary point, the research has also tentatively examined a number of adaptability measurement techniques. Correlation between the methods used suggest the majority have merit despite previous claims (see chapter 2) of the difficulty in measuring adaptability. This finding has practical use for designers wishing to specify a particular amount of adaptability in their commissions.

9.5.3 IMPLICATIONS FOR POLICY

In the cases examined there were clear tensions and synergies in the two sustainability ideals analysed and these allowed teams to create unique blends of attributes pertaining to the sustainable of buildings. As a result, even within the two aspect limitations of this study, the designs demonstrate variety of sustainable outcomes.

Policy that more fully considers the interactions between different sustainability policy goals in the built environment may lead to more predictable outcomes; this is important for a policy area that has struggled to demonstrate consistent gains. For example, policy in relation to sustainable buildings has typically focussed on removing external barriers (funding, opposition etc.). This study has evidenced that these barriers do not merely influence the take-up of sustainability as a whole, but also the relative importance of its different aspects. When developing future policy, cognisance of interaction effects and the resulting indirect consequences of particular claims to sustainability would allow policy makers greater control over the desirability of certain sustainable forms.

The study has also reinforced commentary in other field that interaction effects produce unnoticed and sometimes undesirable interactions – putting off the installation of low carbon technologies for instance. Greater attention by policy makers to unexpected interactions between policies is desirable to ensure their stated goals are met.

9.5.4 CONTRIBUTION TO CONSTRUCTION MANAGEMENT METHODOLOGY

By applying QCA to a built environment problem, this thesis has demonstrated QCA's suitability in the construction management field. As a methodology QCA provides a systematic, repeatable approach to analysing medium-sized samples of qualitative and quantitative data. While its data reduction abilities were found to be more limited than perhaps suggested by its supporting literature, as a direct result of this study future researchers applying the method will have a greater awareness of the type and amount of data collection and analysis required.

The application of QCA as a method produced disappointing results. However, the experience related in this thesis suggests this was largely because the emphasis of the research question was not best suited to a QCA approach; whereas much of the QCA literature suggests a variety of question types can be answered with QCA, in reality the method is much more quantitatively orientated than the literature suggests. For quantitative researchers, QCA is best applied where a multiple regression analysis would be desirable but the sample size is too small or biased to produce reliable, significant results. Further qualitative work is likely to be required to interpret the results. More generally, the study has shown QCA is suited to questions of the form, why are some things X, and others not? The emphasis should be on exploring a known, puzzling difference in an otherwise homogenous group. For studies not of this type, QCA's usefulness is likely to be limited to its visualisation techniques which provide a powerful tool for summarising data, and exploring different combinations of variables that might explain features of the data.

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11 APPENDICES

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B497	Addis & Schouten (2004)	Provide good access for deconstruction, especially connections	Accessibility	Access - easy and safe
B506	Addis & Schouten (2004)	Provide adequate tolerances for assesmbly and deconstruction	Accessibility	
A1	Cowee & Schwer (2009)	Embedded elements free space for easier modifications	Accessibility	
74	CSA (2007)	Accessabilty of components	Accessibility	Exposed componentry most adaptble
A177	Dowie & Simon (1994)	Locate parts with the highest value in easily accessible places.	Accessibility	
A178	Dowie & Simon (1994)	Fastening points should be easy to access	Accessibility	
B341	Edmonds & Gorgolewski (2000)	Seoarate services into cleary accessible locations	Accessibility	to allow easy change and upgrade
B347	Edmonds & Gorgolewski (2000)	Provide sufficient spacing for machinery needed for dismantaling, renovation and addition	Accessibility	
B350	Edmonds & Gorgolewski (2000)	Incorperate each component so it can easily be removed and recycled when obsolete	Accessibility	
B360	Edmonds & Gorgolewski (2000)	Additional knock out panels (to risers) to reduce cable bottelnecks	Accessibility	
B377	Edmonds & Gorgolewski (2000)	Leave beams and columns as accessible as possible	Accessibility	to allow plates to be welded to them to strenghten
A180	Geraedts (2006)	Make construction and installation components readily accessible	Accessibility	
B455	Geraedts (2008)	Accessibility of components	Accessibility	Ditribution networks, zoning
A170	Gorgolewski (2005)	Separate Services into clearly accessible locations (not connected to other layers, easily changed)	Accessibility	
A188	Gorgolewski (2005)	Provide sufficient space for machinery needed for renovation, addition and dismantling	Accessibility	
A309	Groak (1992)	Consider production and assembly tolerances	Accessibility	
A175	Islen and Lamer (1993)	Provide Accessible Service Areas	Accessibility	
A183	Rabeneck (1973)	Services should be easily accessibele	Accessibility	
A182	Rogers (2011)	Place the services on the outside of a building where they are most accessible.	Accessibility	
A169	Russell (2001)	Provide means of access to exterior wall system - inside and outside – e.g. change materiality, transparency	Accessibility	
A181	Schneider & Till (2007)	Services - Need to be accessible, maintainable and exchangeable.	Accessibility	
B81	Schneider and Till (2005a)	Place specialist elements such as services in easily accessible zones	Accessibility	
A172	SDG Nottingham	service installations are easily accessible, preferably on outer or spine walls	Accessibility	
A173	Slaughter (2001)	Improve physical access	Accessibility	
A179	Slaughter (2001)	Enhance system access proximity	Accessibility	
A176	Sundin (2005)	ease of access	Accessibility	
A171	York City (2006)	easily accessible and changeable utilities	Accessibility	
A174	CSA (2007)	Make components of a shorter-life span easily approched and with minimum damage on it and adjacent materials	Accessibility	
46	Arge (2005)	Flat, soundproofed ceilings	Acoustics	
B298	Gann & Barlow (1996)	Acoustic separation	Acoustics	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B442	Remoy & van der Voordt (2014)	thin, light floors	Acoustics	Bad acoustics require floating floors for resi
B145	Wilkinson, James and Reed (2009)	Acoustic separation	Acoustics	
B283	Ball (1999)	External image	Aesthetics	
B201	Bijdendijk (2005)	Preciousness	Aesthetics	(aesthics / 'loveability')
B72	Bullen and Love (2010)	aesthetic appeal	Aesthetics	+
A299	Gregory (2011)	Design a building people like to use and see.	Aesthetics	
B382	Habraken (2008)	Architecture loved by its inhabitants - "loveability"	Aesthetics	
A250	Hill (2006)	An aesthetic of an 'ongoing process'	Aesthetics	
A251	Hill (2006)	Create an aesthetic of ongoing process	Aesthetics	
A291	Hill (2006)	Create seamful experiences, based around behavior not aesthetics; (often includes modular design)	Aesthetics	
9	Kincaid (2002)	Building character – strength of character of the interior and exterior facades	Aesthetics	
B26	Morris et al. (2011)	Character (pre-1945 buildings)	Aesthetics	Makes them desirable to buyers post conversion
B446	Remoy & van der Voordt (2014)	Building appearance	Aesthetics	Should fit with new use
B9	Remoy & Wilkinson (2011)	Percieved as having architectural character that should be preserved	Aesthetics	+
~~7~~	Wilkinson & Reed (2011)	Aesthetics	Aesthetics	Pleasing = adapt rate up
B130	Remoy & van der Voordt (2011)	No 'office building' look	Aesthetics	
B450	Remoy & van der Voordt (2014)	Non use specific facade	Aesthetics	i.e. offices that don't scream workplace
B499	Addis & Schouten (2004)	Avoid hazards	Avoid hazardous materials	Toxic materials, weight, suitable size
B513	Addis & Schouten (2004)	Use alternatives to toxic and hazardous materials	Avoid hazardous materials	
B436	Remoy & van der Voordt (2014)	No asbestos	Avoid hazardous materials	
B487	Webster & Costello (2005)	Design using materials that are non-hazardous, non-toxic and durable	Avoid hazardous materials	e.g. asbestos
A260	Brand (1994)	Some areas in the building should be "cooked" (highly finished and flashy) and some areas left "raw" (unfinished but usuable).	Basic finish	
B351	Edmonds & Gorgolewski (2000)	Provide services such as heating, lighting and power from 'backstage'	Basic finish	
B458	Geraedts (2008)	Basic supply only	Basic finish	Generic distribution of supply (e.g. power, gas, oil) prefered to specific provision (hot water, air)
B47	Gosling et al. (2013)	Basic frame	Basic finish	Leaves space for personalised interpretation by the user
B465	Gu, Xue and Nee (2009)	Identify differentiating features (customizable, short-term) and design as add-on modules	Basic finish	
B383	Habraken (2008)	Provision of unfinished space (no fit out)	Basic finish	
A312	Hill (2006)	Think of platforms, not solutions (overbuild infrastructure, under build features)	Basic finish	
A85	Hill (2006)	Undesigned products, or rather not overdesigned; to invite the user in, to encourage evolution	Basic finish	
A257	Islen and Lamer (1993)	Shell space	Basic finish	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B418	Loch (2009)	Visible concrete ceiling etc.	Basic finish	Suitable for industrial uses but also compatible with gentrification
B429	Loch (2009)	Base build only: screed, bare concrete and basic utility connections	Basic finish	
A258	Neufville (#)	shell space (where areas are built but not yet medically equipped),	Basic finish	
A253	Schneider & Till (2007)	Raw Space: not cooked/ suggestive rather than determining	Basic finish	
B86	Schneider and Till (2005a)	Shell and core only (provision of generic space)	Basic finish	
B467	Warouw, Kobayashi & Jung (2010)	Bare finishing surfaces	Basic finish	Greater freedom to customise space by tiling, painting, installing toilet basis and kitchen cabinets
B470	Warouw, Kobayashi & Jung (2010)	Unfitted kitchens and bathrooms	Basic finish	Allows residents to choose and fit
B208	Bijdendijk (2005)	Provide an attractive, tall and broad entrance	Big entrance	
B124	Remoy & van der Voordt (2011)	Spatiality of entrance	Big entrance	
B522	DfES (2007)	Zoned heating	Building service control	To allow part of the building to be open out of hours
B367	Edmonds & Gorgolewski (2000)	Zone heating and vetilating systems	Building service control	
B398	Finch (2009)	Heating and cooling control	Building service control	
B399	Finch (2009)	Control of mechanical ventilation levels	Building service control	
B400	Finch (2009)	Control of artifical lighting	Building service control	
B166	Geraedts (2001)	Local services controls (e.g. lighting, HVAC)	Building service control	
A80	Geraedts (2006)	Provide local and central control facilities	Building service control	
B451	Geraedts (2008)	Zoning of services to smallest unit (module) possible	Building service control	e.g. control of heating by floor or by unit?
B456	Geraedts (2008)	Adjustability of measurement and control facilities	Building service control	
B276	Kronenburg (2007)	Automated / intelligent building systems	Building service control	
105	Leaman, Bordass & Cassels (1998)	Occupant level adjustment	Building service control	Lighting etc. controllable by user
A256	Leaman, Bordass & Cassels (1998)	return/ give control to individuals vs. management system	Building service control	
B115	Saari & Heikkila (2008)	Adjustable ventilation	Building service control	
B70	Bullen and Love (2010)	Physical footprint	Building size	
B71	Bullen and Love (2010)	Size of floor plate	Building size	
B355	Edmonds & Gorgolewski (2000)	Floor sizes and configurations that enable flexbility of internal layout and subdivisions	Building size	500-2500m2
B289	Eley & Worthington (1984)	Size	Building size	
B291	Gann & Barlow (1996)	Size	Building size	1000m2 - 8000m2
B316	Heath (2001)	Size / height / depth of building	Building size	
B118	Remoy & van der Voordt (2011)	GFA	Building size	
B5	Remoy & Wilkinson (2011)	Size	Building size	Smaller preferred (to very large buildings)
B89	Schneider and Till (2005a)	Floorplates	Building size	
12	Wilkinson & Reed (2011)	Gross floor area (GFA)	Building size	Small floor plates undergo less adapt than med/big
B139	Wilkinson, James and Reed (2009)	Size	Building size	Smaller buildings more marketable
B503	Addis & Schouten (2004)	Mechanical in preference to chemical connections	Connection type	
2	Arge (2005)	Plug and play elementts	Connection type	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
19	Cowee & Schwer (2009)	Connection type	Connection type	Simple connections to neighbouring parts
A90	CSA (2007)	use universally recognized connection methods	Connection type	
A91	CSA (2007)	exposed and reversible connections	Connection type	
A92	CSA (2007)	Choose finishes which do not damage the substrate	Connection type	
20	Cuperus & Brouwen (1992)	Component connectivity	Connection type	Loose connections better
A102	Dowie & Simon (1994)	Fasteners should be easy to remove.	Connection type	
B348	Edmonds & Gorgolewski (2000)	Avoid irreversible process	Connection type	bolts and screws not adhesives, welding and cement.
B352	Edmonds & Gorgolewski (2000)	Loosely coupled layers of constructional elements	Connection type	
B372	Edmonds & Gorgolewski (2000)	Provide a fixing system that permits replacement / substitution of external cladding	Connection type	
B178	Eguchi et al. (?)	No wet connections	Connection type	e.g. avoid glulam
B161	Geraedts (2001)	Components should be deconnectable	Connection type	
A86	Geraedts (2006)	Avoid using penetrating connections between support structures and installation systems	Connection type	
B454	Geraedts (2008)	Disconnectability of components	Connection type	Plug-in connections
A105	Gorgolewski (2005)	Wet construction such as in situ concrete or plastering cannot be reused	Connection type	
A87	Gorgolewski (2005)	Avoid irreversible process	Connection type	
A98	Groak (1992)	Consider methods of jointing material to material or component to component, whether repeat or different	Connection type	
B463	Gu, Xue and Nee (2009)	Design the interfaces between platforms and modules for easy attachment and detachment.	Connection type	
17	Guy & Shell (2003)	the connections between individual materials or components	Connection type	
18	Guy & Shell (2003)	the inter-relationships of building elements	Connection type	
A118	Hashemian (2005)	Physical dependencies among various assemblies should be minimized (e.g. by using flexible interfaces and manufacturing adjustments).	Connection type	
B67	Kelly et al. (2011)	Dry connections between cladding and fixing surface	Connection type	Allow recladding
B224	Kendall & Teicher (2000)	Push fit (non-wet) connection systems	Connection type	
B214	Kendall (1999)	Use click together components	Connection type	
B265	Kronenburg (2007)	Avoid glued connections	Connection type	
B268	Kronenburg (2007)	Bolted together	Connection type	
4	Leaman, Bordass & Cassels (1998)	Plug and play elementts	Connection type	
A100	Mouilek (2009)	Favour indirect relation between the subsystems through intermediary connections	Connection type	
A124	Mouilek (2009)	Minimize number of connections and increase their flexibility	Connection type	
A104	Nielsen (2010)	reversible connections	Connection type	
A99	Schneider & Till (2007)	Design for disassmbly (allow changes to be made without damaging the host) reversible connections	Connection type	
A88	Sundin (2005)	Ease of seperation	Connection type	
A6	Utida (1991)	Consider how they interface between themselves	Connection type	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B483	Webster & Costello (2005)	Easily separable materials	Connection type	Mechanical fastners preferable to adhesives. Composite materials should be avoided e.g. connecting a concrete floor to steel with cast in studs. Lime mortar = good (weak joint), modern brick cement mortar = bad (meaning they suggest don't use masonary.
B207	Bijdendijk (2005)	Generous vertical access for people, piping, ducts and cables	Core location	
A46	Cowee & Schwer (2009)	Number of staircases and emergency exits designed for a scenario of maximal future capacity	Core location	
B365	Edmonds & Gorgolewski (2000)	Allow for good vertical circulation by lifts and stairs, and for servic routing	Core location	2% on plan at least
B366	Edmonds & Gorgolewski (2000)	Design access to permit cellularisation	Core location	
B172	Eguchi et al. (?)	Position cores along the peripheray	Core location	
B397	Finch (2009)	Location of lifts, stairs and corridors	Core location	
35	Geraedts & Vrij (2004)	Entrances, lifts and stairs	Core location	
B260	HBN 11	Fire stair location	Core location	
32	Kincaid (2002)	External and core access – single or multiple?	Core location	More cores / access = better
B427	Loch (2009)	Generous vertical access provision that allows for subdivision	Core location	3 vertical shafts for stairs and lifts (triangular plan example)
B39	Morris et al. (2011)	Stair cores at each end	Core location	ensures adequate fire escape distances
24	Multispace (2004)	Vertical circulation, servicing and core design	Core location	Multiple uses in one buildings = mulltiple cores
B154	Pinder et al. (2011)	Multiple cores	Core location	Facilitates sub letting
B448	Remoy & van der Voordt (2014)	Floor plan configuration (mostly location of cores)	Core location	
B4	Remoy & Wilkinson (2011)	Escape cores located at either end of building	Core location	Meets escape distance for resi
34	Remoy & Wilkinson (2012)	Cores and entrances	Core location	More = better
A162	Russell (2001)	Use Central Core for lateral bracing (allows local modifications)	Core location	
A166	Schneider & Till (2007)	Location of core is critical as it often defines the locations of the most permanent elements (e.g. kitchen & bathroom)	Core location	
B82	Schneider and Till (2005a)	Placing of stair and service cores	Core location	All their examples are centrally located
21	Wilkinson & Reed (2011)	vertical services location;	Core location	Central position most likely to be adapted
B104	Gibb et al. (2007)	No. and size of lifts	Core location	Design on the worst case
22	Leaman, Bordass & Cassels (1998)	Minimised use of lifts	Core location	
A30	Multispace (2004)	Size lifts for worst case scenario	Core location	
A47	Multispace (2004)	Provide number of lifts for worst case scenario	Core location	
B122	Remoy & van der Voordt (2011)	Number of elevators / m2	Core location	
B449	Remoy & van der Voordt (2014)	Design lifts for office occupation	Core location	Will be a higher number of people / m2 meaning redundant shafts can be reused for services
A221	Edwards (2005)	Maximise access to daylight and natural ventilation through form	Daylight and view	
A271	Gregory (2011)	Allow sufficient daylight into the building	Daylight and view	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
26	Leaman, Bordass & Cassels (1998)	Good daylight with glare control	Daylight and view	
B419	Loch (2009)	Daylight on all sides	Daylight and view	
25	Remoy & de Jong (2011)	Daylighting	Daylight and view	
B439	Remoy & van der Voordt (2014)	Only daylight from the north	Daylight and view	bad for apartment conversion
B183	Eguchi et al. (?)	Visual connection to outside	Daylight and view	
A288	Genevro (Duffy) (2009)	Space should have good proximity to the outside	Daylight and view	
B324	Heath (2001)	Views	Daylight and view	
B209	Bijdendijk (2005)	Durability of materials	Durable materials	
B108	Brand (1994)	Foundations and structure should be built of solid stuff that is capable of lasting	Durable materials	
28	CSA (2007)	Durability	Durable materials	Long-life components for non-changeable bits
A58	CSA (2007)	Design components to last a long time (durability)	Durable materials	
A302	Edwards (2005)	design for longlife as a wiser investment	Durable materials	
B180	Eguchi et al. (?)	Durability of materials	Durable materials	
A313	Hill (2006)	Emphasize expenditure on long life elements (e.g. structure, skin)	Durable materials	
B59	Kelly et al. (2011)	Durability of materials	Durable materials	
A12	Sundin (2005)	wear resistance	Durable materials	
A7a	Utida (1991)	durability level	Durable materials	
B182	Eguchi et al. (?)	Structural frame quality	Durable materials	
B35	Morris et al. (2011)	Long life structure	Durable materials	Industrial portal frames are not sufficiently durable
B493	Webster & Costello (2005)	Use robust techniques to prevent the structure from decay	Durable materials	e.g. moisture proof wood
B69	Bullen and Love (2010)	Energy efficiency	Energy efficient	
B475	Langston & Shen (2007)	Should not be reliant on high usage of operational energy for occupant comfort	Energy efficient	Low energy bills = more adaptable
38	Leaman, Bordass & Cassels (1998)	High thermal capacity	Energy efficient	
B27	Morris et al. (2011)	Energy efficiency	Energy efficient	Property can be extensive to get to current regs
C1	Geraedts & Vrij (2004)	Entrances, lifts and stairs	Openings	
B156	Pinder et al. (2011)	Multiple entrance lobbies	Openings	Facilitates sub letting
31	Remoy & de Jong (2011)	Position of entrances / cores	Openings	
B3	Remoy & Wilkinson (2011)	Centrally located entrance	Openings	Ideal for conversion to resi
C6	Remoy & Wilkinson (2012)	Cores and entrances	Openings	More = better
30	Schneider & Till (2007)	Mutliple access points	Openings	
~~123~~	Cowee & Schwer (2009)	Certain devices or connections for future services are installed but not yet activated	Extra connections	
A42	Cowee & Schwer (2009)	Provide additional devices or connections for future services (installed, but not activated)	Extra connections	
B243	HBN 11	Suitable local connection and access points for later connections	Extra connections	
B406	Issac & Saneghpour (2012)	Add buffers - extra components	Extra connections	e.g. connection points, extra waste pipes
B223	Kendall & Teicher (2000)	Use pre-terminating cabling	Extra connections	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
138	Cowee & Schwer (2009)	Potential for additonal surface	Extra space	surface which can be gained : the existing surface AND amount of surface which can be gained without needing additional infrastructure
B363	Edmonds & Gorgolewski (2000)	Allow for future changes in service distribution, outlets and duct sizes	Extra space	
A216	Hanitchak (2005)	Provide soft space – space that is lower intensity use that can be relocated in the future to provide additional high-intensity uses	Extra space	
B261	Kronenburg (2007)	Flat, useable roof	Extra space	
B273	Kronenburg (2007)	Buffer zones between well defined functional spaces	Extra space	Allow overspill and expansion
128	Leaman, Bordass & Cassels (1998)	Surplus space for additional plant	Extra space	
B412	Loch (2009)	Interpretable and subdivideable loft space	Extra space	
A261	Lynch (1958)	Growth forms (low-intensity buffer zones; blurred spaces)	Extra space	
A232	Rabeneck (1973)	A 'spare' room should be provided if possible,	Extra space	
134	Schneider & Till (2007)	Roof type	Extra space	Flat allows storeys to be added more easily
A252	Schneider & Till (2007)	Provide slack space which can be appropriated by the users over time (flat roofs, courtyards, large communal space, an alcove)	Extra space	
B77	Schneider and Till (2005a)	Avoid trussed rafter roof forms	Extra space	
B468	Warouw, Kobayashi & Jung (2010)	Provide attic space	Extra space	Stairs can be added and the space boarded to create additional space
A45	York City (2006)	insulate, ventilate, and damp proof basements (for future expansion)	Extra space	
A276	Ash (2011)	Open up facades/ project success and busy-ness (show activity)	Fenestration	
B304	Gann & Barlow (1996)	Floor to ceiling / tall windows	Fenestration	
B105	Gibb et al. (2007)	Glazing proportion	Fenestration	Max on ground floor, 40-60% upper floor
A286	Gregory (2011)	Up to 33% of total depth (which can increase the possible plan depth)	Fenestration	
A51	Multispace (2004)	Solid to Transparent ratio (amount of glazing) - maximize on ground floor (within fire, noise and cost constraints); 40 – 100% upper floors	Fenestration	
A244	Rabeneck (1973)	Doors & windows should be placed as far as possible to allow a variety of uses	Fenestration	
A245	Rabeneck (1973)	Avoid expression of room functions in external walling (e.g. extreme variations in window sizes, balconies to living rooms only).	Fenestration	
39	Wong (2010)	Fenestration	Fenestration	Designed to allow walls to subdivide
40	Arge (2005)	Fire sprinkling	Fire	allowing for large continuous space units
43	Cowee & Schwer (2009)	Escape routes are designed for a multi-scenario use	Fire	
44	Cowee & Schwer (2009)	Fire compartments have the same fire-resistance rating as the structural elements	Fire	
A234	Cowee & Schwer (2009)	May influence fire design - number of staircases/ emergency exists	Fire	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A28	Cowee & Schwer (2009)	Standardize fire ratings (fire components have same resistance as structural elements)	Fire	
127	Cowee & Schwer (2009)	Number of staircases and emergency exits calculated for maximal future capacity	Fire	
B299	Gann & Barlow (1996)	Fire safety - means of escape	Fire	
45	Geraedts & Vrij (2004)	Fire safety design	Fire	
B102	Gibb et al. (2007)	Design occupancy for fire	Fire	1 person/5sqm (GF), 1 person/6sqm (UF)
B103	Gibb et al. (2007)	Travel distance for fire	Fire	30m two way or 12m one way
A296	Gregory (2011)	Stairs spaced 30m apart where there is a choice of routes and 18m in one direction will cater for most uses	Fire	
B41	Morris et al. (2011)	Over three storeys to include 2+ escape routes	Fire	To compy with resi fire distances
B42	Morris et al. (2011)	Space to provide an external fire escape	Fire	To compy with resi fire distances
B43	Morris et al. (2011)	Over 30m length to have sprinklers installed	Fire	To compy with resi fire rules, easier space planning with no need for lobbies.
41	Multispace (2004)	Fire safety design	Fire	30m travel distance
A235	Multispace (2004)	Design occupancy for fire: (ground floor) 1 person per 5sqm; (upper floors) 1 person per 6sqm	Fire	
A297	Multispace (2004)	Travel Distances for fire: 30m two way (12 m one way)	Fire	
42	Remoy & de Jong (2011)	Regulation - fire and air quality	Fire	Housing specifications normally more onerous
B205	Bijdendijk (2005)	Proportionaly high load bearing capacity	Floor loading	
A17	Brand (1994)	Overbuild structure	Floor loading	
48	Cowee & Schwer (2009)	Loading	Floor loading	Some give for future loading
A18	Cowee & Schwer (2009)	Structural elements are calculated for the highest possible structural load, fire load, and future number of floors related to possible uses	Floor loading	
A20	Cowee & Schwer (2009)	Provide structural redundancy	Floor loading	
A16	CSA (2007)	Provide structural redundancy	Floor loading	
B189	Davison et al. (2006)	Structural redundancy	Floor loading	Allow for the addition of an extra floor
B339	Edmonds & Gorgolewski (2000)	Over designed structural capacity	Floor loading	to allow alternative uses and the option of extending the structure
B356	Edmonds & Gorgolewski (2000)	Floor loading to permit a range of uses	Floor loading	4 kN/m2
B369	Edmonds & Gorgolewski (2000)	Provide modest oevr design of columns and foundations, particulary at the building perimeter	Floor loading	
B374	Edmonds & Gorgolewski (2000)	Strenghtening the structure for local (point) additional loads	Floor loading	
B378	Edmonds & Gorgolewski (2000)	Over design connections to allow future strenghening through bolting	Floor loading	
B169	Geraedts (2001)	Over design structural loadings	Floor loading	
A19	Gorgolewski (2005)	Design foundations to allow some additional capacity	Floor loading	
49	Graham (2005)	Structural loading	Floor loading	strong enough to accommodate different uses
A29	Islen and Lamer (1993)	structural and utilities capacity that do not inhibit future expansion	Floor loading	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B407	Issac & Saneghpour (2012)	Add buffers - extra capacity	Floor loading	e.g. overdesign structural loading, larger service cores
47	Kincaid (2002)	Strength – What structural strength does the building use require?	Floor loading	
51	Larssen & Bjorberg (?)	Slab load capacity	Floor loading	Higher = more variety of uses
137	Larssen & Bjorberg (?)	Capacity to add extra floors	Floor loading	
~~85~~	Lifetime homes	Ceilings able to accommodate hoists (ceiling strenght)	Floor loading	
B422	Loch (2009)	Oversizing the load bearing structure	Floor loading	
B424	Loch (2009)	High loads of 5-10kN/m2	Floor loading	
A37	Martin (1999)	provision for higher floor loadings will allow the positioning of storage spaces, corridors, and plant and computer rooms in the future.	Floor loading	
B33	Morris et al. (2011)	Constraints on floor loadings	Floor loading	unsuitable for office space so makes conversion attractive
A32	Mouilek (2009)	overdesign the foundation to permit the addition of new loads	Floor loading	
A36	Neufville (#)	structural foundations of a building to allow additional floors	Floor loading	
126	Nutt (1988)	Oversizing	Floor loading	Of structure, services and space
B441	Remoy & van der Voordt (2014)	Design to office specification loads	Floor loading	Can accommodate extra floors when converting to resi
A21	Russell (2001)	Design the founcation for potential vertical expansion.	Floor loading	
A22	Russell (2001)	Design the lower 3 floors for 4.8 kPa live load.	Floor loading	
50	Saari & Heikkila (2008)	permissible floor loads	Floor loading	
B112	Saari & Heikkila (2008)	Permissible floor loads	Floor loading	
A31	Schneider & Till (2007)	Design for overcapacity (e.g. foundations)	Floor loading	
121	Slaughter (2001)	Over design of structure, services etc.	Floor loading	
B199	van Zwol (2005)	Overdesigned structure	Floor loading	loading above office specification norms
A23	York City (2006)	high structural standards facilitating a long and useful life	Floor loading	
154	Arge (2005)	Floor to floor height	Floor to ceiling height	allowing for different work place designs or solutions
B202	Bijdendijk (2005)	Proportionally generous floor to floor height	Floor to ceiling height	GF "communicating with the street" = 4.5m-5.0, UF 3.3.- 3.6m; Leaves room for raised floors / suspended ceilings
B184	Davison et al. (2006)	Storey height	Floor to ceiling height	3.3 to 3.5m for a plan depth of 13.5 to 18m
B194	Davison et al. (2006)	Post tensioned slabs	Floor to ceiling height	Thinner, no downstands
B344	Edmonds & Gorgolewski (2000)	Increase floor to ceiling heights	Floor to ceiling height	e.g. allow for a second storey (mezz); that can accommodate a variety of servicing solutions
B368	Edmonds & Gorgolewski (2000)	Avoid tight floor to floor heights	Floor to ceiling height	
B175	Eguchi et al. (?)	Storey Height	Floor to ceiling height	4.1m
B181	Eguchi et al. (?)	Floor to ceiling height	Floor to ceiling height	4.5m and 3.8m are highlighted as "taller", on average ranged from 2.5m to 2.8m
B286	Eley & Worthington (1984)	Floor to ceiling height	Floor to ceiling height	
B336	Ellison and Sayce (2007)	Floor to ceiling height	Floor to ceiling height	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B396	Finch (2009)	Floor to ceiling height	Floor to ceiling height	
B301	Gann & Barlow (1996)	Floor to ceiling height	Floor to ceiling height	Sufficient to add a suspended ceiling, "high ceilings"
158	Geraedts & Vrij (2004)	Floor to ceiling hiegth	Floor to ceiling height	
B98	Gibb et al. (2007)	Internal ceiling height	Floor to ceiling height	GF = 3.5m single storey, 5-7m double, 2.7m on upper floors
A197	Gorgolewski (2005)	Higher floor to ceiling heights – office use requires greater ceiling heights than residential	Floor to ceiling height	
155	Graham (2005)	Floor to floor height	Floor to ceiling height	
B61	Kelly et al. (2011)	Floor to floor height	Floor to ceiling height	
B227	Kendall & Teicher (2000)	Mezzanines	Floor to ceiling height	Can be extended or removed
152	Kincaid (2002)	Slab to slab height (sets "lower limits of acceptability")	Floor to ceiling height	
B20	Lansley et al. (2005)	Changes in floor level within the same floor	Floor to ceiling height	-
157	Larssen & Bjorberg (?)	Floor to ceiling hiegth	Floor to ceiling height	
159	Leaman, Bordass & Cassels (1998)	Floor - ceiling height	Floor to ceiling height	Double height to allow for mezzanines
B426	Loch (2009)	Floor to floor clearance	Floor to ceiling height	over 3.6m
B32	Morris et al. (2011)	Slab to slab floor heights	Floor to ceiling height	Approx 3m (unsuitable for office space so makes conversion attractive)
153	Multispace (2004)	Storey Height	Floor to ceiling height	3.3 - 3.5m
A193	Multispace (2004)	internal ceiling heights	Floor to ceiling height	(ground floor) single 3.5m double height 5 to 7m; (upper floors) 2.7m
A194	Multispace (2004)	Space for ceiling zone (0 – 500mm) and floor zone (100 to 350 mm)	Floor to ceiling height	
B134	Remoy & van der Voordt (2011)	Free ceiling height	Floor to ceiling height	>2.6m
B438	Remoy & van der Voordt (2014)	Low ceilings	Floor to ceiling height	Min 3m floor to floor height; bad for apartment conversion (high-end house buyers like lofty ceilings); also "allowance should be made for addition of floating floors and suspended ceilings"
B445	Remoy & van der Voordt (2014)	Avoid downstand beams	Floor to ceiling height	Reduce available floor to ceiling height
A195	Russell (2001)	Provide more than the minimum floor heights	Floor to ceiling height	
A196	Russell (2001)	Add sufficient height to the lower floor to enable a range of uses	Floor to ceiling height	
156	Saari & Heikkila (2008)	Floor height	Floor to ceiling height	
B110	Saari & Heikkila (2008)	Floor height	Floor to ceiling height	
B79	Schneider and Till (2005a)	Relatively generous space provision (vertically)	Floor to ceiling height	
B90	Schneider and Till (2005a)	Storey Height	Floor to ceiling height	
A198	Song (2008)	Provide generosity in space in height	Floor to ceiling height	
B279	URBED (1987)	Ceiling height	Floor to ceiling height	
B150	Wilkinson, James and Reed (2009)	Floor to ceiling height	Floor to ceiling height	
B203	Bijdendijk (2005)	Columns as supporting structure	Framed	"proportionally few fixed vertical components"
53	Cowee & Schwer (2009)	Structure	Framed	Steel or steel / concrete mix
A48	Cowee & Schwer (2009)	Use steel or concrete and steel for structure	Framed	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B379	Edmonds & Gorgolewski (2000)	Use a steel frame	Framed	Long span capabilities, shallow beams for higher floor to floor etc.
B387	Finch (2009)	Structural steel frames	Framed	
B305	Gann & Barlow (1996)	Steel framed buildings	Framed	Because services can be run close to beams; if concrete beam and slab prefered to flat slab
B250	HBN 11	Framed construction	Framed	
B215	Kendall & Teicher (2000)	Open frame structure	Framed	
B229	Kendall & Teicher (2000)	Concrete framed	Framed	
B263	Kronenburg (2007)	Concrete structure frame	Framed	
B30	Morris et al. (2011)	Framed structure (preferred to load bearing masonary)	Framed	oppourtunity to strip back and reclad
B2	Remoy & Wilkinson (2011)	Structural frame (beams and columns)	Framed	ensures a high level of flexibility, support vertical extension
B11	Remoy & Wilkinson (2011)	Concrete framed	Framed	+
A49	Russell (2001)	Give preference to use of reinforced concrete, since it enables the shifting of internal and external elements without affecting the building's structural integrity	Framed	
B302	Gann & Barlow (1996)	Toilets on each floor	Generous facilities provision	
B123	Remoy & van der Voordt (2011)	Sanitary and pantry facilities /m2	Generous facilities provision	
B505	Addis & Schouten (2004)	Design components sized to suit appropriate means of handling	Handling	
A10	CSA (2007)	Design to a human-scale (consider size and weight of the component, maximizes handability, manageability)	Handling	
A184	Dowie & Simon (1994)	Design parts for stability during disassembly.	Handling	
A11	Nielsen (2010)	modularity and small, lightweight elements,	Handling	
A62	Nielsen (2010)	The smaller and less complicated elements, the better potential for reuse	Handling	
A13	Sundin (2005)	Ease of handling	Handling	
B491	Webster & Costello (2005)	Consider handling and safety	Handling	Provide space for dismantling, lifting points and safety tie offs
B74	Bullen and Love (2010)	Low rise buildings	Height	Uneconomical plot ratio leads to demolition
B292	Gann & Barlow (1996)	Height	Height	
B317	Heath (2001)	Size / <u>height</u> / depth of building	Height	
B14	Lansley et al. (2005)	Accomodation on one level	Height	
B117	Remoy & van der Voordt (2011)	Number of storeys	Height	
13	Remoy & Wilkinson (2012)	Building height	Height	Not "tall"
11	Wilkinson & Reed (2011)	Height (number of storeys)	Height	
B142	Wilkinson, James and Reed (2009)	Height	Height	
B193	Davison et al. (2006)	Ceiling void allowance	Horizontal service space	1.5m was too much, redundant space
B342	Edmonds & Gorgolewski (2000)	Raised floors	Horizontal service space	Permit easy upgrade of services
B371	Edmonds & Gorgolewski (2000)	Increase beam depth where larger opening may be requirred	Horizontal service space	
B392	Finch (2009)	Use of intersistal floors	Horizontal service space	
B393	Finch (2009)	Service corridors	Horizontal service space	e.g. as at SD2

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B164	Geraedts (2001)	Raised access flooring, suspending ceilings, skirting or trunking used to duct systems	Horizontal service space	Improve access to services
A52	Geraedts (2006)	Restrict distribution facilities and ducts	Horizontal service space	
B99	Gibb et al. (2007)	Ceiling zone	Horizontal service space	0-500mm
B100	Gibb et al. (2007)	Floor zone	Horizontal service space	100-350mm
B51	Gosling et al. (2013)	Accessible floor and ceiling systems in standard sizes and interchangeable	Horizontal service space	refers to having carpet and ceiling tiles?
B54	Gosling et al. (2013)	Raised floors and suspended ceilings	Horizontal service space	
B242	HBN 11	Provide adequate infrastructure capacity, plantroom and containment space to upgrade engineering services at a later date	Horizontal service space	
B251	HBN 11	Install suitable surface fixed trunking to allow service outlets to be added / altered	Horizontal service space	
A231	Islen and Lamer (1993)	interstitial space (gap between spaces)	Horizontal service space	
B63	Kelly et al. (2011)	Drop ceilings	Horizontal service space	
B64	Kelly et al. (2011)	Raised floors	Horizontal service space	
B217	Kendall & Teicher (2000)	Access floor or service zones	Horizontal service space	
B222	Kendall & Teicher (2000)	Raised access flooring	Horizontal service space	
B210	Kendall (1999)	Wire management access floors	Horizontal service space	
B157	Pinder et al. (2011)	Raised access flooring	Horizontal service space	
A101	Schneider & Till (2007)	Services - surface mount everything concentrate along structural routes (with raised floors/ dropped ceilings)	Horizontal service space	
B88	Schneider and Till (2005a)	Raised floors and / or dropped ceilings	Horizontal service space	Allow permutation in service outlets
A161	Slaughter (2001)	Dedicate specific area/ volume for system zone	Horizontal service space	
B311	Gann & Barlow (1996)	External noise	Hostile factors	
65	Geraedts & Vrij (2004)	Land contamination	Hostile factors	
66	Geraedts & Vrij (2004)	Air pollution / odours / noise	Hostile factors	
B323	Heath (2001)	Bad neighbour uses / noise	Hostile factors	
64	Kincaid (2002)	Hostile factors	Hostile factors	“is the location hostile ... by reason of excessive noise, smell, hazard, or mess?”
B127	Remoy & van der Voordt (2011)	Low noise, smells, pollution (Environmental health)	Hostile factors	
B432	Remoy & van der Voordt (2014)	Location does not have hazardous activities	Hostile factors	Noise and / or pollution
B149	Wilkinson, James and Reed (2009)	Noise	Hostile factors	
B500	Addis & Schouten (2004)	Provide guidance for deconstruction	Information	
B370	Edmonds & Gorgolewski (2000)	Provide information on the size and number of openings that may be formed in beeam webs	Information	
B220	Kendall & Teicher (2000)	Utilizing information management tools	Information	to show occupants how to change
A190	Mouilek (2009)	Each layer that corresponds to a function needs to be clearly detailed by a listing of its components	Information	
A191	Nielsen (2010)	as-built drawings, photographs of hidden components and connections,	Information	
A192	Nielsen (2010)	advises for operation and maintenance which includes descriptions of materials and instructions for disassembly.	Information	
79	Remoy & de Jong (2011)	Documentation	Information	Availability of (more = better)

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B440	Remoy & van der Voordt (2014)	Drawings / specs did not represent as built	Information	bad for apartment conversion
B96	Schneider and Till (2005a)	Pass on instructions as to how to adapt to occupier	Information	
B471	Warouw, Kobayashi & Jung (2010)	Prepare some type of 'do-it-yourself' (DIY) guideline for self assembly and self finishing	Information	
B492	Webster & Costello (2005)	Safeguard original drawings	Information	Provide a dedicated storage place within the building for construction drawings and the deconstruction plan
B496	Addis & Schouten (2004)	Provide indentification of materials and components	Information	
B486	Webster & Costello (2005)	Label materials	Information	date, material grade, material strenght, any special handling instructions
~~A126~~	~~Brand (1994)~~	~~Design the building as a set of shearing layers based on estimated lifespans~~	~~Layered~~	
~~A106~~	~~Hill (2006)~~	~~Build with an architecture of layers - enable fast layers to change rapidly (learning); slower layers enable stability~~	~~Layered~~	
A109	Kincaid (2002)	Minimum of two layers (long and short life)	Layered	
A130	Nielsen (2010)	component to be hierarchically organized to ensure the layering structure	Layered	
A131	Nielsen (2010)	mutual independency between elements, building layers	Layered	
A103	Utida (1991)	Components with a long life span are not damaged when compoents with a short life span are removed	Layered	
A97	Utida (1991)	At the interface the component group installed later than other groups should provide the final finish to the joining portion. The component group installed first should not cross over these boundary lines.	Layered	
B16	Lansley et al. (2005)	Rooms separately approached (entrance space, not through rooms)	Layout	+
B92	Schneider and Till (2005a)	Rooms accessed from a central hallway	Layout	Rooms not function specific - "indeterminate"
B12	Barlow et al. (?)	Different strings off interconnecting consulting and examination roomss	Layout	Allow departments to flex
B390	Finch (2009)	Space that serves mutliple functions	Layout	e.g. central learning hub surround by classrooms
B200	Habraken (2005)	Common / public central space	Layout	e.g. atria, <u>dominant space with smaller spaces coming off it</u>
B257	HBN 11	Encourage simple layouts around a central corridor	Layout	
B66	Kelly et al. (2011)	Layout that can be split easily	Layout	e.g. central hub with pods coming off it
B187	Davison et al. (2006)	Open plan	Layout	
B287	Eley & Worthington (1984)	Large uninterrupted spaces	Layout	
B391	Finch (2009)	Malleable (open plan) space	Layout	
B395	Finch (2009)	Possibility of cellular or open plan space	Layout	
B48	Gosling et al. (2013)	Open plan	Layout	more permutations of internal layouts possible
172	Guy & Shell (2003)	Open floor plan	Layout	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B385	Habraken (2008)	Large open floor spaces	Layout	Pre-stressed floor slabs are a suggest means
B386	Habraken (2008)	Human size dimensions (in terms of open, non loadbearing element constrained space)	Layout	can stimulate user decisions
B473	Langston & Shen (2007)	Building layouts flexbile for change e.g open plan	Layout	
B409	Loch (2009)	Open floor plans / spatial openess	Layout	
B84	Schneider and Till (2005a)	Open plan	Layout	Not sufficient on its own - need good access and service strategies
B469	Warouw, Kobayashi & Jung (2010)	Open plan with few internal walls	Layout	Allow residents to place walls themselves
77	Guy & Shell (2003)	the ability to “read” the building	Legible components	
B269	Kronenburg (2007)	Colour coded access and service elements	Legible components	People meant to understand from its appearance
B478	Webster & Costello (2005)	Building systems that are visible and easy to identify (transparency)	Legible components	
B502	Addis & Schouten (2004)	Minimise the number of different types of components	Less components	
B512	Addis & Schouten (2004)	Minimise the number of different types of material	Less components	
146	Cowee & Schwer (2009)	A harmonised initial design (passive intelligent architecture design)	Less components	reduces the needs of mechanical engineering making changes easier.
A220	Cowee & Schwer (2009)	Use passive design techniques (reduce need for mechanical)	Less components	
A2	CSA (2007)	Design simply reduces the number of elements	Less components	
A4	Dowie & Simon (1994)	Minimise the number of parts, types of materials and fastners e.g. consideration of component attributes	Less components	
145	Guy & Shell (2003)	No. components	Less components	Limited, but small enough to be practical and handleable
A3	Schneider & Till (2007)	The more successful projects employ only a small number of elements	Less components	
B482	Webster & Costello (2005)	Limited number of components	Less components	Smaller number of larger members can be removed more quicly and with less damage
B489	Webster & Costello (2005)	Avoid using multiple types of structural system	Less components	
B75	Bullen and Love (2010)	Heritage listing	Listed	Prevents demolition
83	Geraedts & Vrij (2004)	Listed building	Listed	Conversion more difficult
B29	Morris et al. (2011)	Listed building	Listed	Can constrain oppourtunties
B23	Pidwill & Hunter (2009)	Listed building	Listed	Prevents demolition and forces adaptation
B125	Remoy & van der Voordt (2011)	Historic listing	Listed	
B433	Remoy & van der Voordt (2014)	Cultural value or listed status	Listed	They highlight this as both a reason for retention and preventing change of facade
82	Remoy & Wilkinson (2012)	Heritage listing	Listed	Barrier to conversion
81	Wilkinson & Reed (2011)	historic listing	Listed	heritage listing = more adaptations than average (they don't give demo rate though)
B138	Wilkinson, James and Reed (2009)	Percieved heritage value	Listed	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B332	Ellison and Sayce (2007)	Located in areas with local workforce	Location	
B334	Ellison and Sayce (2007)	With a variety of transport options in close proximity	Location	
B315	Gann & Barlow (1996)	Location	Location	
93	Geraedts & Vrij (2004)	Bad reputation / unsafe neighbourhood	Location	
94	Geraedts & Vrij (2004)	Nearby amenities	Location	Locally available = adapt increased
167	Geraedts & Vrij (2004)	Nearby public transport	Location	Locally available = adapt increased
168	Geraedts & Vrij (2004)	Road access	Location	
176	Geraedts & Vrij (2004)	Zoning plan (land use)	Location	
B68	Kelly et al. (2011)	Mono-use location	Location	anti - conversion
86	Kincaid (2002)	Street characteristics – degree of integration with streets and urban features	Location	
87	Kincaid (2002)	Amenity assessment – good retail/leisure to derelict area	Location	
165	Kincaid (2002)	Public transport – access to	Location	More = better
166	Kincaid (2002)	Private transport	Location	More = better
B472	Langston & Shen (2007)	Location of a building relative to a city centre or CBD	Location	Reduced if a building is in a relatively low populated area
92	Larssen & Bjorberg (?)	Site location	Location	
174	Lynch (1958)	Local zoning	Location	Coarse grain normally most adaptable?
B24	Morris et al. (2011)	Within established centres	Location	
B28	Morris et al. (2011)	Within a conservation area	Location	Added expense
90	Remoy & de Jong (2011)	Location	Location	
175	Remoy & de Jong (2011)	Zoning plan (land use)	Location	
B128	Remoy & van der Voordt (2011)	Functional mix and facilities nearby	Location	
B430	Remoy & van der Voordt (2014)	Location	Location	Not a business park ("monofunctional"), although this can change with a long time period (UAL like) or if it is very close to the CBD / amenities
B7	Remoy & Wilkinson (2011)	Centrally located site, near public transport	Location	+
B8	Remoy & Wilkinson (2011)	In mixed use areas	Location	+
~~89~~	Remoy & Wilkinson (2012)	Location	Location	Attractive for desired use
91	Saari & Heikkila (2008)	building´s location in the community structure	Location	
B113	Saari & Heikkila (2008)	Building location	Location	
B277	URBED (1987)	Location	Location	Attractiveness, transport
~~88~~	Wilkinson & Reed (2011)	property location	Location	Prime and low prime locations prefered, ffringe = least likely
B140	Wilkinson, James and Reed (2009)	Accessibility	Location	as in location
B504	Addis & Schouten (2004)	Consider using modular construction	Modular construction	
A66	Dowie & Simon (1994)	Make designs as modular as possible, with separation of functions.	Modular construction	
B394	Finch (2009)	Modular layouts	Modular construction	
B306	Gann & Barlow (1996)	Large panel or in-situ cladding systems	Modular construction	+
B163	Geraedts (2001)	Modular coordinated systems	Modular construction	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A132	Geraedts (2006)	Component Morphology & Coordination (accessibility, spacing, organisation of, dimensional reference system, modular coordination)	Modular construction	
B107	Gibb et al. (2007)	1.5m cladding module on upper floors	Modular construction	
96	Guy & Shell (2003)	Modular construction	Modular construction	
B236	HBN 11	Develop a modular approach to planning and construction	Modular construction	
B253	HBN 11	Modular wiring systems for lighting and power	Modular construction	
B255	HBN 11	Modular approach to planning and construction	Modular construction	
A68	Islen and Lamer (1993)	Use modular components	Modular construction	
B403	Issac & Saneghpour (2012)	Modularisation - standard dimensions and interfaces	Modular construction	
B211	Kendall (1999)	Modular systems	Modular construction	Power and data cabling, ceiling and lighting systems
B266	Kronenburg (2007)	Modular structure	Modular construction	
B275	Kronenburg (2007)	Componentised, modular systems	Modular construction	
A69	Schneider & Till (2007)	Modular wall elements may contribute to flexibility by providing a kit of parts	Modular construction	
A65	Song (2008)	Modularity and regularity of architectural elements	Modular construction	
B56	van Nederveen & Gielingh (2009)	Based on modular systems	Modular construction	+
B494	Webster & Costello (2005)	Use modular / panelised systems	Modular construction	precast concrete decks, panelised roof systems
B519	DfES (2007)	Mobile furniture	Moveable furniture	To allow quick classroom set up
B527	DfES (2007)	Avoid fixed benching	Moveable furniture	Use tables instead
B529	DfES (2007)	Rectangle shape rooms	Moveable furniture	Allow flexbility of furniture layouts
B176	Eguchi et al. (?)	Moveable and adjustable furniture	Moveable furniture	
3	Fernandez (2003)	Furntiure type	Moveable furniture	Adjustable, user moveable stuff preferred.
B171	Geraedts (2001)	Free standing furniture	Moveable furniture	e.g. a table over a fixed kitchen unit.
A114	Geraedts (2006)	Make removable user facilities	Moveable furniture	
B53	Gosling et al. (2013)	Modular furniture	Moveable furniture	
B247	HBN 11	Mobile, rather than fixed, equipment and furniture	Moveable furniture	
B65	Kelly et al. (2011)	Unfixed furniture	Moveable furniture	Reconfigure rooms
B271	Kronenburg (2007)	Moveable (retractable seating)	Moveable furniture	
B413	Loch (2009)	Mobile fittings	Moveable furniture	
B95	Schneider and Till (2005a)	Use of sliding or folding components	Moveable furniture	e.g. folding furniture or sliding walls
B515	DfES (2007)	Sliding / folding partitions	Moveable walls	Can be moved to create two spaces
B49	Gosling et al. (2013)	Demountable office partition systems	Moveable walls	
B245	HBN 11	Acoustically treated folding partition walls	Moveable walls	
B404	Issac & Saneghpour (2012)	Allowing components to be easily moved	Moveable walls	e.g. sliding facade shutters, reconfiguarable sliding walls
B62	Kelly et al. (2011)	Moveable partitions	Moveable walls	
B410	Loch (2009)	Sliding walls / moveable screens	Moveable walls	
B114	Saari & Heikkila (2008)	Moveable partitions	Moveable walls	
B94	Schneider and Till (2005a)	Use of sliding or folding components	Moveable walls	e.g. folding furniture or sliding walls

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B45	Stringer, Dunne & Boussabaine (2012)	Foldable partition walls	Moveable walls	Separate a suite of classrooms, can open to teaach larger groups / exams
B516	DfES (2007)	Multifunctional furniture	Multi function furniture	Can perform a number of functions
B414	Loch (2009)	Multifunctional furniture	Multi function furniture	
A82	Schneider & Till (2007)	Built-in furniture which can fold/ 'hide away'	Multi function furniture	
B354	Edmonds & Gorgolewski (2000)	Facility to accomdate a variety of natural / mechancial ventilation systems	Naturally ventilated	
B474	Langston & Shen (2007)	Little reliance on mechanical systems for occupant comfort	Naturally ventilated	e.g. narrow floor plan with high ceilings, significant ventilation openings, covered balconies all around
B262	Kronenburg (2007)	Interlocking living areas	Spacious	
A295	Rabeneck (1973)	no "circulation" space; each room is an antechamber to another	Spacious	
A265	Schneider & Till (2007)	Permeable Circulation: 'a matrix of connected rooms' - dissolves hierarchy and catagorisation of rooms	Spacious	
143	Cowee & Schwer (2009)	Facade independent from adjacent elements	Non load bearing facade	
A113	Cowee & Schwer (2009)	Facade elements independent from adjacent elements	Non load bearing facade	
B340	Edmonds & Gorgolewski (2000)	Separate structure and cladding	Non load bearing facade	to allow independent alteration and replacement, e.g. walls that can accept windows later
67	Guy & Shell (2003)	Skin not sitting on floor slabs	Non load bearing facade	
B226	Kendall & Teicher (2000)	Facade systems distinct from masonary structure	Non load bearing facade	e.g. curtain walling
133	Pinder et al. (2011)	Cladding easily removed	Non load bearing facade	
B131	Remoy & van der Voordt (2011)	Non loadbearing facade	Non load bearing facade	
B1	Remoy & Wilkinson (2011)	Replaceable (non load bearing) facade	Non load bearing facade	non load bearing facilitate facade refresh
A112	Russell (2001)	Make the building envelope independent of the structure	Non load bearing facade	
58	Schneider & Till (2007)	Exterior column location	Non load bearing facade	Suggests slightly stepped in ideal
69	Schneider & Till (2007)	Wall type	Non load bearing facade	Cavity walls are evil
A78	BEAM (2009)	Use of interior partitions that are demountable, resusable, and recycleable, etc.	Non load bearing paritions	
B192	Davison et al. (2006)	Partition walls	non load bearing paritions	
B373	Edmonds & Gorgolewski (2000)	Use demountable internal paritions and shaft walls	non load bearing paritions	
B173	Eguchi et al. (?)	External bracing	non load bearing paritions	Creates an open plan floorplate
B388	Finch (2009)	Elimination of internal structural walls	non load bearing paritions	
B389	Finch (2009)	Relocateable paritions	non load bearing paritions	Convertible space
70	Gosling et al (2011)	Internal partition type	Non load bearing paritions	Stud partition preferred
73	Guy & Shell (2003)	Non-loadbearing walls	Non load bearing paritions	
B17	Lansley et al. (2005)	Internal stud partitions	non load bearing paritions	+
72	Larssen & Bjorberg (?)	Interior walls	Non load bearing paritions	
B421	Loch (2009)	Loadbearing facade	non load bearing paritions	
A84	Rabeneck (1973)	partitions should be relocatable	Non load bearing paritions	
68	Remoy & de Jong (2011)	Facade	Non load bearing paritions	Non-load bearing
B133	Remoy & van der Voordt (2011)	Non-loadbearing walls	non load bearing paritions	
A76	Russell (2001)	(Interior spaces)install interior partitions that are demountable, reusable, and recyclable.	Non load bearing paritions	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
71	Saari & Heikkila (2008)	Flexible partitions	Non load bearing paritions	Moveable one suggested
A158	Schneider & Till (2007)	The continuation of wall and floor finishes past or under partitions should be considered. (e.g. standardise locations)	Non load bearing paritions	
A75	Schneider & Till (2007)	Partition walls should not be loadbearing - not contain electrical or other services.	Non load bearing paritions	
B76	Schneider and Till (2005a)	Reduce load bearing or solid interanl partitions	non load bearing paritions	
B85	Schneider and Till (2005a)	Non loadbearing paritions	non load bearing paritions	
A73	SDG Nottingham	non-structural internal walls	Non load bearing paritions	
B196	van Zwol (2005)	Loadbearing facade	non load bearing paritions	
95	Wong (2010)	Location of shear walls	Non load bearing paritions	
A74	York City (2006)	non-structural or frame internal walls	Non load bearing paritions	
B307	Gann & Barlow (1996)	Openable windows	Openable windows	or ability to put in cheaply
37	Geraedts & Vrij (2004)	Openable windows	Openable windows	Required for residential?
B106	Gibb et al. (2007)	Option for opening casements (windows)	Openable windows	
A81	Martin (1999)	openable windows (natural ventilation, nighttime cooling)	Openable windows	
B155	Pinder et al. (2011)	Openable windows	Openable windows	
B132	Remoy & van der Voordt (2011)	Operable windows	Openable windows	
135	Leaman, Bordass & Cassels (1998)	Oppourtunites to "open up walls and roof for extra capacity"	Openings	get plant in/out, extend etc.
A34b	Morrison (2010)	Create predefined openings in 'party' walls with lintels	Openings	
A262	Rabeneck (1973)	generous openings between spaces	Openings	
106	Schneider & Till (2007)	Overprovision of doors	Openings	
A293	Schneider & Till (2007)	Design access (& services) where extensions might go (circulation pattern is important)	Openings	
A34	Schneider & Till (2007)	Create predefined openings in 'party' walls with lintels	Openings	
B44	Stringer, Dunne & Boussabaine (2012)	dead-end corridors	Openings	future extension facilitation
A274	Edwards (2005)	Maximise access to renewable energy through correct orientation and location	Orientation	
B310	Gann & Barlow (1996)	Orientation	Orientation	
B38	Morris et al. (2011)	Orientation	Orientation	Predominatly north facing apartments not desireable
B146	Wilkinson, James and Reed (2009)	Site orientation	Orientation	
A24	Brand (1994)	Provide excess services capacity	Oversize M&E	
122	Cowee & Schwer (2009)	The dimension of ducts include reserves for future needs.	Oversize M&E	
A25	Cowee & Schwer (2009)	Duct dimensions include reserves for future need	Oversize M&E	
B364	Edmonds & Gorgolewski (2000)	Some over provision in horziontal servicing routing	Oversize M&E	
B168	Geraedts (2001)	Oversize plant capacity	Oversize M&E	
B459	Geraedts (2008)	Overcapacity services	Oversize M&E	
B460	Geraedts (2008)	Distribution oversized	Oversize M&E	
A35	Hanitchak (2005)	over-size service capacity (20%) and branch distribution (30%)	Oversize M&E	
B235	HBN 11	consider future engineering service requirements from the outset	Oversize M&E	
B239	HBN 11	Install sufficient engineering services at the outset to accommodate future uses of the room	Oversize M&E	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B240	HBN 11	Provide adequate infrastructure capacity, plantroom and containment space to upgrade engineering services at a later date	Oversize M&E	
C2	Islen and Lamer (1993)	structural and utilities capacity that do not inhibit future expansion	Oversize M&E	
B57	Kelly et al. (2011)	Over specify mechanical and electrical plant sizing	Oversize M&E	
B216	Kendall & Teicher (2000)	Independent distribution of services to units	Oversize M&E	
125	Larssen & Bjorberg (?)	Electrical supply capacity	Oversize M&E	
27	Leaman, Bordass & Cassels (1998)	Service supply degrees of freedom	Oversize M&E	Ability to switch supply type (with price changes)
C3	Nutt (1988)	Oversizing	Oversize M&E	Of structure, services and space
B116	Saari & Heikkila (2008)	Loose dimensioning of building services and system walls	Oversize M&E	
C8	Slaughter (2001)	Over design of structure, services etc.	Oversize M&E	
B281	URBED (1987)	Adequate sewers	Oversize M&E	
B308	Gann & Barlow (1996)	Separate metering of gas and electricity	Oversize M&E	
B165	Geraedts (2001)	Sub metering	Oversize M&E	
B284	Ball (1999)	Space for parking	Parking	
B333	Ellison and Sayce (2007)	With parking space	Parking	
B312	Gann & Barlow (1996)	Car parking	Parking	
108	Geraedts & Vrij (2004)	Parking space	Parking	
B325	Heath (2001)	Convience of car parking	Parking	
107	Remoy & de Jong (2011)	Space for parking	Parking	
B120	Remoy & van der Voordt (2011)	Parking places	Parking	
B147	Wilkinson, James and Reed (2009)	Car parking	Parking	
B376	Edmonds & Gorgolewski (2000)	Formation of opening in floors and walls for services / stairwells	Penetrable slab	
B293	Gann & Barlow (1996)	Building structure - penetration for services	Penetrable slab	
B18	Lansley et al. (2005)	Timber floors	Penetrable slab	+
54	Larssen & Bjorberg (?)	Floor constructon	Penetrable slab	
A39	Martin (1999)	Allowance for future cut outs in walls or slabs: Flat slabs do not accommodate holes at a later stage without plate bonding	Penetrable slab	
52	Remoy & de Jong (2011)	Avoidance of pre tensioned elements	Penetrable slab	
B136	Remoy & van der Voordt (2011)	No prestressed slab floors	Penetrable slab	Possibility of adding ducts by cutting holes in the floor
B443	Remoy & van der Voordt (2014)	Pre-stressed concretee	Penetrable slab	Limits penetrations, flat slabs prefered.
B151	Wilkinson, James and Reed (2009)	Structure to be penetrable by services	Penetrable slab	
113	Arge (2005)	Building width	Plan depth	allowing for different work place designs or solutions
B188	Davison et al. (2006)	Narrow floors	Plan depth	Allow use of natural ventilation; suitable for everthing but retail (although will scarifice some space efficiency for offices)
B353	Edmonds & Gorgolewski (2000)	Plan depth for daylight and natural ventilation	Plan depth	13.5-18m glass to glass or 9-12m glass to core; 13-17m
B300	Gann & Barlow (1996)	Shallow depth	Plan depth	13.2m

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
114	Geraedts & Vrij (2004)	Plan depth	Plan depth	
B97	Gibb et al. (2007)	Plan depth	Plan depth	
A218	Gregory (2011)	The depth of the room should be no more than 2.5 times the height of the window serving it (1 to 5 open plan w/ windows on both sides)	Plan depth	
A219	Gregory (2011)	Under 15m depth is less likely to require mechanical assistance	Plan depth	
A273	Gregory (2011)	Height of building no more than 3 times the width (preferably 2x)	Plan depth	
A285	Gregory (2011)	e.g. Concentrate 'support' or temporary occupied spaces in the central area which do not need natural day light or ventilation	Plan depth	
B318	Heath (2001)	Size / height / depth of building	Plan depth	
110	Kincaid (2002)	Depth of floor plate	Plan depth	
115	Leaman, Bordass & Cassels (1998)	Sensible plan dept	Plan depth	12- 15m (office), shallow plans
B31	Morris et al. (2011)	Shallow plan width	Plan depth	approx 10-14m for better daylighting opp.
B34	Morris et al. (2011)	Floor space to facade ratio	Plan depth	Restricts positioning of windows to habitable rooms (primarily bad for >=15m deep)
112	Multispace (2004)	Plan depth	Plan depth	13.5 - 21, deeper for retail (15 - 45)
A199	Multispace (2004)	Office design (ground floor) 13.5m to 45m; (upper floors) 15m to 21m	Plan depth	
B447	Remoy & van der Voordt (2014)	Narrow plan / access to daylight	Plan depth	
111	Remoy & Wilkinson (2012)	Plan depth	Plan depth	Shallow prefereable to deep in Europe
B278	URBED (1987)	Depth	Plan depth	
B143	Wilkinson, James and Reed (2009)	Plan depth	Plan depth	
15	Arge (2005)	Building form	Plan shape	allowing for parts of the building to be used by different organisations / groups
A213	Brand (1994)	Shapes that can grow easily (easy to add on to)	Plan shape	
B186	Davison et al. (2006)	Relatively simple floor plate	Plan shape	
B518	DfES (2007)	Ensuring buildings are a shape which allows them to be extended easily	Plan shape	
B329	Ellison and Sayce (2007)	Internal building layout or configuartion	Plan shape	Should not be unduly restrictive
B335	Ellison and Sayce (2007)	Plan layout	Plan shape	
B313	Gann & Barlow (1996)	Floor shape	Plan shape	
A217	Martin (1999)	Geometry should be uniform in plan	Plan shape	
B37	Morris et al. (2011)	Linear blocks	Plan shape	Easier to adapt to suit apartment layouts
173	Pinder et al. (2011)	Building seperates for sub-letting	Plan shape	
A246	Rabeneck (1973)	Plan form should allow many different allocatiosn of functions to rooms,	Plan shape	
B435	Remoy & van der Voordt (2014)	Building shape	Plan shape	
B444	Remoy & van der Voordt (2014)	Linear structures	Plan shape	Easier to convert to apartments
A7	Utida (1991)	standard shapes,	Plan shape	
16	Wong (2010)	Plan shape	Plan shape	Regular preferred
A135	Cowee & Schwer (2009)	Shading elements in line with façade modules (skin)	Planning grid	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A143	Cowee & Schwer (2009)	Power & telecommunication elements are in line with facade modules	Planning grid	
A144	Dekker (1998)	modular and dimensional coordination	Planning grid	
B357	Edmonds & Gorgolewski (2000)	Planning and parition grids to allo wide frontages and vaariable room sizes	Planning grid	0.9m or 1.35m
B380	Edmonds & Gorgolewski (2000)	Standardisationn of routing and dimensioning of services	Planning grid	
B401	Finch (2009)	Flexibility of power, IT, connection points	Planning grid	
B303	Gann & Barlow (1996)	Window spacing	Planning grid	
B159	Geraedts (2001)	Grid based on smallest unit size	Planning grid	
B457	Geraedts (2008)	Location and structure of distribution networks	Planning grid	
A133	Gregory (2011)	Window every 3m on main elevations which would be consistent with likely room widths	Planning grid	
A134	Gregory (2011)	1.5m glazing module (to match partition module)	Planning grid	
A139	Groak (1992)	dimensional coordination of different components and materials – often on the basis of a three-dimensional rectilinear grid and a standard modular dimension	Planning grid	
B231	HBN 01	Use of a planning grid	Planning grid	3.9m (300mm sub grid) and 3.
B238	HBN 11	Standardise position of built-in equipment	Planning grid	
B252	HBN 11	Use of structured wiring for IT	Planning grid	
A93	Hill (2006)	Define vocabularies, or basic patterns of interaction	Planning grid	
B218	Kendall & Teicher (2000)	Using positioning and dimensioning rules	Planning grid	e.g. 10/20cm grid used by SAR
B228	Kendall & Teicher (2000)	Each system given a dedicated zone and rules of deployment	Planning grid	Legibility - know what's where when renovating
A146	Nielsen (2010)	standard dimensioning,	Planning grid	
A145	Rabeneck (1973)	compatibility of modular grids	Planning grid	
A281	Rabeneck (1973)	Avoid central lights & other space constraints	Planning grid	
A142	Schneider & Till (2007)	The more successful projects the dimensions of the building are coordinated throughout.	Planning grid	
A164	Schneider & Till (2007)	Simplicity and Legibility (construction system, predictability of layout)	Planning grid	
B93	Schneider and Till (2005a)	Standard (space/structure) modules	Planning grid	Allows repetition in structural division, they give an example of a 900mm module for resi
62	Slaughter (2001)	Layout	Planning grid	predictable layouts prefered
A160	Slaughter (2001)	Increase layout predictability (standardise the location of things)	Planning grid	
A153	Song (2008)	Evenness of lighting	Planning grid	
A137	Utida (1991)	Dimensional referencing systems (modular coordination)	Planning grid	
A138	Utida (1991)	Consider how the different components relate to the grid lines	Planning grid	
A140	Utida (1991)	Floor and ceiling surfaces should be used as reference planes for vertical dimensions, with a dimension of 240 mm between them.	Planning grid	
A163	Utida (1991)	Establish standard locations even for piping and wiring.	Planning grid	
B198	van Zwol (2005)	Grid / module planned space	Planning grid	1.2m module
B480	Webster & Costello (2005)	Building systems and materials that are laid out in regular, repeating patterns (regularity)	Planning grid	simple, regular layout with similar bay sizes

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A316	BEAM (2009)	design that allows interior fitting-out to use modular and prefabricated components	Prefabrication	
118	CSA (2007)	Prefabrication	Prefabrication	Use of prefab parts where possible
A67	Gorgolewski (2005)	Prefabricated components can be assembled on site and can be disassembled for reuse/ recycling	Prefabrication	
119	Israelsson & Hasson (2009)	Manufacturign	Prefabrication	Prefabricated components prefered
A125	Schneider & Till (2007)	Prefabricated panels inherently contribute to the flexibility since they are not connected to the structure.	Prefabrication	
120	Slaughter (2001)	Prefabrication	Prefabrication	
A63	Slaughter (2001)	use prefabricated components	Prefabrication	
B507	Addis & Schouten (2004)	Design connectors, fixings and components for repeated use	Reusable components	
A57	CSA (2007)	Use recyclable, refurbishible, remanufacturerable and reusable products	Reusable components	
B13	Webb, Kelly & Thompson (1997)	Use building components designed for reuse	Reusable components	allows swopping at low cost
B490	Webster & Costello (2005)	Use salvaged materials	Reusable components	if reused one, can probably be reused again
A156	York City (2006)	make extensive use of reycled and renewable construction materials and techniques	Reusable components	
A107	BEAM (2009)	Reduce the use of embedded infrastructure for power, data, and HVAC systems, etc.	Separation	
A119	BEAM (2009)	seperating long-lived components from short-lived components to reduce the complexity of deconstruction and churning so as to facilitate the collection process for recycling; etc.	Separation	
A110	CSA (2007)	design building systems or layers to stand independantly	Separation	
B517	DfES (2007)	Keep services to the outside walls	Separation	so internal walls can be moved at a later date
A56	Dowie & Simon (1994)	Avoid moulded-in metal inserts or reinforcements in plastic parts.	Separation	
B346	Edmonds & Gorgolewski (2000)	Use independent systems	Separation	Strong inter-dependence reduces the scope for change
B158	Geraedts (2001)	Wiring or ducting in internal walls	Separation	-
A115	Geraedts (2006)	Separate structure from infill elements (well-interfaced)	Separation	
A89	Gorgolewski (2005)	Incorporate each component so that it can easily be removed or recycled	Separation	
A111	Gorgolewski (2005)	Separate structure and cladding to allow independent alteration and replacement.	Separation	
B46	Gosling et al. (2013)	Dividing a building into layers	Separation	so can be adapted without affecting other layers
A116	Gregory (2011)	Separate toilets from structural walls (demountable fit out items)	Separation	o Allow provision and location to vary
141	Guy & Shell (2003)	M&E entanglement	Separation	Services should be easy to remove
B384	Habraken (2008)	Bathrooms and kitchens should be "under user control"	Separation	
A15	Hashemian (2005)	Subsystems should be functionally autonomous and their functions should be meaningful and recurring.	Separation	
B259	HBN 11	Locate electrical trunking on exterior walls	Separation	Avoid internal walls that may be moved

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B402	Issac & Saneghpour (2012)	Separation of building components whose replacement occurs at different intervals	Separation	
B225	Kendall & Teicher (2000)	Integrated pre-fabricated wall panels	Separation	Bad, casts infill into the permanent structure
B212	Kendall (1999)	Piping and wiring should not be buried in concrete slabs	Separation	e.g. raised access floors
B213	Kendall (1999)	Components should be installed in order of durability	Separation	i.e. don't put short life things inside long life ones
A157	Leaman, Bordass & Cassels (1998)	Avoid too much specialized engineering unnecessarily embedded in the backgroun system	Separation	
B417	Loch (2009)	Separte services into the communal space	Separation	
B420	Loch (2009)	Separating load bearing structure from the fit out	Separation	
A123	Mouilek (2009)	Separate the four functions of a building (load bearing, enclosing, servcing, and partitioning)	Separation	
A129	Rabeneck (1973)	Service systems should be disintegrated from the basic building fabric	Separation	
A83	Rabeneck (1973)	No equipment, storage or furniture should be built into the fabric of the building	Separation	
144	Remoy & de Jong (2011)	No integration of structure and services	Separation	
B135	Remoy & van der Voordt (2011)	No services integrated into the load bearing structure	Separation	
C7	Schneider & Till (2007)	Partition walls should not be loadbearing - <u>not contain electrical or other services.</u>	Separation	
75	Slaughter (2001)	Service zoning	Separation	Different element types kept separate
140	Slaughter (2001)	Physically separate building systems	Separation	
A117	Slaughter (2001)	Reduce inter and intra system interaction	Separation	
B488	Webster & Costello (2005)	Layer building systems	Separation	Don't weave wiring etc. through the structure
A275	Ash (2011)	surreal and unusual signage	Signage	
A277	Ash (2011)	sky signs graphics glitter with sun and LED lighting	Signage	
B345	Edmonds & Gorgolewski (2000)	Keep designs simple	Simple construction	
A167	Edwards (2005)	Design for simplicity of operation: Over-complicated buildings are not fit in the long term.	Simple construction	
A8	Gorgolewski (2005)	Simplicity often aids future change – independence of systems	Simple construction	
B221	Kendall & Teicher (2000)	Flat pack furniture	Simple construction	
76	Leaman, Bordass & Cassels (1998)	Simple servicing and maintenance	Simple construction	Passiv design preferred; circuit / web approach not hub and spoke
80	Leaman, Bordass & Cassels (1998)	Legible building - users understand how it works	Simple construction	usable, habitual buidlings
147	Lynch (1958)	Simple	Simple construction	Intricate houses less adaptble
C5	Rabeneck (1973)	Subsystem choices should be as <u>technically simple as possible,</u> based on the long term availability of materials rather than on sophisticated manufactured products. e.g. stud wall partitions	Simple construction	
148	Schneider & Till (2007)	Simplicity ("ordinaryness")	Simple construction	More simple = more adaptable
B80	Schneider and Till (2005a)	Construction repeats a number of simple techniques	Simple construction	Allows change with unskilled labour
B282	Ball (1999)	Access limitations	Site access	(getting to it for conversion work)
B290	Eley & Worthington (1984)	Access	Site access	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B297	Gann & Barlow (1996)	Access	Site access	
B309	Gann & Barlow (1996)	Access for fire brigade	Site access	
B119	Remoy & van der Voordt (2011)	Site access	Site access	
B121	Remoy & van der Voordt (2011)	Street frontage	Site access	
B431	Remoy & van der Voordt (2014)	Easily accessible	Site access	
B6	Remoy & Wilkinson (2011)	Accessible site	Site access	Construction easier
10	Remoy & Wilkinson (2012)	Attachment to adjeacnt structures	Site access	Attachment makes demolition less attractive
29	Wilkinson & Reed (2011)	Site access	Site access	
103	Wilkinson & Reed (2011)	street frontage;	Site access	narrower street frontage < 50 = higher adapt (austrailia specific?)
149	Wilkinson & Reed (2011)	Site boundaries	Site access	Less attached to others = more likely to undergo adapt
B148	Wilkinson, James and Reed (2009)	External access	Site access	
B152	Wilkinson, James and Reed (2009)	Fire brigade access	Site access	
139	Atlas & Ozsoy (1998)	Potential for growth	Site utilisation	
B195	Davison et al. (2006)	Courtyard or atrium forms	Site utilisation	when depth of building < site depth
151	Douglas (2006)		Site utilisation	Congestd urban sites - bad
104	Geraedts & Vrij (2004)	Outdoor space	Site utilisation	
B453	Geraedts (2008)	Extendable	Site utilisation	addition of more or new installation components
A226	Gregory (2011)	Design a generous courtyard space (social, surroundings) - o Acts as a social focus, a service access, and a space for expansion	Site utilisation	
A270	Gregory (2011)	Leave room to expand	Site utilisation	
A272	Gregory (2011)	Allow for public realm spaces	Site utilisation	
B237	HBN 11	Provide space for future expansion	Site utilisation	
A228	Hill (2006)	Leave space to evolve (if physical/ spatial, build with modular shapes which can extend easily)	Site utilisation	
B22	Lansley et al. (2005)	Restricted space around a property	Site utilisation	Prevents addition of extras like ramps
150	Larssen & Bjorberg (?)	site size	Site utilisation	
109	Lifetime homes	Ability to convert parking to disabled size (soft strip next to it etc.)	Site utilisation	
B36	Morris et al. (2011)	Relatively large site	Site utilisation	Space for parking and bin storage
14	Multispace (2004)	Building proximity, form and denisty	Site utilisation	Courtyard arrangements preferred
A269	Multispace (2004)	Plot density (leave space for growth) - expansion space (e.g. courtyards)	Site utilisation	
136	Remoy & de Jong (2011)	Possibility for horizontal / vertical extension	Site utilisation	
B437	Remoy & van der Voordt (2014)	Lacking private outdoor space (or ability to provide it)	Site utilisation	Structure should be able to support addition of balconies; bad for apartment conversion
B241	HBN 11	Provide adequate infrastructure capacity, plantroom and containment space to upgrade engineering services at a later date	Spacious	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B254	HBN 11	Provision of adequate spare plant and service access space	Spacious	Includes ceiling void depth and service risers
A200b	Bradley (2010)	provide slightly wider circulation spaces that can be used for other activities (permanently or intermediately) – (space plan, social)	Spacious	
B73	Bullen and Love (2010)	Built to minimum space standards	Spacious	-
B185	Davison et al. (2006)	Generous room sizes	Spacious	
B343	Edmonds & Gorgolewski (2000)	Loose fit to allow some redundancy	Spacious	
B330	Ellison and Sayce (2007)	Overdesign	Spacious	can have too much of it (esp in a high change building type)
B167	Geraedts (2001)	Oversize space	Spacious	
A204	Gorgolewski (2005)	Loose fit – allow some redundancy to accommodate future addition (plan)	Spacious	
B58	Kelly et al. (2011)	Over specify floor area provision	Spacious	
B15	Lansley et al. (2005)	Spacious layout	Spacious	+
B21	Lansley et al. (2005)	Small spaces	Spacious	-
131	Leaman, Bordass & Cassels (1998)	"Elbow room"	Spacious	
23	Lifetime homes	Stairs wide enough to accommodate stair lift	Spacious	
132	Lifetime homes	Space for shower installation in GF loo	Spacious	
177	Lifetime homes	Space on ground floor suitable for use as temp bed space	Spacious	
B415	Loch (2009)	Shared gallery access	Spacious	"broad", big enough to dwell on, 2.5m wide
B423	Loch (2009)	Oversizing spatial dimensions	Spacious	
A205	Lynch (1958)	Over capacity (extra space - plan)	Spacious	
B40	Morris et al. (2011)	Minimum internal space requirements	Spacious	
A200	Morrison (2010)	provide slightly wider circulation spaces that can be used for other activities (permanently or intermediately) – (space plan, social)	Spacious	
C4	Nutt (1988)	Oversizing	Spacious	Of structure, services and space
A207	Rabeneck (1973)	10% increase in net area (i.e. about 6% cost increase) would provide the additional 'slack'	Spacious	
A208	Rabeneck (1973)	Loose space standards is the only true safe guard for the future	Spacious	
A202	Russell (2001)	(Interior spaces)Provide more than the minimum spatial areas	Spacious	
129	Schneider & Till (2007)	Space	Spacious	Slack, unfinished space provision. Rooms not sized for specific activities
130	Schneider & Till (2007)	Circulation spaces	Spacious	Oversized - better
A201	Schneider & Till (2007)	Circulation increasing the dimensions can allow for other functions (1.1 m, 1.6m, 2.5 m)	Spacious	
A230	Schneider & Till (2007)	Provide excess space – more space (lower specification)	Spacious	
B78	Schneider and Till (2005a)	Relatively generous space provision (horizontally)	Spacious	
A203	Song (2008)	Provide generosity in space both in plan	Spacious	
A212	Venturi and Brown, #	form accommodates functions as a mitten rather than as a glove, to allow wiggle room for the varying fingers inside!	Spacious	
B204	Bijdendijk (2005)	Large spans	Span	Few obstacles / open floor areas

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B109	Brand (1994)	Columns	Span	Encourage people to span walls between them
B191	Davison et al. (2006)	Large spans	Span	14.8m; multispace = 6-12m (cost effective)
B362	Edmonds & Gorgolewski (2000)	Minimise the number of internal columns	Span	
B101	Gibb et al. (2007)	Structural slab and spans	Span	min span 7.5m
B60	Kelly et al. (2011)	Span depth	Span	
63	Larssen & Bjorberg (?)	Spans	Span	Large free spans preferred
B425	Loch (2009)	Broad spans	Span	
A152	Lynch (1958)	Zoning and concentration of structure (wide span)	Span	
A282	Martin (1999)	largest economical grid is in the region of 15m by 6m to give optimum column-free spaces	Span	
55	Multispace (2004)	Structural design	Span	6 - 12 m spans
A148	Russell (2001)	Wide spacing (minimum of 6m, suggest 7.5 to 9m)	Span	
A151	Russell (2001)	Large grids that can be subdivided	Span	
61	Saari & Heikkila (2008)	Spans	Span	
B111	Saari & Heikkila (2008)	Spans	Span	
A280	Schneider & Till (2007)	Provide clear spans across the width of a (residential) unit +/- 6 m	Span	
B83	Schneider and Till (2005a)	Large spans	Span	
B326	Ellison and Sayce (2007)	Structure type	Specification	Should conform to a standard for the type of building
B327	Ellison and Sayce (2007)	Type of services	Specification	Should conform to a standard for the type of building
B328	Ellison and Sayce (2007)	Quality of finishes	Specification	Should conform to a standard for the type of building
B331	Ellison and Sayce (2007)	Over specification (e.g. high spec finishes)	Specification	Place a large maintenance burden on building (making it more attractive to demo)
5	Kincaid (2002)	Fabric (interior and exterior) specification quality – unique or standard?	Specification	
B477	Langston & Shen (2007)	Quality of the building	Specification	Langston suggests elsewhere measuring this using cost/m2; rationale is that higher quality leads to higher compliance levels against future (usually increasing) statortory requirements.
B126	Remoy & van der Voordt (2011)	Facade quality / aesthetics	Specification	
~~8~~	Remoy & Wilkinson (2012)	Quality	Specification	Middling qualit offices most likely
6	Wilkinson & Reed (2011)	Property Council of Australia building quality grade	Specification	Higher grade = more adaptation (not conversion)
A64	Brand (1994)	Use local materials (materials than can grow easily - interior & exterior)	Standard components	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B528	DfES (2007)	Limit the range of furniture	Standard components	Rooms are multi-purpose and do not contain furniture only one subject can use
B381	Edmonds & Gorgolewski (2000)	Standardisationn of routing and dimensioning of services	Standard components	
B177	Eguchi et al. (?)	Standardised desks (all the same size)	Standard components	Two types were used
B179	Eguchi et al. (?)	Standard size structure and envelope components	Standard components	
B462	Geraedts (2008)	Universal (standardised) components	Standard components	Components can be removed and used elsewhere
B52	Gosling et al. (2013)	Accessible floor and ceiling systems in standard sizes and interchangeable	Standard components	
B464	Gu, Xue and Nee (2009)	Identify common or recurring elements, either functional or structural..design these elements as a shared platform	Standard components	
A9	Hashemian (2005)	Standard components and generic forms should replace product-specific designs when possible.	Standard components	
B405	Issac & Saneghpour (2012)	Standardisation	Standard components	Allowing one component to be easily replaced with another
B264	Kronenburg (2007)	Standardised components	Standard components	less dependent on having the specific part
A70	Lynch (1958)	Design an additive structure (modules, lattices)	Standard components	
A38	Martin (1999)	Rationalize perimeter with interior column sizes: greater load capacity than necessary (cladding has generally increased in weight over time)	Standard components	
A40	Martin (1999)	Reinforcement design: (do not be too sophisticated, instead rationalize bar sizes).	Standard components	
A71	Neufville (#)	standardization of equipment	Standard components	
A72	Rabeneck (1973)	Subsystem choices should be as technically simple as possible, based on the long term availability of materials rather than on sophisticated manufactured products. e.g. stud wall partitions	Standard components	
A155	Schneider & Till (2007)	Use simple and robust construction techniques, which allow future intervention - e.g. taken off-the-shelf (catalogue architecture; a range of standard, and not necessarily industralized solutions).	Standard components	
B55	van Nederveen & Gielingh (2009)	Use available components	Standard components	+
B479	Webster & Costello (2005)	Building systems and materials that are similar throughout the building (regularity)	Standard components	
B481	Webster & Costello (2005)	Building systems and interconnections that are simple to understand, with a limited number of different material types and component sizes (simplicity)	Standard components	
B484	Webster & Costello (2005)	Avoid non standard components	Standard components	
B509	Addis & Schouten (2004)	Use the minimim number of different types of connectors	Standard components	
B510	Addis & Schouten (2004)	Use the minimim number of interfaces and connectors	Standard components	
B162	Geraedts (2001)	Standardised connections	Standard components	
B249	HBN 11	Standard data outlets	Standard components	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B219	Kendall & Teicher (2000)	Select 'open' systems with standardized interfaces	Standard components	i.e. it connects in a standard way so as to not limit later choices
B508	Addis & Schouten (2004)	Consider using standard grids	Standard grid	
56	Arge (2005)	Structural grid	Standard grid	allowing for different work place designs or solutions.
59	Cowee & Schwer (2009)	Grid	Standard grid	Regular
A147	Cowee & Schwer (2009)	Regular structural grid	Standard grid	
B190	Davison et al. (2006)	Regular grid	Standard grid	"tartan grid"; 9x9 and 9x12 are listed for multispace
B337	Edmonds & Gorgolewski (2000)	Use simple strucutral grids with clear support lines	Standard grid	
B174	Eguchi et al. (?)	Uniform grid	Standard grid	10.8m
B314	Gann & Barlow (1996)	Structural grid	Standard grid	
A150	Gorgolewski (2005)	Optimise structural girds to allow changing uses of space.	Standard grid	
B50	Gosling et al. (2013)	Standardised grid	Standard grid	
60	Graham (2005)	Structural grid	Standard grid	
B258	HBN 11	Standardised building spans and grids	Standard grid	
A154	Mouilek (2009)	Standardize the structural layout by decomposing it into simple forms with standard dimensions.	Standard grid	
57	Remoy & de Jong (2011)	Structural grid	Standard grid	
B137	Remoy & van der Voordt (2011)	Standard grid	Standard grid	suggest multiples of 1.8m, e.g. 7.2m, is fine by reference to generic example
B434	Remoy & van der Voordt (2014)	Measurements of structural grid	Standard grid	5.4 and 7.2m or to match standard apartment sizes
B10	Remoy & Wilkinson (2011)	Standard measurements	Standard grid	+
B197	van Zwol (2005)	Grid structure	Standard grid	7.2m grid
A233	CSA (2007)	Consider multiple/ temporay uses for spaces (polyvariant spaces)	Standard spaces	
B525	DfES (2007)	Use a standard set of plan sizes	Standard spaces	56m2 to 63m2 classrooms
B526	DfES (2007)	Standard colour scheme to rooms	Standard spaces	
B530	DfES (2007)	Avoid narrow or L shaped rooms	Standard spaces	Will restrict furniture arrangements
A266	Hanitchak (2005)	standardization of room sizes allows for interchangeability	Standard spaces	
B230	HBN 01	Set of standardized room sizes	Standard spaces	12, 16 and 32m2
B232	HBN 11	Use generic patient / client contact spaces	Standard spaces	
B233	HBN 11	Limit the number of specialist spaces	Standard spaces	
B234	HBN 11	Standardise room sizes	Standard spaces	8, 12, 16, 32 m2
B244	HBN 11	Include wash hand basins	Standard spaces	increase flex of interview / group rooms
B246	HBN 11	Changeable signage	Standard spaces	Allowing names and routes to be easily modified.
B256	HBN 11	Adopt a limited number of room sizes	Standard spaces	
B267	Kronenburg (2007)	Equal sized spaces	Standard spaces	
B411	Loch (2009)	Spatial indeterminancy / neutral use spaces	Standard spaces	
B416	Loch (2009)	Modular construction (spaces)	Standard spaces	e.g. 14m2
A214	Lynch (1958)	e.g. Unspecialized forms (of generic spaces)	Standard spaces	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A263	Lynch (1958)	Different types of spaces which can support a variety of activities (certain amount of variation is good)	Standard spaces	
A267	Neufville (#)	standard room categories	Standard spaces	
A243	Rabeneck (1973)	Rooms should be 'neutral' in terms of form (simple volumes)	Standard spaces	
A268	Rabeneck (1973)	Spaces should avoid extremes of size (small or large)	Standard spaces	
A247	Rabeneck (1973)	little overt expression of room function (not predetermined by built-in furniture)	Standard spaces	
A248	Rabeneck (1973)	names can be given to rooms based on the uses to which they are put at a given time of day.	Standard spaces	
A233b	Russell (2001)	Consider multiple/ temporay uses for spaces (polyvariant spaces)	Standard spaces	
A236	Schneider & Till (2007)	Design rooms without labels (designation of rooms)	Standard spaces	
A240	Schneider & Till (2007)	Provide functionally neutral rooms (used in a variety of ways)	Standard spaces	
B91	Schneider and Till (2005a)	Similarly sized rooms	Standard spaces	Rooms not function specific - "indeterminate"
A214b	Song (2008)	e.g. Unspecialized forms (of generic spaces)	Standard spaces	
B524	DfES (2007)	Community storage space	Storage space	In addition to school storage
B19	Lansley et al. (2005)	Large walk in cupboards	Storage space	+
A223	SDG Nottingham	generous storage space standards with built-in expansion areas	Storage space	
A224	York City (2006)	include adaptable storage (minimizing need for future expansion)	Storage space	
99	Arge (2005)	Client / developer type	Tenants and ownership	Owner occupiers / long term interest in building
B285	Ball (1999)	Ownership conditions	Tenants and ownership	
164	Cuperus & Brouwen (1992)	Descion responsibility	Tenants and ownership	Single point decisions = adaptabiliyt up
B288	Eley & Worthington (1984)	Mutli-occupancy	Tenants and ownership	Allow a company to expand in the same building
160	Geraedts & Vrij (2004)	Land ownership	Tenants and ownership	
161	Kincaid (2002)	Tenure – whole or partial required?	Tenants and ownership	
B476	Langston & Shen (2007)	Owner occupied space	Tenants and ownership	More adaptable than fully rented space (they consider the actual act of the building being rented to make it less adaptable, presumably because it easier to sell?)
162	Remoy & Wilkinson (2012)	Ownership	Tenants and ownership	Owner-occupied more likely to undergo conversion
163	Remoy & Wilkinson (2012)	Tenants	Tenants and ownership	<4 preferable
B206	Bijdendijk (2005)	Generous vertical access for people, piping, ducts and cables	Vertical service space	
B358	Edmonds & Gorgolewski (2000)	Integral communications risers	Vertical service space	
B359	Edmonds & Gorgolewski (2000)	Vertical risers	Vertical service space	Occupying 2% gross floor area
B461	Geraedts (2008)	Vertical shafts distributed centrally and within units	Vertical service space	
A136	Gregory (2011)	Group services with stairs – most services (mechanical, electrical) have a comfortable reach of 30m before needing some form of boost or additional risers (structure, services)	Vertical service space	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B408	Issac & Saneghpour (2012)	Add buffers - extra capacity	Vertical service space	e.g. overdesign structural loading, larger service cores
B428	Loch (2009)	Closely spaced, sufficiently dimensioned utility shafts	Vertical service space	Make all components easily accessible
A165	Schneider & Till (2007)	Services should be grouped in vertical risers and service rooms located close	Vertical service space	
B87	Schneider and Till (2005a)	Collect vertical services in easily accessible ducts	Vertical service space	
B520	DfES (2007)	Wireless technology	Wireless	More freedom over where to position ICT provision
B170	Geraedts (2001)	Minimise service distribute e.g. wireless systems	Wireless	
B248	HBN 11	Wireless and /or internet protocol technology	Wireless	
B498	~~Addis & Schouten (2004)~~	~~Design for simple, cheap dismantling~~	~~x~~	
B501	~~Addis & Schouten (2004)~~	~~Design for simultaneous, parellel disassembly and deconstruction~~	~~x~~	
B511	~~Addis & Schouten (2004)~~	~~Consider the use of prefabrication~~	~~x~~	
B514	~~Addis & Schouten (2004)~~	~~Make inseparable sub-assemblies from the same material~~	~~x~~	
100	~~Arge (2005)~~	~~Perception of change~~	~~x~~	~~Buildings designed expecting change = more adaptable~~
~~169~~	~~Arge (2005)~~	~~Servicing strategy~~	~~x~~	
~~171~~	~~Arge (2005)~~	~~Functional organisation~~	~~x~~	~~allowing for parts of the building to be used by different organisations / groups~~
~~A237~~	~~Ash (2011)~~	~~Create pop up (temporary) activities (daily, weekly, seasonally, annually)~~	~~x~~	
~~A238~~	~~Ash (2011)~~	~~Activate public spaces, flea market, garden~~	~~x~~	
~~A239~~	~~Ash (2011)~~	~~Enroll spaces for events (an evening, a day, a weekend, one week) - e.g. music festival, local food tasting, art show~~	~~x~~	
~~A278~~	~~Ash (2011)~~	~~Open the building up, showcase, exchange, activate underused spaces~~	~~x~~	
~~A301~~	~~Ash (2011)~~	~~Use a social media to communicate (e.g. website, facebook)~~	~~x~~	
~~A287~~	~~Brand (1994)~~	~~Separate high and low volatility areas (classes of spaces)~~	~~x~~	
~~A307~~	~~Brand (1994)~~	~~Don't anticipate future technology~~	~~x~~	
~~A254~~	~~Dekker (1998)~~	~~user orientated design and construction~~	~~x~~	
~~A127~~	~~Dekker (1998)~~	~~system approaches to building~~	~~x~~	
B521	~~DfES (2007)~~	~~Flexible multi-use areas~~	~~x~~	~~Allow inclusion of community activities into the building during the school day~~
~~A159~~	~~Dowie & Simon (1994)~~	~~Locate unrecyclable parts in one area which can be quickly removed and discarded~~	~~x~~	
~~B338~~	~~Edmonds & Gorgolewski (2000)~~	~~Allow some redundancy~~	~~x~~	
B349	~~Edmonds & Gorgolewski (2000)~~	~~Avoid complex composite materials that are difficult to separate~~	~~x~~	
B375	~~Edmonds & Gorgolewski (2000)~~	~~Facilitating attachment to or extension of the existing structure~~	~~x~~	
~~A241~~	~~Edwards (2005)~~	~~Avoid functional specificity (over-specific buildings are inherently inflexible)~~	~~x~~	
~~A311~~	~~Freidman, #~~	~~Sequence of construction is important establishing a hierarchy of relations~~	~~x~~	
~~B294~~	~~Gann & Barlow (1996)~~	~~Building envelope and cladding~~	~~x~~	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
~~B295~~	~~Gann & Barlow (1996)~~	~~Internal space layout~~	~~x~~	
~~B296~~	~~Gann & Barlow (1996)~~	~~Building services~~	~~x~~	
B160	~~Geraedts (2001)~~	~~Make the floor plan partitionable~~	~~x~~	
~~A120~~	~~Geraedts (2006)~~	~~Set specific requirements for the interconnections of construction and installation components~~	~~x~~	
~~A26~~	~~Geraedts (2006)~~	~~Ensure that there is a surplus capacity~~	~~x~~	
~~A149~~	~~Geraedts (2006)~~	~~Maximum partition plan (partitionable)~~	~~x~~	
B452	~~Geraedts (2008)~~	~~Partitionable~~	~~x~~	~~splitting up, rearranging or combining spatial units in a simple way~~
~~A211~~	~~Gordon, RIBA#~~	~~long life, loose fit, low energy~~	~~x~~	
~~A27~~	~~Gorgolewski (2005)~~	~~Allow some redundancy so that additions and changes to the building can be accomodated.~~	~~x~~	
~~A55~~	~~Gorgolewski (2005)~~	~~Avoid complex composite materials that are difficult to separate~~	~~x~~	
~~A94~~	~~Gorgolewski (2005)~~	~~Finishes should be designed to allow for easy upgrade/ replacement~~	~~x~~	
~~A264~~	~~Groak (1992)~~	~~Consider the proportional systems and geometries of architectural composition~~	~~x~~	
B466	~~Gu, Xue and Nee (2009)~~	~~Provide extra features and functionalities in a design for possible future needs.~~	~~x~~	
~~A308~~	~~Hashemian (2005)~~	~~The design should begin from the components that interact with the environment and then proceed to develop necessary internal mechanisms.~~	~~x~~	
~~A44~~	~~Hashemian (2005)~~	~~Extra features which help with future adaptations and do not add to the cost should be considered.~~	~~x~~	
~~117~~	~~Hassler (2009)~~	~~Planning regulations~~	~~x~~	~~More = restrictive~~
~~B319~~	~~Heath (2001)~~	~~Space / layout / access / circulation~~	~~x~~	
~~B320~~	~~Heath (2001)~~	~~Building structure~~	~~x~~	
~~B321~~	~~Heath (2001)~~	~~Building envelope and cladding~~	~~x~~	
~~B322~~	~~Heath (2001)~~	~~Building services~~	~~x~~	
~~A79~~	~~Hill (2006)~~	~~Enable users to manage the at-hand information and interactions (surface layers)~~	~~x~~	
~~A300~~	~~Hill (2006)~~	~~Support, engage the occupancy process over time~~	~~x~~	
~~A283~~	~~Islen and Lamer (1993)~~	~~Unconstrained spaces~~	~~x~~	
~~78~~	~~Israelsson & Hasson (2009)~~	~~Awareness~~	~~x~~	~~Owners and users aware buidling is capable of change~~
97	~~Israelsson & Hasson (2009)~~	~~Material choice~~	~~x~~	~~Low effect overall (no suggestion as to what preferable)~~
101	~~Israelsson & Hasson (2009)~~	~~Planning during design~~	~~x~~	~~Buildings planned to change are more adaptable~~
102	~~Israelsson & Hasson (2009)~~	~~Financial~~	~~x~~	~~Money for change available~~
~~142~~	~~Israelsson & Hasson (2009)~~	~~Installations (services)~~	~~x~~	~~Should be easily changeable~~
B272	~~Kronenburg (2007)~~	~~Fold out fields~~	~~x~~	~~Change in surface~~
~~B274~~	~~Kronenburg (2007)~~	~~Kinetic construction elements~~	~~x~~	~~(bits that move)~~
~~124~~	~~Larssen & Bjorberg (?)~~	~~Restrictions on servicing~~	~~x~~	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
A242	Leaman, Bordass & Cassels (1998)	Generic Buildings reducing the number of unnecessary variables	x	
A128	Leaman, Bordass & Cassels (1998)	Hiearchial Layering	x	
A168	Leaman, Bordass & Cassels (1998)	Bringing action as close as possible to the points of need	x	
A186	Leaman, Bordass & Cassels (1998)	Develop contingency planning strategies.	x	
A304	Leaman, Bordass & Cassels (1998)	make sure the right people 'own' the problems,	x	
A305	Leaman, Bordass & Cassels (1998)	avoid fantasies and wish lists, not rely too much on performance specifications	x	
A61	Leaman, Bordass & Cassels (1998)	seek robust, generic solutions	x	
178	Lynch (1958)	Specifity	x	Designed for non-specfic client = more adaptable
A121	Lynch (1958)	Temporary structures	x	
A290	Lynch (1958)	Communication substitutes (good communication network)	x	
A294	Marsh, #	provide variable options for access, circulation and separation/ adjacency	x	
A59	Marsh, #	Work with a malleable form of construction	x	
1	Minami ()	Presence of adaptable system (implied)	x	
B25	Morris et al. (2011)	Office (B1) space	x	Most suitable to conversion to resi (over other B types)
A310	Mouilek (2009)	Privledge a parallel scenario for the assembly sequence	x	
36	Multispace (2004)	Cladding design	x	
A303	Neufville (#)	flexibility in terms of organization, management, and the use of facilities.	x	
A259	Rabeneck (1973)	users have an active involvement,	x	
170	Remoy & de Jong (2011)	Servicing	x	Suitable for a range of room layouts
B129	Remoy & van der Voordt (2011)	Zoning plan permitting change of use	x	
A41	Russell (2001)	Install isolation joints to prevent differential settlements (foundation)	x	
A141	Russell (2001)	Design a versatile envelope capable of accommodating changes to the interior space plan.	x	
A206	Russell (2001)	(Interior spaces) design spaces for a loose fit (plan)	x	
A215	Schneider & Till (2007)	spaces which can be split, shared or joined	x	
A289	Schneider & Till (2007)	The ways in which rooms are oganised (consider the organisation of spaces)	x	
A306	Schneider and Till (2007)	more an exercise of common sense than it is the application of expert knowledge.	x	
33	Slaughter (2001)	Circulation	x	Improviing flow of people things - more entrances / cores etc.
A185	Slaughter (2001)	Simplify partial/ phased demolition	x	
A187	Slaughter (2001)	Phase system installation	x	
A292	Slaughter (2001)	Improve flow	x	
A33	Slaughter (2001)	design for an overcapacity	x	
A122	Slaughter (2001)	Phase system installation	x	
A284	Song (2008)	Consider the location of spaces (relationships between)	x	
B280	URBED (1987)	Condition	x	

APPENDIX 2A - ADAPTABILITY CHARACTERISTICS IDENTIFIED IN THE LITERATURE

Ref	Source	Parameter / Guideline	Basic	Effect
B485	~~Webster & Costello (2005)~~	~~Avoid mixing material grades~~	~~x~~	~~e.g. different types of timber or strengths of steel~~
B495	~~Webster & Costello (2005)~~	~~Preference precast concrete over cast-in-place~~	~~x~~	
98	~~Wilkinson & Reed (2011)~~	~~age~~	~~x~~	~~Older buildings more likely to undergo major adaptation~~
~~B141~~	~~Wilkinson, James and Reed (2009)~~	~~Layout~~	~~x~~	
~~B144~~	~~Wilkinson, James and Reed (2009)~~	~~Envelope and cladding type~~	~~x~~	
~~B153~~	~~Wilkinson, James and Reed (2009)~~	~~Purpose built offices~~	~~x~~	~~more adaptable than speculative offices~~
A14	Cowee & Schwer (2009)	Integrate connection points into façade elements (skin)		
B523	DfES (2007)	Zoned security		To allow parts of the building to be open out of hours
B361	Edmonds & Gorgolewski (2000)	Building envelopes that can respon to external conditions and provide stable internal environment		
A108	Geraedts (2006)	Integrate the design of installation systems into the structural building design (two different decision levels)		
A227	Gregory (2011)	Contribute to the public realm (open, not turn your back)		
~~116~~	~~Kincaid (2002)~~	~~Use class order~~		~~if B2-B7 = non-viable to change~~
B270	Kronenburg (2007)	Opening roofs		
~~84~~	Lifetime homes	Bathroom walls etc. strong enough to support grab rails etc.		
A50	Russell (2001)	Choose a structural floor system that accommodates a number of mechanical and electrical service distribution schemes		
A53	Russell (2001)	Use hybrid HVAC systems (balance centralized and distributed components).		

Parameter	% coverage	Count Sources (max=107)	Addis & Schouten (2004)	Arge (2005)	Ash (2011)	Atlas & Ozsoy (1998)	Ball (1999)	Barlow et al. (?)	BEAM (2009)	Bijdendijk (2005)	Bradley (2010)	Brand (1994)	Bullen and Love (2010)	Cowee & Schwer (2009)	CSA (2007)	Cuperus & Brouwen (1992)	Davison et al. (2006)	Dekker (1998)	DfES (2007)	Douglas (2006)	Dowie & Simon (1994)	Edmonds & Gorgolewski (2000)	Edwards (2005)	Eguchi et al. (?)	Eley & Worthington (1984)	Ellison and Sayce (2007)	Fernandez (2003)	Finch (2009)	Freidman, #	Gann & Barlow (1996)	Genevro (Duffy) (2009)	Geraedts & Vrij (2004)	Geraedts (2001)	Geraedts (2006)	Geraedts (2008)	Gibb et al. (2007)	Gordon, RIBA#	Gorgolewski (2005)
Accessibility	18%	19	2		0		0		0		0		0	1	2		0		0		2	5	0		0		0		0		0		0	1	1		0	2
Acoustics	4%	4	0	1	0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0		0	
Aesthetics	11%	12	0		0		1		0	1	0		1		0		0		0		0		0		0		0		0		0		0		0		0	
Avoid hazardous materials	3%	3	2		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Basic finish	12%	13	0		0		0		0		0	1	0		0		0		0		0	1	0		0		0		0		0		0		1		0	
Big entrance	2%	2	0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Building service control	8%	9	0		0		0		0		0		0		0		0		1		0	1	0		0		0	3	0		0		1	1	2		0	
Building size	9%	10	0		0		0		0		0		2		0		0		0		0	1	0		1		0		0	1	0		0		0		0	
Connection type	25%	27	1	1	0		0		0		0		0	1	3	1	0		0		1	3	0	1	0		0		0		0		1	1	1		0	2
Core location	21%	22	0		0		0		0	1	0		0	1	0		0		0		0	2	0	1	0		0	1	0		0	1	0		0	1	0	
Daylight and view	8%	9	0		0		0		0		0		0		0		0		0		0		1	1	0		0		0		1		0		0		0	
Durable materials	10%	11	0		0		0		0	1	0	1	0		2		0		0		0		1	2	0		0		0		0		0		0		0	
Energy efficient	4%	4	0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		0		0		0	
Extra connections	4%	4	0		0		0		0		0		0	2	0		0		0		0		0		0		0		0		0		0		0		0	
Extra space	11%	12	0		0		0		0		0		0	1	0		0		0		0	1	0		0		0		0		0		0		0		0	
Fenestration	7%	7	0		1		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0	1	0	
Fire	8%	9	0	1	0		0		0		0		0	5	0		0		0		0		0		0		0		0	1	0	1	0		0	2	0	
Floor loading	25%	27	0		0		0		0	1	0	1	0	3	1		1		0		0	5	0		0		0		0		0		1		0		0	1
Floor to ceiling height	28%	30	0	1	0		0		0	1	0		0		0		2		0		0	2	0	2	1	1	0	1	0	1	0	1	0		0	1	0	1
Framed	10%	11	0		0		0		0	1	0		0	2	0		0		0		0	1	0		0		0	1	0	1	0		0		0		0	
Generous facilities provision	2%	2	0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0		0	
Handling	6%	6	1		0		0		0		0		0		1		0		0		1		0		0		0		0		0		0		0		0	
Height	7%	8	0		0		0		0		0		1		0		0		0		0		0		0		0		0	1	0		0		0		0	
Horizontal service space	15%	16	0		0		0		0		0		0		0		1		0		0	2	0		0		0	2	0		0		1	1	0	2	0	
Hostile factors	7%	7	0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0	2	0		0		0	
Layout	14%	15	0		0		0	1	0		0		0		0		1		0		0		0		1		0	3	0		0		0		0		0	
Information	9%	10	2		0		0		0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0	
Layered	5%	5	0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0	
Legible components	3%	3	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Less components	7%	7	2		0		0		0		0		0	2	1		0		0		1		0		0		0		0		0		0		0		0	
Listed	8%	9	0		0		0		0		0		1		0		0		0		0		0		0		0		0		0	1	0		0		0	
Location	17%	18	0		0		0		0		0		0		0		0		0		0		0		0	2	0		0	1	0	5	0		0		0	
Modular construction	16%	17	1		0		0		0		0		0		0		0		0		1		0		0		0	1	0	1	0		1	1	0	1	0	
Moveable furniture	10%	11	0		0		0		0		0		0		0		0		3		0		0	1	0		1		0		0		1	1	0		0	
Moveable walls	8%	9	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0	
Multi function furniture	3%	3	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0	
Naturally ventilated	2%	2	0		0		0		0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0	
Non load bearing facade	8%	9	0		0		0		0		0		0	2	0		0		0		0	1	0		0		0		0		0		0		0		0	
non load bearing paritions	20%	21	0		0		0		1		0		0		0		1		0		0	1	0	1	0		0	2	0		0		0		0		0	
Openable windows	6%	6	0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0	1	0		0	1	0	
Openings	9%	10	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0	
Orientation	4%	4	0		0		0		0		0		0		0		0		0		0		1		0		0		0	1	0		0		0		0	
Oversize M&E	16%	17	0		0		0		0		0	1	0	2	0		0		0		0	1	0		0		0		0	1	0		2		2		0	
Parking	7%	8	0		0		1		0		0		0		0		0		0		0		0		0	1	0		0	1	0	1	0		0		0	
Penetrable slab	8%	9	0		0		0		0		0		0		0		0		0		0	1	0		0		0		0	1	0		0		0		0	
Plan depth	15%	16	0	1	0		0		0		0		0		0		1		0		0	1	0		0		0		0	1	0	1	0		0	1	0	
Plan shape	12%	13	0	1	0		0		0		0	1	0		0		1		1		0		0		0	2	0		0	1	0		0		0		0	
Planning grid	21%	22	0		0		0		0		0		0	2	0		0	1	0		0	2	0		0		0	1	0	1	0		1		1		0	
Prefabrication	6%	6	0		0		0		1		0		0		1		0		0		0		0		0		0		0		0		0		0		0	1
Reusable components	5%	5	1		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		0		0	
Separation	24%	26	0		0		0		2		0		0		1		0		1		1	1	0		0		0		0		0		1	1	0		0	2
Signage	1%	1	0		2		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Simple construction	8%	9	0		0		0		0		0		0		0		0		0		0	1	1		0		0		0		0		0		0		0	1
Site access	8%	9	0		0		1		0		0		0		0		0		0		0		0		1		0		0	2	0		0		0		0	
Site utilisation	14%	15	0		0	1	0		0		0		0		0		1		0	1	0		0		0		0		0		0	1	0		1		0	
Spacious	22%	24	0		0		0		0		1		1		0		1		0		0	1	0		0	1	0		0		0		1		0		0	1
Span	14%	15	0		0		0		0	1	0	1	0		0		1		0		0	1	0		0		0		0		0		0		0	1	0	
Specification	6%	6	0		0		0		0		0		0		0		0		0		0		0		0	4	0		0		0		0		0		0	
Standard components	20%	21	2		0		0		0		0	1	0		0		0		1		0	1	0	2	0		0		0		0		1		1		0	
Standard grid	16%	17	1	1	0		0		0		0		0	2	0		1		0		0	1	0	1	0		0		0	1	0		0		0		0	1
Standard spaces	13%	14	0		0		0		0		0		0		1		0		3		0		0		0		0		0		0		0		0		0	
Storage space	4%	4	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0	
Tenants and ownership	7%	8	0	1	0		1		0		0		0		0	1	0		0		0		0		1		0		0		0	1	0		0		0	
Vertical service space	7%	8	0		0		0		0	1	0		0		0		0		0		0	2	0		0		0		0		0		0		1		0	
Wireless	3%	3	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		1		0		0	

Parameter	Gosling et al (2011)	Gosling et al. (2013)	Graham (2005)	Gregory (2011)	Groak (1992)	Gu, Xue and Nee (2009)	Guy & Shell (2003)	Habraken (2005)	Habraken (2008)	Hanitchak (2005)	Hashemian (2005)	Hassler (2009)	HBN 01	HBN 11	Heath (2001)	Hill (2006)	Islen and Lamer (1993)	Israelsson & Hasson (2009)	Issac & Saneghpour (2012)	Kelly et al. (2011)	Kendall & Teicher (2000)	Kendall (1999)	Kincaid (2002)	Kronenburg (2007)	Langston & Shen (2007)	Lansley et al. (2005)	Larssen & Bjorberg (?)	Leaman, Bordass & Cassels (1998)	Lifetime homes	Loch (2009)	Lynch (1958)	Marsh, #	Martin (1999)	Minami ()	Morris et al. (2011)	Morrison (2010)
Accessibility	0		0		1		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0	
Acoustics	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Aesthetics	0		0	1	0		0		1		0		0		0	3	0		0		0		1		0		0		0		0		0		1	
Avoid hazardous materials	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Basic finish	0	1	0		0	1	0		1		0		0		0	2	1		0		0		0		0		0		0	2	0		0		0	
Big entrance	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Building service control	0		0		0		0		0		0		0		0		0		0		0		0	1	0		0	2	0		0		0		0	
Building size	0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		0	
Connection type	0		0		1	1	2		0		1		0		0		0		0	1	1	1	0	2	0		0	1	0		0		0		0	
Core location	0		0		0		0		0		0		0	1	0		0		0		0		1		0		0	1	0	1	0		0		1	
Daylight and view	0		0	1	0		0		0		0		0		1		0		0		0		0		0		0	1	0	1	0		0		0	
Durable materials	0		0		0		0		0		0		0		0	1	0		0	1	0		0		0		0		0		0		0		1	
Energy efficient	0		0		0		0		0		0		0		0		0		0		0		0		1		0	1	0		0		0		1	
Extra connections	0		0		0		0		0		0		0	1	0		0		1		1		0		0		0		0		0		0		0	
Extra space	0		0		0		0		0	1	0		0		0		0		0		0		0	2	0		0	1	0	1	1		0		0	
Fenestration	0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Fire	0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		3	
Floor loading	0		1		0		0		0		0		0		0		1		1		0		1		0		2		1	2	0		1		1	
Floor to ceiling height	0		1		0		0		0		0		0		0		0		0	1	1		1		0	1	1	1	0	1	0		0		1	
Framed	0		0		0		0		0		0		0	1	0		0		0		2		0	1	0		0		0		0		0		1	
Generous facilities provision	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Handling	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Height	0		0		0		0		0		0		0		1		0		0		0		0		0	1	0		0		0		0		0	
Horizontal service space	0	2	0		0		0		0		0		0	2	0		1		0	2	2	1	0		0		0		0		0		0		0	
Hostile factors	0		0		0		0		0		0		0		1		0		0		0		1		0		0		0		0		0		0	
Layout	0	1	0		0		1	1	2		0		0	1	0		0		0	1	0		0		1	1	0		0	1	0		0		0	
Information	0		0		0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0	
Layered	0		0		0		0		0		0		0		0	1	0		0		0		1		0		0		0		0		0		0	
Legible components	0		0		0		1		0		0		0		0		0		0		0		0	1	0		0		0		0		0		0	
Less components	0		0		0		1		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Listed	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1	
Location	0		0		0		0		0		0		0		0		0		0	1	0		4		1		1		0		1		0		2	
Modular construction	0		0		0		1		0		0		0	3	0		1		1		0	1	0	2	0		0		0		0		0		0	
Moveable furniture	0	1	0		0		0		0		0		0	1	0		0		0	1	0		0	1	0		0		0	1	0		0		0	
Moveable walls	0	1	0		0		0		0		0		0	1	0		0		1	1	0		0		0		0		0	1	0		0		0	
Multi function furniture	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0	
Naturally ventilated	0		0		0		0		0		0		0		0		0		0		0		0		1		0		0		0		0		0	
Non load bearing facade	0		0		0		1		0		0		0		0		0		0		1		0		0		0		0		0		0		0	
non load bearing paritions	1		0		0		1		0		0		0		0		0		0		0		0		0	1	1		0	1	0		0		0	
Openable windows	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1		0	
Openings	0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0		0	1
Orientation	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1	
Oversize M&E	0		0		0		0		0	1	0		0	3	0		1		0	1	1		0		0		1	1	0		0		0		0	
Parking	0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		0	
Penetrable slab	0		0		0		0		0		0		0		0		0		0		0		0		0	1	1		0		0		1		0	
Plan depth	0		0	4	0		0		0		0		0		1		0		0		0		1		0		0	1	0		0		0		2	
Plan shape	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1		1	
Planning grid	0		0	2	1		0		0		0		1	2	0	1	0		0		2		0		0		0		0		0		0		0	
Prefabrication	0		0		0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0		0	
Reusable components	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Separation	0	1	0	1	0		1		1		1		0	1	0		0		1		1	2	0		0		0	1	0	2	0		0		0	
Signage	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Simple construction	0		0		0		0		0		0		0		0		0		0		1		0		0		0	2	0		1		0		0	
Site access	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	
Site utilisation	0		0	3	0		0		0		0		0	1	0	1	0		0		0		0		0	1	1		1		0		0		1	
Spacious	0		0		0		0		0		0		0	2	0		0		0	1	0		0	1	0	2	0	1	3	2	1		0		1	1
Span	0		0		0		0		0		0		0		0		0		0	1	0		0		0		1		0	1	1		1		0	
Specification	0		0		0		0		0		0		0		0		0		0		0		1		1		0		0		0		0		0	
Standard components	0	1	0		0	1	0		0		1		0	1	0		0		1		1		0	1	0		0		0		1		2		0	
Standard grid	0	1	1		0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0	
Standard spaces	0		0		0		0		0	1	0		1	6	0		0		0		0		0	1	0		0		0	2	2		0		0	
Storage space	0		0		0		0		0		0		0		0		0		0		0		0		0	1	0		0		0		0		0	
Tenants and ownership	0		0		0		0		0		0		0		0		0		0		0		1		1		0		0		0		0		0	
Vertical service space	0		0	1	0		0		0		0		0		0		0		1		0		0		0		0		0	1	0		0		0	
Wireless	0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0	

Parameter	Mouilek (2009)	Multispace (2004)	Neufville (#)	Nielsen (2010)	Nutt (1988)	Pidwill & Hunter (2009)	Pinder et al. (2011)	Rabeneck (1973)	Remoy & de Jong (2011)	Remoy & van der Voordt (2011)	Remoy & van der Voordt (2014)	Remoy & Wilkinson (2011)	Remoy & Wilkinson (2012)	Rogers (2011)	Russell (2001)	Saari & Heikkila (2008)	Schneider & Till (2007)	Schneider and Till (2005a)	SDG Nottingham	Slaughter (2001)	Song (2008)	Stringer, Dunne & Boussabaine (2012)	Sundin (2005)	URBED (1987)	Utida (1991)	van Nederveen & Gielingh (2009)	van Zwol (2005)	Venturi and Brown, #	Warouw, Kobayashi & Jung (2010)	Webb, Kelly & Thompson (1997)	Webster & Costello (2005)	Wilkinson & Reed (2011)	Wilkinson, James and Reed (2009)	Wong (2010)	York City (2006)
Accessibility	0		0		0		0	1	0		0		0	1	1		1	1	1	2	0		1		0		0		0		0		0		1
Acoustics	0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		0		1		0
Aesthetics	0		0		0		0		0	1	2	1	0		0		0		0		0		0		0		0		0		0	1	0		0
Avoid hazardous materials	0		0		0		0		0		1		0		0		0		0		0		0		0		0		0		1		0		0
Basic finish	0		1		0		0		0		0		0		0		1	1	0		0		0		0		0		2		0		0		0
Big entrance	0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0
Building service control	0		0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0
Building size	0		0		0		0		0	1	0	1	0		0		0	1	0		0		0		0		0		0		0	1	1		0
Connection type	2		0	1	0		0		0		0		0		0		1		0		0		1		1		0		0		1		0		0
Core location	0	3	0		0		1		0	1	2	1	1		1		1	1	0		0		0		0		0		0		0	1	0		0
Daylight and view	0		0		0		0		1		1		0		0		0		0		0		0		0		0		0		0		0		0
Durable materials	0		0		0		0		0		0		0		0		0		0		0		1		1		0		0		1		0		0
Energy efficient	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0
Extra connections	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0
Extra space	0		0		0		0	1	0		0		0		0		2	1	0		0		0		0		0		1		0		0		1
Fenestration	0	1	0		0		0	2	0		0		0		0		0		0		0		0		0		0		0		0		0	1	0
Fire	0	3	0		0		0		1		0		0		0		0		0		0		0		0		0		0		0		0		0
Floor loading	1		1		1		0		0		1		0		2	2	1		0	1	0		0		0		1		0		0		0		1
Floor to ceiling height	0	3	0		0		0		0	1	2		0		2	2	0	2	0		1		0	1	0		0		0		0		1		0
Framed	0		0		0		0		0		0	2	0		1		0		0		0		0		0		0		0		0		0		0
Generous facilities provision	0		0		0		0		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0
Handling	0		0	2	0		0		0		0		0		0		0		0		0		1		0		0		0		1		0		0
Height	0		0		0		0		0	1	0		1		0		0		0		0		0		0		0		0		0	1	1		0
Horizontal service space	0		0		0		1		0		0		0		0		1	1	0	1	0		0		0		0		0		0		0		0
Hostile factors	0		0		0		0		0	1	1		0		0		0		0		0		0		0		0		0		0		1		0
Layout	0		0		0		0		0		0		0		0		0	2	0		0		0		0		0		1		0		0		0
Information	1		0	2	0		0		1		1		0		0		0	1	0		0		0		0		0		1		2		0		0
Layered	0		0	2	0		0		0		0		0		0		0		0		0		0		2		0		0		0		0		0
Legible components	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1		0		0
Less components	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		2		0		0
Listed	0		0		0	1	0		0	1	1		1		0		0		0		0		0		0		0		0		0	1	1		0
Location	0		0		0		0		2	1	1	2	1		0	2	0		0		0		0	1	0		0		0		0	1	1		0
Modular construction	0		0		0		0		0		0		0		0		1		0		1		0		0	1	0		0		1		0		0
Moveable furniture	0		0		0		0		0		0		0		0		0	1	0		0		0		0		0		0		0		0		0
Moveable walls	0		0		0		0		0		0		0		0	1	0	1	0		0	1	0		0		0		0		0		0		0
Multi function furniture	0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		0		0
Naturally ventilated	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0
Non load bearing facade	0		0		0		1		0	1	0	1	0		1		2		0		0		0		0		0		0		0		0		0
non load bearing paritions	0		0		0		0	1	1	1	0		0		1	1	2	2	1		0		0		0		1		0		0		0	1	1
Openable windows	0		0		0		1		0	1	0		0		0		0		0		0		0		0		0		0		0		0		0
Openings	0		0		0		1	1	1		0	1	1		0		4		0		0	1	0		0		0		0		0		0		0
Orientation	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		1		0
Oversize M&E	0		0		1		0		0		0		0		0	1	0		0	1	0		0	1	0		0		0		0		0		0
Parking	0		0		0		0		1	1	0		0		0		0		0		0		0		0		0		0		0		1		0
Penetrable slab	0		0		0		0		1	1	1		0		0		0		0		0		0		0		0		0		0		1		0
Plan depth	0	2	0		0		0		0		1		1		0		0		0		0		0	1	0		0		0		0		1		0
Plan shape	0		0		0		1	1	0		2		0		0		0		0		0		0		1		0		0		0		0	1	0
Planning grid	0		0	1	0		0	2	0		0		0		0		2	1	0	2	1		0		4		1		0		1		0		0
Prefabrication	0		0		0		0		0		0		0		0		1		0	2	0		0		0		0		0		0		0		0
Reusable components	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0	1	1		0		1
Separation	1		0		0		0	2	1	1	0		0		0		1		0	3	0		0		0		0		0		1		0		0
Signage	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0
Simple construction	0		0		0		0	1	0		0		0		0		1	1	0		0		0		0		0		0		0		0		0
Site access	0		0		0		0		0	2	1	1	1		0		0		0		0		0		0		0		0		0	3	2		0
Site utilisation	0	2	0		0		0		1		1		0		0		0		0		0		0		0		0		0		0		0		0
Spacious	0		0		1		0	3	0		0		0		1		5	1	0		1		0		0		0	1	0		0		0		0
Span	0	1	0		0		0		0		0		0		2	2	1	1	0		0		0		0		0		0		0		0		0
Specification	0		0		0		0		0	1	0		1		0		0		0		0		0		0		0		0		0	1	0		0
Standard components	0		1		0		0	1	0		0		0		0		1		0		0		0		0	1	0		0		3		0		0
Standard grid	1		0		0		0		1	1	1	1	0		0		0		0		0		0		0		1		0		0		0		0
Standard spaces	0		1		0		0	4	0		0		0		1		2	1	0		1		0		0		0		0		0		0		0
Storage space	0		0		0		0		0		0		0		0		0		1		0		0		0		0		0		0		0		1
Tenants and ownership	0		0		0		0		0		0		2		0		0		0		0		0		0		0		0		0		0		0
Vertical service space	0		0		0		0		0		0		0		0		1	1	0		0		0		0		0		0		0		0		0
Wireless	0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0		0

APPENDIX 4A – SUMMARY OF POSSIBLE CASE POPULATIONS EVALUATION

	Design Intent		Expected Design Outcomes		Diversity - Conditions	Access
	Adaptability	Low Carbon	Adaptability	Low Carbon		
Purpose built retail	Yes	Exemplar stores only	Always? Lack of variety in outcome	Generic industry level – few leaders / laggards. Variation an issue.	Different types of retail building and retailers with different design requirements.	By negotiation. Limited projects available.
Schools	Most	Building regulations compliance, with some exemplar builds	Some	Common specification for schools performance.	Different stakeholders and locations but standard process and design requirements	By negotiation.
Healthcare	Yes	Generally building regulations only.	Middling and would likely be similar across cases.		Different stakeholders and locations but standard process and design requirements	By negotiation.
Higher Education	Variable	Variable	Some	Highly likely to have variety	Yes.	By negotiation.
Commercial office space	Yes	Some, potentially lots of variety in goals	Always? - Lack of variety in outcome	Some	Some	By negotiation.
Conversions	Potentially any or none Difficult to ascertain	Likely to be older buildings, diff legislative context and less overt drive for LC	Adaptability guaranteed by conversion. Non-convertible buildings required for balance	Highly likely to have variety, exemplar buildings probably harder to find	Difficult to ascertain design conditions.	By negotiation. Limited projects available.
TSB Climate adaptation projects	Yes – (CCA only)	Yes, requirement for funding	Some – not all elements implemented	Level of variety Unknown	Variety of project sizes, values and types.	Large quantity of data publically available.

APPENDIX 4B: LIST OF ALL TSB PROJECTS (SAMPLE POPULATION)

Project Name	Location	Typology	Value	New / Refurb	Tranche	Stage
Admiral Insurance Headquaters	Cardiff	office	£25 M	new build	2010	Pre planning
Cornwall Council office rationalisation programme	Cornwall	office	£29 M	mixed	2010	Refurb complete, new build 2013
Ellingham Primary School	London	school	£8 M	new build	2010	Landscaping / Operation
British Trimmings Extra Care Home	Leek	care home	£10 M	new build	2010	Planning approved
Welland Primary school	Peterborough	school	£6 M	new build	2010	construction
Wyre Forest Primary Schools	Worcestershire	school	£25 M	mixed	2010	Construction
Harris Academy	Purley	school	£20 M	new build	2010	Construction
Exeter Royal Academy for Deaf Education (ERADE)	Exeter	school	£18 M	new build	2010	Stage C/D
Technical Hub @ EBI	Cambridge	office / lab	£23 M	new build	2010	Construction
Edge Lane - Time Project	Liverpool	healthcare	£22 M	new build	2010	RIBA E/F (awaiting financial close)
ExtraCare4Exeter	Exeter	care home	£6 M	new build	2010	C/D
100 City Road	London	office	£76 M	new build	2010	C - planning
The Mill	Cardiff	residential	£100 M	new build MP	2010	Planning
London School of Tropical Medicine	Keppel Street	higher edu	£10 M	refurb	2010	A/B complete
NW Bicester Ecotown development	Oxfordshire	residential	£1200 M	new build MP	2010	design
Central St Martin's King's Cross campus	London	higher edu	£120 M	new build	2010	Complete
Oxford University Press offices	Oxford	office	£11 M	mixed	2010	Planning approved
PortZED	Hove	mixed use	£23.5 M	new build	2010	Stalled at planning?
University of Greenwich - Stockwell st.	London	higher edu	£6 M	new build	2010	Construction, opens 2014
Church View	Doncaster	office	£6.5 M	refub	2010	P1 complete (ran out of funding)
Great Ormond Street Hospital (Phase 2B)	London	healthcare	£45 M	mixed	2010	Enabling works
North West Cambridge (phase 1)	Cambridge	residential	£900 M	new build MP	2010	planning
Trowbridge County Hall	Trowbridge	office	£25 M	refurb	2010	Construction
University of Sheffield Engineering Graduate School		higher edu	£11.5 M	new build	2010	Construction
11-16 phase school (Ebbw Vale)	Wales	school	£27 M	new build	2010	Construction
M&S Metrocentre (Climate Adaptation Plan)	Gateshead	retail	£10 M	refurb	2010	Operation (changed project?)
Lightwave (Management before fabric)	Bradford	museum	£36 M	mixed	2011	Feasability?
One Gallions	East London	mixed use	£40 M	new build	2011	Stuck post planning?
Acton Gardens	Ealing	residential	£341 M	new build MP	2011	pre planning
Climate Adaptive Neighbourhoods	Norwich	residential	£0.1 M	new build	2011	Design?
The Cooperative Head Office	Mancester	office	£100 M	new build	2011	Construction
Swin4Exeter	Exeter, Devon	leisure	£8 M	new build	2011	Pre planning
Carrow Road	Norwich	residential	£8.5 M	new build	2011	Outline planning
University of Salford	Salford	higher edu	£300 M	mixed	2011	C/D
Environment and Sustainability Institute	Cornwall	higher edu	£12 M	new build	2011	Construction
Devonshire Gate	Tiverton	office	£12.5 M	new build	2011	Post planning (D?)
Betws Washery	Camarthenshire	mixed use	£13 M	new build	2011	Design / planning
Site J, New England Quarter	Brighton	mixed use	£25 M	new build	2011	?? Planning denied ??
Octavia Housing	London (west)	residential	£0.9 M/yr	refurb	2011	Rolling maintenance programme
Oakham North: Phase 1	Leicestershire	residential	£26 M	new build	2011	Detailed design
St Paul's RC School Leicester	Leicester	school	£0.1 M	refurb	2011	initial design?
The New QEII Hospital	Hertfordshire	healthcare	£21 M	new build	2011	Enabling works
St Faith's School	Cambridge	school	£5 M	mixed	2011	Phased, ongoing to 2020
Dalby Square (Cliftonville)	Cliftonville	residential	£20 M	refurb MP	2011	??? (Funding awarded)
Dragon Junior School for the Future	Oxford	school	£5.5 M	new build	2011	???
Hinguar Primary School	Essex	school	£5 M	new build	2011	Construction (phase 1)
Westbrook primary school (Andrew Ewing school)	Hounslow	school	£9 M	new build	2011	Construction
London Bridge Station	London	rail station	£35 M	refurb	2011	Post planning, construction 2013
Princes Park	Liverpool	residential	£10 M	new build	2011	Planning app due sum 2012
Project Angel	Northampton	office	£44 M	new build	2011	Feasability (may 2012)

APPENDIX 4C – QCA SAMPLE SIZE DATA

In order to assess common practice, a brief survey of published QCA papers was conducted (partially citation searching from known QCA reference texts, partially database searching using QCA and/or “qualitative comparative analysis” terms). The search was by no means exhaustive and does not include an extensive search of the COMPASS website which includes extensive lists of published and working papers using QCA. The citation searching focused on papers the fields main writers consider useful examples of key techniques, the database searching element on uncovering studies demonstrating a research design similar to the one proposed. Results, on which the following discussion is based, are tabulated in appendix A.

Appendix A: QCA Studies

Reference	Number of cases	Notes on conditions	Notes on selection	
Scovart et al. (2007)	7		Cases considered at 3 time periods	
De Meur, Bursens & Gottcheiner (2006)	9 cases (5/4 outcome split)	44 variables over 5 categories	Outcome classified according to 9 EU initiatives	
De Meur & Berg-Schosser	18 EU countries (8/10 split)	61 variable of 7 categories		
Jordan et al. (2011b)	15 communities, but they are comparing two sets I believe (i.e. an initial QCA of 15, then another QCA of 15, compare the results).	6 'categories' measured by 4-6 'indicators'	" based upon a recommendation of 10 to 40 cases for an intermediate-N analysis with between four and seven conditions (Rihoux 2009)"	
Chan et al. (2011)	14 cases - six transportation projects and eight power plants	7, fuzzy dichotomization.	They apply both theory (what is relevant) and practical (can we get enough info to study it properly) criteria in selecting their cases.	They primarily use documents (news etc.) to get data, and see interviews as an added corrobatory bonus.
McAdam et al. (2010).	A total of 11 projects, spanning 16 countries, each project ⁄ host country pair became a case (n =16).	five categories are: threat, opportunity, resources, prior conflict, and compensation. 1-3 factors within each category. 2 outcome conditions	Case selection criteria 1. All projects had to be located in developing countries to ensure our work would fill a gap in the relevant literatures 2. Projects selected had to include a range of funding mechanisms Discussions with experts in the field convinced us that the sources of funding could be a critical determinant. 3. Projects selected had to be relatively recent to ensure some data availability.	
	15 cases, although it is presented in combination with the McAdam study meaning 27 projects/32 cases from project-country pairs	2 outcome conditions (as McAdam), 3 variable categories containing 1-5 fuzzy variables.	Purposive case selection. They use a database to define the population and identify 600 possible cases.	Primarily desk study augmented with interviews of experts.

Greckhamer et al. (2008)	2,841 cases of business-unit performance during a 4-year period, which are embedded within 2,451 corporations and 184 industries.	Conditions defined 'a-priori': "In selecting the set of theoretically relevant attributes...theoretical relevance, previous research, and parsimony drove our choices." They use conditions that can be objectively taken from documented sources, the qualitative element being in the dichtomisation.	They define a population using a database and standard labelling, as you would for a statistical approach.	This study appears to be conducted in a very 'quant', generalisation vein. One of the few studies to actually publish the truth table.
Ragin et al. (2003)	41 cases (villages)	6 variables, based on what they think will be relevant and restricted by what is extractable from the original report by Wade. They code all of their variables in a number of ways (multiple measures).		Secondary analysis of an original study by Wade (1988)
Stevenson & Greenberg (2000)	4 events , which are then disaggregated into a number of event chains (e.g. on event has 12 chains) 2 actor groups are compared	Outcome = success/none 3 conditions describing the nature of the interaction with others, although the 2 groups could possibly be considered variables, as could the 'centrality' measure they define for each actors position in the network.	Purposive sampling followed with snowball sampling for interviews, using respondents to "assist in identifying the boundary of the network".	This is a mixed methods study (data collection and analysis phases), and has some striking parallels to what I want to do. It is also really confusing to follow!
Gordin (2001)	12 political parties	4 conditions (derived from literature and related to the hypotheses to be tested), outcome of success or failure	uses entire population available	Choice of conditions is somewhat restrictive – competing explanations not really considered
Blake and Aldino (2001)	20 countries	5 "independent variables" that are chosen because theory indicates the outcome (NHI, no NHI) to be dependent on them H=*f*(S,U,E,L,C)	Define population (countries) and then use the specificity of their research question / hypotheses to reduce the population size.	Very quantitative orientated study.
Coverdill and Finlay (1995)	22 textile plants	5 variables (extended from 4 in a previous publication)	Part research question driven, part practicality	Data collected through semi-structured interviews. Very good overview of the pros and cons of the technique in practice.
Gross and Garvin (2010)	16 PPP cases	5 variables (msQCA analysis); dichotomous outcome on a single measure.		This is a construction example, but it mainly highlights the use of the method with little procedural detail given.
Krivokapi-	11	Pre-selected, defined arid measured across all		Historical comparative study

Skoko (2005)		the cases. There appears to be two categories of causal variable based on 2 hypotheses that are then operationalised through a number of conditions - but details are scant.		of ethnic entrepreneurship in New Zealand during the nineteenth and twentieth centuries
Romme (1995)	10 cases	Initial coding (based on lit established categories) followed by coding against 8 variables "on the basis of the results from the first stage". While they code for 8 variables, the minimisation is performed using only 3 or 4 each time.	Uses existing case reports for data collection. Makes the valid point that the "set of actually existing cases may be smaller than the total setoff theoretically possible cases, as a result of institutional or other evolutionary constraints" but fails to pick up on this as a limitation of QCA in identifying constraints across all empirical cases?	Deductive, theory testing approach. Self organising teams based on complexity theory? Only use necessary, not sufficient conditions for their analysis.
Kogut, MacDuffie & Ragin (2004).	62 plants (57 used for one outcome, 45 for the second)	Fuzzy set variant used. Outcomes x2: productivity, quality 6 variables, of which 3 are described as 'controls' (normal exp/stats sense).	90 plants contacted (representing 24 producers in 16 countries, approx 60% of world assembly plant *capacity*) Survey responses received from 70 plants, which were divided into 2 categories "on the assumption that the production systems for these product types might differ substantially". They exclude any incomplete surveys from the analysis.	'Case' data collected through surveys, 60% response rate. This paper follows Ragin's statistical approach, there are loads of equations and they cover the idea of 'not important' options (i.e. beyond 1 and 0).
Kogut and Ragin (2006).	1- 49 countries 2 – 20 countries	1 - 2 dependent variables (outcomes), 4 independent variables (conditions). 2 – "six time-invariant coordination variables in our analysis of average growth rates, dichotomized into faster growing vs slower growing."	1 - "all the OECD countries plus middle and low income countries" 2 – "Hall and Gingerich (2001) focus on testing the theoretical claim of the weak middle by looking at the institutional complements and their relationship to growth for 20 rich OECD countries in the period 1971–1997." They are specifically interested in the 'limited diversity' of a population, so the sampling appears to reflect this in that unobserved cases are expected not to exist.	This is a secondary analysis two studies initially done using normal quantitative methods.
Kahwati et al. (2011)	22 Project sites (11 high achievers and 11 low	17 conditions, identified from the literature	They purposively select from the top and bottom of the outcome range (they want	This is a MM study, with QCA being augmented with qual

	achievers)		to find the differences between high and low achievers) and then sample for variety in complexity and geography "to ensure a broad representation" – i.e. generalisability	interviews to elaborate on the conditions (what exactly is important about the useful ones?) They also embed a quant element in the stats analysis of patient records at each site.
Marx & van Hootegem (2007)	16 jobs (reduced from 19 initially), each containing on average 15 workers.	6 conditions identified, but the effects of three are known so these become 'constants' that are used to direct the sample. Outcome determined by clinical tests	They draw a grid using the 3 'known' conditions, and limit cases to those occupying a given area of it.	MM study – they add a qualitative analysis to identify mechanisms.
O'Neil (2008)	53 visual artists	5 common themes are identified in the paper, although it is apparent only the most frequent are being considered and others exist. No outcome is defined.	Sample restricted by UoA and a chosen location. Variation in the artists medium, sex, age, ethnicity was sought. Snowball sampling.	This is an example of typology building, considering which 'conditions' are found together and which not. MM study, although this is not made clear.

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Reconciling Low Carbon and Adaptable Design

Participant Information Sheet

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What is the purpose of the study?

The examination of a retail scheme provides a unique opportunity to study a building subject to frequent change, exploring how can adaptability make the building more responsive and how change impacts on the sustainability of the building?

We hope to draw conclusions on the effectiveness of the scheme design in permitting later change, and provide insights into how the adaptability of future schemes could be improved so as to minimise costs and allow a greater number of changes to occur.

Who is doing this research and why?

This case study forms part of a four year ESPRC funded Adaptable Futures project, and is being undertaken by researchers from the Adaptable Futures team.

The Adaptable Futures project is investigating adaptability of the built environment through a combination of detailed review of the existing literature, industry workshops, interviews, and case studies. The project is due to conclude in September 2011.

Once I take part, can I change my mind?

Yes. After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please contact us using the details above. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

How long will it take?

The interviews are expected to last approximately one hour. Interviewees may be asked to provide, where appropriate and available, additional information they have referred to during the interview. If you permit it the interview will be recorded.

What personal information will be required from me?

You will be asked to provide general information on your job role and professional background.

Will my taking part in this study be kept confidential?

It has been agreed that the St David's Partnership will be able to view and comment on all outputs, and also retain the right to restrict the publication of commercially sensitive material. Individuals will be anonymized but it is possible the scheme (St David's 2) and client organisation (St David's Partnership) may not be.

All raw data will be kept confidential and in accordance with the Data Protection Act. Information will not be passed to other researchers without prior express permission of participants.

What will happen to the results of the study?

The research team hopes to produce a report for presentation to the St David's Partnership in early June, detailing the initial findings and recommendations of the study. Findings relevant to the wider research community may be submitted for publication.

What if I am not happy with how the research was conducted?

The University's policy relating to Research Misconduct and Whistle Blowing is available online at www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm.

Loughborough University

Recipes for Low Carbon, Adaptable Design

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name ______________________________

Your signature ______________________________

Date ______________________________

Admiral HQ, Cardiff

1. Can you explain the rationale for the project, summarising the brief and key objectives?

2. Have there been any particular challenges or successes?

3. Has the Cardiff location (e.g. local planning regulations, land prices) had an effect on the development? How?

4. Has the building's function as a call centre influenced the design? How?

My project is looking at how non-domestic building designs integrate the demands of low carbon policy and aspirations with the need for flexible, adaptable structures and spaces. With this in mind:

5. Do you see low carbon policy as influencing how buildings are designed for adaptability? Does the Admiral HQ provide any examples of this?

6. Are low carbon and adaptable design issues congruent and synergistic requirements, entirely separate, or contradictory? Again, could you evidence this with examples from the HQ building?

Adaptability

7. Would you describe the building as flexible or adaptable? Why?

8. Were issues such as multi-occupancy, future flexibility and alternate use capability were taken into account? Could you describe how?
   - Is the building designed to allow sub-letting?
   - Is there any provision for floor area expansion post construction?

Low carbon design

9. Would you describe the building as low carbon? Why?

10. Are you contractually obliged to deliver a certain level of energy performance?

11. Stoford's "*Green Policy is based firmly in the grounds of delivering buildings with intrinsically low energy requirements in the most efficient manner possible, whilst providing effective, comfortable, functional and economic workspace that can be simply adapted for the different requirements demanded of a modern workplace*." Can you describe how the Admiral HQ building delivers on this?

12. Why an EPC target of 40?

13. Are you still using BREEAM 2008 offices? What is the expected score? (The Design and Access statement gives a pre-assessment score of 68% which is below Stoford's Excellent target)

14. Is the soft landings framework being applied, or will there be any post occupancy evaluation undertaken?

15. Is embodied energy considered? e.g. minimising waste on site, green guided rated materials

16. Did you undertake a low and zero carbon technologies feasibility study for BREEAM ENE05 credit?

    - Which technologies were unfeasible and why?
    - Were any technologies assessed as suitable?
    - Could I have a copy of the report?

Procurement

17. Is this a pre-let of a building you would have built anyway, or were you approached by Admiral?

18. The planning drawings suggest a base build and tenant fit out:

    - Is the design team the same for both elements?
    - Is the contractor the same for both elements?
    - What is provided as base build and what is not?

19. How involved with the build is the tenant? Are any elements of the design a direct result of their involvement?

The Climate Adaptation and the report by the BRE

20. Are you aware of the study of the building undertaken by the BRE with funding from the technology strategy board?

    - Did you change anything as a result of the BRE's findings? Why / why not?

21. Do you think the building is resilient to climate change? Why?

Quick questions about the building specification:

- The planning application makes reference to a solar thermal system; is this being installed?
- Is the PV being installed? On the roof or integrated with the cladding?
- What is the floor loading specification?
- Is any of the construction modular?
- The columns appear to be located centrally and at the perimeter – is there a spatial planning grid for partitioning / services imposed over this? What is it?
- What is the floor to floor height?
- Is there any plant in the basement?
- Is the drainage strategy based around attenuation tanks or have SUDs principles been incorporated?

Wyre Forest Schools

The adaptation report

Why do you think the new build schools performed so well under the future climate files?

- What features of the buildings make them particularly resilient?
- The report mentions that both schools are of heavy weight construction – can you describe the structure to me?

Both the schools have really comprehensive SUDs strategies, which creates flooding resilience. I'm curious as to whether this standard practice for your school designs?

Why did you apply for the TSB funding?

Why did you choose to model with the 2050 data?

Do you have any views on the usefulness of BB101's overheating criteria?

Why did you adopt a progressive, kit of parts approach for Franche? Where did the idea come from?

- If the new schools had overheated – would you have used the same approach or something different given the ability to design in resilience?

About the buildings generally

Can you describe the basics of the servicing strategy to me? (This is really difficult information to find but it's extremely helpful when comparing buildings).

- How is heating distributed through the building? - underfloor, radiators or an alternative?
- How are other services, such as lighting and data, distributed?
- How does the servicing strategy address sustainability?

Examining the planning applications, the two schools have several differences in their design – why is this? The particular differences I've noticed and found interesting are:

- Offmore has no PV panels indicated, while St Catherine's has a small area shown.
- The planning drawings for St Catherine's show a moveable wall between the main hall and the smaller hall, presumably so they can be combined for use as a single large space. Offmore has the halls separated by a corridor space.
- St Catherine's has dedicated group rooms and cloakrooms, whereas Offmore school seems to utilise enlarged, open corridor space.
- St Catherine's has entrance lobbies while Offmore does not. (What is the purpose of the lobbies?)
- Did the schools have the same budget? I gather Offmore is a 1.5FE and St Catherines a 2FE?

The planning statements for the schools mention that "the brief is based on the criteria set out in Building Bulletin 99". BB99 has adaptability and flexibility as one of its "key requirements" – was this incorporated in the brief? If it was, how did you address it in the design of the building?

- Classrooms are all approximately the same size (60m2), why?
- None of the classrooms are designed to connect together?
- Check floor to floors
- Are either of the schools scaleable? Response to policy D19.

Sustainability Strategy

I have the BREEAM rating for Offmore from the BRE website, (which did really well in achieving an Excellent rating) – was St Catherines also rated under the scheme?

- Offmore has a slightly better EPC asset rating than St Catherine's – are there any obvious reasons why?

How well are the schools performing relative to their modelled / designed performance?

Does Offmore have sedum roof to the single storey areas? The planning documentation describes a zinc roof, but the pictures I've seen look very grassy!

Most of the schools I've been looking at have a very 'green bling' approach to low carbon technologies – more is better, with demonstration wind turbines being a particular favourite. The Wyre schools seem to take a more restrained approach. Was this a particular choice or the result of external pressures?

- Why biomass boilers? Were any other low carbon technologies incorporated?

The adaptation report mentions that a small budget was found for some works, not those suggested by the report, at Franche – do you know what work was completed?

As the scheme was designed 'in house' did you use a more traditional procurement method?

Did you have to compromise in any way?

General Questions

My study is using 24 of the Technology Strategy Board's Design for Future Climate Change funded projects as examples of designs that have actively engaged with adaptation and mitigation to understand how the two aspects interact. The study uses a broad definition of adaptation encompassing ideas such as flexibility in space planning, replaceable facades or services and change of use. The project aims to better understand how we can design flexible, resilient and low carbon buildings.

1. Why did you get involved in the TSB competition?

2. Why didn't you use any of the 2030 files? And why only one percentile?

3. AECOM seem to have an established process for climate adaptation, in comparison to many of my other cases who've started from scratch. Is the view of you as 'experts' a correct one?

4. Why separate teams for the building designs and climate adaptation studies?

Technical Hub @ EBI

5. What do you know about the 'sustainable' features of the design?

    - Why A/C for an 'eco' building?

    - The energy strategy seems to suggest Part L 2010 as the limit to energy efficiency and that to go beyond this renewables are required – is this a correct interpretation?

6. What do you know about the building generally?

    - Is any of the construction standardised?
    - Internal walls – stud partitions?
    - Cladding – load bearing? Removeable?
    - Service distribution (ceilings?)
    - Is the lab / office furniture fixed?

7. You essentially find the building is already well adapted – correct?

    - What do you think in particular was important for this? [esp. given it's basically a glass box]
    - If you had been able to influence the design earlier – would you have suggested more fundamental changes?
    - The cost planning in the AR demonstrates that the extra A/C required will increase costs from £71k to £73k pa between now and 2080. After discounting, what would the point be in adaptation as they believe the building is not going to overheat?

8. "The building is projected to be operational until around 2080" (ARv3, p16) Is this simply the design life of the building?

    - How long does the EBI Hub funding last for?
    - What is the intended use of the building beyond this?

9. The AR models the effect of reducing internal gains "down to figures considered to be achievable either today or in the near future", but the figures are not sourced. How did they decide what was "achievable"?

10. The AR authors suggest that insulation is not v helpful in keeping a building cool, which is in contradiction to other reports?

11. You are one of the few projects to attempt flood modelling in any depth – why?

    - You fully model the flood plain from first principles, but are only interested in river flooding when you do this, you do not model the effect of surface water and there is little consideration given to oversizing the drainage pipes (the uplift seems to be considered a satisfactory solution, which is perhaps rather contrary to their scathing critique of the EA's flood uplift method.)

Technical Hub @ EBI

12. Why are they refurbishing the building – what's LSHTM's primary driver?

13. Is the refurbishment going ahead? [the report suggests cost issues]

- What's the budget? (TSB has it at £10M)
- How far have they got?
- Are any of the climate adaptation measures being adopted? Which ones and why?

14. Do you have a floor plan / section I could take away?

- Floor to ceiling heights
- Plan depth
- Frame – grid pattern?
- Cladding – part of structure?
- Daylighting?
- How are the services distributed?

15. The report talks a lot about the constraints of working within an existing heritage protected building. How easy was the building to adapt? What helped and what hindered? [adapt features]

- Impact of the desire for a lower energy consuming building?

16. You're forced to install A/C for peak lopping to restrict overheating to comfortable levels – do you see climate adaptation and mitigation efforts coming to conflict in the future?

- There is some limited detail of the overlap between the CA suggestions and the refurbishment package – can you elaborate?

17. You use adaptive comfort to offset the energy impact – will CIBSE's move to adaptive comfort based design have an influence on our ability to use this 'slack' in future?

18. Low carbon targets? There is a reference to BREEAM very good, is there anything more specific?

Edge Lane

My study is using 24 of the Technology Strategy Board's Design for Future Climate Change funded projects as examples of designs that have actively engaged with adaptation and mitigation to understand how the two aspects interact. The study uses a broad definition of adaptation encompassing ideas such as flexibility in space planning, replaceable facades or services and change of use. The project aims to better understand how we can design flexible, resilient and low carbon buildings.

1. Why did you get involved in the TSB competition?

2. Why did you get Oxford Brookes involved?

3. Your paper talks about incremental and sequential upgrading, am I right in thinking your approach to the climate adaptation strategy was one of providing a good base building that would allow this to happen?

    - The Adaptation report talks about building manuals which allow users to "deviate knowingly from the way in which the building was conceived originally, or enhance or extend the concept sympathetically." - What kinds of things go in these manuals?

4. Your paper says it "explores what designers of the built environment can do in the context of such change, to add value to their clients' estates, <u>by changing the way they design</u>." – if you had to summarise, what would these changes to the way they design be?

    - The provision in the structure for a green roof obviously helped – is this still in? Are there any other features of the base design that were particularly helpful?

    - The adaptation report looks at altering the construction to a heavy weight frame. I know the building is for the most part single storey and so a framed choice was unlikely, but I'm curious as to why a timber frame was chosen? [Prompt him about the structure of the internal and external walls]

5. There is an article in the Liverpool Echo early in the year which suggests the building would not go ahead at the Edge Lane site after difficulties over the sale of land – is this true? (Medical Architecture's website lists the project at stage E/F)

6. How much is the project worth? I've got conflicting figures from £18M (MA website), £23.5M on the TSB factsheet and £30M in the Trust's press information – who's right?

Can we talk about BREEAM? It's referenced heavily in the adaptation report – you talk both about it not demanding enough adaptation and also of the ability to use it as a form of design defence in the closing out the contractors proposals. Was it a help or a hinderance? What about its effect on mitigation – you have a brilliant predicted EPC rating - would the building have been as energy efficient as it is without the BREEAM requirement?

- The low carbon / energy features of the building seem to have been somewhat agonised over – they were in, they were value engineered out, the adaptation report suggests putting them back in. In the absence of planning, what would have been the initial approach – there seems a heavy focus on energy efficiency?

7. In the adaptation report it states that medical architecture were “pre-disposed to incorporate adaptability in its broadest sense” at the early stages – can you talk a little bit about how the practice is ‘pre-disposed’ and how this manifested in the design?

   - How are the services distributed? With a normal hospital its suspended ceilings but this is a secure facility.

   - One of the drawings I have identifies as site for future expansion – why was this included?

8. Thinking generally, in your experience of hospital design, does the NHS, at trust level, not in the lofty standard setting level, prioritise the flexibility or the efficient operation of their facilities? Is one more important than the other?

9. Are the ambitious low carbon targets the NHS has for its estate affecting the design of their new facilities? In particular their flexibility?

Central St Martins / University of Arts London (16)

My study is using 24 of the Technology Strategy Board's Design for Future Climate Change funded projects as examples of designs that have actively engaged with adaptation and mitigation to understand how the two aspects interact. The study uses a broad definition of adaptation encompassing ideas such as flexibility in space planning, replaceable facades or services and change of use. The project aims to better understand how we can design flexible, resilient and low carbon buildings.

1. Did you know a TSB climate study was performed for UAL?

    - Why nanotechnology?
    - What did you think of the study?
    - Have you seen any of the presentations or maybe talked to any of the other teams? What did you think of them?

    - The TSB study concentrated entirely on overheating, but in 2050. Anecodatally (or otherwise!) how did the building standup during this summer's heat wave?
    - Did you think about overheating or any other climate change impact – flooding, drought etc. during the design?
        - What did you consider?
        - Why did you look at it? (The M&E consultant appears pretty clued up - they produced one of the best look at climate impacts I've seen from the reports, but it's buried in an appendix)
        - Has the building got any solar shading?

THE DESIGN BRIEF

2. How involved in the briefing and design stages were you?

3. Why the move from Holborn to King's Cross?

4. The AR talks a lot about daylight, how important was this to you?

    a. What other things were central to the brief?

    b. Did you ask for it to be adatable?

ADAPTABILITY

The building has been touted by the architecture media as highly flexible and encouraging of its occupant to customise and appropriate – is this the reality?

- How well is the street working as a space? What was it supposed to do?

- Did you bring the old CSM furniture with you?

- Have you added any new furniture, especially ADJUSTABLE stuff – walls, benches

The planning drawings show a very basic room layout with no small spaces , I'm guessing you broke the space up a bit when you moved in?

- What types of spaces do you have? (sizes)

How long does UAL plan to stay at XC? Does it expect to grow?

Why shell and core?

What was the budget like? Some of the media reporting suggests that some of the raw, adaptable edges might be an incremental, as we have the funds build? If you'd had a bigger budget would it still be as adaptable?

LOW CARBON

I have conflicting BREEAM evidence – Very Good or Excellent?

Why did the Western Shed get a better EPC and BREEAM result?

Compared with my other Higher Education case I have lots that says this building is adatable and not a lot that says 'green'. Was sustainability a big issue for UAL?

- What about specifically energy efficiency?

The DEC shows you got worse from 2012 to 2013 – is that because 2012 was a part year (or people were still moving in)?

Other parts of XC are all singing all dancing with their green technologies. The planning application suggests the heritage status of the granary would restrict the technologies applicable – what got put in and why?

- Is there anything you would of liked you couldn't have?

QUICK FIRE BASIC QUESTIONS

1. Cooling – displacement ventilation or chilled beams?
2. Did you add insulation to the envelope?
3. Frame type – concrete or concrete/steel mix?
4. Column grid – regular? Span?
5. Internal walls - stud partitions?
6. Are there windows onto the street and if there are do they follow any kind of pattern?
7. Raised floors, suspended ceilings, neither? - Where are the services?
8. Can the occupants control the HVAC / daylight etc. locally?

Case 20 and 24 Interview Schedule

1. Why did you get involved in the TSB competition?

   - (20) Was the TSB project targeted as a way to keep the design work afloat between phases while searching for further funding?

2. What was your involvement with each of the projects?

3. At what design stage were the climate adaptation studies undertaken? (20) was during phase 1 works or after?

4. The two schemes have very different approaches –

5. (24) talks about the main design and climate change teams being the same, but also talks about informal communication between teams. Can you explain a little about the structure of the teams?

What measures were installed as a result of the studies?

6. (20) What work was completed prior to the loss of funding and what was abandoned?

   - Were any of the Low Carbon improvements installed e.g. insulating the roof, ASHPs, PV?
   - [go down the LC checklist]
   - Was the demolition of structures within the courtyard completed?
   - The factsheet suggests blinds and ceiling fans were installed on the instruction of the client – is this correct?

7. Did the basic design (24) have any shading incorporated? What did the client agree to add as a result of the study?

8. The appendices to (24) detail changes to lighting and equipment efficiencies – were these recommended, and were they incorporated?

9. (24) suggests that exposed thermal mass was incorporated into the design - was this in the form of exposed ceilings as per the modelling? Where exactly?

10. (24) has an atrium "to facilitate ventilation across the floor plates" but the ELD removes it – are atria helpful to ventilation or an architectural feature?

11. How interested in the climate adaptation study was the client?

Climate Adaptation

12. Do you think the buildings are resilient to climate change? Why?

Approach

13. You chose not to examine ground heave, drought, flooding or drainage (above and below ground). Is this because you believe the building to be adequately designed for these risks? Can you explain why with reference to aspects of the building design?

14. Why did Church View use the UKCP02 projections and not the Prometheus data?

15. Arup seem to have an established process for climate adaptation as part of their overall climate change approach, in comparison to many of my other cases who've started from scratch. Is the view of you as 'experts' a correct one?

    - You're approach is more qualitative than other 'experts' e.g. AECOM, who concentrate on hard numbers – is this a correct interpretation? Why this approach?
    - For an architect led report (20) is extremely quantitative – why the emphasis on the quantifiable?
    - Do regularly apply the climate change appraisal framework?

16. Why did you decide to examine an ELD?

17. I think you applied for a smaller grant than virtually all the other projects (£65,668) – why?

18. The report suggests the project was to be tendered traditionally; did this have an impact on the study and/or the building's design? How might it have been different under D&B?

Adaptability

19. (20) is wholly incremental while (24) changes the design – was one approach was more effective?

20. Given that climate change adaptation strategy you adopt is partly (24) or entirely (20) incremental – how well suited to progressive change is the building? – assumption of refit-ability

21. Would you describe the building as flexible or adaptable? Why?

    - The space is an old building, originally designed as an art college. How easy was the space to convert – for climate change and for change of use generally?
    - The design and access statement talks about the building being part of an expansion strategy - is there any provision for expansion post construction?

Low carbon design

22. Would you describe the building as low carbon? Why?

23. Can you describe any features of the building you consider are significant to the building's carbon performance?

24. (24) Would the client have used BREEAM if it wasn't a condition of planning?

    - What were their main interests? (The Design and Access statement talks about "expansion", "connectivity" and "highest quality affordable" as client criteria)

25. No renewables (other than the CHP) are included for (24) – why?

26. Your facade study (24) looks at the embodied energy of the various solutions – is this a normal practice? Was embodied energy a consideration for other aspects, or the main design?

27. Did you complete the mitigation side of Arup's Climate Change Appraisal Framework (CCAF)? [Can I have a copy?]

My project is looking at how non-domestic building designs integrate the demands of low carbon policy and aspirations with the need for flexible, adaptable structures and spaces. With this in mind:

28. Do you see low carbon policy as influencing how buildings are designed for adaptability? Does either building provide any examples of this?

29. Are low carbon and adaptable design issues congruent and synergistic requirements, entirely separate, or contradictory? Again, could you evidence this with examples from the buildings?

30. Was there intent for the buildings to be low carbon and adaptable from the client?

Building Specifications (quick)

- Development cost?
- Is any of the construction modular?
- Who is the architect (24)?
- Who is the client (20)?
- Planning suggests the facade to be brickwork (possibly as a result of the planning process) – was it changed from the Metsec the AR suggests?
- (24) is a concrete structure – is this plain slabs? Is anything, e.g. underfloor piping, being cast into the structure?
- Do you know anything about the structure of the (20) –load bearing masonry or framed? Is there a structural grid?
- Can the occupants self-manage their environment?
- Is there is a BMS?
- What is the service provision like – uniform? Flexible? E.g for (24) could you move the space types between levels within the current provision?
- Has the building's function influenced the design? How?

Case 20 and 24 Interview Schedule

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28. Do you see low carbon policy as influencing how buildings are designed for adaptability? Does either building provide any examples of this?
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- Can the occupants self-manage their environment?
- Is there is a BMS?
- What is the service provision like – uniform? Flexible? E.g for (24) could you move the space types between levels within the current provision?
- Has the building's function influenced the design? How?

Site J, Brighton

Icebreakers and scoping

1. How did you get involved with the TSB project?

2. What information about the building did you have available to you?

3. Why were Hyde interested in participating?

4. Can you explain how the project was organised?

    i. What are the design team like?

The Project

5. What were your general impressions of the building?

    - Good design?
    - Any particular adaptable or low carbon features?
    - Favourite or particularly naff bits of the design?
    - What's unique about the project?

6. Would you describe the building as low carbon? Why?

The Strategy

7. How would you describe your approach?

    i. Was the intent always to be innovative?

    ii. Why did you make the balcony adaptation refit-able?

        - What made the building suitable for a refit-able solution?
        - For other elements (water conservation) the report frames refit-ability as problematic, in allowing tenants to 'undo' adaptation work. Why the difference?

    iii. Why did you opt for energy efficient adaptations?

        - Did the decision not to reduce insulation restrict your options in any way?

8. What else influenced the strategy?

    i. Did the Brighton or NEQ setting influence the approach?

        - Did the attitude of the planners affect the solution choice?

    ii. Did the domestic setting or affordable elements suggest or preclude certain adaptations?

9. Do you think the strategy was a success?

    i. Did the client adopt any of the measures you suggested?

    ii. Did the client adopt any measures you didn't suggest?

My project is looking at how building designs integrate the demands of low carbon policy and aspirations for flexible, adaptable structures and spaces. With this in mind:

10. Do you see low carbon policy as influencing how buildings are designed for adaptability? Does the building provide any examples of this?

11. Are flexible low carbon buildings possible?

    i. The report identifies conflict between RWH pipework and the need for adaptable homes

12. Are low carbon and adaptable design issues congruent and synergistic requirements, entirely separate, or contradictory? Could you evidence this with examples from the building(s)?

Quick questions about the building specification:

- Is any of the construction modular? E.g. bathrooms, cladding…
- What type of frame is the building?
- Would you describe it as simply constructed?
- Is there any oversizing of the M&E systems?

Hinguar Primary School

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The adaptation report

1. Why did you apply for the TSB funding?

   - The AR suggests the aim was to develop a 'toolkit of parts' – was this an exercise in widening your offer?

2. How did the schools location in a coastal flood plain influence the design?

   - Did it make you think about climate adaptation earlier?

3. What did you learn from the project?

4. Do you think the school performed well under the future climate files?

   - Would the pre-VE scheme have been more adapted, or less?

5. You've used the 90th percentile data – did this make it more difficult to suggest cost-effective solutions?

6. The report talks about the trade-offs in maximising winter solar gain, minimising it in winter and ensuring there is sufficient daylight. How difficult was this balance?

About the buildings generally

7. Where did the design concept come from?

   - What were the main things that influenced how the building was designed?

8. Quick questions about the building:

   - The D&A suggests the school has sprinklers?
   - The original design (pre-TSB) already had a fairly onerous glazing G value specified – why?
   - What are the floor to ceiling heights?
   - Can you give me an idea of the structure – spans and the regularity of the grid?

9. The D&A and the AR articulate a desire to go beyond part L. Why, and how did you plan to achieve it?

   - There was a lot of low / zero carbon technologies included in the original scheme – why?
   - The original scheme has both horizontal and vertical GSHP options illustrated, with the former being cheaper. Was this the only driver for the choice of one over the other?

10. Thinking about BB99's definitions of adaptability and flexibility how did you address it in the design of the building?

    - How much say did the school have in the flexible, shared space arrangement that seems to have been adopted?
    - Accommodating the community – ability to isolate parts of the building. How did this affect the building design?

11. The building is designed to be extended – other than the extra loading how else was the addition accommodated?

    - How did you ensure the phase 2 design would be coherent with phase 1?

12. Is the building sustainable?

13. Have you any post-occupancy feedback?

    - Are they using the flexible partitions?
    - What do they think of their new school?
    - Do you have any idea how well are the schools performing relative to their designed performance?

14. At some point in the second half of 2010 the school's budget gets cut:

    - How did you approach making the building cheaper? (remove items, lower specification, smaller, complete redesign?)
    - The TSB has the schools budget as £5.2M – is this pre or post cuts?
    - Could the school add the low carbon technologies in later if the funds become available?

15. There is a comment in the AR about Gove's schools: "'budget' standardised school designs for now, rather than allowing sufficient flexibility for the future". What is wrong with Gove's schools?

    - Were there any elements of standardisation within the school design?

16. The BSF budget school has a really comprehensive SUDs strategy that has double the capacity for attenuation of the later scheme. What was the driver for such a comprehensive attenuation strategy?

    - Why was the more onerous SUDs attention scheme (with 450m3 of storage v the 266m3 installed) omitted? VE? If the increased volume was not required by EA / planners (as would be suggested if they could VE it out) what was the original driver for having twice as much attenuation? OR did they engage in more detailed drainage modelling to prove they didn't need it (and therefore let them VE it out)? - See AR, p21.

Source	Measure Name	Requirements	Type	Typology	Adaptability Type	
Geraedts & Vrij (2004)	Transformation Meter	Convert to use, projected income, estimated project cost	Checklist	Offices	Convertible	Three assessments - a preliminary 'quick scan', an economic feasbility assessment and a more detailed checklist of things to consider. Requires knowledge of new use to be most effective.
Remoy & van der Voordt (2007)			Checklist	Offices	Convertible	
Langston (2008)	Adaptive reuse potential (ARP)	Costs, various variables for the building.	Analytical, qualitative assessment scales			Actually measuring obsolence (so which buildings would be most economically / sustainably sensible to adapt) rather than measuring adaptability directly.
Larseen & Bjorberg (?)	Multiconsult tool	Building survey, access to users (functionality element only)	Critical Parameters, Qualitative assessment scale	Building portfolios (schools, hospitals)	Adjustable, Versatile, Refitable, Convertible	This uses 1) a matrix of adaptatbility parameters, with a series of descriptions against which the building can be mapped 2) a matrix of required parameter values for a building and what it's proposed adaptation use is to asssess the match
Ross, Rhodes and Hastings (2008)	Filtered Outdegree Method	Cost and benefit for options, specification of multiple (all?) change options. Designs (options) envisaged as variable sets.	Analytical	Design		"the outdegree...is the number of possible ened states for a design when analyzed within a tradespace network" (Shah et al., #?). This method accounts for adaptability being a product of how much you are willing to pay.
Li, Xue and Gu		Change costs (parts, labour), probabilites for different changes, ease of change	Analytical	Design		Assesses extenability of functions, upgradabilty of modules and cusstomizability of components as aspects of adaptability. Largely based on cost of change.
Fletcher, Brennan and Gu (2009)	Adaptability Quantification Framework		Analytical			Based on an mathematical examination of the systems product architecture. Mathematically complicated, difficult to understand.
Olewnik and Lewis (2006)	DBD Framework for flexible systems	"Multiple performance criteria athat the system needs to be be optimal for", specification of design variables	Analytical	Design		This is a simple optimisation technique, so it assumes you know what you are optomising for.
Kincaid (2002, 2004)	Use comparator	Requires access to spreadsheet (?), basic building properties (slab loads, facade type, floor - ceiling heights)	Critical parameters, objective assessment with some qualitative interpretation	Reuse, all types	Convertible	13 Charateristics, 77 use classes. Effect of partial demolition / extension considered seperatly (i.e. tool only considers adaptation without significant strutural alteration).
Shah et al. (200?)	Change Propogation Analysis (CPA - Suh, 2005; Eckert et al.,2004)	Detailed knowledge of the system to calculate change paths, scenarios, likelihood etc.	Analytical, DSM.	Design	All	As this is meant as a design tool, no indication of an apt CPI (change propogation index) is given to benchmark against.
Tilstra, Seepersad and Wood (2009)	HD-DSM	BoQ, all interactions (multiple types) across all elements	Analytical, DSM / Checklist	Design		Very data intensive, with mutliple steps required to create the DSM. Considerable room for error in systems with large numbers of components. Only guidelines that are quantifiable within the DSM (which they creatively manage with quite a few) are possible to assess.
Lifetime Homes	Code for Sustainable Homes, Credit HEA04	Design documentation	Design guidelines	Housing	Adjustable, versatile, refitable	Design guidelines for five principles: inclusivity, accessability, adaptability, sustainability, good value. So not an ideal measure.
Cowee & Schwehr (2009)	Flexibility Degree	Cost, time, effort for proposed change	Qualitative assessment		All	This is a nice simple method, with a useful diagramatic representation. No single measure proposed, and requires a change scenario to make sense.
Russell & Moffat (2001)			Checklist, qualitative assessment statements			Also propose an elemental method, whereby individual building components are assessed rather than the whole building.
Remoy, de Jong & Schenk (2011)	n/a		Qualitative assessment, Scenario			Costs the implications of changes required for various invisaged changes. They first use a qualitative assessment to ascertain which of their buidling types is the more adaptable - i.e this is not overtly presented as a measurement method.
Saari and Heikkila (2008)	FlexD (Flexibility Degree)	Cost of rehabilition, cost of comparable new build.	Analytical, cost based		All	Soley based on the cost of adaptation works. Assumes building exists and change is known.
Arge (2005)	n/a		Checklist, statements defining 'adaptable' performance			This method is component based, i.e. it assesses individual elements rather than looking at the building holisitcally. Comparative rather than absolute assessment.
Atlas & Ozsoy (1998)	n/a	Floor plans (to use as is also require users, multiple versions of each building)	Spatial, statistical (POE)	Housing	Scaleable	Three potential measures observable in their approach: 1) potential for growth 2) alteration percentage (amount of possible growth actually undertaken) 3) users who found flexible % - they can do tis as they have multiple versions of the same four house types.
Century Housing System						
Minami (2007)	n/a	Access to residents, longitudinal data (multiple records at occupation + 2 more); original floor plans	Spatial, POE	Housing	Versatile	Retrospective look at the ways in which residents used an installed moveable partition and storage systems. Presents counts (%'s) of the rearragements relative to the units without the adaptable systems installed.
Cuperus & Brouwer (1992)	Capacity to change index (CTC)	?	Qualitative assessment			3 aspects of a buildings capacity to change are listed, and it hints that DSM can be used to measure one of them but lacks any detail on the others, or how the three aspects might be combined.

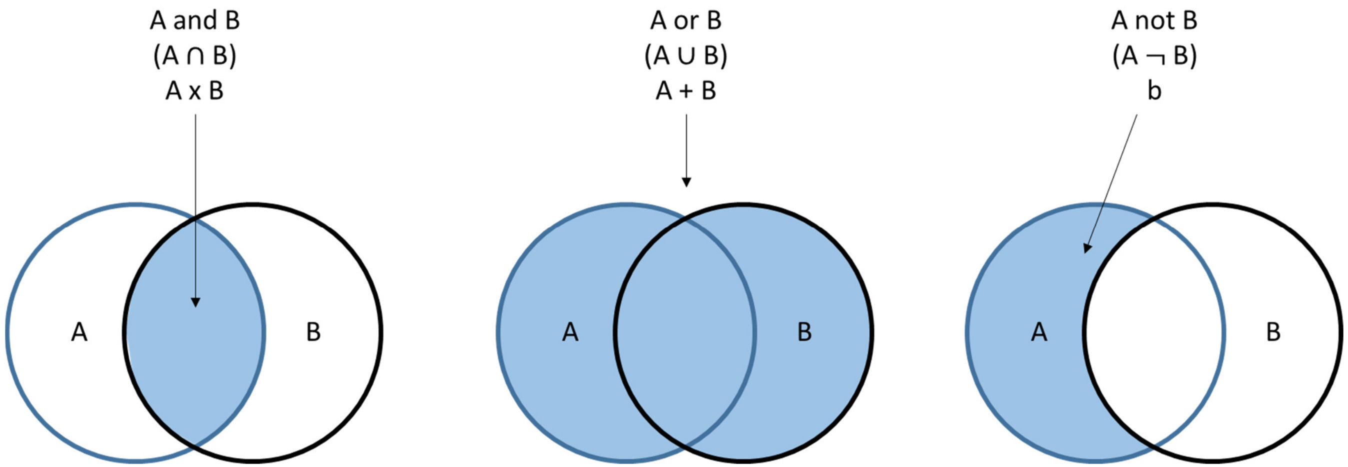
Measure	Designed to measure	Units / name of measure	Availability	Coverage
Display Energy Certificate (DEC)	"intended to provide information to operators of larger public building about how well they are actually being run, based on metered consumption data" (CIBSE TM46, 2008)	Operational Rating (linear scale, 0 = zero net emissions, 100 = 'median' stock CIBSE TM46 benchmark)	DECs are available from www.ndepcregister.com using a post code search	All large public buildings (>1000m2) "that are occupied by a public authority or an institution providing a public service to a large number of people, and are frequently visited by members of the public" (CIBSE TM46,2008)
Metered Energy Use	Primarily for utility charging, newer buildings may have ancillary sub meters for monitoring purposes.	kWh, convertible to kWh/m^2 if GIFA known	1) via building owner - likely confidential and difficult to obtain 2) direct measurement - costly, time consuming, requires access to meters etc.	All buildings, though metering may be at a level inappropriate for the analysis (per tenancy, campus wide etc.)
National Calculation Methodology (NCM) outputs (BER/DER, SER, TER)	Designed to satisfy the requirements of the EBPD, - comparison of buildings based on their "standardised [energy] performance".	BRUKL output gives kgCO2/m2, kWh, building area, Key U-values	From case - Part L compliance outputs	Required for statutory approvals for all newly constructed buildings
Standard Assessment Procedure (SAP)	As NCM (SAP is the NCM for dwellings)	Dwelling Emission Rate (DER) in $kgCO_2/m^2$	From case - Part L compliance outputs	Required for statutory approvals for all newly constructed dwellings
ENE01 BREEAM credit (interim assessment)	ENE01 – Reduction of CO_2 emissions aims to "recognise and encourage buildings designed to minimise operational energy demand, consumption and CO2 emissions. (BRE, 2011). It is a weighted compound measure inclusive of demand (built form and fabric efficiency), consumption (systems efficiency) and emissions (renewables)	Credits (max 15), aligned to a verbal rating (very good, excellent, outstanding)	From Case - Either: 1) the data for the BREEAM assessment OR 2) input NCM data to the BREEAM calculation tool	BREEAM accredited schemes (credit calculable for non accredited schemes with appropriate data - see left)
Building Services Modelling Outputs	As required for design - thermal performance, electrical and other loads etc.	various	From case - requires a more open approach to data collection that may be misinterpreted / result I too much data / take too much expert time to compile	Simpler buildings unlikely to have undergone extensive modelling.
Energy Performance Certificate (EPC) / Asset Rating (AR)	Asset Rating reports on "the intrinsic, as-built energy performance based on standardised operating patterns and internal conditions for the mix of activities taking place in the building." (SBEM technical manual DCLG, 2011) "energy rating for a building which is based on the performance potential of the building itself (the fabric) and its services (such as heating, ventilation and lighting)." (DCLG, 2008)	Asset Rating (linear scale, 0= zero regulated emissions, 50 = SER (standard emissions rate = notional building x 0.765)	Domestic EPCs can be retrieved by postcode search from: www.epcregister.com, non-domestic EPCs available from www.ndepcregister.com.	EPCs are required following construction, sale or let for any building that is expected to have a 'conditioned climate'. EPCs are not required for: places of worship; temporary buildings (> 2years); stand alone buildings with a total useful floor area of less than 50m2 that are not dwellings; industrial sites, workshops and non-residential agricultural buildings with low energy demand; buildings due to be demolished.
Code for Sustainable Homes (CSH) Category 1	Energy and CO2 emission reduction measures in dwellings (ENE1 - limit CO2 emissions arising from the operation of a dwelling and its services; ENE2 "improve fabric efficiency thus future proofing reductions in CO2 for the life of the building; ENE7 - "encouraging the specification of low and zero carbon energy sources" to minimise CO2 emissions (CSH - DCLG, 2010)	Credits aligned to verbal 'levels' (qualitative indicators of performance well understood by industry)	SAP Worksheet, Building Regulations compliance documents	Dwellings only
LEED Energy and Atmosphere credits	Minimisation of energy costs for user; minimisation of impact of emissions. Based on reduction from ASHRAE 90.1-2007	Imperial units, focus on energy COST ($) rather than absolute values	No cases known to be pursuing LEED certification.	All building types, although has not be harmonised in the same way as BREEAM so different scoring systems are used for different typologies.

Design Stage available from	% cases now	% cases covered	inclusive of	Regulated energy	ICT	Small power / plug in loads	Specialist functions	User behaviour (occupancy etc.)
15 months post occupancy (requires 12 months of in use data, max variation of +/- 31 days permitted) (CIBSE TM46:2008)		48%	In use energy, with minimal allowance for occupancy, weather and separable energy uses	Yes	Yes	Yes	Can be removed where separately metered (regional server room, trading floor, bakery oven, sports flood lighting, furnace / heat treatment process, blast chilling or freezing - CIBSE TM46: 2008)	Can be used to adjust the calculation where data available (to a limited extent)
Use		100%	All metered energy (regulated + unregulated)	Yes	Yes	Yes	Yes	Yes
The RIBA green overlay to the outline plan of work (RIBA, 2011) suggests Part L compliance checks at Stages C and D. CIBSE (2012) advise "both qualitative and quantitative checks should be carried out at various stages during the design process to ensure it meets the energy targets set". "Design forecast emissions … are calculated through the use of thermal modelling techniques or steady state calculations by the M&E engineers. They are normally outlined in the M&E report from stage C onwards and as part of the Part L assessment" (CarbonBuzz, 2008).		100%	Regulated energy	Yes	No	No	No	No (standard assumptions for heating and lighting)
As NCM		24%	Regulated energy	Yes	n/a			"Standardised assumptions about occupancy and heating patterns" based on the size of the dwelling (BRE, 2007) "based on intermittent heating (morning and evening for weekdays, all day at weekends, with heating being off at night) with a mean internal temperature of approximately 18C" (BRE, 2007)
BREEAM certification stages have been altered for the 2011 version: interim assessment is undertaken following a submission post Stage D (detailed design); full assessment is undertaken at post completion.		16%+ (estimate based on projects known to have BREEAM targets)	Primary energy (as of 2012). Regulated loads only, as relies on NCM outputs, with the exception of exemplar performance that includes estimates of plug-in loads.	Yes	For assessment criteria 5-7 only (exemplar level)	For assessment criteria 5-7 only (exemplar level)	For assessment criteria 5-7 only (exemplar level)	No
"Design forecast emissions … are calculated through the use of thermal modelling techniques or steady state calculations by the M&E engineers. They are normally outlined in the M&E report from stage C onwards and as part of the Part L assessment" (CarbonBuzz, 2008) Energy strategy report (including LZC tech) and initial Part L model and EPC estimate submitted with planning app @ concept (stage C) (CIBSE Guide F, 2012)	?	?	Various as specified	Yes	Possible, variable in included loads and accuracy of assumptions	Possible, variable in included loads and accuracy of assumptions	Possible, variable in included loads and accuracy of assumptions	Possible if specified in brief etc.
Building Completion	100%	100%	Regulated energy	Yes	No	No	No	Standardised (Shell EPCs are calculated based on "assumed fit out" (DCLG, 2008) for instance)
"Code assessments are normally carried out in two stages: Design stage (DS), leading to an interim certificate and Post construction stage (PCS), leading to a final certificate. The assessment process for these two stages is very similar." (CSH, DCLG 2010). "The DS assessment is carried out on the detailed design of each dwelling in the period up to the issue of tender documents, sometimes referred to as RIBA Stages A–G." (DCLG,2010)		24%	Regulated energy	Yes	n/a	Net zero definition (Code level 6) currently includes "those associated with appliances and cooking" (DCLG, #)	n/a	Standardised
AS BREEAM - pre and post completion assessments. Pre - completion assessment is not mandatory.	0%	0% (100%)	Regulated energy, allowance for unregualted energy. Measures to reduce unregulated energy recognised.	Yes	Standardised	Standardised		No

Building management	Benchmarking	Consistency	Known issues
Yes	uses CIBSE TM46, recently validated by a CIBSE working group (ref#) Graded on an A to G scale, differentiated for 29 building categories (roughly aligned to planning classes)	Good, standard method	There are problems with defining the unit to which a certificate should be attached, including how to allocate communal areas of shared buildings: "there can be significant problems in linking asset, letting unit and EPC unit data" (McAllister & Furest, 2011). Poor building management will create a high rating despite good design Data quality issues - recent CIBSE benchmarking assessment exercise (bruhns et al., 2011) found "significant data quality and categorisation problems in the [DEC] database"
Yes	Difficult, limited data available in literature for comparison; TM46 comparisons most plausible.	High, where accurate and complete data can be obtained.	
No	EPC rating scale; comparison of BER/TER improvement to building regulation targets;	Good (although note manipulation possible - see known issues); common procedure but each scale is building specific (due to the matching of notional buildings to the designed building)	"It was generally accepted that the SAP/SBEM assessor is not part of design team but tasked with taking a given design and managing the input into the software to result in compliance. Note that this tends to be the reality in many cases." (Bell, Smith, & Palmer, 2010) Using different software will give different results (SBEM v DSM for instance) so designers will run both and select the one that gives the 'right; answer. Excludes significant unregulated loads "It is widely agreed that several assumptions in the NCM can give rise to discrepancies between the simulated prediction of energy uses and those which are likely to occur in reality (e.g. hours of operation)" (CIBSE, 2012) - i.e. there is a known performance gap due to the modelling of only standardised regulated loads.
	EPC rating scale; comparison of BER/TER improvement to building regulation targets;	Good (although note manipulation possible - see known issues); common procedure but each scale is building specific (due to the matching of notional buildings to the designed building)	As NCM, plus due to the simpler nature of SAP compared to the non-domestic models: "the 'ACDs (Approved constructional details) to be used' box in the SAP/SBEM software is likely to be ticked in order to gain a more favourable result. SAP/SBEM assessors may or may not know what ACDs are and be unlikely to be able to spot their actual use on the detail design plans" "There was a lack of confidence shown in workshops from all sectors that there is a proper correlation between the building as modelled in SAP/SBEM and the building as built" (e.g. "Changes to the design are not fed back into SAP/SBEM") (Bell, Smith, & Palmer, 2010)
No	BREEAM has predefined limits for awarding credits that are well understood, clearly defined and subject to extensive review and validation. The scale defines very good, excellent and outstanding energy performance. BRE (2012) has recently revised the calculation methodology to ensure the benchmarks accurately represent best practice and are consistent across building types and with the credits goals.	High	Use of BREEAM energy efficiency credits for comparative purposes is complicated by alterations to the calculation method from the 2008 to 2011 releases. While both used outputs from the building regulations modelling software (SAP or SBEM), BREEAM 2008 relied on comparison to a single benchmark scale which is impractical given recent Part L (REF#) revisions whereby the percentage reduction required varies by building type: "because the level of improvement [in carbon emissions] that can be reasonably expected varies significantly by building sector, and so a blanket improvement factor would be inequitable. The specification delivers an overall 25 per cent reduction in CO2, emissions across the new-build mix for the non-dwellings sector (the so-called 'aggregate' approach. Some building types will be required to improve by more than 25 per cent, some by less, but all should achieve the required level of improvement at approximately the same cost of carbon mitigation.)" (HM Government, 2010)
Possible if specified in brief etc.	Limited data available in literature, no guarantee of comparable data. Use of CIBSE deign guidance.	Low	Dynamic thermal modelling is known to be good for comparing options, but less adequate in predicting absolute energy performance (Carbon Trust, 2011; CIBSE, 2012)
No	EPC rating scale	Good, standard method (although manipulation possible, see NCM known issues)	There are problems with defining the unit to which an EPC should be attached, including how to allocate communal areas of shared buildings: "there can be significant problems in linking asset, letting unit and EPC unit data" (McAllister & Furest, 2011). - EPCs reflect the "accommodation being sold or let" (DCLG, 2008) and so buildings with multiple tenants will have multiple certificates.
No (provision elsewhere in code for visual metering etc.)	CSH has predefined limits for awarding credits. The scale defines very good, excellent and outstanding energy performance. There is some ambiguity in the Level 6 definition.	High	Ambiguity in the level 6 definition of a zero carbon home
No	121 listed projects in the UK with certification (no credit detail provided). Because of LEED demands for PO data, LEED has been more extensively reported from an energy perspective within the literature. EA1 credit awards up to 19 points, on a sliding scale (12%- 48% reduction on ASHRAE standard)	High	While LEED provides a wider range of low carbon aspects than perhaps BREEAM does (energy use, renewable generation, measurement and verfication), these are not tuned to the UK context and so aren't entirely consistent with the version of the low carbon convept the study seeks to measure.

APPENDIX 4K – BOOLEAN NOTATION

The figure below indicate the three main operators in Boolean algebra, AND, OR and NOT. In each Venn diagram, the area being described is shown shaded in blue. A description is first provided, followed by typical Boolean notation and then notation typically found in QCA studies for reporting recipes.



The operators can be combined to produce equations.

(AB) + (CD) + (eF) would be read A and B, or C and D, or F but not E.

(Note the multiplication / AND symbol has been omitted as typical in usual algebraic formulae, in the body of the thesis a * sign is also used to represent AND).

Principle	Criteria	Application notes	Assessment notes
Location	Good access to PT (walkable within 5 minutes (london), 10 mins elsewhere) = +1; Good access to main (A roads and motorways) roads = +1		Kincaid's (2002) criteria used for public transport and roads.
	Central location	Cases located in areas of substaintial redevelopment allocated half 'desirable location' score (+0.5).	Combines local area and zoning criteria from literature.
	Location suitable for a range of uses (not a mono-planning district)	Mono planning district examples include business or industrial parks, large residential suburbs.	
	No nearby hostile factors	Noise, odours, land contamination, pollution	
Site Access	Street frontage		
	No of sides accessible by vehicle		
	Attached to other buildings		
Site utilisation	Room for expansion within site boundary	Record: site size, ground floor footprint, total floorspace. Reference for areas (inc type of area - GIFA, Net area etc.)	Typical density?
	Space for parking	No minimum parking provision, but no. of spaces should be recorded (with source). Parking should be onsite.	
	Courtyard arrangement		
Occupancy	Single occupier		
Building height	Not tall	<6 storeys	March et al.'s criteria
Storey height	Ground Floor: ≤ 2.7m (residential only) = 0 2.7 - 3.6m (offices) = 1 3.6m - 4.4m (retail) = 2 ≤ 5.5 (double height retail) = 3 AND upper floor: ≤ 2.7m (residential only) = 0 2.7 - 3.6m (offices) = 2 ≤ 3.6m (retail) = 1	Level should be consistent across the storey - undulating floors (where floor levels vary significantly across the floor plate) are not regular.	Values obtained from: Manewa (2012), Kincaid (2002), Mulitspace (#), Buro Happold (2011), Metric Handbook, SD2 design brief. Literature varies but the rang 3.3-3.5m is referenced by many.
	Inclusion of mezzanies	Floor to ceiling heights allowing the addition of extra floors covered above.	
Plan depth	13.5 - 21m = 1 13.5 - 15m = 2		Criteria for 1 point is based on prefered plan depths for types other than retail (45m+), determined from Buro Happold (2011), Kincaid (2002) and Mulitspace (2004) advice. CIBSE Guide F (2012) suggests NV by windows works well up to 6m from a window (12m depth), but class buildings as >15m as 'deep plan'. Two points allocated for a building capable of NV, based on really basic rule of thumb citeria: CIBSE AM10 (2009) concurs with the 15m rule of thumb. Rennie and Parand (1998) - Environmental design guide for naturally ventilated and daylit offices (BRE) suggest 5 x storey height as max, which for a 3m office gives 15m.
Building form	Regular shape, limited curves	"regular" shape refers to rectangular forms that are capable of being zoned and subdivided in a number of ways.	
	Linear plan		
Daylighting	Access to natural light on all sides = 1 Good daylighting (windows < 6m away) = 2		CIBSE LG10 (1999) *"In a typical building with a window head height of 2.5 m and room width of 3.75 m, daylight can penetrate about 6 m from the window elevation (see section 2.1.2). This sets a design constraint, producing plans that are about 12 m deep for a dual-aspect building."* BCO recommendations for good daylighting: The depth of the room should be no more than 2.5 times the height of the window serving it .
	With glare control/shading		
Aesthetics	Listed status		
Building quality	Basic finish	e.g. base build and fit out, "unfinished" areas	
	Quality	cost / m2	
Standard components	Evidence of use of standard components		
Durability	Durable structure and substructure	Record design life times for components where available. Note items with unusually short lives (e.g. items deisgned to be temporary) should be noted in the evidence also. Foundations > 100 years = +1 Frame and slabs ≥ 75 years (steel and concrete will normally satisfy, timber will not) = +1	Emphasis placed on durability of longer lasting components for compatability with layering criteria. Roofing has been excluded as non-residential type roofs are largely expected to undergo periodic maintenance (life 30-40 years). Literature suggests services are generally replaced, so durability of this layer is not specified. Values given are median life expectancies, sourced from: BCIS (2006). Life expectancies of building components. London: RICS BREEAM credit MAT05 assesses durability, but this is primarily durability to traffic impacts and is not considered a useful metric for this assessment.
Loading	Office loading or above	Live loads only, no allowance for partitions of services (normally standardised at 1 kN/m2 and 0.25 kN/m2 respectively). Any evidence of substantial deviation from loading norms to be recorded. 2 kN/m2 (good residential standard) = 1 3 kN/m2 (good office and schools, allows corridor movement) = 2 4 kN/m2 (basic retail and other non industrial uses) = 3	Values based on Eurocode 1 guidelines for minimum live loads.
	Evidence of foundations being oversized	Evidence of substantial over sizing is unlikely to be found (suggests uneconomic design). Large basement structures are likely to indicate foundation redundancy.	
Grid spacing	Regular	Regualr grids are those that are predictable - distances between columns is standard, and columns have been rationalised to the minimum number of sizes.	
Span	Span ≥ 6m	Record typical grid dimension.	Madden's study (from Rsiii - data source?) suggest 6m is the minimum to accommodate 3+ of the typical uses, and this is broadly in line with other adapability guidance. In the absence of any kind of consensus on upper spacing this has been omitted (upper limit will vary with frame type - basically looking for a span that allows for holes and not too deep beams?)
Framed	Framed construction	Framed / unframed to be recorded. Frame material (concrete, timber, steel, masonary) also to be noted, with reference.	
External Walls	Non-load bearing external walls	Non-load bearing walls are those that do not support floors (i.e. cladding supporting its own weight is allowable).	Conflicting evidence on column location (in line or off grid) led to the exclusion of this criteria.

Principle	Criteria	Application notes	Assessment notes
Planning grid	Standard / repeated pattern to external facade	Fenestration allows for different room sizes (1.5m or 3m modules) was suggested but limited agreement.	BCO suggests a window module of a multiple of 1.5 m to support planning module. More complicated suggestions by Rsiii omitted because they are not well covered by the lit and were considered to difficult to apply, requiring knowledge of off the shelf window sizes.
	Evidence of use of a planning grid in positioning services and partitions		
	Eveness of services distribution (lighting, sprinklers etc.) and everyday connection points	Criteria relates to the ability to replan a room without altering service outlets or with minor alterations achieveable by a non-expert: raised floors with repositionable boxes, ceiling level plug and play tracks, Wireless IT provision installed	
Separation	Services not embedded in structure		
Service distribution space	Accessible horizontal service zone	Raised floor (100-350mm suggested) and/or suspended grid ceiling/service zone (0-500mm suggested), intersital floor, service corridor.	
	Pentrable slab	Not post tensioned	
	Generous vertical riser provision		
Accessibility	Plant located in an accessible location	e.g. adjacent an external wall, on an exposed roof	
Legible components	Exposed components	unfinished ceilings etc.	
Service redundancy	Over sized distribution	Includess ducting, sewerage pipes, etc.	
	Oversized or additional plant	Where allowance has been made in space and loading for additional plant at a later date, and this provision is considered practical, point may be awarded.	
	Extra connection points	Bus bar, unfinished connections	
Less components	Simple servicing (basic passive design, no BMS)		
Layout	Hub and spoke arrangement of spaces	e.g standard sized classrooms around a central space	
	Open plan spaces		
Internal walls	Non-load bearing internal walls		Combines internal wall and loading: non-floor criteria from literature.
	Moveable walls		
Storage space	Generous provision of support spaces (storage areas etc.)		
Space provision	Provision of extra space	Lofts, flat roofs, waterproofed basements not currently forming part of the useable space but could be appropriated as such.	
	Circulation large enough to be used as space / no hallways		Statatory minima from UK building regualtions (Part M, para. 3.14). Minimum used is the minimum without the necessity for 'passing places'.
	Evidence of providing space above the minimum required, "elbow room"	Bigger spaces than required will be difficult to assess for speculative developments. Briefing documents will often give required areas, proivison beyond this would be sufficient to be awarded the point. Where there is no evidence of room size specification, this element may be omitted (max score revised to 2).	
Standard spaces	Rooms demonstrate resonable standardisation in sizing	Standardisation in sizing refers to provision of generic spaces - i.e. 3 or 4 room types / sizes throughout the development. Developments with are all rooms a single size are not eligible.	Numerical definition of 'resonable' to be decidied.
	Generic finish and / or fittings		
	Rooms are predominatly regular in shape, limited use of circular or awkward dimesions		
Cores	No. of core groupings / GIFA [scoring to be determined during pilot] OR max distance	Marked plan to record core locations. Record no. of stairs, goods lifts, passenger lifts where possible.	Use of plan area to account for effect of building size on no. cores 1 lift for every 45,000 net usable square feet. number of floors : number of elevators = 2:1 or 2.5:1 depending on occupancy of the building (more dense = more elevators) http://elevatoradvisors.com/
	Location of vertical cores		Both central (for residential conversion) and multiple (fire regulation compliance and sub division) are suggested by the literature.
Openings	No. of openings	Opening for vehicular or pedestrian access. Opening groupings are to be counted once (i.e. do not count the number of doors individually).	Scoring criteria to be derived from pilot, as literature does not suggest a benchmark value.
	At least one oversize entrance	Large enough for a van to pass into the building	
	Main entrance space central to the plan		
	provision for additional openings	Provision for additional openings e.g. preinstalled lintels	
Fire	Escape distance < 30m		Building Regulations (Part B - Fire) Escape in one direction = 7.5m flats, 9-18m other types Escape two+ directions = 30m flats, 18-45 other types
Moveable furniture	Occupants capable of furniture arrangement (not fixed)	For speculative, shell and core developments this principle should be omitted and recorded as n/a.	
Building service control	Occupants have some control over local servicing	e.g. - lighting, openable windows, blinds. Provision for retrofitting openable windows allowable	
	Zoned controls		
Information	Evidence of provision of building documenation beyond statatory compliance	e.g. labelled components	

APPENDIX 5A - INTERACTIONS LONG LIST

Case	Interaction reference	Description	Low Carbon principle	Adaptability principle	Included in short list?
1	01A	Green policy based on delievery low energy buildings that can be adapted to different workplace requirements	Building with low energy requirements	Space that can be adapted	Y
1	01B	BREEAM sub-metering requirements allow monitoring of energy use should the building be divided into separate tenancies.	Sub metering	Zoned controls	Y
1	01C	Planning policy definition of good design incorporates efficient use of resources and provision of adaptbility for changing requirements	None ("efficient use of resources" might be interpreted as including carbon reduction)	Providing adaptability to changing requirements	N
1	01D	HVAC ensures building will remain comfortable in a changing climate, but will increase energy use.		Oversized plant	Y
4	04A		passive cooling strategy	solutions allowing a degree of control	N
4	04B	Full roof coverage with PV panels would restrict ability to provide roof pentrations.	PV panelling	Roof aperture location flexibility	Y
4	04C				N
4	04D				N
4	04E				N
4	04F	Roof will be designed to allow retrofitting of PV panels at a later date.	Renewable energy - solar PV or solar thermal	Retrofitting of renewable systems / over size structure	Y
4	04G	Recommendation to install improved natural ventilation to prevent occupiers retrofitting energy consuming air conditioning in response to climate change.	Natural ventilation	Changeable HVAC	Y
6	06A	Occupants cover windows with artwork to reduce glare and solar gain resulting in increased energy use for lighting.	Daylighting	Adjustable daylight; decoration	Y
6	06B				
6	06C				
6	06D	Earth tubes reduce energy use but require later work to 'build round them'	Earth tubes	Landscape flexibility	Y
6	06E				
7	07A	Raised access flooring for flexibility and energy efficient displacement ventilation.	Energy efficient heating (underfloor)	Raised access floor for flexibility	Y
7	07B	Heating and ventilation systems chosen for energy efficiency can potentially restrict furniture arrangements.	Natural ventilation	Furniture layout	Y
7	07C	Educational buildings are expected to maintain a comfortable environment without compromising flexibilty of the space or unreasonable energy consumption	reasonable energy consumption	flexible buildings	Y
7	07D	Designers stated that mitigating against climate change traditionally took priority over adapting buildings to climate change	Mitigation	Climate adaptation	Y
9	09A	Building is designed for high visitor numbers making it imposible to guarantee use of energy efficient equipment and a need to design equipment gains for the worst	Low energy IT	Visitors moveable IT e.g. laptops	Y
9	09B	Recommendation for modular boilers to allow decommisioning with climate change predicted increases in temperature.	Modular boilers / energy efficiency	Modular plant	Y
10	10A	Provision in structural design for retrofitting of PV panels or a green roof.	Later addition of PV panels	Additional roof structural allowance	Y
10	10C	Openable windows included for patient benefit despite contradicting low carbon air tightness and heat recovery strategy.	Sealed envelope and managed heat recovery	Openable windows, user control	Y
11	11A	Buildings orientated and designed to allow later upgrade with renewable technologies.	Maximise solar energy absorption	Allow for future LC upgrade	Y

APPENDIX 5A - INTERACTIONS LONG LIST

11	11B	Buildings to be demolished rather than reused due to being unadaptable and incapable of meeting CSH Level 3.	Level 3 code compliance	Ability to be upgraded for LC	Y
11	11C	Natural ventilation chimneys puncture building fabric, impacting on air tightness making windows the prefered ventialtion option.	Air tight envelope	Manual window based ventilation strategy	Y
11	11D	Clear spanning offices, with good cross ventilation and thermal envelope will be easiest to reuse.	Good cross ventilation and thermal envelope	Adaptability	Y
11	11E	Simple PassivHaus M&E design also provides easy access to frequently replaced items.	Simple, kink-free services	easy access to M&E	Y
14	14A	Lightwells for daylighting infilled to provide additional accomodation/	Daylighting and natural ventilation	Extra space for infill	Y
14	14B	Listed status of building restricts ability to adapt. Adaptable solutions might allow retrofitting of low carbon solutions with limited impact on heritage asset.	Low carbon retrofitting	More flexible listing	Y
14	14C				N
14	14D	Structural soffits exposed for thermal mass, floor slabs isolated from thermal mass by installation of a raised access floor.	Thermal mass	Raised floor	Y
14	14E	Exposed soffits for thermal mass impose a sustainable aesthetic that might not be appropriatee for all spaces and will restrict client decoration choices.	Thermal mass	Interior design freedom	Y
14	14F				N
14	14G	Multiple HVAC connections to theatre to allow for reduced output when space is divided.	Limit mechanical ventilation and cooling use	Divisible lecture hall	Y
16	16A.1	Design for disassembly and long life reducing through life carbon emissions (embodied energy)	Lower embodied energy	DfD, long life structures	Y
16	16A.2	Reduced environmental impact of repeated refurbishment where buildings are designed to adapt.			Y
16	16B				N
16	16C				MERGED (16A)
16	16D	Design CHP system to be compatible with bio-fuel ahead of its widespread availability.	CHP conversion to biofuel when viable	Fuel adaptable plant	Y
16	16E	Exposed structural mass reduces cooling requirements and is compatible with a base build only route.	Thermal mass	Exposed soffits	Y
16	16F				N
16	16G	Modular, progressively installed CHP	Efficient running of CHP	Modular plant	Y
16	16H	Ability to retrofit PV and other renewable technologies	PV panels	Enable retrofitting of new technologies	Y
16	16I				MERGED (16H)
16	16J	Shell and core decision seperating design decisions (particulary relating to BMS controlled systems) resulting in less efficient operation of the building.	BMS coordination	Base build and fit out	Y
17	17A	Adaptability listed within features of the design included to achieve energy efficient and sustainable scheme	General low carbon design principles	Flexible design solution	Y
17	17B	Atrium included to provide adaptable space and increase daylight / natural ventilation	Daylighting	Flexible office space	Y
17	17C	Air conditioning (A/C) designed with sufficient capacity for differing climates, meaning design effort is focussed on reducing the need to use the A/C and	Thermal mass and energy efficient HVAC	Overdesigned HVAC system	Y
17	17D	Provision for retrofitting a low carbon cooling solution (discourging a less sustainable solution to overheating in future)	Low carbon / energy cooling	Blanked pipes	Y

APPENDIX 5A - INTERACTIONS LONG LIST

17	17E	Roof loading allowances and knock out panels to allow retrofitting of energy consuming cooling plant if required.	Reduce cooling requirements	Overdesign structure and sacrificial structure	Y
17	17F	Recommendation for modular boilers to allow decommisioning with climate change predicted increases in temperature.	Energy efficient boiler operation	Modularity	Y
19	19A	Scheme designed to allow retrofitted connection to any future district heating system.	Later connection to CHP	Connection provision for new CHP plant	Y
19	19B				N
19	19C				N
19	19D	Reducing energy use reduces carbon allowance payments and makes a building more viable in the long term.	Reduce carbon allowance payments	Futureproof against LC taxation	Y
19	19E	Pursuing TSB climate change study BREEAM innovation credit in leiu of a more expensive embodied energy reduction credit.	Embodied energy	Usable roof space	Y
19	19F	Mixed mode HVAC providing a low energy solution that allows for user intervention locally.	Mixed mode ventilation	Adjustable ventilation, multiple ventilation options	Y
19	19G	Visable ductwork providing easy access and knowledge of the energy being consumed by the building.	Energy consciousness	Exposed accessible ceiling distribution	Y
19	19H	Reinforced roof slab to permit retrofitting of additional cooling plant if required in future, which would increase the buildings energy use.	Low carbon cooling	Reinforced roof for later A/C	Y
19	19I	Roof loading allowance for retrofitting PV panels that are currently not permitted due to planning conditions.	Later installation of PV	Services and loading allowances for roof use	Y
19	19J	Single taps to wash hand basins to allow switch to cold water only (saving water heating energy).	Reduced water heating requirement	Ability to convert wash basins	Y
19	19K	Desire for natural ventilation removing the ability to have a café at ground floor level.	Natural ventilation	Unrestricted spaces	Y
19	19L	Standard low energy lighting and services module throughout the building, restricts the use of high powered computers outside designated areas.			Y
20	20A	Provision to retrofit solar panels post completion.	PV to roof	Retrofitting PV	Y
20	20B				N
20	20C				N
20	20D				N
21	21A	Dual fuel CHP system (gas and biofuel) to allow switch to a lower carbon fuel should it become viable.	Biofuel CHP in future	Multi-fuel CHP	Y
23	23A				N
23	23B	Air tight floor plenum for low energy, efficient ventilation displacement. Restricted access underflooring for maintenance access and grilles placed within fixed	Energy efficient HVAC		Y
23	23C	ETFE roof highly insulating (reducing heat loss and associated energy use) and adaptable to external climate via variable solar shading.	Insulation		Y
24	24A				N
24	24B				N
24	24C	Requirements for natural ventilation having "significant implication" for façade deisgn, floor to floor heights and plan depth coupled with a requirement to align	Minimise carbon emissions	Design to enable change	Y
24	24D				MERGED (24C)

APPENDIX 5A - INTERACTIONS LONG LIST

24	24E				N
24	24F	Fully naturally ventilated solution compromised client brief for a flexible scheme fully linked with the adjacent existing building.	Maximise natural ventilation	Open plan spaces	Y
24	24G	Open plan spaces used to facilitate natural ventilation.	Natural ventilation	Open plan spaces / choice of cellular v open plan	Y
24	24H	Labs designed to function as naturally ventilated (reducing energy use now) with provision for mechanical ventilation if required for future lab uses.	Minimise cooling requirements	Multiple ventilation possibilities	Y
24	24I	Concrete frame selected for flexbility and thermal mass properties.	Thermal mass	Framed	Y
24	24J				N
24	24K	District heating system can be easily scaled to provide more or less heat.	District heating	Modular heating systems	Y
25	25A	Fully accessible floor void providing adaptable floor plan, accessible services and low energy displacement ventilation solution.	Exposed ceilings / thermal mass	Raised access flooring	Y
25	25B	Adding additional buildings to an existing CHP plant will increase its operating efficency.	CHP Energy centre	Add buildings / spaces	Y
25	25C	Energy centre includes space for additional low carbon generation technologies, e.g. a fuel cell.	New renewables e.g. fuel cells	Extra plant space to expand into	Y
25	25D	Openable windows provided for occupant local adjustment and as part of a low energy ventilation strategy.	Natural ventilation	Openable windows	Y
25	25E	Mixed mode ventilation allowing for passive ventilation (low energy) in the current climate and a move to more mechanical ventilation and comfort cooling in future if	Mixed mode ventilation	Multiple ventilation strategies	Y
25	25F	Low carbon and adaptability both included as aspects of "environmental sustainability"	Minimise the demand for energy	Adaptable design	Y
25	25G	Central energy centre provides low carbon power and is more easily scaled for any future expansion and kept current than multiple plant sites.	Centralised energy		Y
31	31A	Dual fuel CHP system (gas and Biofuel) to allow a switch to gas if subsequent occupier can not obtain biofuel reliably.	Biofuel CHP	CHP can run on biofuel or others	Y
31	31B	Building designed to "plu-in" to future low carbon energy solutions such as district heat.	Future innovative energy solutions e.g. district heating, GSHPs, ESCo	Capability to plug into new energy sources	Y
31	31C	Deliberate choice to prevent occupiers opening windows and influencing the energy efficent ventilation strategy.	Energy efficient HVAC	Flexibility in office spaces, user control of ventilation	Y
31	31D	Smart grid - adapts local power supply (lighting, small power) to reflect occupancy. Performative building, allowing for hot desking and more flexbile use of spaces.	Automatic small power switch off	Virtual desktop technology for hot desking	Y
31	31E	Concrete soffits painted white to allow a reduction in lux and associated energy saving. Also percieved as providing "a blank canvas which the workers wsill be able	Daylighting / reduced artificial lighting levels	Blank canvas for personalisation	Y
31	31F	Building described asachieving a balance of sustainability and space flexbility.	Operational efficiency	Space flexibility	Y
31	31G	Larger floor to ceiling heights and narrow floor plan creating an adaptable (divisible) floor plan that also allows daylight to penertrate reducing the need for	Daylight	Generous floor to ceiling height	Y
31	31H				N
31	31I	Long life, fit for purpose (adaptable) building reducing total embodied carbon emissions through reduced need for demolition and rebuild.	Embodied energy reduction	Buildings should be long life	Y
31	31J	Low energy displacement and stack ventilation strategy designed to work in mulitple letting scenarios (single tenant, multiple tenants).	Environmental (HVAC) strategy	Ability to segregate the floor plate	Y
31	31K				MERGED (31C)
31	31L	CO2 sensors and smart grid planned on a 3x3m grid to ensure if internal partitions replanned they remain effective at minimising energy use.	Automatic occupancy based HVAC and lighting controls	Fine grained partitioning grid	Y

APPENDIX 5A - INTERACTIONS LONG LIST

31	31M	Decision not to automate blinds and allow local user control, despite the potential for blinds to be left down/up at inappropriate times and effect the buildings low			Y
35	35A	Portrayal of wind turbines (low carbon renewable technology) as difficult to retrofit.	Roof mounted wind turbine	Fixings and structural design for fitting turbine	Y
35	35B				N
35	35C	Buildings designed to allow retrofitting of renewables such as PV.	Renewables	Designed such that integrated renewables can be retrofitted	Y
35	35D	GSHPs restrict choice internal heating systems to low temperature type.	GSHP cooling	Flexibility in heating system choice	Y
35	35E	Community heating scheme (centralised CHP) provides low carbon energy and improved ability to upgrade in future if required (only one system need be	CHP Energy centre	Capability to plug into new energy sources	Y
38	38.1A				N
38	38.2A				N
46	46A	Not possible to retrofit GSHPs due to the high cost and disruption to the site involved.	GSHPs	Landscaping adaptability	Y
46	46B	Adjustable solar shading to allow solar gains in winter (heating benefit) but exclude in summer.	Reduce winter heating requirement, minimise energy use	Adjustable shading, user control	Y
46	46C				N
46	46D				N
46	46E				MERGED (46A)
47	47A				N
48	48A.1	Centralised, energy efficient plant removing retailer fit-outs which are potentially inefficient. Central plant is also compatible with later connection to a local district	Centralised plant for efficiency	Allow connection to future heat network	Y
48	48A.2	Base build in retailer fit out areas maximises retailer flexibility but minimises client control over energy consuming items such as lighting.		Base build and fit out	Y
48	48B	Large spaces provide adaptable, legible spaces. Large spaces also used to ensure the natural ventilation scheme is effective.	Natural ventilation and daylighting	Grand space with room for growth (oversize space)	Y
48	48C				MERGED (48A)

Case	Interaction reference	Reason for removing from the interactions short list
1	01C	Statement of planning policy, no interaction between the agendas they are merely discussed in close proximity. Unclear if a low carbon element is present.
4	04A	CCA interaction - outside of studies scope.
4	04C	No indication of a low carbon motive.
4	04D	CCA interaction - outside of studies scope.
4	04E	CCA interaction - outside of studies scope. No adaptable motive.
6	06B	No obvious adaptability motive.
6	06C	No obvious adaptability motive.
6	06E	CCA interaction - outside of studies scope.
14	14C	Implied adaptabilty component only.
14	14F	CCA interaction - outside of studies scope.
16	16B	No explict adaptabilty component
16	16C	Merged with 16A
16	16F	Implied adaptabilty component only.
19	19B	Implied low carbon and adaptable elements only.
19	19C	Low carbon and adaptability noted as sustainable, no interaction.
20	20B	CCA interaction - outside of studies scope.
20	20C	Implied low carbon and adaptable elements only.
20	20D	Low carbon and adaptability noted as sustainable, no interaction.
23	23A	Low carbon and adaptability noted as sustainable, no interaction.
24	24A	Implied low carbon element only.
24	24B	Implied low carbon element only.
24	24D	Merged with 24C
24	24E	Implied low carbon and adaptable elements only.
24	24J	Implied impact on adaptability only.
31	31H	Implied impact on adaptability only.
31	31K	Merged with 31C
35	35B	Masterplan. Not building specific.

38	38.1A	CCA interaction - outside of studies scope.
38	38.2A	Case removed from analysis.
46	46C	Implied adaptabilty component only.
46	46D	No clear adaptability and low carbon actions.
46	46E	Merged with 46A
47	47A	Implied impact on adaptability only.

01 Admiral

INSTANCE 01A

“Stoford’s approach to sustainability is to understand the needs of a particular project, the context it sits within, and then to procure a sustainable solution. Out ‘green’ policy is based firmly on the grounds of delivering buildings with intrinsically low energy requirements in the most efficient manner possible, whilst providing an effective, comfortable, functional and economic space than can be simply adapted for the different requirements demanded of a modern work place.” **OneNote**

INSTANCE 01B

I: We've done a lot. Can we talk a bit more about the flexibility of the office space? I know you've said it's meant to be cut in half.

R: “So within BREEAM anyway there were certain requirements within and EPC guidelines nowadays that every floor is sub-metered. We have the ability to control each floor so each floor will be controlled. So the lighting is all controlled by floor or by zone. Heating and ventilating is controlled by floor and by zone. The sub-division works on Cat A only, not on Cat B necessarily. For example, they'll have an alarm system which is the whole of the building. Security is the whole of the building. But these are all fit out items, swipe card systems. But under the Cat A if you can just imagine that's an empty floor plate. Everything within that floor plate, so what we provide, the lighting, the mechanical and electrical and the water all sub-metered. So heating and ventilating, water, lighting.” **Interview 01**

INSTANCE 01D

“Due to the internal climate being wholly maintained by mechanical HVAC systems, sized to accommodate significant changes, the actual comfort of the occupants would be preserved. Hence, the real challenge lay in addressing the increased energy demand that would result from maintaining this level of comfort in the face of a changing (external) climate.” **BRE Information Paper IP 2/13**

04 British Trimmings Extra Care

INSTANCE 04B

“Based on the available roof area of 3062m2 the maximum size array of up to 400Kwp. The approximate output would be 330,500 -355,285 kWh per year. However, this option would be extremely costly and would limit the apertures through the roof which are discussed for options 1 and 2.” **M&E Report SI Sealy**

INSTANCE 04F

[under the heading – “which measures are being implemented?”]

“Renewable energy options

No solar panels will be installed at the outset but the roof structure will be designed to enable their future installation. PV panels would be relatively simple to connect to the electrical system in future. In future, solar thermal panels could also be connected to the hot water system but would require more involved adaptation work, e.g. to run pipework etc.” **Adaptation Report p83**

“Renewable Energy Options

Solar hot water or PV panels can be added at any time subject to adequate structure and plant space for hot water systems. PV-T panels would maximise the limited roofspace to good effect giving a higher overall energy yield. It is suggested that 60% of hot water demand and approximately 11% of electrical demand could be met with the current roof layout.” **Adaptation Report p76**

INSTANCE 4G

“We would recommend that the full natural ventilation is installed from the outset as it would achieve immediate comfort benefits within the current climate and increasingly in the near future. Immediate installation would avoid the inevitable additional costs and disruption involved with retrofit in a few years. It also reduces the risk of alternative unsustainable inventions being made by the housing management or owner’s e.g. providing powered cooling equipment.” **Appendix 3.3. M&E Report SI Sealy**

06 Wyre Forest Schools

INSTANCE 06A

"…their adaptation is usually – if it's a sixties school with lots of single glazing you just block out the windows with artwork and posters and things, so you cut down on some of the solar gain. But then what that quite often meant on duller days, the lights were on longer than they should be. So that puts up electrical consumption. So it wasn't perfect." **Interview 06**

INSTANCE 06D

"…earth tubes, it's quite a high capital cost associated with all the ground works on that. And of course they do affect your future site development because you're then, you've got to try and build round them." **Interview 06**

07 Harris Academy

INSTANCE 07A

"the project considers a raised access floor with underfloor heating providing enhanced flexibility, energy efficiency and comfort." **OneNote**

INSTANCE 07B

"The building should be easy to operate: *Required+ "There is on-going debate in the industry about the inefficiency and problems created by designing a building that is totally or nearly totally naturally ventilated. An appropriate balance needs to be found between energy efficiency and the psychological benefits of opening windows. The use of heat recover systems, natural stack effect etc. need to be considered and bidders must demonstrate the impact of their chosen ventilation systems on CO2 levels and temperatures, and the carbon footprint of the building. The impact of the chosen heating and ventilation systems on furniture layouts need to be carefully considered." **Planning application notes**

INSTANCE 07C

"The nature of educational buildings is that they need to remain flexible whilst maintaining an environment conducive to learning (and without unreasonable energy consumption)." **Final Report**

INSTANCE 07D

"Both designers stated that mitigating against climate change traditionally took priority over adapting buildings to climate change." **Adaptation Report (Report on designer interviews)**

09 Technical Hub @ EBI

INSTANCE 09A

"…there's always an element of objection there because part of that facility is visiting researchers will turn up with whatever equipment they're using. So there's an element to which you can say, 'our policy is that everybody uses energy star computers that are really low energy,' but if you turned up as a visiting researcher you would use the machine that you've got and I don't think we could stop you. So yeah, there's that sort of thing going on as well." **Interview 09/14**

INSTANCE 09B

"…buildings may not need as large a boiler capacity in the future. For the EBI2 building, it might be worth considering modular units of smaller sized boilers, which when not required, could be switched off so that ones that are operating will continue to run at optimal efficiencies."

10 Edge Lane

INSTANCE 10A

“Green roofs / transpiration cooling

Green roof technology was an integral part of the original vision for the scheme. It was seen as an important part of the urban design strategy, a boost to the local ecology and a visual amenity from the multi-storey building. The decision to remove the sedum roof from the project proposal came about as the extent of the required photovoltaics was realised. Through subsequent value engineering exercises it was agreed that the requirement for renewable energy could be met be a comparable reduction in carbon emissions, thus the photovoltaic were removed. Although it did not survive design development, the structural allowance for the green roof remains with the intention that it may be added at a later date.”

“Roof to be designed to allow future installation of PV’s” **Detailed Renewable Energy Statement 14-02-11**

“Spare structural capacity to allow the imposed loads of sedum planted roofs or renewable technologies.” **BREEAM Case Study**

“And the whole design of the system was robust enough to be able to take additional load on the roof, at a later date, to be able to convert the energy [11.14] and maybe sort of micro CHP, or photovoltaic arrays on the roof, or solar thermal on the roof for instance. The weight of that, it would be possible to install those. Even that was a difficult task to persuade them that it was worth investing in. Just a slightly beefier roof construction to be able to take that load, because of cost constraints being so tight.” **Interview 10**

“The large flat roof areas at both Mersey Care sites are perfect for PV (most buildings are one storey)”

INSTANCE 10C

“The openable windows are counter to the concept and science of a sealed envelope and managed heat recovery, yet the benefit to patients of feeling a breeze and being able to directly affect their environment is paramount.” **Adaptation Report v2**

11 Extra Care 4 Exeter

INSTANCE 11A

“The site layout, building orientation and design should be arranged to maximise the absorption of solar energy and to allow for future upgrade options including incorporation of renewable technologies on most dwelling types.”

INSTANCE 11B

“A detailed assessment of the remaining buildings on site has concluded that they are of no historic or townscape value, are not suitable for conversion without substantial works affecting the exteriors, and would not achieve Code Level 3 compliant development. The layout has been developed without the retention of these buildings.”

INSTANCE 11C

“You can’t really get chimneys up with buildings and it would just puncture them and they would not be air tight so you’ve actually just got to open the windows and close them, the simple stuff. Just sticking in wind chimneys and things I just don't think is the case I’ve designed wind chimneys before [30.40 missing word] rubbish basically in the winter. You’re just knocking holes in your insulated envelope of your building its ridiculous so that’s why we don’t do it.” **Interview 11**

INSTANCE 11D

Well certainly the office, I mean that’s basically clear spanning space and that can be adapted in any way we see fit really, as the client sees fit. So they’re quite ways to adapt I think, office buildings, particularly if you’ve got good cross ventilation and you’ve got good thermal envelope.” **Interview 11**

INSTANCE 11E

“Jason and I can’t speak German so we went to the [passive house] pool, with our trunks on and we just experienced the, you know, actually sussed it out see and we went down to the basement of the building and had a quick look at the M&E kit in there, beautifully lined up, no corners and things because every time you turn a corner with a pipe you have to have a bigger pump basically to push it through, beautifully laid out, you know, extremely good engineering and that’s what we need to do.” **Interview 11**

“DG:…certainly making it easier to adapt the mechanical and electrical systems you know sort of easy access etc. so you know they will be replaced, it’s those items that will be replaced regularly.

Interviewer: Is that because they have learnt on the old pool that that’s difficult to do? [referencing earlier talk and the report on the problems with the existing Victorian pool that is not fit for purpose]

DG: No, erm…possibly but it’s mainly us learning from the German example of laying things out nicely and having access to them and you know.” **Interview 11**

14 LSHTM

INSTANCE 14A

"The original building provided two functional, paved light-wells on either side of the central lecture theatre. The roof of the lecture theatre was also paved to give an area of roof terrace. … the subsequent addition of the Manson Theatre and the infilling of the east light well have reduced the accessible space within the courtyard to the west light well for service access alone." **South Courtyard Planning Application Design Statement**

"The original lightwells have been infilled to provide additional accommodation" **Adaptation Report**

"6.2 DaylightIng

In traditionally artificially lit buildings, lighting consumes approximately 30% of the prime energy requirement, and is responsible for 30% of the energy and maintenance costs. It therefore follows that a building that is designed to maintain natural daylighting levels will significantly affect the building's emissions if artificial lighting is simply, but adequately, interfaced with natural light illumination levels.

Daylight is measured in terms of a daylight factor, which is the percentage of daylight that falls onto the task surface compared to a similar surface external to the building envelope. An average daylight factor of 2% - 5% is achieved throughout the building, this being achieved through a surrounding atrium and significant elements of the facade being fenestrated." **Courtyard planning Application Sustainability Statement p8**

INSTANCE 14B

"you could argue it [the building being listed] made it easier because a whole lot of things there was no point in thinking about."

"One of the things we were flagging up is that might need to be challenged, to say – rather than saying, 'It's listed, so you can't change it,' because the interesting thing here is that the policies of the local authority become in conflict with themselves. And that's an opportunity to kind of talk that through and rationalise it. They're driving this building towards air conditioning because they won't allow us to put shading on the windows. And which is the lesser evil? Arguably, it's not for us as the building designers to decide which is the lesser evil. You want to get together with the Council departments and they can fight each other over does heritage or carbon win in that respect, and can you design shading that could be taken off without it damaging the building, as an interesting example." **Interview 09/14**

INSTANCE 14D

"Under both options it is proposed that the structural slab is open to the internal environment to enable the thermal mass to assist beneficial environment stability to the areas. Floor slabs will be isolated from thermal mass cooling by the installation of a raised floor system for the distribution of electrical and IT systems." **Stage C M&E Report (South Courtyard Development Planning Application) p28**

INSTANCE 14E

"The use of building thermal mass requires exposed soffits, which could dictate a major change in the interior design of some spaces. This may not necessarily be desirable client design intent and could impose conflict or restriction over the usage of space within the building. It may also impact of the acoustic characteristic of the existing place, which then requires further counter measures." **Adaptation Report**

[note that the report also outlines the difficulties in using thermal mass from an LC / retrofit perspective, and because of its central London location, see extract below]

"For this approach to work there needs to be energy efficient, preferably zero energy, night time ventilation to achieve the cooling. This requires the building to be suitable, with the possibility of large opening areas on both sides of the building to encourage cross ventilation or the possibility of large vertical stacks to draw air through the building. Neither of these are possible for the LSHTM, and so using thermal mass would require the use of fan power to achieve the required air change rates. This fan energy would negate much of the benefit of the reduced cooling.

Clearly the solution requires there to be exposed thermal mass within the building, i.e. relatively heavy materials (stone, brick, concrete) which are in good thermal contact with the room air. This means they cannot be insulated with e.g. false ceilings or floors or thick carpets. The LSHTM already has adequate exposed thermal mass, so no further exposed thermal mass would be needed." **Adaptation Report**

INSTANCE 14G

"Two connections to each side of the theatre will allow the ventilation cooling system to operate in reduced 50% mode." **South Courtyard Application, Stage C M&E Report p9**

"A retractable partition will allows the auditorium to be separated into two separate lecture theatres." **South Courtyard Application, Stage C M&E Report p9**

"The airflow to the auditorium will be variable controlled for occupancy using air quality sensing." **South Courtyard Application, Stage C M&E Report p9**

16 University of the Arts London, Central St Martins

INSTANCE 16A.1

"Future Proofing

14.3.39. As previously mentioned, the Applicants have stated ambitious aspirations to deliver further carbon emission reductions than committed to already. This can be achieved, for example, by designing buildings for de-mountability, to invest in long life fabric components and structures and providing infrastructure that accept change. The Applicants acknowledge the need to approach building design from this perspective, however, these measures can be incorporated into the designs for reserved matters and do not need to be addressed at this stage." **P494 of 2004P Officer's report notes.**

INSTANCE 16A.2

"5.34 Design for adaptability and flexibility - Installed flexibility and adaptability within the design of commercial buildings allows for a greater degree of freedom in terms of their use and re-use. This can be achieved by design features such as higher floor-to ceiling heights and larger column spacing. When trying to incorporate flexibility into designs, the needs of occupiers is a major consideration. Features such as easily movable partitions within offices enable changes to be made in response to the needs of occupiers. There are also environmental benefits in terms of reduced impacts from repeated refurbishment." **2004P – Environmental strategy**

INSTANCE 16D

"The application of biofuel technologies represents the most significant advance and the influential measure in meeting the 10% target. This is similar to other large developments in London that have also identified significant energy production (and therefore carbon emission reduction) from this renewable technology. It is expected that biofuels could be used in CHP plants and/or boilers across the site. It is possible to retro-fit, or better to install plant at the beginning that is adaptable to new fuel systems when they are installed." **P494 2004P Officer's report**

"Condition 17(d) ii and iii relates to biofuel and requires information to assess the current potential for the district heating system to be run on this source. The T1 energy centre will include room for biofuel storage with the intention that this be either wood chip or wood pellet. The cost effectiveness and supply chain of these sources within London is currently unreliable, although this may change in the future. Officers would expect further information to address this issue to be submitted when the T1 proposals are brought forward." 2007P Officer's Committee Report

INSTANCE 16E

"In addition, accommodation is to be left with exposed soffits to gain benefit from exposed structural thermal mass. This type of system will also be recommended to tenants of the Western Transit Shed 'flexible shell' for use in their fit outs."

INSTANCE 16G

At present, the only demand known for certain on site is that of UAL. It is anticipated that Building R4 (117 affordable housing homes) will hopefully be on site next year. The demand load of UAL and R4 together, let alone on its own, would be insufficient to run the boilers and CHP engines tabled above in an optimum or efficient way.

"As such KCCLP propose to retain the long-term strategy outlined above. However it proposes to meet the initial heat demand of UAL and R4 by installing a modular 'energy pod' on Plot Q1, where it can be connected to the York Way gas supply and the district heating infrastructure along Goods Street. The Pod includes two 3MW gas boilers.

It is proposed that the Energy Pod installation be completed by September 2010 in order to provide heat for the commissioning of plant during the construction of the Granary Complex. This use will continue until approximately June 2011 at which point the Pod will be used to provide heat to both R4, for commissioning of plant between July 2011 and February 2012 (approx), and to UAL to meet occupier demand from September 2011.

At the same time and as explained above, KCCLP remains committed to completing the T1 Energy Centre building and installing the primary electrical sub-station at T1. It also remains committed to completing the works on site to install utilities and district energy infrastructure.

It is envisaged that the next major building, after R4, may trigger the installation of CHP engines and boilers in the T1 Energy Centre. At that point the Energy Pod on Q1 may either be decommissioned, or retained (either at that location or elsewhere) for a period of time, to provide service resilience." **Energy Strategy**

INSTANCE 16H

"Solar electric photovoltaics offer considerable future [potential, but currently carry a considerable cost premium, particularly as grant aid is limited for developers. Recent experience suggests that the same funding can achieve considerably greater carbon reduction through investment in energy saving. Future-proofing buildings would be explored to ensure that buildings can, as far as practicable, later accept PV as it becomes viable." **2004P Energy Strategy**

"King's Cross Central should have the ability to change with time in response to new standards and targets for carbon emissions. Feasibility studies would consider the ability to add technologies as they become more cost-effective and proven. This may involve initially providing some elements of infrastructure in anticipation of reasonable imminent future viability. This could facilitate the application of more easily adding centralised renewable technologies like fuel cells and mains hydrogen fuel, as they become available and cost-effective." **2004P Energy Strategy**

INSTANCE 16J

"**Why did you end up with shell and core? It's a bit of an unusual way of building a university? Normally, we'll have one of those over there please, and you've got a base build and a fit out?**

Yes. And it was done, it does have its problems but it was done on financial planning concepts because it was felt that to make decisions at the, sorry and there is also a design consideration as well. So the option with Argent, the developers was about some of it was about VAT liabilities, and whether we'd buy freehold of the land, long lease on the building etc. I don't, I wasn't involved in all that financial thinking, but there was definitely a view that if they bought a building back in 2008, or commissioned the start of it in 2008, that they didn't know what they actually wanted, in the fit out itself. They knew what they wanted in terms of square meterage and ability to expand it, but they didn't know how they would like to see it in its final form. So I think the decision was made to let the fit out contract as a separate contract. The difficulties that brings with it are that you've got one contractor installing the base plant [missing 12:10] and another contractor picking up all those connections, the final delivery installation, on top of which the BMS sits…" Interview 16A

[This comment sits within the context of the previous conference session (where they had been discussing difficulties with commissioning and systems talking to one another influencing energy efficiency) and Ian Lane's comments over the phone about the problems with commissioning being part responsible for the building's disappointed energy peformance – "I think it must have been done in a day" – as UAL pushed for occupation.]

17 Oxford University Press

INSTANCE 17A

“The energy efficiency and sustainability of the proposed scheme has been an important feature of the design development across the team. The brief anticipates that the design will achieve a BREEAM ‘excellent’ status. The main features of the design which have been incorporated in order to achieve these aspirations are:

1. Installation of high levels of insulation in excess of the current building regulations.
2. Use, wherever possible, of recycled materials, materials from sustainable sources or with good environmental pedigrees including materials within a twenty-five mile radius of the site.
3. Establishment of a waste management plan to reduce potential for wastage through design, ensure minimum site construction wastage and implementation of a materials recycling strategy.
4. Use as far as possible natural forms of ventilation through passive air movement by use of the atrium space.
5. reduction of solar gain through use of building orientation and solar control by protecting south facing glazing with louvres and other forms of solar shading and by using solar control glass.
6. Use of renewable energy sources as far as practicable, including ground source heating and cooling using deep boreholes, photo voltaic cells for electricity generation and rainwater harvesting for flushing of wc’s etc.
7. Maximisation of daylight to working spaces through good window design, roof glazing and light reflecting internal surfaces.
8. Provision of robust control systems on heating, ventilating and artificial lighting installations to prevent energy waste.
9. Use of high mass structure to retain heat and assist in passive night time cooling through night ventilation provision.
10. Use of low energy plant and fittings including luminaries.
11. Inclusion of low maintenance, long life materials.
12. Development of a flexible design solution to maintain a high level of adaptability over time and reduce building redundancy and obsolescence.”

INSTANCE 17B

“Demolition of the C Wing buildings allows the opening up of the existing D Wing building bringing daylight to all floors and increasing its potential to provide flexible office space.” **Design and Access Statement**

“The proposal is to remove the complete south façade of the existing building and construct a new atrium space against the exposed structure. This will allow light down to all floors enabling the use of the complete building as office space, as well as providing the opportunity for passive ventilation.” **Adaptation Report p9**

INSTANCE 17C

"[20:15 missing words] what did come out is that things are designed with so much bunce in them it's going to be a long time before say the climate change is going to have an impact where 'oh my God, add these systems' I think the key seems to be mitigating the impact from an energy point of view so instead of using more energy the building connection absorbs some of it, things like thermal mass, that side. So yeah, mitigation is, probably has more of an impact than mitigation." **Interview 17/19**

INSTANCE 17D

"To help reduce the risk of the risk of future overheating the exposed concrete ceilings could be coffered with blanked pipes contained within. This is to allow a future chilled ceiling system to be installed with minimal impact to the structure." **Adaptation Report p5**

"Adaptation measure proposed: To help reduce the risk of the risk of future overheating the exposed concrete ceilings could be coffered with blanked pipes contained within. This is to allow a future chilled ceiling system to be installed with minimal impact to the structure. Summary of reason for selection: As above, this would help reduce electrical use today so is applicable to today's conditions." **Adaptation Report Rev B p31**

"no drilling or fixing into the slab allowed post concrete pour" **Appendix 3, note on drawing**

INSTANCE 17E

"Alteration to the roof design on the west end of the building to allow for a future plant mezzanine. The chillers are predicted to be sufficient to cope with the load until after 2040, however the changes to the roof design to allow for additional plant should be included as part of the current structural design to ensure the structure is capable of holding the extra weight." **Adaptation Report p31**

"The inclusion of a 'knock-out panel' next to the south east riser to allow for future additional services. As the cooling is not predicted to be required to be increased until sometime after 2040 the additional services would not be needed until then. However the knock-out panels would need to be installed today to avoid unnecessary structural work." **Adaptation Report p31**

"While investigating the implications of additional cooling, the team also discussed various ways to reduce the risk of overheating. One area that already suffers from overheating is the second floor of C Wing. While the new build section of the project, and the majority of the refurbishment both contain large amounts of concrete, the top floor of the refurbishment contains a lightweight ceiling. This is because of structural issues with adding heavyweight mass at this level. However, the team investigated 'light weight' materials available that could increase the amount of thermal storage while not impacting negatively on the structure." **Adaptation Report**

[Ducts to old pub are not included as they are concerned with continuity of supply rather than energy efficiency (or lack of – the 'implications' paragraph above is the only reference to attempts to reduce energy consumption, despite a/c being described as a 'crude' solution.]

INSTANCE 17F

"it should be noted the decreasing amount of time that boiler two is activated, and the decrease in its maximum load. In fact in 2020 it is modelled that boiler two, although sized at 70kW will only in fact ever call for 17kW. A fully modulating boiler will have the capability to reduce to 17kW, however having a 70kW boiler that is only ever required to meet 17kW of load is not recommended as it works less efficiently and is an unnecessary expense." **Adaptation Report**

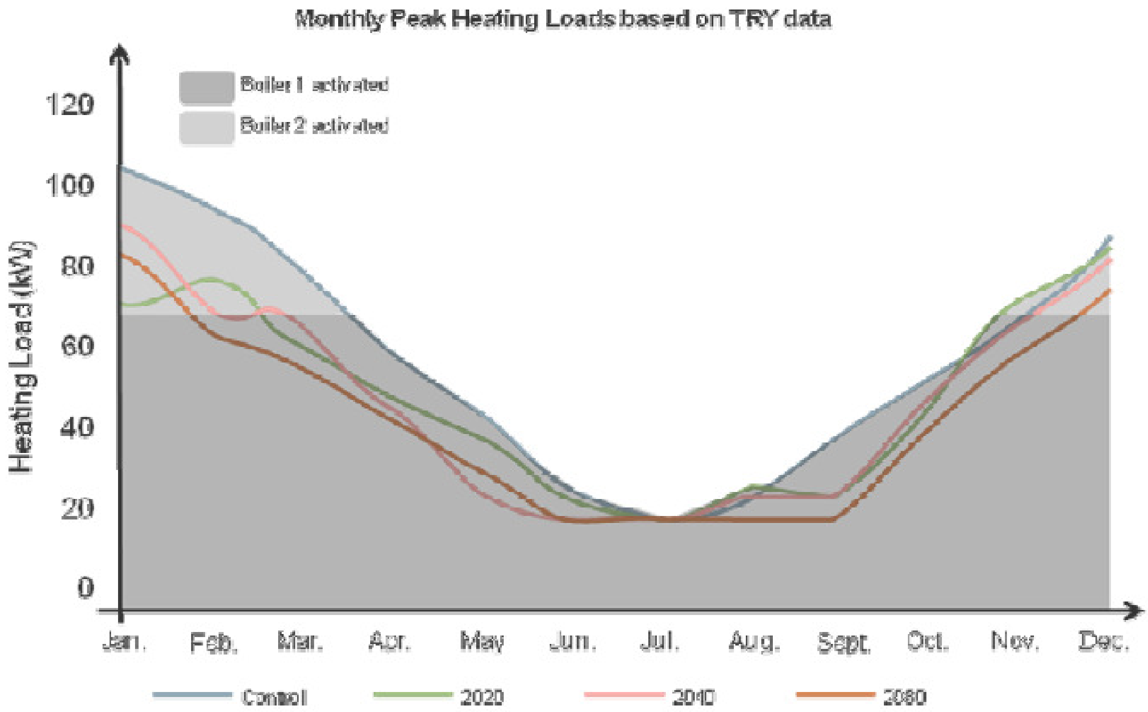


Chart 3 - Monthly Peak Heating Loads

[this is Eimear talking about the chillers but there is similar about the boilers @ Greenwich] "But I understand that and I think that was the right approach also there is a life span for that equipment and by the time the next chiller needs to go in you know, just put in a bigger one they might be the same size because the technology advances." **Interview 17/19**

19 Greenwich University

INSTANCE 19A – ENABLING

“There is no existing district energy scheme in the proximity of the site, but the plant room has been designed to allow connection to a district heating scheme, should one be available along Stockwell Street in the future.” Energy Statement 08022011

“It is therefore considered at this stage that there is currently little opportunity for the Stockwell Street development to form part of a district energy scheme served by CHP. The building services will however be designed to allow connection to such a scheme, should one go ahead in the future. In particular, space has been allowed in the plant room, in proximity to Stockwell Street, to allow for a heat exchanger with a district scheme – see Figure 7 below.” Energy Statement 08022011

“A single plant room will serve the development. The scheme will have the capacity to connect to a district energy scheme should one become available in the future. Please refer to the Energy Strategy for a full overview of the energy infrastructure proposed for the development.” **Documents - Sustainability Statement 08022011**

“So all of the plant rooms are able to be – all of the equipment is able to be removed and connected to a CHP in the future.” **Interview 19**

INSTANCE 19D

“Carbon allowance payments are now a direct cost to the university and has been estimated to add approximately 10% to the annual electricity spend. By making carbon management a key strategy the University will position itself to deal with the potentially negative financial impact of this and future legislation and by engaging with both staff and students now, its ability to adapt to future legislative change will be improved.” **University of Greenwich - Carbon Management Plan**

INSTANCE 19E

“But one of the BREEAM credits that we were looking to try and get, so we would meet our target of BREEAM excellent, at one point very early doors days, was using stent. China clays of the off cast material of the china clay production in Cornwall, and using the stent in the matrix of the concrete, because it would make it white. And the structural engineers were happy to sign that off, and the cost of that was about £100,000. So we would have got a BREEAM credit for it because it’s part of the BREEAM application, and it would have been a tick. But instead of choosing to spend that, we just chose to see if we could get an innovation credit for the TSB Study, which we did, not realising that in that time, the roof gardens would evolve to the point of where they are. And then we ended up needing a little bit more money to make them what they are to meet the planning requirement.” **Interview 19**

“It is proposed to generally use a concrete mix which uses ground granulated blast furnace slag (GGBS) as a replacement for 50% of the cementitious material in the mix. The use of this recycled material reduces the energy used in the manufacture of the concrete and therefore reduces the carbon footprint of the building.” **Adaptation Report**

INSTANCE 19F

"So it's a mixed mode, and when you say mixed mode it is, because these have actuators on them, these areas. So when it does heat up the actuators will open rather than the cooling come on." **Interview 19**

[The implication of the AR is that these spaces can be converted to a/c later if required.]

"The majority of the mechanically cooled spaces adopt a mixed-mode approach which uses mechanical ventilation whenever possible, topped up by mechanical cooling for peak times. In some spaces this is provide by a central air handling unit. In order to achieve the same off-coil temperature throughout the coils would have to be replaced with a larger capacity coil as early as 2020. We have deduced that, although the kW rating of the coil will increase as the years go by, the coil product selected will be sufficient until at least 2040." **Adaptation Report**

"Windows will be openable where possible in order to provide users with the option to benefit from natural ventilation." **Energy Statement**

[discussing the railway facade] "the current design does not include for openable windows so in this situation the window panes would have to be changed. The current glazing system does not allow for this change to be made simply so an adaptation measure is proposed to alter the current glazing system to allow for future openable windows to be installed. This will allow the spaces to be naturally cooled and ventilated for a proportion of the time, and would increase the level of night cooling to the building - thereby improving daytime internal conditions and reducing energy use." **Adaptation Report**

INSTANCE 19G

"you can see the ductwork when you look up, and that's part of the feature of the building. So you're conscious of the energy that you're using, because you're able to see all the services that are providing you a comfort in that space. And that is part of their design concept, is that it's all exposed because you need to know." **Interview 19**

"So the services are all exposed so that access to them will be gained if and when needed." **Interview 19**

INSTANCE 19H

"And one of the adaptation measures, we reinforced this concrete, the roof of this plant room here because this has got to be the services and air handling cool plant. We've obviously enclosed it to make it look like part of the building. This one we reinforced structurally because if in the future in 2020 and 2040, 2040 I think it comes into play, air conditioning will be needed." **Interview 19**

"this one because this one already has cooling plant on it and air handling units on it. So that will be increasing capacity. So this one has nothing on it but this has the ability to have an enclosure because the slab is reinforced. So we could put more weight on it in 2040 is the proposal. Because 2020 I think we don't reach maximum temperature because of the ventilation possibilities in the building and this one. But then what will happen in order to get that, is the planners will need to allow it. At the moment, that's not possible, and I remember talking about it with everyone. And what Rebecca said, which was again, to her amazement that she'd just, she really grasped it and took it well, is that she said "Well, you're building the structure now, reinforce it now and then you can deal with the planners in 2040." And she's absolutely right." **Interview 19**

INSTANCE 19I

"we wanted PV all on this roof. Because of Network Rail, they refused to allow anything or any access onto this roof. So we couldn't put – this is a perfect roof, there's no shadow. You've got cores here that will potentially make some shadow onto any of these roofs. And this is the absolute perfect roof to get PV on but we just couldn't get it for Network Rail's sake. So in the future if they did need it we have a water tap allocated to every roof. So that if we can get the Sedum off and panels on and they need cleaning or however it works then yeah, it might be a possibility." **Interview 19**

"The panels are very light yeah. The structure would be fine. Each of these roofs at the top level have been designed for 200mm of soil. We're actually only installing I think 80mm of soil they can hold the capacity of 200mm which then gives that extra. But for instance we're putting 80mm on this top level but if we decided in a year's time the planners let go and use it, we could just fill it with PV." **Interview 19**

INSTANCE 19J

"just simple things like the basins. We've put in two, two tap basins originally. You know simply, but hang on, if we decided in ten years' time that we were only ever going to have cold water for people to wash their hands and a sanitiser for really grubby hands, so that we didn't have to heat hot water, as an energy saving, then we only really need a single whole basin right? So at the moment, we have single hole basins…" **Interview 19**

INSTANCE 19K

"We removed cooking facilities in the building because of the natural ventilation system that we have. Sort of the mixed mode where we had these two stair cores that act as chimneys. We have a café on the ground floor area here, and this café, which is in the area here, has no cooking facilities because of the air, the smell, the ventilation, the extract. They're all part of our power uses and also the smells would just whoosh, straight up the chimney and everyone would suffer on every other floor upstairs." **Interview 19**

INSTANCE 19L

"So this light is effectively applying to the entire building. It creates a singular type of space, that then your use of it would be like furniture flexibility. You can move whatever you want underneath it. It's not a bespoke design, so this is not designed for office work, and this is not designed for model making, and this is not designed for computer use. It is designed for multi-function.

This section here, they indicated they did want some high powered computers in. So we put in a couple of cooling units. Whether or not they all get turned on, on day one, who knows? But what we've said to the School of Architecture is, if you can keep your high powered up that end, because they do need some of that. And then the rest of its designed for thin clients, for very light computer use, computer machines with low heat generation and the cooling ventilation system has been designed accordingly." **Interview 19**

20 Church View

INSTANCE 20A - ENABLING

"Investigations are being undertaken to assess the viability of providing photovoltaic panels on the roof of the building at a later date." **Demolition Planning Application Notes**

21 Great Ormond Street Hospital Phase 2B

INSTANCE 21A

"The redevelopment programme has set a target of 120 per cent carbon reduction and 60 per cent renewable contribution by 2017 when the Mittal Children's Medical Centre is complete. These targets reflect reducing carbon dioxide emissions and increasing the amount of renewable energy created.

- A reduction of 120 per cent carbon means that the Mittal Children's Medical Centre will provide all its own energy carbon free, and also supply some green energy to other parts of the site.
- These figures are based on the agreed plan to use biofuels but the system is also able to use gas, if this is necessary." **GOSH website 'Sustainability – What's happening now and next'**

"The option will be available in future, when a reliable bio-oil fuel supply becomes available, to turn the hospital over to a full low carbon fuel burn with natural gas back up." **Energy Demand Assessment**

23 Trowbridge County Council

INSTANCE 23B

“Harrison concurs but reveals one potential weakness which he readily concedes was not a substantial issue at Trowbridge and could be easily addressed on other projects where the system might be used. “Although maintenance access has been provided, the degree of access is relatively limited so as to not compromise the airtightness and due to the bonded composition of the panels. It’s a small consideration and one that is justified at Trowbridge by the excellent performance of the integrated air plenum.”” **www.building.co.uk/trowbridge-walking-on-air/5057384.article**

[“The plenum works by means of cool air pumped into the 750mm to 900mm void underneath the floor and then released into the courtyard through up to 300 factory-cut air diffuser panels integrated into the floor and through vents discreetly embedded into fixed furniture such as seats and benches. As Harrison explains “this reduced the amount of visible ventilation grilles required for the floor.”” **www.building.co.uk/trowbridge-walking-on-air/5057384.article**]

INSTANCE 23C

“The space is covered by a Texlon® ETFE roof that excellent insulation thanks to the compressed air inside the eight cushions, supported by steel trusses. The Texlon®ETFE cushions provide variable solar shading while maintaining natural light as well as providing intelligent climatic control, ensuring that the internal climate is comfortable for staff and visitors at all times.“ **www.vector-foiltec.com/en/projects/pages/gb-trowbridge-council-office.html**

24 Sheffield Engineering Graduate School

INSTANCE 24C

"This means that any development must achieve the lowest possible carbon emissions, as its emissions are a direct addition to the baseline. The conceptual design of the Graduate School must focus on providing a robust platform to allow the building usage to change over its Lifetime whilst minimising increases in carbon emissions." **Design and Access Statement**

"A key driver for the university is the need to reach set carbon reduction targets across the estate. The University is already served by Sheffield Heat and Power, which provides a sustainable energy source. In order to further reduce carbon requirements it will be necessary to target a reduction in electricity consumption. In order to achieve this it is proposed that the development is naturally ventilated and naturally day-lit as far as possible. This key driver for the building will have significant implications on facade design in order to naturally ventilate the building while controlling break-in traffic noise and pollution. This driver will also impact on suitable plan depth, and floor-to-floor height to allow these criteria to be met." **Design and Access Statement**

"Levels D and E of the proposed development have larger floor to floor heights suitable for natural ventilation, and use the atrium chimneys as the return air path respectively. As these spaces have a greater floor-to-floor height than the lower levels, these spaces are able to accommodate a raised access floor depth and be naturally ventilated. As a result the large open plan flexible teaching spaces have been located on these levels as these will benefit from a raised access floor to distribute services." **Design and Access Statement**

"Locate the open plan teaching spaces within the larger floor-to-floor heights to allow a raised access floor to be accommodated to facilitate flexible servicing." **Design and Access Statement**

INSTANCE 24F

"However, the Engineering Led Design was not without compromise. A number of aspects of the client brief had to be put to one side in order to truly maximise the opportunity for natural ventilation. However, it would be possible to take a pragmatic approach to the implementation of individual aspects without significantly compromising the overall effect." **Climate Adaptation Study Rev B**

"All designs are a compromise of the many influencing drivers that exist in any building project. The original design by Bond Bryan Architects (Figure 7), an undoubtedly excellent design solution, incorporated many of the principles necessary to create a low-carbon naturally ventilated building. However, the need to accommodate the required floor area within the number of storeys led to the need to adjoin the building to the surrounding structures." **Climate Adaptation Study Rev B**

"Open plan offices: internal walls were removed to allow more ventilation airflow" **Climate Adaptation Report p13**

INSTANCE 24G

“On each level there will be post-graduate research and post-doctorate research accommodation. These will be open plan spaces to facilitate the ventilation strategy and return air path to the atrium zone.” Design and Access Statement

INSTANCE 24H

“The laboratory requirements have been developed through the end user consultation process. The currently envisaged usages are able to function within a mechanically assisted naturally ventilated space. Two of the three laboratories accommodate the provision of make up air to facilitate the use of fume cupboards within these spaces. If at a later date the Faculty wished to incorporate extremely specialist equipment or environmental controls for research purposes it may become necessary to fully mechanically ventilate and comfort cool the laboratories dependent on function. If this were the case locating the laboratories on these floors would not compromise the ability to naturally ventilate the upper levels.” **Design and Access Statement**

INSTANCE 24I

A key factor behind the proposed structural frame solution is providing the University with the maximum long-term flexibility in adjusting internal partitions. Also the ability for the frame to provide a thermal sink and assist with nighttime cooling and thermal regulation throughout the year. To this end it is proposed that the building be constructed using a structural concrete frame and slabs, which results in non-load bearing internal room partitions.” **Design and Access Statement**

INSTANCE 24K

User notes: The heating system is intended to be served from the Sheffield central district heating scheme. As such the only heat generation equipment (per se) in the building are the heat exchangers from the central system which are effectively infinitely modulable.” **Climate change appraisal framework, Appendix 2.1**

“A key driver for the University is the need to reach set carbon reduction targets across the estate. The University is already served by Sheffield Heat and Power, which provides a sustainable energy source. In order to further reduce carbon requirements it will be necessary to…” **Design and Access Statement**

25 Ebbw Vale 11-16 Phase School

INSTANCE 25A

“Full accessible floor void serves as: a concealed route for services, a supply air plenum and a flexible future proof solution to changes in future or floor plan layout.”

“The building has been designed to utilise exposed thermal mass via concrete soffit ceilings with raised access floors to encompass the services. In the summer this allows the building to absorb heat from the internal gains in the day – cooling the spaces. At night, the ventilators, rooflights and windows (on a purging strategy) open allowing the cooler night air to cool the mass of the building. In the winter the windows/ventilators are kept shut and the heat in thermal mass remains in situ reducing the need for heating.” **Adaptation Report Appendices**

“A simple floor void servicing strategy enables change of use, expansion and adaption of spaces as the user requirements change and evolve” **Adaptation Report**

“This displacement ventilation system provides high volumes of air at low speeds with low noise, providing energy and comfort benefits and described in the Stage C report.” **Adaptation Report p22**

INSTANCE 25B

“Community Heating Community heating entails an Energy Centre that connects buried pipes that pump hot water for heating to individual buildings. The main energy users will be the hospital, the Learning Campus and Leisure Centre. New buildings can be added to the system as development progresses. This will allow for the use of efficient combined heat and power and renewable energy.”

INSTANCE 25C

(Energy centre sketch) “Site for future technologies e.g. fuel cell”

INSTANCE 25D

“Natural ventilation air supply via:

- High level windows with actuators controlled by the BMS to ensure control of CO2 levels and for night time purpose of heat in summer
- Low level windows manually controlled for supplementary ventilation.” **Final Report**

“In addition to the above, open able windows will be provided in the large majority of spaces, however they are not formally part of the ventilation strategy, including them will improve occupant satisfaction.” **Adaptation Report p22**

“In order to avoid the mechanical ventilation systems running whilst acoustic ventilators are open a indicator panel will be provided in each room with a simple annotated description on the wall. This will indicate what mode the system is on:

Mode 1 - Outside of the heating / cooling seasons - no mechanical systems operating, acoustic ventilator open - GREEN

Mode 2 - Cooling season - mechanical systems operating with tempered air from the earth tubes, acoustic ventilator closed - AMBER

Mode 3 - Heating season - mechanical systems operating with tempered air from the earth tubes, heating on, acoustic ventilator closed – RED" **Adaptation Report p22**

INSTANCE 25E

"Mixed mode ventilation to minimise energy use year round"

"The bulk of the building will be classed as "mixed mode" ventilated spaces. This is the option of either mechanical ventilation (for heat recovery in winter, and when passive cooling is being used in summer) or natural ventilation..." **Adaptation Report p22**

"Building and systems based around a mixed mode approach, which will initially maximise the passive operation but can in time the systems are adaptable to deal with higher temperatures or gains." **Adaptation Report p18**

"Mixed-mode approach

The mixed-mode systems in the teaching spaces takes the robust approach to environmental comfort; by designing a façade which enables natural ventilation, whilst also installing a passively cooled mechanical ventilation system to control temperature and acoustic conditions. This increases the capacity and flexibility of the buildings ability to regulate occupant comfort in future."
Adaptation Report, p15

INSTANCE 25F

"LOW CARBON DESIGN INTENT

…Aims & Objectives

The aim of environmental sustainability is to incorporate:

- Sustainability measures to reduce the environmental impact associated with buildings and minimise the demand for energy, water, and materials and creation of waste;
- Approaches to development which create new opportunities to enhance biodiversity; and
- Adaptable and flexible development that can respond to social, technological, economic and environmental conditions/changes (e.g. the current and future effects of climate change) over time to minimise the need to demolish and rebuild." **Adaption Report**

INSTANCE 25G

"Central energy centre

The energy centre will supply heat and potentially power to a number of building in the Vale, by located energy supply centrally it is easier to scale up the capacity more efficiently and quickly in order to adapt to potential climate changes or reduced availability of fossil fuels." Adaptation Report p15

31 Cooperative HQ / 1 Angel Square

INSTANCE 31A

“A major contribution towards these attainments is form the use if a pioneering pure plant oil fed combined heat and power system. It contains 2, 400kw reciprocating engines capable of running on multiple fuels. Rapeseed oil, which is being grown on the Co-operative’s own farmland, will be used to run the engine making it a true closed loop system. It supplies the entire complex, can export excess energy back to the grid , waste heat is sent through an absorption chiller which is then used to cool the building and it’s IT systems.” **BCO Submission**

“the two CHP boilers in the basement which run off rapeseed was a big contribution to the energy as was the fact that— I think the client paid additional money for the fact that the boilers could run on – initially they can run on rapeseed, but they can also run on other fuel as well. So it’s almost like that car you’re buying. You pay a little bit extra so your car can run on diesel, but it can run on petrol as well if needed to. So, there was some sort of future-proofing there as well.” **Interview 31**

INSTANCE 31B

“The building must be designed to have the ability to ‘plug-in’ to, or provide, future innovative energy solutions such as district heating systems, ground source heating systems, connection to an Energy Service Company”

INSTANCE 31C

(section through the building showing) “raised access flooring for service distribution” **Final Report**

“Considerations on fire and smoke ventilation strategy, condensation risks, flexibility in office spaces, simplicity in controls and operation have led to the use of a mechanical ventilation solution introduced to each office floor via underfloor supply and exhaust via atrium.” **Final Report**

“The client at the outset, “Oh, we want our building to be naturally ventilation with opening windows.” We set off down that route looking to see how we can make that work. After quite a long time of trying to make it work, we were finding there were insurmountable problems…” **Interview 31A**

“As soon as you open a window you obviously get the noise in. Also we found it difficult to control the energy demand because you had no control over who was opening windows and who wasn’t. Actually, once somebody opens a window, the warm air then comes into the building. Whilst people may open the window to get a breeze and some fresh air, they’re actually letting warm air in.

There was the acoustics, there was the control aspect of it, and then there were practical things like, Who goes round and closes all the windows at night time? Because people will go home and leave the windows open, so the poor night watchman would have to walk – and it’s a quarter of a kilometre walk round every floor and there’s ten full floors – so there’s two and a half kilometres he’s got to walk every night closing windows. If the windows are left open overnight the building could be too cool in the morning when people come in, especially in the summer – actually you could get some really cold evenings – when then means that the heating has got to work harder in the morning to get the building up to temperature. We went through all these scenarios and Buro Happold did a lot of work in terms of simulation of different scenarios and we demonstrated to the clients that, from an energy point of view, that's where this building was conceived: This building is about low energy. If you want to have a building that consumes at least energy as possible, then I know it goes about your preconceptions about what you wanted, but actually, we can demonstrate that controlling the ventilation makes a more energy-efficient building." **Interview 31A**

"The deep building plan and the close proximity of the Manchester inner ring road meant that a fully naturally ventilated solution would not be possible on its own. It was therefore decided to develop an energy efficient mechanical ventilation system that was responsive to the levels of building occupation." **Hitchmough et al. (2011) – [moved from 31K]**

INSTANCE 31D

"In order to increase utilisation of the new office and reduce corporate carbon footprint, the building's spatial plan and IT strategy has been designed to maximise efficiency using hot desk, thin client IT equipment and smart grid." **Final Report**

"rolling out virtual desktop technology that not only uses less heat and energy but will also enable flexible working, including home working and hot desking to drive maximum space efficiency." **Sale and Leaseback Brochure**

"Currently the building has smart grid and intelligent small power control system so that the equipment load for any one area of the open plan office can be switched off automatically by an intelligent Building Management System." **Adaptation Report**

"Smart grid has been installed for all desks throughout the building to facilitate the management of the building. This measure is effective in monitoring the desks usage and cut down small power energy wastage." **Adaptation Report**

INSTANCE 31E

"Also, although most architects like exposed concrete, most people don't. So we painted the concrete white, which not only softens the character of the space but enables the artificial lighting's lux levels to be reduced from 550 to 300, representing a significant cost and energy saving. Finally, the white surfaces create something of a blank canvas which the workers will be able to personalise over time to evolve the identity of their workplace." **OneNote Part 2**

"The soffit of the concrete is painted white and that's not because the quality of the concrete was in any way inferior – the quality was superb. But by painting the concrete white, we were able to reduce the lux level of the light. Rather than operating the light at five hundred lux, we can use the light at a lower intensity. We can get that down to three fifty lux on a working plane rather than— Because there's so much reflected light coming down. By painting the soffit white, we reduce the energy amount and going from five hundred to three fifty, you're almost reducing that by almost a half, which is a significant amount of money." **Interview 31A**

INSTANCE 31F

"The building sets a new benchmark for commercial office design, achieving a balance of sustainability, operational efficiency, space flexibility and high quality." **OneNote**

INSTANCE 31G

"Most impressive of all is the enormous amount of natural daylight present. Light not only pours in through the glass "eyelid" ceiling but over the balconies themselves. This is because, with the exception of the three cores on alternate sides of the atrium, (accentuated by oak rather than white balconies), every balcony fronts onto entirely open-plan offices on the lower nine floors, allowing light from the external wall to permeate into the heart of the building." **One Note Part 2**

"Floor to ceiling is 2.6 and 2.75. We're slightly above, so we've got slightly higher ceiling heights because that helps with the daylight." **Interview 31**

"The main driver for the plan form and size is the requirement for flexible open plan office space forming approximately 80% of the building. The floor-plate is organised around a large central atrium space in an equilateral triangle with continuous office space forming 3 equal wings and 3 vertical circulation and toilet cores. The office wings are 16.5m at their widest point between external wall and atrium. The relatively narrow floor-plates ensure a good level of daylight for all occupants and facilitate the natural ventilation of the building." **Design and Access Statement p68**

"Energy for artificial lighting is one of the most significant operating costs for a typical office building. The team adopted a number of strategies to firstly minimise the reliance on artificial light by maximising daylight in to the office space and secondly reducing the energy required to provide artificial lighting." **BCO submission summary**

INSTANCE 31I

"First and foremost, you can't do a project like this without having a client that's wholly committed to delivering a sustainable building in the broadest sense of the word. For a lot of people, sustainability is focussing on energy and carbon, whereas actually, sustainable buildings are about adaptability and physical change as well. Because there's plenty of examples of buildings, and I think probably the decade that was probably the most guilty seems to be the seventies and the eighties where buildings of that vintage – which, over the grand scheme of things in the life of buildings is not a long time— The prospect of a building that's twenty-five or thirty years old being demolished because it's obsolete or no longer fit for purpose is ludicrous, I think, and completely unsustainable. That is linked, effectively, always back to carbon emissions because the making of that building in the first place, the embodied energy in the building only has a life of twenty-five or thirty years.

From the very outset on this project, the client had the vision to create something quite ambitious in its sustainability agenda, but the sustainability agenda in its wider sense, so that embodied carbon energy, health and well-being for the staff and the people that are going to use it and the adaptability and the resilience of the building in use. The building could accommodate a degree of change and flux within it without having to be based about too much and things to be changed wholesale. " **Interview 31A**

INSTANCE 31J

"All of the floor plates were designed to be fully open to the atrium, but the building needed to be designed so that, if in the future they were to be glazed in, because— Let's go back to the beginning. If this is sub-let, then you have somebody in there and you have a completely different business in here, the likelihood is that whilst they're all sharing accommodation, they want a glass screen between themselves and the atrium. We had to design the building anticipating that the edges of the floor place would be glazed in at a later date. The ventilation system needed to be designed to work for both scenarios. That's been taken into account with the base design, so that those glass screens can be slotted in, slotted out and the environmental strategy still works." **Interview 31**

"The atrium is fundamental to the building's ventilation strategy. Each of its three corners houses one of the building's vertical service cores. Some 50m3/s of fresh air is sucked into the building from its landscaped forecourt through three giant earth tubes buried beneath the building; this helps temper the air, cooling it in summer and warming it in winter. Air is heated or cooled in a huge basement plant room before giant fans push it up the service cores to the floor plates." **OneNote part 2**

"The building's 2,700m2 concrete floor plates are divided into 12 control zones; each core delivers fresh air to four zones." **OneNote part 2**

"A displacement system delivers fresh air to the offices through a 350mm raised floor void. As the air is warmed it rises 4m to the soffit and out of the offices into the central atrium, which acts like a giant chimney. In the atrium the air ascends to roof level, where it is drawn through a heat recovery system before being ejected." **OneNote part 2**

INSTANCE 31L

"The rafts have sensors in them for CO_2 so if, for example— This room, if you take an average of one person per eight square metres, this room should hold four or five people. If, however, we had a meeting – if we had this room full – twelve people, the sensors in the ceiling would realise that there's a lot of people in the room because of the amount of CO_2 being exhaled, and as a result of that, detection of an enhanced concentration of CO_2, it would increase the ventilation and the cooling in this room. By contrast, if it senses that there's nobody working down that end of the office, it shuts all the systems down, but that works on a three metre by three metres grid, so there's an invisible grid across the whole ceiling on a three metre by three metre lattice." **Interview 31**

INTERACTION 31M

I:Was that remotely frightening, because that's something that you haven't got a lot of control over?

"Absolutely, because you— Yeah. That's down to the owner occupiers, whether they leave the lights on all night long or— But again, with this project, the client is so acutely focussed on cost in use of this building that there will be staff training, there will be all sorts of protocols that – almost like a user's manual, so every member of staff will know how this building works, what their responsibility is and how they use the space. Simple things like the blinds on the windows. We have blinds on the window to deal with glare – not necessarily solar control because the double skin does that – but on a day like today, if I'm standing, if I'm sitting— Well firstly, we designed the workspace so no computer has its back to a window. Every computer, is align to the window is to the side. If I'm sitting near this window on a grey sky like today, you can see a glare on your computer. You can see it now on that screen there, can't you? So a grey-white sky actually is difficult to deal with, as is a sunny day.

We have blinds on every window to deal with glare, but we've worked out that if the blinds remain down when they should be up— We did look at automatic blinds, but it was about five hundred pounds a blind. By the time you'd got a motor and linked it back to the BMS— The cost of automating the blinds was phenomenal. It also takes away some user control as well. People like to feel a little bit of control about their workplace. But the message that we're going to get through to the staff is that if you pull your blind down and then leave it down when actually it should be up, because the sun's gone in or you don't get glare any more— The bureau's did an exercise to say that if – they assumed that fifty percent of the blinds were down over the course of a year when they should be up. It added ten thousand pounds onto the energy bill for the building, for the year. So it's things like that.

Staff are going to be reminded, "Look, if your blind is down when it should be up, you are causing this building to consume more electricity than it should do.' Those parts of the building that the staff are responsible for and where they can make a difference, there will be a programme of education to ensure that they understand the small role they can play. This all helps to give people a sense of control and ownership and they're doing their bit as well, which again, goes to the very heart of what the Co-op are all about." **Interview 31**

35 Environment and Sustainability Institute

INSTANCE 35A

“ROOF MOUNT GUIDANCE

Fixings for roof mounted turbines on new build projects can be incorporated into the building structure at minimal additional cost. Retrofitted turbines tend to require structural works to carry the loads back to the building structure. Careful consideration of various issues is required for roof mounted turbines including: waterproofing; cold bridging; air tightness; fatigue and vibration.” **P3 Wind Turbine Application Notes**

“In order to ensure the necessary structural support for the turbine as part of the construction of the building, planning permission is needed. Otherwise, the cost of installing the roof mounted turbines would increase sharply if they were retrofitted.” **Wind turbine application, planning statement p3**

INSTANCE 35C

“>80% of the academic buildings will be designed such that integrated renewables can be installed at a later date.” **Outline Application Sustainability Assessment** (this is a response to a local authority requirement to “encourage the future use of active solar techniques where they are not initially supplied to enable occupants to use low-carbon energy.”)

[Note this relates to the master plan – ESI has renewables already attached in the form of PV cladding and 2 no. wind turbines located on the roof. It is also connected to a nearby CHP plant presumably constructed during an earlier building phase.]

INSTANCE 35D

[Outlining a case for not including GSHPs] “A heat pump system would be able to supply cooling at temperatures as low as 6'C and heating at temperatures up to 45'C. This would require the use of low-temperature/high-volume heating systems throughout the development, typically in the form of underfloor circuits. This places a restriction on the future design of heating and cooling systems. Another barrier is the reliance on electrical power to provide heating; this may be an issue in the long-term as electricity prices are predicted to rise.” **Outline Planning Application Sustainability Assessment**

INSTANCE 35E

“During the life of the community heating network, which may be in excess of 50 years, different heat generators or additional thermal storage can be added into the scheme as economics change. For instance a CHP engine or biomass boiler could be added at any time, or the network could be linked to another neighbouring scheme. In the same way the network can be adapted to include new clients whenever they arrive.

Community heating schemes can be used with existing and new buildings but would require careful planning regarding flexibility to meet changes in future energy demands. A community heating scheme would serve to 'future proof' the development as it allows for review and addition of other renewable technologies as they become available. In such a system, only the central technology would need to be replaced rather than individual technologies within each building." **Sustainability Statement p61**

Case 38.1 Site J Residential Blocks

Case 46 Hinguar School

INSTANCE 46A

"Option A7 – GSHPs: Drawing shows the pipes covering a large area, almost the whole site – implications for site adaptability?" **Appendix 3A notes [n.b this is my note on the drawing not a project comment]**

"Now, in the report said, "Well actually it would have been good to have and could we reinstate it," it would just not be practical to do that now because the landscaping has just grown. You know, so that's why we then looked at vertical ones." **Interview 46**

"Unfortunately flexibility (such as slightly larger ceiling voids, designating spaces for future installation of GSHP /ASHP and adapting services to connect to them, etc.) all tend to come at an extra cost to the client." **Adaptation Report**

"The option of installing an ASHP was shown to be about 50% cheaper than a GSHP, though CO2 emissions for the former option are slightly higher (but still much below the AC units!)." **Adaptation Report**

"In order to keep the project alive, the team had to look at significant value engineering, including the replacement of the GSHP with gas boilers, omitting the wind turbine on the school grounds (which was also considered a potential noise issue by the neighbours) and installing less photovoltaic panels on the roof. This resulted in a decreased CO2 emissions reduction rate of 38 % above Building Regs 2002. A 10% reduction in carbon emissions from a renewable energy source will still be achieved in the form of the photovoltaic panels" **Adaptation Report p4**

"if you did it now you would only serve the extension, because if you put a source heat pump in it kind of makes if the extension gets built because there's major works anyway. But then you've already got the gas boilers for the other buildings so it kind of makes sense to sort of do that to serve a part of the building." **Interview 46**

INSTANCE 46B

"minimise energy use through passive means, user control and through energy creation from on site renewable energy sources." **Design and Access Statement**

"…anything that was completely fixed just gave us, you know, an increased heating requirement in winter." **Interview 46**

"Further permanent shading would lead t heat loss in winter month increased heating demands, but fabric roller shutters would address this by being flexible." Appendix 3 Part 2

48 London Bridge Station

INSTANCE 48A.1

"Centralised plant installed in either one or two energy centres will be used to supply the heating requirements of the site. The use of centralised plant removes the need for installation of plant in retailer fit -out with consequent improvements in efficiency. The heating approach put forward by the applicant is compatible with future connection to an external heat network should be one available in the future." **Planning Application Notes**

"District heating or cooling networks can have a low carbon dioxide emissions rate and may reduce the station's emissions rate further. The development could potentially be connected to a district network in the future. The surrounding area has major developments with CHP systems that could be connected to a district heating or cooling network. The station has a relatively low heating demand and the cost-effectiveness of connecting into a network needs to be demonstrated. Initial investigations however show that the cost for linking into these district heating schemes are so prohibitively high as to be unsustainable for the small element of power required." **Sustainability Statement**

INSTANCE 48A.2

"The centralised plant, sized to enable close load matching and ensure efficient primary plant operation, removes the requirement for installation of plant in retailers fit-out." **Energy Statement Part 1**

Regarding retail and ancillary land use spaces, Network Rail is unable to dictate the lighting solutions and requirements for unknown future tenants although Network Rail anticipates that these will be energy efficient in their operation and control to achieve building regulation compliance." **Energy Statement Part 1**

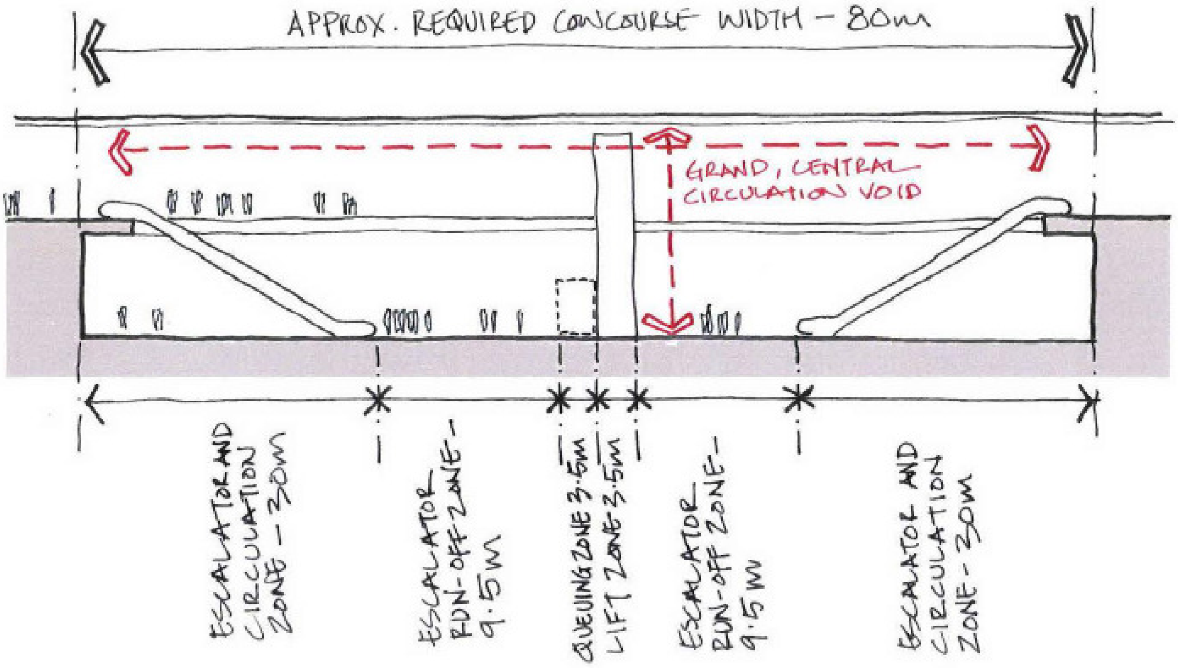
INSTANCE 48B

"enhancing the passenger journey from concourse to platform by providing natural daylight and generously proportioned spaces where they are most required." **Design and Access Statement**

"The following proposed passive measures will be considered during the design of the proposed scheme and could improve the energy efficiency of the station concourse and platform areas:

- Natural Ventilation - Utilising natural ventilation to reduce mechanical ventilation energy and cooling demand.
- Daylighting - The proposed scheme's form will allow daylight into accommodation when practical to reduce lighting energy demand." **Energy Statement Part 1**

"As shown in the diagram the central void space between each bank of escalators has the potential to be a grand four storey high space through which passengers will make the journey from concourse to platform. These spaces will occur as rhythmic recurring openings between the Viaduct bridges running across the concourse space creating drama and spatial variety across the concourse while assisting with spatial legibility by drawing attention to the routes up to each platform." **Design and Access Statement Chapters 3 and 4**



STATION SECTION DIAGRAM - CONCOURSE WIDTH

"The concourse is sized to allow for 66% increase in capacity." **Design and Access Statement Chapters 3 and 4.**

Case	Tactic	Why	Tactic (refined)	Installation
1	All building U values will be in excess of the requirements of the building regulations part L	To reduce the heating load and cooling load in the building	U values 20% better than part L	y
1	The air permeability for the building will be inn excess of the requirements of the building regulations Part L	To reduce the heating load and cooling load in the building	Air permeability better than part L (target 5m3/m3 @ 50Pa	y
1	Introduce natural light wherever possible	Passive strategy	Introduce natural daylight	y
1	A solar shading strategy has been developed with an appropriate glazing specification, … this is through a combination of window	To limit the solar gain into the spaces	Reduce solar gains through the windows	y
1	PV integrated glazed panel; 600 sqm of solar PV	to reduce the electrical demand further and achieve an EPC of minimum 40.	PV on the roof or integrated with the walls	y
1	Movement and daylight controlled lights	to ensure lighting is only used when needed	Motion and daylight sensors to lighting	y
1	The main mechanical ventilation systems will incoperate heat recovery systems	reduction in the remaining ["after passive design solution fully considered"] carbon emissions... through energy efficient systems	Heat recovery to ventilation system	y
1	Heating and cooling systems have zoned controls local to space served	reduction in the remaining ["after passive design solution fully considered"] carbon emissions... through energy efficient systems	Zoned controls for heating and cooling	y
1	Smart metering strategy	to allow the occupier to monitor and hence reduce their energy demand	Smart metering strategy	y
1	solar hot water system	to meet the hot water demands of the building	Solar hot water	?
1	heat recovery boiler from the comfort cooling system	capturing heat that would normally be rejected to the atmosphere to meet the hot water demands of the building	Heat recovery from cooling plant for HW	?
1	High efficiency cooling systems	reduction in the remaining ["after passive design solution fully considered"] carbon emissions... through energy efficient systems	Highly effiicient chillers	y
1	Shelves to reflect daylight back into the building	reduction in the remaining ["after passive design solution fully considered"] carbon emissions... through energy efficient systems	Light shelves for daylighting	y
4	Photovolatics	to assit wit the reduction of energy usage and associated carbon reductions	Solar thermal panels	R
4	Solar thermal; solar hot water panels	to assit wit the reduction of energy usage and associated carbon reductions	PV panels	R
4	Combined PV and solar hot water panels (PVT)	to assit wit the reduction of energy usage and associated carbon reductions	Combined PV and solar thermal panel	R
4	Natual ventilation is anticipated throughout		Natural ventilation	y
4	Timeclocks, photocells	Control energy consumption	Time clocks and photocells	
4	Specifying energy efficient fittings		Energy efficient equipment	R
4	Zone controls can be added to the lighting	Preventing lights being on needlessly wen only a specific area is needed	Zoned controls to lighting	
4	Insulation is likely to be installed at a reasonably high level; energy standards wil be met by fabric efficiency	due to BREEAM requirements	Fabric efficency (insulation)	y
4	CHP	considered as renewable technologies	CHP	n
4	Insulation…increasing this to a PassivHaus level	no appreciable climate change benefit was shown in increasing this [fabric insulation] to passivhaus standard	PassivHaus insulation levels	n
6.1	A north-eastern aspect	Gives good daylighitng whilst avoiding overheating from the south	North east aspect for good daylighting	y
6.1	Use of the insulated render construction	providing a warmer and airtight facade by easing the continuity of insulation and finish	Insulated render exterior finish	y
6.1	Sunlight is not excluded…but brought into the building in a controlled manner by rooflights and balconies	Control of solar gains removes the need for energy using mechancial ventilation	Control of solar gains (through rooflights, balconies)	y
6.1	The buildings are being designed to perform better than required under current building regulations...the fabric will be highly insulation	Energy saving	Roofs and external walls with high levels of insulation and air tightness	y
6.1	A biomass boiler will be installed	reducing the use of gas to standby only	Biomass boiler	y
6	Light internal finishes	reflect daylight more effectively and so improve the internal daylight	Light internal finishes	
6.2	A biomass boiler will be installed	reducing the use of gas to standby only	Biomass boiler	
6.1	Large windows	Reduce the time lightings need to be switched on	Large windows	y
6.2	Large windows	Reduce the time lightings need to be switched on	Large windows	y
6.1	Reduced use of south facing windows	limit unwanted solar gain that might otherwise give need for mechanical ventilation	Reduced use of south facing windows	y

6.1	Heavyweight construction	to provide thermal mass, limit unwanted solar gain that might otherwise give need for mechanical ventilation	Heavyweight construction	y
6.1	A board will be mounted in the entrance area allowing pupils to see and monitor energy and water use		Energy wall	y
6.1	Small window into the plantroom	so that the way the building is serviced is made visible to pupils	Window into the plantroom	y
6.2	Reduced use of south facing windows	limit unwanted solar gain that might otherwise give need for mechanical ventilation	Reduced use of south facing windows	y
6.2	Heavyweight construction	to provide thermal mass, limit unwanted solar gain that might otherwise give need for mechanical ventilation	Heavyweight construction	y
6.2	A board will be mounted in the entrance area allowing pupils to see and monitor energy and water use		Energy wall	y
6.2	Small window into the plantroom	so that the way the building is serviced is made visible to pupils	Window into the plantroom	53 The buildi
6.2	PV panels will be installed on the wast roof of the kitchen	so that an amount of renewable electricity can be generated	PV panels	?
7	The use and control of natural light has been engineered into the new building	reduces the energy consumption	Use of natural daylight	
7	Central and local light switching	low carbon technology	Central and local light switches	
7	lighting control system will provide automatic control of all areas of the new block..daylight dimming, local presence/absence detection	In accordance with the BREEAM requirement;	Movement sensors and daylight control	
7	Low energy fluorescent lights	low carbon technology	Low energy floruescent lights	
7	Varible speed drives on pumps; air handling plant; extract fands; heating pumps; water booster sets	Modulation of speed to match demand; to throttle down the motors and save energy when full power isn't needed	Variable speed drives on pumps, air handling plant etc.	
7	Heating controls to optomise boiler efficiency	low carbon technology	Heating controls to optomise boiler efficiency	
7	The majority of the rooms are naturally ventilated	to minimise the risk of high energy consumption associated with mechanical ventialtion	Natural ventilation	
7	Heat recovery on mechanical ventilation plant	low carbon technology	Heat recovery on mechanical ventilation plant	
7	Exposed slabs and night cooling	to reduce the building running cost and environmental impact; stabilise internal temperatures	Exposed soffits for thermal mass (night cooling)	
7	Soft landing; the commissioning in accordance with BSRIA, CIBSE and BREEAM Man1; operating and maintenance manuals	To improve the operational performance of the buidling	Soft landings, commissioning and manuals	
7	Installation of photovoltaic panels on the roof	meet the renewable energy target of 15%	PV	
7	Wind turbine	for educational purposes and will marginally contribute to the CO2 emissions reduction	Wind turbine	
7	A solar hot water system comprising of high efficient flat solar panels, a stratifying hot water sotrage tank, pump, controls and	shall be provided for education purposes and will marginally contribute to the CO2 emissions reduction	Solar hot water system / solar thermal panel	
7	Water saving devices to be included in toilets, taps and showers	will reduce the water usage of the building but also reduce the amount of heating energy required by the hot water	Water saving devices	
7	Energy and water metering	to comply with the requirements of Part L and BREEAM	Energy meters and submeters	
7	Raised access flooring with underfloor heating	low operating temperatures will increase the length of time when the boilers will run in condensate mode at high efficiency	Underfloor heating for boiler efficiency	
7	High level automated openings, low level manual openings and a transfer grille ..at the back of the classroom	to encourage cross ventilation	Opening and actuated windows for natural and night ventilation	y
7	ICT rooms employ a mixed mode strategy	Minimise the use of active cooling	Mixed mode strategy (peak lopping) to ICT rooms	y
7	Active cooling systems are provided by air source heat pumps	supplement the natural ventialtion	ASHPs for peak lopping in ICT rooms	y
7	Windcatchers will be passivvent Airscoop or similar	provided in areas that can not be naturally ventilated via the facade	Windcatchers	y
7	stacks located strategically around the building	The natural ventilation "engine" will be driven by [the stacks]...will also provde natural light to the circulation spaces	Stacks for daylight and natural ventilation	y
7	g value of 0.4	to provide natural daylight and reduce solar heat gain	Solar control glass	y
7	High performance thermal envelope (circa 30% improvement on 2010 Part L for roof, walls, windows)		U value reduction on 2010 Part L	y
7	50% improvement on air permeability from 2010 Building regulations		50% improvement on Part L air permeability	y
7	Two new wings of the classrooms were to be constructed, deliberatly facing north/south	the optimum orientation for reducing solar heat gain	North / south orientation to reduce solar gain	No
7	Double height glazing ... in the internal courtayrd area	to allow light deep into the plan to the new main hall	Double height glazing to the courtyard	y

7	use of lightshelves	to maximise daylight	Lightshelves	No
7	benefit of these [renewable] technolgies wll be displayed on an energy wall	for educational purposes	Energy wall	y
9	The long facades are north and south facing	will use passive solar gain to boost wintertime internal temperatures	Building is orientated for solar gain	y
9	PV panels installed on its roof	to offset its CO2 emissions; prefered solution to meet the 10% renewables target	Photovoltaic panels	y
9	Large expanses of external glazing and through the atrium	Natural daylighting	Large expanses of glazing, rooflights and atrium for daylight	y
9	The building is entered via a draft lobby	n/a - ME	Draft lobby	y
9	Opening windows	for natural ventilation to each studio space	Opening windows for NV	y
9	U values of walls, floor, roof, glazing reduce relative to part L requirements		U values improved on Part L by 16-38%	y
9	The infiltration rate has been improved by 50% from the part L minimum of 5m3/hr/m2 @ 50Pa		Air permeability better than part L (target 5m3/m3 @ 50Pa	y
9	Green roofs	A considerable aid to energy efficiency	Green roof	No
9	metering to include 'out of range' values, daylight dimming, occupancy controls	to reduce emissions as a result of lighting	Lighting controls	y
9	High performance building services	building services have a large effect on the carbon emissions of the building	High performance building servies	n
9	Heat recovery specified		Heat recovery	y
9	Improving lighting and equipement efficiency	Expected to save approximatly 200MWh/year	Improve equipment efficiency	n
9	an extensive structure of external shading louvers along its south façade	allows low angle soalr gain to prenetrate into the perimater spaces during heating periods for passive heating but subsequently minimse	Solar shading designed to solar gain in winter but excludes it in summer	y
9	Modular units of smaller sized boilers	buildings may notneed as large a boiler capacity in future…when not required, could be switched off so that ones that are operating	Modular units of smaller sized boilers	n
10	Gas combined heat and power (CHP)	to provide approximatly 10% of the building load	CHP	y
10	Air Source Heat Pumps (ASHPs)	can be used with space heating if required	ASHPs	
10	the Part L 2010 U values for the structure were improved by at least 50% and the glazing was improved by at least 30%	to minimise heat gain and loss from external temperature variations	Super insulation	y
10	Super insulation standards; increase insulation to a minimum of 300mm	to reduce heat losses and therefore plant size and CO2 emissions	reduce U values	
10	Air permeability was designed to 3m3/hr/m2; improved construction details for air tightness	MVHR units rely on this;	Improved construction details for air tightness	y
10	Photovoltaic panels	extremly good investment for reducing carbon emissions as they offset using national grid electricty (which has a very high embodied	PV	n
10	Design will be capable of accomodating photovoltaic panels in future		Allowance for PV in the roof structural design	y
10	large flat roof areas; roof aligned with the south facing grid	perfect for PV	Flat roof, orientated for PV panels	y
10	Mazimise daylight factors in all areas	to reduce the reliance on energy consumption	Maximise daylight factors to all areas	y
10	Room design to optimise natural ventilation strategies		Room design to optomise natural ventilation	y
10	Concrete structure	used as part of a passive solar heating and cooling system; results in smaller temperature band chnges and therefore less heating and	Concrete structure for thermal mass	
10	Biomass wood pellet boilers	low carbon technology	Biomass boiler	n
10	Integration of dimmable, zoned and PIR activated systems	minimise ernegy use in unoccupied areas	Lighting controls with occupancy detection; zoned and PIR activated	y
10	Hgh efficiency lighting		High efficiency lighting	y
10	high efficiency gas fired boilers	to provide the remaining heat load [after the CHP lead]	Efficient gas fired boilers	y
10	Mechanical ventilation and heat recovery (MVHR) units; heat recovery of 95% was applied to all bedrooms and 70% to offices and	run continuosly on low speed to provide a comfortable environment with manual speed control to provide higher air flow during warm	MVHR	y
10	Smart energy metering systems	to monitor energy use	Smart metering strategy	y
10	Reduction in lighting levels where possible; photocells	to automatically turn off lightings in areas where daylight levels are sufficient	Daylight dimming to lighting	y

10	Passive orientation of the building	to take advantage of solar gain	Orientate for solar gain	
10	Solar hot water (SHW) - solar collectors (panels)	can provide up to 60% of annual hot water demand; meet the required 10% renewable target	Solar thermal panels	n
10	Energy efficient equipment (rated A+ or above)	ENE15 credit	Energy efficient (A+ or better) equipment	y
10	Small scale wind turbines	produce electricity; meet the required 10% [renewable] target	Wind turbine	n
10	Energy efficient lifts	ENE08 credit	Energy efficient lifts	y
10	Heat pumps from natural source (air, ground, water)…optimal used with underfoor heating	provide space heating and, in some cases, to re-heat hot water	Other heat pumps (ground = GSHPs, water) in combination with underfloor heating	n
11	Solar water heating panels	about 50-60% of hot water demand could be provided…reducing the primary energy demand	Solar thermal panels	
11	PV	Renewable energy systems [meet planning targets]	PV	
11	Biomass	Renewable energy systems [meet planning targets]	Biomass boiler	n
11	Wind	Renewable energy systems [meet planning targets]	Wind	n
11	Cool larders…an insulated cupboard kept cool by the supply of aire chilled via underground clay pipes	reduce the size of the fridge required	Coolstore: air chilled via underground clay pipes	n
11	Stack ventilation or cross flow ventilation through opening windows		Stack / cross natural ventilation	y
11	New buildings...should be designed and orientated to maximise passive solar gain	to ensure in winter heat load is no more than 15 kWh/m2/yr [passivhaus]	Orientate for solar gain	
11	wall, floor and roof insulation enhanced	to ensure in winter heat load is no more than 15 kWh/m2/yr [passivhaus]	PassivHaus insulation level	y
11	Air tightness will be in the region of 0.6ac/h at 50Pa	to reduce unwanted infiltration both in summer and during winter	PassivHaus air tightness	y
11	walls 0.13, roof 0.11, floor 0.11 and triple glazing 1.0 W/m2K U values	to ensure in winter heat load is no more than 15 kWh/m2/yr [passivhaus]	Reduce U values (e.g. triple glazing)	y
11	Small renewable energy source such as coppiced timber	during exceptional cold periods heat load can be met	Coppiced timber fired boiler	n
11	Small renewable energy source such as…ground source heat pump	during exceptional cold periods heat load can be met	GSHPs	n
11	Low energy mechancial heat recovery ventilation	during exceptional cold periods heat load can be met; [winter ventilation]	MVHR	y
11	light coloured finishes on wall, ceilings and floors	help to reflect light	Light coloured finishes to reflect daylight	y
11	Thermal mass…in the internal walls and general structure	to reduce daily and seasonal fluctuations of intenral temperatures	Thermal mass	y
11	Provision of a combined heat and power plant		CHP	n
11	Energy saving fluorescent bulbs or LEDs		Low energy floruescent lights	y
11	The primary heat sources will have to utilise high efficiency plant	PassivHaus design	Highly efficient plant	y
11	Compact	PassivHaus design	Compact built form	n
11	use of deciduous trees [for shading]	need for winter solar gain to reduce energy consumption	Deciduous trees	y
11	Heating strategy could be changed to a gas based system	Gas has a lower CO2 conversion factor than electricity	Gas not electric boilers	
11	25mm air based insulation to pipes		Insulated pipes	y
11	Use of appropriatly designed rooflights, glazing and windows	minimising electrical lighting demand	Maximise daylight factors to all areas	
14	Plant and equipment will have appropriate controls	to minimise energy and water use	Appropriate controls to plant and equipment	y
14	An automated metering and targeting system will be installed	actions taken as a result of installing and monitoring meters ofer save 5-10% of the energy being metered	Modern metering techniques	y
14	Tamperproof thermostatic radiator valves	can be set to 18C and locked, prevent overheating	Thermostatic tamper proof radiator valves	y
14	Installation jackets will be fitted to all uninsulated valves [steam and LPHW]; [and] pipework	will substantially reduce heat losses	Insulate steam and LPHW pipe and valves	y
14	use of appropriate lighitng controls and automatic lighting management systems	energy savings are likely to be more than 30%	Approriate lighting controls (e.g. occupancy sensing)	y

14	cooling set point to other offices and administrative spaes that are mechancially cooled is raised from 22 to 24C	to counter the unavoidable increase in cooling demand and expense of energy as a consequence of introducing comfort cooling	Raise the cooling set point	?
14	Improve the thermal bridging between the windows and the reveals	improving overall fabric energy efficiency	Improve thermal bridging between windows and reveals	y
14	Heat recovery of 50%; currently no effective methods of heat recovery from passive ventilation systems		Heat recovery	n
14	Efficient lighting; 12-15W/2		Efficient lighting	y
14	Green roof		Green roof	?
14	Reduce AHU SFP from 4 to 3; Improve chiller SCoP from 2.5 to 3.5		More efficient / newer plant (e.g. AHU specific fan power, chiller SCoP)	y
14	Improve the glazing U value to 2.2		Improve the glazing U value	n?
17	Significant improvements in insulation	complying with building regulations and providing an efficient thermal envelope	Increased insulation	y
17	Replacing all glazing with high performance windows	complying with building regulations and providing an efficient thermal envelope	High performance windows (U value)	y
17	Replacing all the outdated building services and using new efficient building services	to reduce energy consumption	Efficeint building services	y
17	New atrium space	providing natural light and ventilation	Atrium	y
17	fixed, internal, vertical oak lourves are located behind all ground, first and second floor office windows	through being located behind the glazing, permit beneficial solar gain in winter months	Shades located behind the glazing	y
17	Photovoltaic panels which are to be mounted on the existing roof of D wing and the roof of the proposed extension	to comply with oxford councils NRIA and 20% renewables requirement	PV	?
17	building orientation	Optimisation of solar gain	Optimise orientation for solar gain	y
17	Vertical bore hole ground source heat pumps	Use of renewable energy sources; connected to the heating and (where app.) the HW system	GSHPs	?
17	light reflecting internal surfaces	maximisation of daylight to working spaces	Light reflecting internal surfaces	y
17	Where the existing building has high thermal mass, this will be exposed; heavyweight concrete structure	to retain heat and assist in passive night time cooling	High thermal mass / expose thermal mass	y
17	Provision of robust control systems on heating, ventilating and artifical lighting installations	to prevent energy wastage	robust control systems for plant	y
17	LED luminaries will be used…[or if not suitable] high-efficiency fluorescent	Efficiency will be paramount…in achieving the target BREEAM rating	low energy lighting	y
17	We propose lowering the lighting levels [from lighting guidelines for offices]	will generate energy savings, demonstrating an appealing eco-concious feel	lowering the lighitng levels	y
17	G value (solar transmittance)	minimise energy consumption through passive measures; reduction of solar gain	solar control glass	y
17	protecting south facing glazing with louvres and other forms of solar shading	minimise energy consumption through passive measures; reduction of solar gain	solar shading lourves	y
17	The scheme will be augmented with daylight and PIR detection ; local controllers will ensure full override is possible	to ensure that lighting is not left on unecessarily	PIR presence detection; daylight dimming; local control	y
17	Variable speed drives on the majority of fans and pumps	energy efficient measure	Varible volume pumps	y
17	Plate heat exchangers	to recover energy from the extracted air and provide it to the supply air	Heat recovery	y
17	CHP has been considered as part of the energy strategy	electricity generation; [aim] 20% of the buildings energy load can be provided by low and zero carbon technologies [planning	CHP	n
17	Solar thermal (water and space heating)	minimise energy consumption through passive measures	Solar thermal	y
17	Wind turbine	electricity generation; [aim] 20% of the buildings energy load can be provided by low and zero carbon technologies [planning	Wind turbine	n
17	Biomass heating	electricity generation; [aim] 20% of the buildings energy load can be provided by low and zero carbon technologies [planning	Biomass heating	n
17	Heating and cooling will be provided by roof mounted air source heat pumps [old pub]		ASHPs	y
17	we recommend … air leakage of no greater than 5m3/hr/m2 @ 50 Pa	a reduction in running costs and an improvement in occupant comfort	Improve air tightness	?
17	Recommended that products have an AAA rating	As part of the BREEAM process the client will be informed of the benefits of new appliances	AAA rated equipment	?
17	Entrances from other zones of the existing office complex will be fully enclosed connections	to prevent external air ingress during opening of doors	entrances fully enclosed	y
17	Manually openable high and low level windows in the buildings facade	natural ventilation to offices	manually openable windows	y

17	Control [of opening windows] will be automatic based on internal temperatures	building will be primarily naturally cooled and ventilated	actuated windows	y
17	The office wings are predominatly narrow plan, both adjoining a central lightwell	d to maximise natural daylight	narrow plan depth	y
17	Good window design, atrium glazing	maximisation of daylight to working spaces	Good window design for daylighting	y
17	Energy metering	energy efficient measure	Energy meters	y
19	Geometry aligns the facades in a predominatly north - south direction	highly beneficial for the environmental control of the building	North / South orientation to facades	y
19	Courtyards and lightwells	bringing natural light and air through the spaces	Internal courtyards / lightwells	y
19	20% of the roof area will be used for energy generation by photovoltaic cells	low zero carbon (LZC) technology will be implemented to further reduce CO2 emissions	PV	?
19	Roof vegitation on 80% of the roof area	will give a high U value rating to the construction	Green roof	y
19	Lifts will not be as prominent [as the stairs]	Use of the stairs will be encouraged	Lift hidden behind stairs and at the rear of the building	y
19	Solid elements will represent approximatly 60% of the facade area	compared to a highly glazed building, this will significantly limit winter heat lossses (thus reducing heating consumption) and summer	Limited glazing %	y
19	The building mass is broken down into narrow 'fingers'	Overshading from neighbouring bands will limit solar gains	Finger layout / banding	y
19	Efficient services will be implemented throughout; efficient chillers; AHU will be direct drive type and provided with inverter	will ensure energy demand is reduced as much as possible	Highly efficient services throughout (chillers, fans, ventilation, AHU)	y
19	highly efficient lighting systems	will ensure energy demand is reduced as much as possible	Efficeint lighting	y
19	Daylight (photocell) dimming; presence detection sensors	savings in lighting consumption	Lighting controls - daylight dimming, prescence detection	y
19	solar hot water system	low zero carbon (LZC) technology will be implemented to further reduce CO2 emissions	Solar hot water	?
19	The concrete frame will be exposed throughout the building	thermal mass of the concrete will assist in contolling the heating and cooling of the buidling, thereby reducing energy demand	Exposed concrete frame	y
19	High occupancy dark spaces requiring mechanical ventilation...are housed in the basement and ground floor	organise the programme of the building to take advantage of light and air wherever possible	High occupancy spaces requiring mechancial ventilation in basement	y
19	Mixed mode ventilation strategy	to reduce energy use [by fans]	Mixed mode ventilation strategy	y
19	Combined heat and power (CHP)	[low carbon heating and cooling]	CHP	n
19	Combined cooling, heating and power (CCHP)	use of the heat output from a CHP plant to drive an absorption chiller to provide cooling	CCHP	n
19	Open loop system; closed-loop systems	[low carbon heating and cooling]	GSHPs (closed and open loops)	n
19	Biomass boilers	biomass heating approaches a carbon neutral process	Biomass boilers	n
19	6 No. 6kW wind turbines	generate electricity	Wind turbine	n
19	Lower levels are more highly glazed..Proportions of glazing decrease at the upper levels	to maximise daylighting [at lower levels that are shaded from solar gain while protecting the more 'exposed' upper levels]	Glazing concentrated at the base of the buidling	y
19	[connection to a] district energy scheme served by CHP	[london planning rules]	Connection to district energy	n
19	space has been allowed in th plant room...to allow for a heat exchanger with a district energy scheme	[london planning rules]	Allowance for later connection to district energy	y
19	U values will exceed the requirements of Part L1A 2006	to reduce carbon dioxide emissions has been to incorporate passive design and energy efficiency measures	U values better than part L 2006	y
19	reduce air infiltration rates through the incorperation of robust detailing and high quality construction techniques	where the fabric is not airtight, higher heating energy is required in winter as a result of the higher heat losses due to air infiltration	Reduce air permeabillity	y
19	Solar control glazing (G=0.6 north, 0.4 S+E, 0.2W)	minimise the risk of excessive summe solar gains	Solar control glazing	y
19	Deep stone facade on stockwell street allows glazing to be set back; shading from recesses and fins	limiting solar gain	Deep set windows and fins for solar shading	y
19	Thermal distribution network will be insulated to high standards	to reduce distribution losses	Insulated thermal distribution	y
19	The building services systems have been designed to use variable speed pumps, fans and motors	uses less energy than traditional pumps or fans	Variable speed fans	y
19	Lifts will be provided with variable speed motors and possibly a regenerative unit	to return electricty to the grid when feasible	Efficient (regenerative) lifts	y
19	Lighting will be zoned in the larger spaces	Allowing occupants to only turn on lighting where it is needed rather than for whole rooms	Zoned lighting	y

19	Heat recovery will be introduced on the extract air ... of very high recovery efficiency (current target of 70%)	to pre-heat the incoming outside air	Heat recovery to extract	y
19	Heat and electricity meters will be fitted to the main plant on a floor by floor basis; . The smaller retail spaces, if rented to tenants, are	allowing building users to monitor energy consumption, identify unexpected patterns of consumption, and implement remediation	Energy metering	y
19	Where white goods are provided, they will be energy efficient (i.e. minimum of A-rated where products are available, otherwise B-		Energy efficient white goods	y
19	provide space heating and domestic hot wate to all areas from a single plantroom	compared to developments where tenants are left to fit out their own heating, cooling and ventilation, this ensures that services will be	Single plantroom to school and retail units	y
19	High levels of insulation	passive design / energy efficiency measure	High levels of insulation	y
19	volume of air delievered to the occupied zone will be altered...to account for the variation in occupancy and gains within a space	During low occupation the volume of air supplied to the space will be minimised to reduce fan energy use	Mechanical ventilation powers down with occupancy and NV	y
19	Openable windows will be controlled automatically, to allow fresh air to enter the space and cross ventilate by mechanical	Ventilating the studio level with cool night air, the heat can be removed from the exposed thermal mass	Night cooling	
19	use a concrete mix which uses ground granulated blast furnace slag (GGBS) as a replacement for 50% of the cementious	reduces the energy used in manufacture of the concrete and therefore reduces the carbon footprint of the building	Low embodied energy concrete mix	?
20	reduced proportion of gaizing to unsulated roof [i.e windows to replace rooflights for daylight]	for optimal thermal performance	Reduce the number of openings in the roof	
20	Roof should be insulated to well beyond current part L building regulations requirements	to avoid heat loss	Insulate the roof	
20	Energy-efficient gas space and water heating systems should be fitted		Energy efficent gas space and water heating	
20	Low temperature under floor heating should be considered in ... areas where the floor slab can be exposed and high ceilings favor a low	works well with solar thermal low grade heat source	low temperature underfloor heating	
20	Solar thermal system	sized to meet 50% of the hot water demand	Solar thermal panels	
20	Individual units to be metered seperatly	to encourage accountability and efficiency	Units metered separatly	
20	Central display system	to enable tenants to keep track of individual and communal service costs and characteristics of use	Central energy display system	
20	triple glass suggested	optimise the building regarding passive energy	Triple glazing	no
20	installation of double glazing to a standard that meets of surpasses building regulation requirements	passive external fabric measures / improvements to the current building envelope	Double glazing	y
20	Constructing the wall with a bright surface	would reflect additional light into	Bright (reflective) walls	
20	over-clad the external walls with a light-coloured insualted render	more sustainable than insulating the outside of th building is the most efficient	External render insulation	
20	board and insulate the internal walls	to retain the appeatance of the brick and stone street facade whilst also improving thermal performance	Internally board and insulate	
20	air source heat pumps	planning requirements for a 15% renewable provision; for heating and cooling	ASHPs	
20	Provision of insulation to the ground floor slab	contribute in meeting sustainable development targets	Insulate ground floor slab	
20	The use of natural ventilation principles wherever possible	contribute towards the improved energy efficiency of the building	Natural ventilation	y
20	Provision of internal blinds	to reduce solar gain	Internal blinds	
20	Large existing window openings	for natural light and ventilation	Large existing windows / good daylighting	
20	aspiration to achieve an air permeability rating of 7m3/hr/m2 @ 50 Pa	passive internal fabric measures / improvements to the current building envelope	Good air tightness	
20	High efficacy luminaries complete with high frequency control gear		High efficiency lighting	
20	Provision of 3 new energy efficient lifts		Energy efficeint lifts	
20	Daylight linking to areas adjacent perimeter windows; time clock / dusk-dawn controls for external lighting		Time control lights / daylight dimming	
20	Absence / presence detection in appropriate areas		Presence / absence detection	
20	PV panels on the roof	to offset the base load and provide a proportion of the grid supplied electricty	PV	
21	A tri-generation plant is incorperated, providing heating and cooling and at the same time generating electricity	Supplying Energy Efficiently	CCHP (tri-generation)	y
21	Natural Ventilation Flue: Restaurant	will be used as an air extract in the mid seasons, thus lowering energy use for ventilation	Natural ventilation flue	y
21	use of natural and mixed mode ventilation wherever possible	reducing the primary energy demand of the development	NV / mixed mode ventilation to non-critical areas	y

21	Exposed Concrete Soffit: Restaurant Space	Thermal mass and night cooling will be used in the restaurant through a combination of exposed concrete slabs and open able	Exposed concrete slabs for thermal mass	y
21	Care has been taken with the position and size of window openings	to minimise solar gain	Care in sizing and postion of window openings	y
21	Solar protection using clear solar performance glass	s optimum solar protection, maximum daylight and minimum impact on clinical function; Solar protection properties reduces solar gain and	Clear solar control glass	y
21	Installation of a site wide building management system	can regulate heating, cooling etc. across the site	BMS (automated control)	y
21	Heating/Cooling transfer Loop	The hospital is a 24/7 operation with many embedded process systems using considerable amounts of energy for the operation of the	Heat loop to reclaim low grade energy / heat from primary energy units	y
21	Adiabatic cooling from Cooling Towers	for Low grade cooling water systems; cooling of return air stream	Adiabatic cooling towers	y
21	use Bio Oil for the primary fuel to the site	for firing Boilers and CCHP plant	Biofuel (bio-oil) for CCHP	n
21	dropping of distribution temperatures	reduction of distribution losses	replace HTHW boiler with MTHW (drop the distribution temperature)	y
21	decentralising the site boiler plant	The system will reduce distribution losses by virtue of MTHW generation where load is required. The scheme will achieve a higher	Replace 1 no. HTHW boiler with 2 No. MTHW boiler houses - decentralised boiler plant	y
21	De-steamin g Sit e	As the loads are generally small and intermittent a considerable amount of energy is lost through the distribution pipelines	De-steaming the site	y
21	Sedum Roof	will improve the thermal insulation	Sedum roof	y
21	Design of staircases and lift lobbies to maximize daylight penetration	Reduces need for artificial lighting during daylight hours	Maximise daylight to stairs and lobbies	y
21	A 5% improvement on Part L of the 2006 Building Regulations in terms of U-values for walls	Reduces heat loss, and thus energy required for space heating and cooling	5% improvement of 2006 U values for walls	y
21	variable volume air and water systems	design of the engineering systems has addressed the requirements to reduce the primary energy used	Variable volume air and water systems	y
21	air will be introduced to the areas using the displacement principle	The solutions to comfort condition the hospital's internal areas have employed Low Energy Systems technology where clinically	displacement ventilation	y
21	low gradge energy terminals to non clinical internal areas i.e., chilled beams; Under floor Heat / Cooling to Restaurant	comfort condtion using low energy systems technology where clinically acceptable	Low grade heating and cooling systems (chilled beams, under floor heating)	y
21	Wind turbine	Renewable energy source	Wind turbine	no
21	Introduction of solar collectors	as an integrated part of the building thermal system	Solar thermal panels / collectors	no
21	Ground source heat pumps	Renewable energy source; heating / cooling	GSHPs	no
21	Energy reclaim from air handling systems; Heat Reclaim from Air Systems and Adiabatic Cooling	Efficiency of Energy Usage	Energy reclaim from air handling	y
21	Energy efficient lighting	reducing the primary energy demand of the development	Energy efficient lighting	y
21	energy efficient … appliances	passive design energy efficency measures	Energy efficient appliances	y
21	Photovoltaic (PV) - roof and cladding	Renewable energy source	PV (roofing and cladding)	?
21	use of high efficiacy gas fired boiler plant with flue gas condensing units	Energy saving	High efficiency boilers	y
23	Additional insualtion will be introduced into the existing cavoity of the external walls of the MECH	to reduce the energy demand of the building	Improve insulation - cavity wall fill	n
23	improving air tightness	to reduce the energy demand of the building	Improve air tightness	y
23	Additional insulation to the walls of County Hall would need to be introduced on the inside skin of the building	to deal with thermal comfort	Improve insulation - internal wall insulation	y
23	Careful specification of the solar properties of the ETFE roof	roof posed some challenges due to the very high solar gain	Careful specification of solar properties of the roof	y
23	Solar control glass	to reduce solar gain and associated cooling	Solar control glass	y
23	ventilation heat recovery; recovering heat from high level within the atrium courtyard	Energy efficiency	Ventilation heat recovery	y
23	heat pump chiller with integrated heat recovery	providing free heat whenever there is a cooling demand	High efficiency chillers with heat recovery	y
23	Automatic daylight dimmable and PIR controlled lighting	energy efficiency	Automatic daylight dimming and PIR dectection to lighting	y
23	Introducing a secondary internal glazing system	to improve the performance of the building envelope	Secondary double glazing	y
23	maintain the ability to natually ventilate…by means of opening existing windows	for reasons of energy efficiency	Natural ventilation using openable windows	y

23	Heat recovery measures utilising the mass of the existing concrete structures	[work with the dispacement ventilation system?]	Use of existing concrete structure thermal mass	y
23	Green roof	original use was as an insulator	Green roof	n
23	Fixing double glazed units into the existing timbe sash frames	improve the peformance of the building envelope	Double glazing (within existing frames)	?
23	by creating an atrium the walls…that face onto the courtyard effectively become internal walls	avoiding the need to upgrade insulation	Enclosing the 'atrium' space	y
24	central district heating system which uses municipal waste as a fuel	will provide space heating and domestic hot water generation. … a significant portion of the building's energy requirements being	Connection to district heating (energy from waste)	y
24	limit the depth of the floor plans in proportion to the floor to floor heights. A height to depth ratio of 1:2.5 is required for natural ventilation	building to be naturally ventilated and naturally day lit where possible	Limit depth of floor plans in relation to floor to floor height	y
24	Windows to the office spaces will be openable	to support natural ventilation	Openable windows to office space	y
24	Acoustic louvre system, with small banked opening lights, which is to be screened by the clay baguette system	an acoustically attentuated air path…to distribute air to the internal spaces [where is is noisy]	Attenuated lourves	y
24	an atrium…to the interior of the site	support natural ventilation by using the atrium as a return air path; allows natural light to penetrate into the depth of rthe building and	Atrium	y
24	Glazing to the facades is mazimised…atrium makes use of a glass roof	to allow maximim achieveable natural daylight into the teaching spaces	Maximised glazing; atrium glass roof	y
24	Generally level F houses two meeting rooms, and a large number of cellular individual offices	located on this level to facilitate natural ventilation through single sided ventilation	Cellular office located at the top of the building	y
24	7% of floor area is required as free area	for ventilation required across the building facade or window	7% of floor area provided as free area (windows and other openings) for ventilation	y
24	On each level there will be … open plan spaces	to facilitate the ventilation strategy through sungle sided ventilation	open plan spaces	y
24	use of framed glass lourves [within the curtain walling] over top hind opening lights	due to the requirement to maximise the free area for ventilation	Framed glass opening lights	y
24	Level E ventilation return air path is facilitated by chimneys rather than through the atrium	due to level E being located at the head of atrium and a draw being required	Chimney ducts to the top floor	y
24	Windows are taken up to the soffit of the ceiling slabs	to achieve an even light spread into the depth of the building	Full height glazing	y
24	internal spaces are appropriate to their purpose without excessive area or volume	natural ventilation can be used in the majority of spaces and…energy for space heating will be minimised	Minimally sized spaces	y
24	Efficient space heating systems	energy for space heating will be minimised	Efficient space heating systems	
24	Ventilation openings controlled by the building management system	to minimise heat loss during the heating season	BMS controlled openings	y
24	Exposed thermal mass	will remove the need for cooling in many spaces	Exposed thermal mass	y
24	Heat recovery systems…where mechanical ventilation is necessary	to minimise space conditioning energy	Heat recovery where mechanically ventilated	y
24	Daylight linking control	will reduce lighting energy when the natural daylight is available	Daylight linked lights	y
24	Occupancy detection for lighting and ventilation systems	to reduce system operation times	Occupancy detection for lighting and ventilation	y
24	Variable speed pumps and fans	will reduce energy requirements when systems are running at part load, which represents the majority of the operational year	Variable speed pumps and fans	y
24	sectional arrangement	to maximise natural ventilation and daylight to support the long term carbon reduction objectives of the university	maximise natural ventilation and daylight [within connectivity constraints]	y
24	Renewable energy technologies		Renewable energy technologies	n
24	Fire resisting floor has been provided at level C+ and E, and a fire-resisting wall construction has been prvided to the back of corridor wall	Allows a greater proportion of the facades to be unprotected and facilitates the areas required to satisfy the daylighting and	Compartmental fire proofing to allow large free area in the facade for ventilation	y
25	District heating system; Combined Heat and Power (CHP)	sustainable energy; provided with low carbon heat	Connection to distict heating (CHP)	
25	Energy efficient, low maintenance lighting	sustainable as well as aesthetically pleasing	Energy efficient lighting	
25	earth tubes; network of tubes buried 1.5m below the soft landscaped areas	for passive heating and cooling	Earth tubes	
25	Exposed concrete soffits above teaching spaces	provide passive thermal comfort	Exposed thermal mass	
25	Mixed mode ventilation (NV in spring and autumn, mechancial in summer and winter)	to minimise energy use yeat round	Mixed mode ventilation strategy	
25	High building fabric performance - air tightness	passive design approach; carbon savings	High fabric performance - air tightness	
25	High building fabric performance - U values	passive design approach; carbon savings	High fabric performance - U values	

25	Natural daylight	passive design approach; carbon savings	Natural daylighting	
25	AHUs … in winter with heat recovery	to minimise energy use	Heat recovery from AHUs	
25	Variable speed inverted drives; variable speed pumping … on LTHW	Energy efficeint approaches	Variable speed fans and pumps	
25	Design for low specific fan powers	Energy efficient approaches	Efficient fans	
25	Daylight linked lighting controls	to minimise power consumption	Daylight dimming to lighting	
25	Presence detection control for lighting	Energy efficeint approaches	Presence / absence detection	
25	Photovoltaic array was sized at 100m2 with all panels facing south	[use future sunshine increases to generate building's energy]	PV	
25	High level windows with actuators controlled by the BMS	to ensure control of CO2 levels and for night time purge of heat in summer	Actuated high level windows controlled by BMS	
25	low level windows manually controlled	for supplementary [natural] ventilation	Manually openable low level windows	
25	Timber constructed cluster core	locks in carbon dioxide and provides a low embodied carbon solution	Timber frame	
25	Acoustically attenuated air paths between teaching and circulation spaces	[natural cross ventilation - passes over corridors]	Acoustically ventilated cross ventilation ducts	
25	Displacement ventilation	Heat gain from lighting can be directly exhausted; Potential for reduced peak plant loads	displacement ventilation	
25	Vertical / horizontal axis wind turbine	Low zero carbon technology	Wind turbine	no?
25	GSHP - boreholes; GSHP - closed loop	Low zero carbon technology	GSHPs	n
25	Pipework will be … insualted against heat loss	[reduce heat loss]	Insulated pipework	y
25	a indicator panel will be provided in each room with a simple annotated description on the wall	in order to avoid the mechanical ventilation systems running whilst acoustic ventilators are open	Indicator panel	
31	on site combined heat and power (CHP) plant; trigeneration using bio-fuel CHP and absortiion cooling	to generate low carbon electricty; provide cooling	Bio-oil fueled tri-generation CHP	y
31	energy efficient IT purchasing and operation policies	reduce demand through energy efficiency measures	Thin client / energy efficient ICT	y
31	Active double skin facade	acts like a duvet that insulates the bulding in winter and facilitates ventilation in summer; minimise the reliance on artifical light by	Double skin facade	y
31	ingenious modulation of the balde depths to the bronze mullions …depths are determined by the mullionsc position in relation to the	enables them to act like blinds that minimise solar glare when necesssary	Slar shading fins within mullions	y
31	tri of giant earth tubes	temper the incoming air, providing an element of free colling in summer and heating in winter	Earth tubes	y
31	local user control of lighting	energy efficient measure	Local user control of lighitng	y
31	Chilled beams for heating and cooling the office floor plate	energy efficient measure	Chilled beams	y
31	Exposed structural concrete slab	to provide thermal mass; reducing cooling load and therefore energy consumption	Exposed thermal mass - concrete slabs	y
31	soaring open atrium	minimise the reliance on artifical light by maximising daylight; [stack ventilation using atrium as extract]	Atrium for daylight and ventilation	y
31	The building is orientated to face the sun	maximising passive solar gains and daylighting	Orientated south for passive solar gain	y
31	Regenerative motors on lifts with destination control	energy efficeint design	Regen lifts with destination control	y
31	underfloor plenum sealing	[air tightness?]	Underfloor plenum sealing	y
31	reduce infilration rates	minimses heating loads	Air tightness	y
31	Heat recovery from the atrium and IT systeems	to heat the building	Heat recovery	y
31	substantial energy uses submetered	for monitoring	Sub metering	y
31	demand based variable air volume systems	efficent ventilation systems control - maximise the diversity in the operation of central plant	Variable air volume systems	y
31	Adibatic cooling by cooling towers	low energy strategy	Adiabatic cooling towers	y
31	Low energy LED lighting	low energy strategy	low energy lighting (LEDs)	y

31	high efficiency ventilation systems	passive design features	High efficiency HVAC	y
31	using bypass route to supply fresh air directly to the ventilation plant	can increase the energy savings	Earth duct bypass	no
31	solar coating to the glass	solar control	Solar control glass	y
31	High insulation standards of the building fabrics	to achieve ambitious environmental targets	High insulation standards	y
31	automated and efficent lighitng	to maximise energy efficiency	Lighting controls	y
31	smart grid..intelligent small power control system	allowing equipment in any area of the open plan office to be switched off by the building management system	Smart grid	y
31	the triangular form ensures that the offices face due south, north west and north east	largely avoiding the problematic effects fo low east and west sun [easiliy shaded, while enabling daylighting and passive solar gain]	Triangular building form	y
31	The building will have the ability to 'plug into' or provide, future innovative energy solutiosn	[to avoid lock in to an out moded technology if a lower carbon / better one comes along]	Ability to 'plug into' new low carbon energy sources	y
31	Automated gas readers…recording half hourly usage		automated gas readers	y
31	glass 'eyelid' ceiling; the diagonal slice is titled to the north	to grab as much energy as possible; allow sunlight from the south to flow into the upper floors and atrium	glass eyelid ceiling to atrium / diagonally sliced facade (daylight and passive solar gain)	y
31	exposed concrete soffit is painted white	enabled the lighting to be reduced from 550 to 300 lux, saving significant amounts of energy	white soffits	y
31	Solar panels	environmental 'add ons'	solar panels	no
31	Wind turbines	environmental 'add ons'	Wind turbine	n
31	carbon dioxide sensors regualte the amount of fresh air supplied to each zone	to minimise the volume of air treated	CO2 sensors to regulated ventilation supply	y
31	every balcony fronts onto entirely open plan office on the lower nine floors	allowing light from the external wall to permeate into the heart of the building; reduce use of artifical lighting	open plan spaces	
35	Triple glazed low-e to achieve u value of 0.9 W/m2.K	diminishes heat losses / gains thus reducing the energy required to maintaina comfort temperature	Triple glazing	
35	Cooled by an absorbtion chiller which is powered by a gas fired CHP plant	delievering the 10% CO2 savings from renewable energy [if used with biomass]; to provide the base load heat and hot water	CHP with absorbtion chiller	y
35	High efficiency T5 fluorescent and LED lighting	offer a higher level of illumination per unit energy	High efficiency lighting	y
35	Tree and shrub planting within the scheme	storing carbon and helping to minimise the impacts of climate change	Tree and shrub planting	y
35	buying the wind turbines at Roskrow Barton, buying the energy from the turbines, increasing the size of the existing turbines or	as a source of renewable energy	Off site wind turbines	n
35	two roof mounted turbines	economic option for delievering the 10% CO2 savings from renewable energy	On site wind turbines	y
35	North facing lab spaces	for natural light and no solargain	North facing labs	y
35	East-west orientation	passive design measure	East - west orientation	y
35	Courtyard microclimate	[protect from wind] leaky surfaces exposed to wind increase air infilatration	Courtyard microclimate	y
35	high thermal mass	to store coolth	Thermal mass	
35	Deep reveals to south	passive design measure	Deep reveals to south elevation	y
35	Reception desk … will include… an information screen	will relay the energy performance of the building	Info screen in reception	y
35	Excellent U values; using materials with less conductivity	reduce heat gain into the building in the height of summer	Excellent U values	y
35	Waste heat are proposed to be recovered from air exhaust and reused	possible to use fresh air in significant quantities with a reduced level of carbon emissions	Heat recovery	y
35	Solar hot water collectors	low carbon and renewable energy generation option	Solar hot water collectors	no
35	Biomass boilers	low carbon and renewable energy generation option	Biomass boilers	n
35	Array of photovoltaics	low carbon and renewable energy generation option	PV	y
35	Ground source heat pumps	low carbon and renewable energy generation option	GSHPs	n
35	Improve air tightness; sealing joints along windows and doors	help to improve air tightness; Buildings with high air change rates ... have higher energy consumption because infiltrating air needs to	Air tightness e.g. sealing joints around windows	y

35	Intelligent control systems	so that energy consumption is minimised and optimum conditions are achieved in the building	Intelligent ventilation control	
35	Lighting controls can be designed to take account of the presence of people (e.g. pyroelectric infrared) in their area with	use of modern lighting controls… can result in a 30-40% reduction in the resultant lighting use	Lighting control - PIR, daylight dimming	y
35	High efficiency plant and small power equipment	if plant equipment (e.g. pumps, fans, motors, boilers, chillers, etc.) efficiency is high, less energy will be required to produce the same	High efficiency plant and equipement	y
35	Increasing the thickness of the materials used for insulation	diminishes heat losses / gains thus reducing the energy required to maintaina comfort temperature	Increase thickness of insulation	
35	Energy monitoring	is needed to prevent energy wastage and ..knowing if other CO2 saving measures are working properly	Energy monitoring	y
35	keep doors closed with automatic actuators	help to improve air tightness; Buildings with high air change rates ... have higher energy consumption because infiltrating air needs to	Keep doors closed with automatic controls	
35	maximising facade facade to floor plate ratios	maximise the use of natural daylight….reduction of energy related CO2 emissions associated with lighting	Maximise facade to floor plate ratio	
35	minimising the depth of the floor plate	maximise the use of natural daylight….reduction of energy related CO2 emissions associated with lighting	Use of shallow plan	
35	Installation of luminaries that properly reflect the light	can save further electricty	Mirror luminaries	y
35	manual window openings…some form of automatic control…,normally via a BMS system	Natural ventilation	Manually openable and / or actuated windows	y
35	Use of atria is encouraged	useful for naturally ventilated / mixed mode buildings	Atria	n
35	zones of the building with different solar exposure, occupancy or use should have separate time and temperature control	central plant would only operate when the zone systems require it	Zone mechancial systems	y
35	Manually operated switches no more than 6m…. From the luminaires they control	use of modern lighting controls… can result in a 30-40% reduction in the resultant lighting use	Manual light switches placed close to lights	y
35	fans rated higher than 1,100 W should be equiped with variable speed drives	high efficiency plant and small power equipment	Variable speed drives to fans	y
35	Small power equipment like IT equipment, washing machines and small appliances with 'A' energy ratings	high efficiency plant and small power equipment	A rated appliances	y
38.1	large areas of photovoltaic panels on the roof	For renewable energy generation	Roof PV	y
38.2	Vertical PV panels are set flush into the glazing	For renewable energy generation	Facade PV	
38	Ground Source Heat Pump (GSHP); 6 kW energy output per bore hole, 20 No. bore hole	will reduce the development's carbon emissions by 6.98%.	GSHPs - 20 No. boreholes	
38.2	air source heat pumps	LZC (low or zero carbon technology); provide heating and cooling	ASHPs	
38.2	Combination of CFL and LED throughout	Best practice energy strategy - lighting	Energy efficeint CFL and LED lighting	y
38.1	Low energy lamps throughout	Most likely energy strategy - lighting	Energy efficient lamps	y
38	Robust detailing will be provided in order to guarantee efficeint levels of air tightness	affects the heating and cooling demand of the building	Robust detailing for air tightness	y
38	The buildings are highly insulated; thermally insulated windows	reduce the amount of heat lost	More insulation e.g. thermally insulated windows	y
38	% improvement [of U values] on part L [range 14% to 23%]	reduce the amount of heat lost	U values better than regs	y
38	Low emissivity (low-e) glass such as K glass	designed to reflect heat back into the building, greatly improving its thermal efficiency	Low emissivity (e) glass	y
38	low iron glass such as optiwhite as the outer pane section	increased light transmission helps to reduce the need for artifical lighting	low iron outpane	
38	Centralised bio-mass CHP	utilises the heat produced in electricity generation rather than releasing it wastefully into the atmosphere; [makes best use of mixed	CHP	n
38	Centralised bio-mass CHP and ACh (tri-generation system)	utilises the heat produced in electricity generation rather than releasing it wastefully into the atmosphere; [makes best use of mixed	CHP with tri-generation	n
38.2	this hotel operator does not use air conditioning	ensure that their hotels will have a very low level of energy consumption	No use of air conditioning	n
38.2	No use of mechanical cooling; natural ventilation where possible	Best practice energy strategy - lighting; The hotel operator is likely to be travelodge or equivalent..highly sustainable systems	Natural ventilation	n
38.2	controls for heating avoiding use when rooms are empty	The hotel operator is likely to be travelodge or equivalent..highly sustainable systems	Controls to avoid heating use when building empty	y
38.2	Controls for heating to turn off radiators when room is at design temperature	The hotel operator is likely to be travelodge or equivalent..highly sustainable systems	Controls to turn heating off when room reaches design temperature	?
38.2	COP of chillers 4 or better. The efficiency of the boilers shall be 95% or better		Efficient plant: boilers, chillers	y
38.2	submetering of lighting which automatically warns of "out of range" values	Energy efficency measure	Sub-metering of lighting	

38.2	Daylight sensors located in appropriate zones of the office (i.e. along windows). Automatic dimming to take maximum advantage of the	Energy efficency measure	Lighting controls - daylight dimming, prescence detection	y
38.2	The ventilation systems shall employ heat recovery	Energy efficency measure	Heat recovery to ventilation systems	y
38.2	All pumps and fans shall be selected with high efficiency variable drive motors	Energy efficency measure	Variable drive motors to fans	y
38	Regenerative lifts will be specified for all high-usage lifts within the development	generate energy on their way down which they then use on their way back up	Regenerative lifts	?
38	Maximise the natural light		Maximise natural light	?
38	Solar water heating panels	high demand for domestic hot water in the development driven by the hotel and residential uses	Solar hot water heating	n
38	On – site wind turbines	installing wind turbines with a total equivalent capacity of 50kW would reduce the annual carbon emissions of the development by	On-site wind turbines	n
38	Bio-diesel boiler	if the source of energy is switched to bio-diesel fuel, the boiler system becomes a highly cost-efficient method to meet the London Plan	Bio diesel boiler	n
38	Site smart metered	information used to help evolve energy management scheme	Smart meters	y
38.1	a pack be provided to each dwelling containing information on…energy efficiency	to encourage sustainable lifestyles	Info pack for residents	y
38.1	MVHR for all dwellings	Most likely energy strategy - ventilation	MVHR	y
46	Ground source heat pumps	has the potential to reduce the buildings energy use by some 75% for the heating installation with a CO2 reduction of 50%	Ground source heat pumps	n
46	outdoor swimming pool has been moved so that it is no longer below the school building.	is now within the playground where it can benefit from … soalr gain during the summer months	Swimming pool relocated from under building to within grounds	y
46	Lift access…can be controlled so that only staff/pupils given proximity fobs can use the lift		Restricted (fob) access to lifts	y
46	New building is orientated on an east-west axis	to maximise the potential for natural ventilation and daylight	New building is orientated east - west	y
46	use of rooftop wind catchers	passive ventilation	Wind catchers	y
46	Careful design of the building cross section	ensure that each classroom base enjoys excellent natural light and natural ventilation	Careful design of cross section for cross ventilation	y
46	North facing clerestory windows to the second floor classrooms	will ensure even daylight throughout the room. Daylighting from a single direction does not give an acceptable uniformity of daylight	North facing clerestorey windows	y
46	introducton of a central light well	Natural daylight will penetrate even these central break out areas	Lightwells / rooflights to corridor break out spaces	y
46	Photvoltaic panels on the roof	to reduce the emissions of the building and lead by example; produce 54% of the energy required for the ground source heat pumps	PV panels	y
46	Glazed floor-lights in the play deck above	will allow light to penetrate to the undercroft play area	Glazed floor lights in play deck	y
46	The external lighting will be controlled via photocell light sensors, with an option of time-clock override		External lights controlled by photocell light sensors with time clock override	y
46	Some lighting around the perimeter of the bulding especically in the sunken 'moat' garden and on the access bridge will be	to provide security	External security lights controlled by PIR	y
46	Improved U values and insualtion levels	key to achieveing low energy performance	Improved U values and insulation	y
46	Large low level openings manually operated	for summertime ventilation	Manually operated large low level opening windows	y
46	The south facing elevations are externally shaded by brise soleil and the projecting balconies	to cut out high angle direct sun in the summer [while allowing good daylighting at other times]	External shading	y
46	Condensing boilers	high efficiency gas boiler ..to enable the building to pass current building regulation	Condensing boilers	y
46	1 no. 15 kW wind turbine	provide a visual aid for the production of energy from natural resources; produce energy from a natural resource and require	Wind turbine	n
46	10m2 of solar collectors for connection to hot water cyclinder	Council's planning policy details that a minimum of 10% of the carbon emissions are achieved from a renewable energy source	Solar thermal panels	n
46	Biomass boilers	regarded as a carbon neutral energy source [i.e. can be used to meet planning's 10% renewables]	Biomass heating	n
46	High efficiency T5 lamps; energy efficient light fittings shall be utliised throught the external and internal areas	energy saving solutions	Energy efficeint lighting	y
46	Automatic natural ventilation strategy utilizing mechancal opeing, closing dampers and motorized windows all controlled by CO2 and	energy saving solutions	Natural + night ventilation using actuated windows controlled by CO2 and temperature sensors linked to BMS	y
46	Services are strategically metered	to allow energy use to be monitored	Sub metering	y
46	Air source heat pumps	he use of renewable energy techniques would greatly reduce the emissions for the heating and hot water installations	Air source heat pumps	n

46	generous areas of glazing toeach classroom	to maximise daylighting	Generous glazed areas	y
46	lighting to classrooms and offices be controlled by integral daylight / presence sensors...PIR control will be provided to WC's and stores	allowing the building to adjust to user requirements and minimising energy use	Lighting controls - internal	y
46	underfloor heating is being provided throughout the building	provide low temperature heating; is particulary effective with ground source heat pumps and condensing boilers where low	Underfloor heating	y
46	interactive displays to demonstrate the production of energy and the extent of carbon saved	provide a visual aid for the production of energy from natural resources.	Energy generation displays	
47	design team elected in principle to follow a natural ventilation strategy		Natural ventilation	n
47	Earth tube cooling	solutions which would not only have a low impact on the environment, but would also consider how the prevailing aircraft noise	Earth tubes / underground air labrynith	y
47	Building form has been designed using a narrow plan	designed to maximise natural daylight	narrow plan depth	y
47	Two storey pitched roof building	provide plant space for the low energy paasive cooling and ventilation plant	Pitched roof	y
47	Solar G value 0.4, U value below 2.0 w/m2K...air cavity 16mm	The building envelope and services have been designed to 'work hard' at energy conservation	Double glazing	y
47	Rigid insualtion base layer to acieve 0.15 U value; high insualtion specification	The building envelope and services have been designed to 'work hard' at energy conservation	High insulation standards	y
47	largest classroom facades facing south or west	make best use of the site's north/south axis (orientation)	Classrooms face sout and west	y
47	air permeability: 3.0 m3/hr/m2 @ 50 Pa; seal gaps between PPC panel for airtightness"	The building envelope and services have been designed to 'work hard' at energy conservation	Air tightness	y
47	Window systems are designed to optimise daylight and minimise solar gain	as the building does not require heating from this [passive solar gain] source	Natural light while minimising solar gain	y
47	100kW GSHPs serving 50% space heating load	opportunities for further reducing energy, carbon emissions and running costs	GHSPs	n
47	100kW ASHPs serving 50% space heating load	opportunities for further reducing energy, carbon emissions and running costs	ASHPs	n
47	CHP	opportunities for further reducing energy, carbon emissions and running costs	CHP	n
47	Biomass boilers	opportunities for further reducing energy, carbon emissions and running costs	Biomass boiler	n
47	Solar thermal hot water (STHW)	opportunities for further reducing energy, carbon emissions and running costs	Solar thermal hot water (STHW)	n
47	lighting...(complete with daylight linked controls)	The building envelope and services have been designed to 'work hard' at energy conservation	Daylight linked lighting controls	y
47	Energy efficient lighting - 10W/2	The building envelope and services have been designed to 'work hard' at energy conservation	Energy efficeint lighting	
47	Thermal wheel heat recovery	building would perform at the highest level without any additional (LZC technology) measures	Heat recovery	y
47	Gas fired condensing boilers	building would perform at the highest level without any additional (LZC technology) measures	Condensing boilers	y
47	Building U values	The building envelope and services have been designed to 'work hard' at energy conservation	U values	y
48	Specifically designed to be naturally ventilated	will not require heating or air conditioning	Designed for natural ventilation	y
48	Centralised plant installed in either one or two energy centres	removes the need for installation of plant in retailer fit-out with consequent improvements in energy efficiency; compatible with future	Centralised plant	y
48	high efficient electric chillers	Active efficiency measure	Highly efficient plant (e.g. chillers)	y
48	The retention of 64-84 Tooley street...will lead to the need for artificial lighitng aroud the clock	reduce the station's intended energy efficiency	Demolition of Tooley street	y
48	Choice of canopies over a single roof	was made to provide as much light as possible	Canopies chosen over the provision of a single roof	y
48	The sloping southern walls of the wavesa re rather more solid, with more occasional glazing	to allow lint from the south to pass directly into the concourse; to reduce lighting energy demand	Additional glazed openings (daylighting)	y
48	Each canopy is twisted locally, in the area above the concourse, to provide a north facing area of vertical glazing	will bring much needed light down to the area below	Curved form of canopies / norh clerestorey lights	y
48	Ground source heating and cooling in the form of a series of energy piles	heating and cooling	GSHPs	y
48	Energy efficent luminares with high efficiency lamps	lighting demand may be reduced	Efficient lighting	y
48	Viaducts have been splayed inwards	improve the daylight penetration in the concourse below	Viaduct splayed inwards	y
48	Recycled materials such as ground-granualted furnance slag (GGBS) and fly ash (PFA) will be used as replacement for ordinary portland	identified as the single biggest oppourtunity to reduce embodied energy and carbon	Use of recycled materials in the concrete	y

48	A site wide energy loop with decentralised chilling but centralised heat and coolth rejection into an energy loop thereby	will reduce the amount of wasted energy exhausted to the atmosphere	Heat receovery	y
48	Fitting of movement sensors to internal lighting, daylight sensors to lighting	reduce lighting energy demand	Lighitng controls	y
48	Thermal insulation that exceeds current building regulations	heat energy demands can be reduced	Thermal insulation	y
48	Distributed transformers close to load centres	to minimise distribution losses	Transformers close to loads	y
48	Utilising the proposed scheme's thermal mass	to passively cool and therefore reduce energy demand	Exposed thermal mass	y
48	Solar gains throught the facades will be reduced by solar shading	will reduce the cooling demand	Solar shading	y
48	Low U values / Low E glazing	increasing the thermal efficiency of the proposed scheme's envelop to reduce heating and cooling demand	Low U values	y
48	Low air permeabiity; set at 5m3/hr/m2 @ 50Pa	Reduce external air infilration to reduce heating and cooling demand	Low air permeability	y
48	Variable speed pumping	to maximise efficeincy in use	Variable speed pumps to central plant	y
48	Evaporative cooling coils within central air handling plant		Evaporative cooling	no?
48	Comprehensive metering linked to the BMS system; Accurate control and monitoring - A building management system (BMS)	can help the occupant control systems easily, moitor and set energy targets	Metering / BMS for monitoring and control	y
48	Strategic commissioining	to ensure efficient operation	Strategic commissioning	y
48	Energy efficient escalator systems - regenerative technology and efficeint control gear which reduces operating speed when not	reduce escalator energy usage	Energy efficient escalators	y
48	Energy efficient lift systems - regenerative drives and highly efficient motor systems	to reduce lift energy use	Regenerative lifts with optimised controls	y
48	existing or planned district heating networks	connection to an existing low carbon heat distribution network	Connect to district heat	n
48	CHP system		CHP	n
48	Trigeneration (CCHP)	uses waste heat from a CHP systems to generate cooling (via an absorbtion chiller)	CCHP (tri-generation)	n
48	Platform canopies have a significant roof area that could be occupied by PV panels	to generate electricity	PV to station roof	no
16	new timber double glazed windows; high performance glazing	to meet current regulations; limits heating requirements	Double galzing	y
16	new atrium; atrium or lightwells	flood the interior spaces with natural daylight	Atrium / lightwells	y
16	The presence of heritage buildings means that, where practicable, these can be refurbished and re-used	avoids the waste of demolition and reconstruction, reducing the embodied energy within the site	Resuing existing structures	y
16	predominant east-west orientation for the buildings	assists in maximising the oppourtunities for lower energy buildings not reliant on solar shading; good daylighting and reduced cooling	North / south grid (east / west facing buildings)	
16	High quality fair faced concrete is exposed...under the coffered soffit of the cantilevered upper spaces	to deliver the desired level of temperature control without mechanical cooling	Exposed concrete soffits	y
16	West Handyside canopy on the ast side of UAL contains a large photovoltaic array of 860M2	power the fountains in granary square	Photovoltaic panels	y
16	Solar hot water collectors	for generating hot water	Solar thermal hot water (STHW)	n
16	14 No. Wind turbines	wind generated electricity	Wind turbines	n
16	Biomass boilers	Low carbon heat and power	Biomass boilers	y
16	The use of green energy tariffs	active renewable energy systems	Green energy tariffs	n
16	Combined heat and power (CHP)	Low carbon heat and power	CHP	n
16	Combined cooling, heating and power (CCHP)	very energy efficient way to heat the buildings; low carbon heat and power	CCHP (tri-generation)	y
16	The CHP systems installed...shall include at least one 250kW fuel cell	to showcase such technology	Fuel cell	
16	Cooling systems will use the latest chilled beam technology	to minimise energy use	Chilled beams	
16	Active heating and cooling using ground source heat pumps	emerging renewable energy technology	GHSPs	n
16	too deep plan and cellularised	to utilise natural ventilation	Shallow plan depth, open plan for natural ventilation	n

16	Appropriatly sized windows	recent experience showing that oversized windows fail to achieve electric lighting saving because of increased glare blind use	Optimise window size	y
16	off grid PV street lighting		PV street lighting	y
16	Design for adaptability: Higher floor to ceiling, larger column spacing	reduced impacts of repeated refurbishments	Design for adaptability - higher floor to ceiling depth and bigger column spacing	y
16	Design for adaptability: moveable partitions	reduced impacts of repeated refurbishments	Moveable partitions	y
16	All high mass elements (external walls, roofs, upper floors) would attain an "A" rating under the BREEAM standard	[reduce embodied energy and materials impacts]	"A" rated materials	y
16	Basements [for plant]	less expensive roof clutter vying with green / brown roofs and photovoltaic panels	Basement for plant	y
16	low velocity air distribution from displacement ventilation	air supply temperature can be lower than a conventional system; chiller has to work less hard to create cooling	displacement ventilation	y
16	"Free cooling"	where external air temperature is cold enough to allow the spaces to be cooled without the need for additional mechanical cooling	"Free" cooling	y
16	Low energy, high efficieny, fluroescent, linera light fittings; LEDs in the mesh are highly energy efficient		Low energy lighting	y
16	At night, LEDs would be dimmed	to conserve energy	Night time dimming of LED display	
16	Lighitng control systems will be installed; service corridors will be controlled via timers and PIR movement detectors and will dim the	will further reduce the energy consumption of the complex	Lighting controls	y
16	Plant sizing has been designed…by matching installed capacity to building demand	to optimise efficiency	"right sizing" plant	y
16	Use of insulation by adding it to some of the less sensitive heritage walls	Reducing heat loss	Insulation	y
16	use of variably transparent ETFE roof above the covered street	used to control the light and heat entering the space …provide a comfortable space without the use of energy	Variably transparent ETFE roof	y
16	LED mesh	offering solar shading to the granary offices	LED mesh	n
16	Unheated entrance space of the granary building; the street and east-west link are also naturally ventilated during the summer	negates the need for mechancial ventialtion / cooling	Unheated (unconditioned) public through route and entrance spaces	y
16	allowing the temperature to float +/- 3C in summer	the cooling loads were significantly reduced	Floating set point for cooling	y
16	Peer+ …window that self transforms into a solar panel when UV level is sufficient for energy harvesting		Window / PV panel hybrid	n
16	Air tightness	Reducing heat loss	Air tightness	
16	Thermal bridging detailing	reducing heat loss	Thermal bridge detailing	
16	[collection of] waste heat from the displacement air handling units	Reducing heat loss; used to provide background heating to the street	Heat recovery	y
16	Air source heat pumps	heat generation technologies	ASHPs	n
16	Suggest that both buildings and external spaces arte sheltered from the south and south west	due to the presence of cold winds from the south...will reduce internal heating loads	Building sheltered from cold winds	
16	Investing in long life fabric components and providing infrastructure that excepts change	[reduce embodied energy]	Durable, long life components	y
16	Water efficiency measures…outlet flow limiters, low flush toilets, short final run outs for domestic hot water, grade 'A' domestic	water efficeincy leads to reduced impacts associated with its supply and disposal, including energy (c. 0.5kWh per cubic metre of	Water efficient fixtures, fittings and appliances	y
21	Nordicons thermal purlins (cladding type)	Oval slots in the purlins webs reduce their thermal conductivity which enabled the facade to achieve a U value 15% lower than required		y
21	Water efficiency measures such as sensor taps, showers and appliances	Listed under carbon / sustainable credentials		y
21	Presence detection control for lighting	for energy reduction		y
1	Sub metering floor by floor	Required to comply with BREEAM Ene 02 and Ene 03.		y
16	All energy consuming appliances provided must be 'energy saving recommended'.	UAL sustainable design brief.		y

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Correlations

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Descriptive Statistics

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InteractionCount	3.9091	2.97464	22

Correlations

		Acount	InteractionCount
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	Sig. (2-tailed)		.016
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InteractionCount	Pearson Correlation	.506*	1
	Sig. (2-tailed)	.016	
	N	22	22

*. Correlation is significant at the 0.05 level (2-tailed).

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Correlations

Descriptive Statistics

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Mcount	18.8636	8.23636	22

Correlations

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	Sig. (2-tailed)	.001	
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tegory())
  DATA: COUNT=col(source(s), name("COUNT"))
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  GUIDE: axis(dim(2), label("Count"))
  SCALE: linear(dim(2), include(0))
  ELEMENT: interval(position(InteractionCount*COUNT), shape.interior(shap
e.square))
END GPL.
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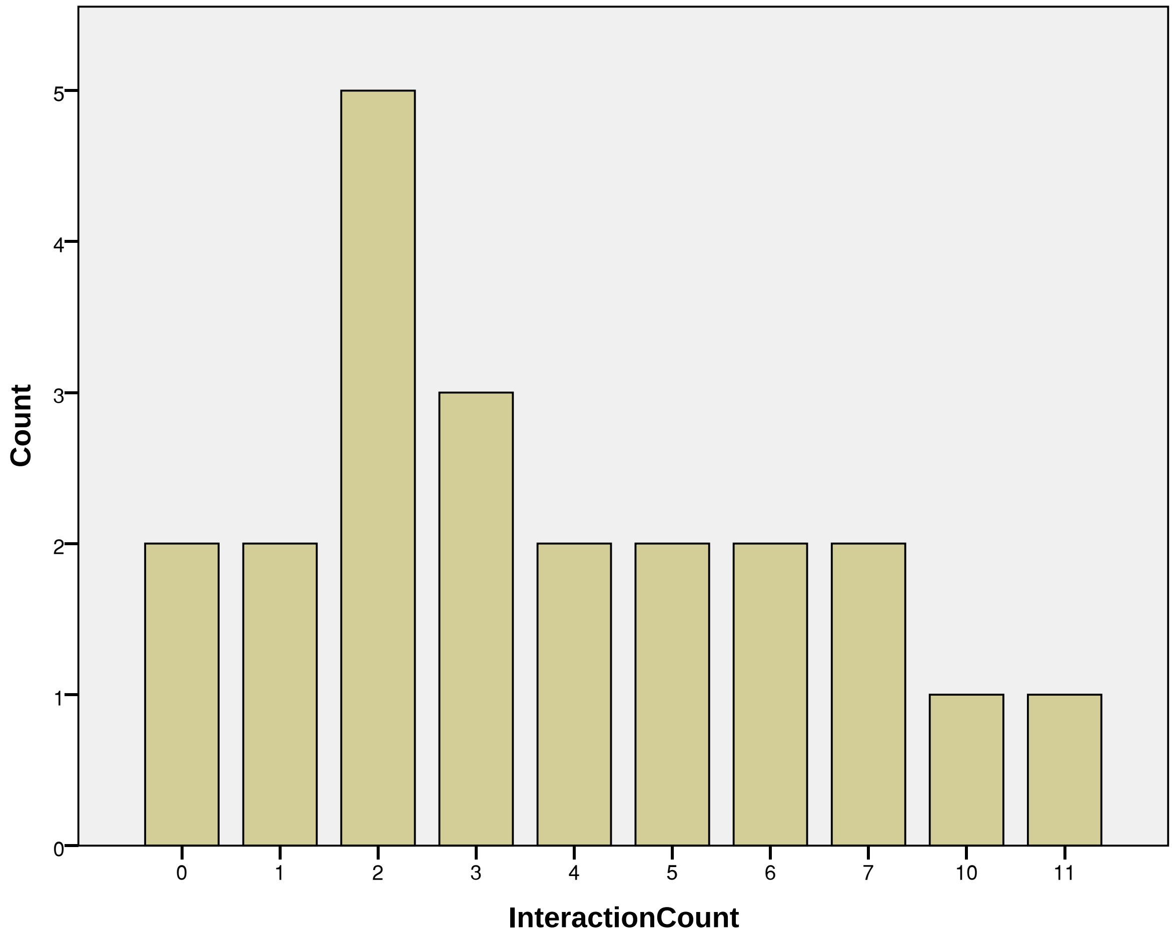
GGraph

[DataSet0]



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* Chart Builder.
GGRAPH
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  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
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tegory())
  DATA: IntPresent=col(source(s), name("IntPresent"), unit.category())
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  GUIDE: axis(dim(1), label("InteractionCount"))
  GUIDE: axis(dim(1), opposite(), label("InteractionCount"))
  GUIDE: axis(dim(2), label("Count"))
  GUIDE: axis(dim(3), label("IntPresent"), opposite(), gap(0px))
  GUIDE: legend(aesthetic(aesthetic.color), null())
  SCALE: cat(dim(3), include("0", "1"))
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terior(IntPresent))
END GPL.
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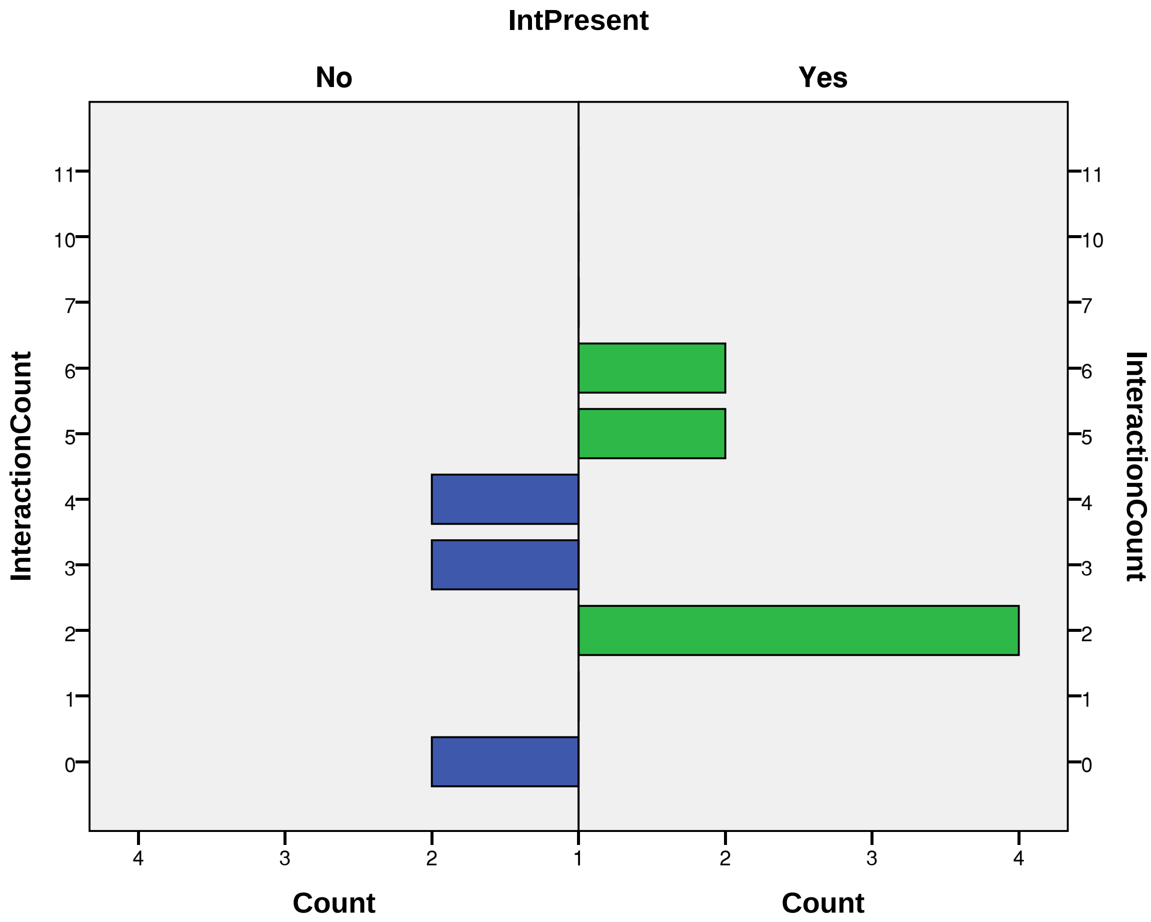
GGraph

[DataSet0]




```
T-TEST GROUPS=IntPresent(0 1)
  /MISSING=ANALYSIS
  /VARIABLES=InteractionCount
  /CRITERIA=CI(.95).
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T-Test

[DataSet0]

Group Statistics

	IntPresent	N	Mean	Std. Deviation	Std. Error Mean
InteractionCount	No	9	2.67	2.236	.745
	Yes	13	4.77	3.193	.885

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
InteractionCount	Equal variances assumed	1.509	.234	-1.702	20
	Equal variances not assumed			-1.817	19.982

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
InteractionCount	Equal variances assumed	.104	-2.103	1.235
	Equal variances not assumed	.084	-2.103	1.157

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
InteractionCount	Equal variances assumed	-4.679	.474
	Equal variances not assumed	-4.517	.312

CASE 1

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		Deep, basement foundation due to high rise building. Roof currently used for attentuation of rainwater. Office loading	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Portland stone precast cladding with glass. Interior finishes will be selected by the tenant.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Tenant brief specifies that finishes are to be "durable, maintainable and repairable using long design life	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.				4		Located in central Cardiff.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Central cardiff location, 10 minute walk to Cardiff central station and bus station. Basement parking (c120 spaces).	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Plot described as tight by developer. Entire plot is developed. While tall (views to the bay on upper floors) it is	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.					5	Open plan spaces with no internal columns. Central core designed to allow building to be split in half. Almost	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				Designed as base build and fit out, so fit out is removeable but unlikely to be recycled.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.		2				One small 'winter garden' per floor, alternating ends of the building. No adjacent open space, although collonade has	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.					5	Open plan spaces with no internal columns. Central core designed to allow building to be split in half.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Raised floors and suspended ceilings throughout. Risers located in central core. No service corridors although plant	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.		2				Orientation was ditacted by plot shape to some extent, although effort has been made to work with this as far as	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		"Solar gain is reduced through the vertical facade system resonding to the building's orientation. 450mmm deep	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Insulated to current building reg standard. Further insulation would be problematic (building internally	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Building is sealed and airconditioned. Deep plan, although atria are provided at either end on alternating floors.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5	BREEAM Excellent target	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		Building will have a BMS system. Sub metering in accordance with BREEAM requirements.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build = n/a?	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building was approved by CABE Wales during the planning process. Proported to be a 'landmark' building due to its	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.			3			Building will have retail uses at ground floor.	
The building displays a high standard of construction and finish consistent with current market expectations.					5	BCO Grade A specification office.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		High density workplace, but break out areas provided and good daylighting. A/C HVAC, limited user control. Task	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.		2				Building is developed on a brownfield site. Proposals for rainwater harvesting were not adopted and there is no	
The building displays a high level of community interest and political support for its future care and preservation.			3			Local support in cardiff, mostly because it retain 3000 jobs within the city. Land Securities have an interest in it as it is	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Development sits in the SD2 redevelopment context, with improvements to public realm etc. and appropraite land	

CASE 4

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		Following the AR building is now constructed totally on piled foundations.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.			3			Timber frame omitted in leiu of brick and blockwork.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.			3			Owned by an RSL so low maintenance would be expected in the specification, but it is also an extra care facility and is	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Located in Leek, rural town.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			"Within close proximity are located three bus stops" (D&A, p11); "To the south of the site, Ball Haye Road connects	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Resonably spacious plot with access from two directions. Rural-ish location although in a residential area with no	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				Individual flats are designed in accordance with lifetime homes, but it would be difficult to change the flat plan itself	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of demountable elements.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Building is formed around a number of courtyard spaces, one of which is enclosed.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.		2				Residential floor to ceiling heights (2.7m max), 15m deep wings with support by loadbearing party walls.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.		2				Underfloor heating, distributed via corridors. Plant room at ground floor adjacent an external wall.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.		2				Rooms mostly facing NE or SW, although building plan results in a range of orientations	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.	1					Solar shading prevented by planning consent (which did not include it). Solar glass may be used but only to meet	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Residential thermal performance to 2010 regs. 6/15 ENE01 credits targeted.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			All flats will have daylight to living areas, bathroom and kitchens are located corridor side and will not. Building will	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			BREEAM very good / 6 credits for ENE01 at preliminary assessment stage.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Residents have control over individual flats. Sub metering will be included.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a - new build	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.		2				Building is a fairly normal extra care brick building, nothing special architecturally.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		The building will be an extra care facility: "Additional communal facilities include an onsite restaurant, guest	
The building displays a high standard of construction and finish consistent with current market expectations.		2				RSL owned flats. Some will be sold and likely to a higher specification, remainder will be low end of the market.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build residential standards.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.			3			Not a workplace. Subject to residential standards for IAQ.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.		2				BREEAM pre-assessment = no detriment to existing but no improvements in biodiversity either.	
The building displays a high level of community interest and political support for its future care and preservation.			3			None evident, although it will be manged by an RSL indicating a community commitment to its operation for the	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Surrounding areas are residential. Land itself if a redeveloped industrial site.	

CASE 6.1

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building’s foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				No evidence to support this.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Insulated render envelope, zonc standing seam roof. Blockwork internal walls and steel frame. Assume durable	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Primary school design for low maintenance.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	1					Located in residential Kidderminster.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			Adjacent bus stop. Train station a 25 minute walk. Some space for staff car parking.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Plot large enough for a sports field to the rear. Only one vehicular access point. Site is at the bottom of the size	
The building’s interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				No provision of moveable walls between spaces. A range of size of ancillary spaces are provided but classrooms are	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to support this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		No atria, but the entrance forms a semi-enclosed space and there are several large spaces within the building (e.g. the	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Schools are steel framed with internal blockwork walls. Columns along one side of the corridor line (approx	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.	1					Plantroom sticks out of the back of the building, although it is cut into the slope and essentially buried. No raised access	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Classrooms all face NE, allowing for light but minimising the risk of overheating.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Large windows but these are protected by overhangs where they face south.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Designed to current building regulations. Insulated render for improved air tightness.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.					5	Naturally ventilated. Wings narrow enough for daylighting, supplemented with clerestorey.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5	BREEAM Excellent @ Interim	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS system installed. Classrooms use actuated windows for night purge. Display panel in reception showing energy	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a new build	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is not a work of art but is not unattractive. Compatible scale to surrounding residential housing.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Ground floor designed in such a way that community access would be possible. Share use of field with local football club	
The building displays a high standard of construction and finish consistent with current market expectations.			3			Good standard of construction consistent with a new build school. Tight budget is unlikely to have led to high quality	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Environment will be improved on the old SCOLA school. Designed for lower solar gain to reduce overheating.	
The building’s design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		SUDs scheme and retention of playing fields. Some loss of (less important) trees, although replacement planting.	
The building displays a high level of community interest and political support for its future care and preservation.			3			None evident for or against.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Conforms to use as a primary school in a residential area.	

CASE 6.2

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				No evidence to support this.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Envelope is a mix of materials including render, brickwork, curtain walling (stairwells). Steel frame.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Primary school design for low maintenance.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	1					Located in residential Kidderminster.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.		2				40 minute walk to train station. Adjacent bus stop. Car parking for staff.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Only one vehicle access point to site between two houses. Second pedestrian access also an alley way between	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.			3			Wind distribution allows the accomdation to be split. Placement of storage and toilets between classrooms limits	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to support this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		No atria but as offmore there are hall spaces.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Storey heights vary because of the semi-pitched roof, this makes them smaller than standard at one end and	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Biomass plantroom is remote from the main structure. Suspended ceilings, no raised access flooring. Services likely	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Classrooms face either east or west. Overhangs are used for shading. Large windows for daylighting. Spoke design	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.			3			Large windows for daylighting. Overhangs used for shading.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Insulated facade in line with Building Regulations.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.					5	Building is naturally ventilated with large windows to maximise daylight. Roof lights are used to light corridors.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			Asset rating 50 (B). No BREEAM rating achieved.	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS system installed. Classrooms use actuated windows for night purge. Display panel in reception showing energy	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a new building	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is not a work of art but is not unattractive. Compatible scale to surrounding residential housing.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		One wing can be separated off for community use. Additional entrance provided to facilitate this.	
The building displays a high standard of construction and finish consistent with current market expectations.			3			Good standard of construction consistent with a new build school. Tight budget is unlikely to have led to high quality	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Environment will be improved on the old SCOLA school. Designed for lower solar gain to reduce overheating.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Slowworn population were not moved as a result of construction. Mature boundary trees retained. SUDs	
The building displays a high level of community interest and political support for its future care and preservation.			3			None evident for or against.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Conforms to use as a primary school in a residential area.	

CASE 7

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			No evidence of the building being specifically designed for expansion or additonal loads, although the foundations	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		"At low level brickwork has been selected to provide a robust fi nishes to protect the building from the wear and	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				3		Old and worn out areas of the building have been replaced and the remainder refurbished.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Located in a residental suburb of London.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			20 minute walk to train station. Bus stop on nearby road. Two parking areas provided.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Large plot with space for playing fields. Views out over further playing fields / open space to the rear. Two vehicle	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.			3			The layout is a very strange shape due to the add on nature by which it was constructed, making segmentation more	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to support this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Courtyard space is reinstated. Main hall, dance studios and workshops provide big open spaces, in some instances	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			3.25m floor to ceiling. Column placement follows the external elevation with an internal line along one corridor	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Plantroom located in undercroft, accessible from ground level. Raised access flooring. No suspeneded ceilings for	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Building is quad shaped meaning it has significant elevations facing all directions.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		"The façade design is built upon this strategy, which also takes into account the differing façade orientations	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Building insulated to current building regulation standard in new build.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Double hieght glazing to courtyard to push daylight into main hall. Windows having opening vents for natural	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			BREEAM Very Good. Asset rating B (50)	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		Zoned heating and lighting controls. Boiler controls. Automatic daylight sensors. BMS system.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			Non evident, although the building has been retained and extended several times over its lifetime.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building has been reclad to update its apperance, but has rather a prodigous use of the school colours (blue and	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.					5	Changing facilities placed with community use in mind. Building designed to allow out of hours community access	
The building displays a high standard of construction and finish consistent with current market expectations.			3			This is a refurbishment, so likely some elements remain less than ideal (e.g. circulation, finishes in unimproved areas).	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		New build elements meet current standards. Old elements have been upgraded to comply, but soe narrow corridors	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.			3			New build provides a good level of thermal comfort and meets BREEAM daylight criteria.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Reuse of an existing builidng footprint. Retention of boundary trees etc.	
The building displays a high level of community interest and political support for its future care and preservation.				4		An existing school. Some concerns over transfer to Academy status.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	In a residental area near to other schools.	

CASE 9

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			No evidence to support this, although there are significant numbers of solar panels placed on the roof.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.			3			Building is clad in glass and metal cladding panels.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Commissioned by the building owners who will be responsible for maintenance. New build.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Located on the Welcome Trust campus outside of Cambridge.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.		2				Located adjacent the M11 and with car parking, the building is highly accessible by vehicle. There does not appear to be	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Large, greenfield plot within the campus. Site slopes. Views out across fields and into the countryside.	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.			3			Upper two floors consist of a series of identical lab spaces. Lower floor has two training rooms and a lecture theatre	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to support this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		3 storey atrium runs through the heart of the building.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Approx 3.5m (higher on training ground floor). Atria distrupts the floor plan size. Two column lines run along	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.		2				Plant room located to the building rear, semi underground (access via car park?) No plant on roof. Services are routed	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Building is predominatly orientated to minimise impact on neighbours. Glazing faces SE and NW.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.		2				Building was initally designed without shading but this was required to comply with building regs. Glazed facades.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Thermal performance in line with building regulations.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Fully glazed facades to two sides for daylight, and an atrium. Building is mechanically ventilated and cooled.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		BREEAM Excellent rating	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS system connected to main campus systems. Components standardised across the campus to make	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build n/a	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is new and designed to complement the surrounding campus buildings. Odd looking.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.		2				Private laboratory building. No community facilities.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Finished compatible with use as rentable lab and conferencing space.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		A/c controlled internal environment. BREEAM Excellent rating suggesting achievement of a number of HEA credits.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Built on a greenfield site. Earlier provision for flood compensation in the form of new wetlands. Landscaping	
The building displays a high level of community interest and political support for its future care and preservation.			3			None evident, although the funding for the Hub that occupies it is part of a significant EU wide initative.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Conforms to Welcome Trust phased development plan and council designation as area of employment.	

CASE 10

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.					5	Green roof was removed but loading provision remains.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.		2				Timber framed, overclad with brickwork and render.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		NHS LiFT building, designed for low maintenance as far as possible.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.			3			Located outside of, but on the main route into, central Liverpool. Within a regeneration area.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Located on a main arterial route, close to city centre transport options.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Large plot with space for outdoor activities and parking. Site is sloping. Adjacent a mental hospital (not an issue for	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				Room-corridor-room layout along square corridors. Limited potential for alternative arrangements due to wiggly facade.	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of design for demountability, although the rooms are designed as modules.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.					5	Atria/courtyards to each wing and surrounding the building.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.		2				Ward floor to floor 4.1m indicates reasonable allowance. Timber frame will create intrusions into the plan space.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Underfloor heating. Corridor running past each building likely contains main service distribution.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Orientated primarily for views and to fit within the L-shaped plot. Roof designed for PV.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.		2				Blinds but no shading due to ligature risk.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.					5	Passive solution using 'super-insulation' to reduce heat losses	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		All rooms have daylight access. MVHR is provided (partly because of the risks associated with open windows in a	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5	BREEAM Case study. Designed to BREEAM Excellent standard.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Sub metering must be included for BREEAM. Assume involvement of LiFT co. will have minimised FM costs.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			Designed as a landmark building. New build = n/a	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Designed as a landmark building, although will be surrounded by a high wall for security reasons.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Sports courts may be available for community use. Building is an NHS building therefore intrinsically serves the	
The building displays a high standard of construction and finish consistent with current market expectations.			3			NHS LiFT project so would expect a decent, but basic finish designed for durability.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		MVHR to all rooms to ensure adequate ventilation.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Green roofs have been omitted but still substantial greening / landscaping.	
The building displays a high level of community interest and political support for its future care and preservation.			3			No evidence for or against.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Part of the Edge Lane regeneration. Compatible with nearby mental health facility.	

CASE 11

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				Some talk of a green roof but this is not a planning condition.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Rendered facade, blockwork walls.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Owned by RSL who has removed any high maintenace elements.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	1					Located on the edge of an existing residential area, will form part of a retirement development.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.		2				Located on the outskirts of Exeter.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Small plot. Overall site slopes towards a stream at the rear (that sometimes floods). Good views across open	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.	1					Curved plan shape would make different spatial layouts difficult, as would the changing height profile around the	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.	1					No evidence of design for demoutability. Evidence of wet connections (e.g. wet plaster).	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Building is semi-circular with a space that could be considered a courtyard.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.		2				Residential floor to floor heights. Load bearing parition walls.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Corridors no longer run straight making horizontal runs more complicated, assume some regular vertical provision	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Building designed for double sided ventilation. Orientation predetermined and not ideal but adequate.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.		2				Fenestration matches room layout. Currently no solar shading although AR demonstrates how it could be	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.					5	PassivHaus design.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		MVHR for winter, but otherwise double sided ventilation and daylight to all rooms in most flats.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5	PassivHaus design.	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		Due to centralised servicing, assume some level of central control as well as local metering. Centralising plant makes it	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.		2				Will be taller than surrounding buildings, although is located down the slope of the site to minimise the visual impact.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		ExtraCare - "a Central Facilities Building to include: restaurant, bar, snooker room, library and meeting/activity	
The building displays a high standard of construction and finish consistent with current market expectations.			3			RSL developer is likely to reduce specifiction as part of VE. Final finishes will be the responsibility of the occupant.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Architects are concerned with indoor polluntants and care has been taken to minimise them.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Central courtyard garden but minimal availabiltiy of space for attenuation. Brownfield site but much of it was	
The building displays a high level of community interest and political support for its future care and preservation.			3			Non evident, but no particular objections of note. Will be a community facility on a 25 full operation lease.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Retirement estate.	

CASE 14

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		6-storey above ground development with lower ground floor and basement, totalling a floor area of 20,000 m2.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.					5	Steel framed building with stone facades and solid internal construction.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.	1					Building currently has a high maintenance profile (which is what triggered the investigation).	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.					5	Located in central London.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Central London, close to a tube station and major rail stations. No parking space and approach by car would be	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Building fills the plot. Accessible on three sides (although this is public road). In an area containing a number of high	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				Building is deep plan and currently highly cellularised with solid paritions. Ground floor houses a lecture theatre that	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of demountable elements.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.	1					All atria / lightwells have now been filled in.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.						Large floor plates.	x
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.		2				Plant is located on the roof and within the basement, but is congested.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Most of the facade faces NE or SW.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.		2				No shading permitted due to listed building status. Fenestration in a regular pattern.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.		2				Building envelope has degraded and there is potetial for improvement.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.		2				Deep plan necessitates some areas being mechanically ventilated, although a number of areas are NV.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.	1					No.	
The building supports efficient operational and maintenance practices including effective building management and control systems.		2				No, this is the reason for the refurbishment.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.					5	Listed building. "its part of their identity that they are where they are and they don't want to move" (Interview #)	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Listed building.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.			3			LSHTM offers lectures in the basement theatre to the public. Library access is also permitted.	
The building displays a high standard of construction and finish consistent with current market expectations.			3			Durable, imposing building but internally in need of refurbisment.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		Old building but likely to have been upgraded in part to meet access requirements.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.		2				Building overheats. Some areas have insufficient ventilation.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.		2				Old building, no contribution to ecology.	
The building displays a high level of community interest and political support for its future care and preservation.				4		Listed buildling, owned by LSHTM who attach historic sigificance to it.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Good match with surrouding institutional buildings.	

CASE 16

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				Old frame has been reused in part, although an additional frame has been added too. No green roofs (small terrace to	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Largely stone / brick facade. Central atrium solid flagstones. Interior fit out is less permanent, designed to be replaced.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Newly refurbished with a quality base design. CHP located off site with others.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.					5	Located in central London, behing St Pancras Station.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.					5	Adjacent King's Cross St Pancras with rail links to UK and Europe.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Central location within KingsX, originally with views of the city (will be restricted by surrounding high rise). Very large	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Partition walls, currently unfinished. Large open central space.	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.					5	Large central 'street', with warehouse style access doors to one end.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		Very large building, deep plan. 4.55m floor to floor for all of the new build, granary slighly less. Had to retain original	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Exposed ceilings and raised floors. Plant in basement and on roof.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			High thermal mass retained. Building runs roughly north-south, east elevation is blocked by an adjacent shed	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.			3			Minimal glazing but no shading due to heritage restrictions. Atrium roof has UV control.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Reclad as far as possible within heritage limits.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Atria / street for daylight with a number of new punched rooflights/lightwells. Mechanical ventilation throughout.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			BREEAM Very Good.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Building does not perform as well as its tenant had hoped, partly due to use of more floor space than planned. Sub	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.					5	Listed building.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.					5	Listed building. Award winning design.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Theatre to the rear. Public access through the front atrium to shops on the other side. Used as an arts university, with	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Base build to a high specification. Fit out more basic, but perhaps in-keeping with an art school.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		Significant conversion and new build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Mechanically ventilated using CCHP. DDA compliant. Large atria distributes light. Large public space to front and	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			No landscaping. Reused an existing derelict industrial site.	
The building displays a high level of community interest and political support for its future care and preservation.					5	Listed building. UAL invested considerably. Centre point to the King's X redevelopment.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Part of the Kings X redevelopment scheme.	

CASE 17

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.	1					Old structure is already been made to cope with additional loads. Unlikely to be further scope.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		"Inclusion of low maintenance, long life materials." (AR Appendix 1) Glazed links, stone cladding. Existing D block	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		D block is deemed in sufficient state of repair to be retained, with the cladding removed and the building	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.				4		Located in Oxford city centre.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			Walking distance of train station. Bus stops along the road frontage. Limited parking.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Small, awkward site adjacent to the existing complex and squeezed between listed buildings.	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Open plan office space, designed for more flexbility.	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.			3			Knockout panels to risers to permit extension.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Narrow atria links the old D and new blocks.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			D Wind is steel framed -"Columns are generally set out on an 8.1m grid longitudinally and 3.4m transversally although	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Ceiling has been removed (for thermal mass). Raised access flooring. Plant located on the roof with some in the	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.		2				Orientated to maximise use of site. Shaded on all sides.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Punctuated windows with covering to minimise overlooking (these blinds could also be used for shading). Shaded site.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		"Installation of high levels of insulation in excess of the current building regulations." (AR Appendix 1)	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Mixed mode strategy, using natural ventailation until the temperature / air quality requires mechanical assistance	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			BREEAM Excellent (target)	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		"Provision of robust control systems on heating, ventilating and artificial lighting installations to prevent energy waste."	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			Adjacent buildings are listed. Building is only visible from the road in a very limited way. Retained old pub is listed.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Building will complement the heritage setting.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.	1					No facilities provided other than office space.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		High quality finish to exterior (required due to historic setting). Internal specification commesurate with a new	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	Part new build, part retained. Will meet new build fire standards and DDA.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.					5	Improved daylighting and office facilities. Mixed mode ventilation.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Minimal landscaping to courtyards proposed. No specific commitments to biodiversity. Brownfield site. Reuse of	
The building displays a high level of community interest and political support for its future care and preservation.			3			None evident, although the council are keen to retain a large employer.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Fits with the use of the site by OUP for some considerable period.	

CASE 19

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		The roof currently houses a large number of intensive gardens, if these were removed there would be significant	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.					5	Exposed concrete throughout. Stone facade in keeping with heritage area.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		MAN11 BREEAM credit (ease of maintenance) was expected to be achieved. Durable materials, owner-occupier	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.				4		Located in Greenwich, London.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Located in Greenwich, London. No car parking but extensive bike storage.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Plot has been totally filled by the building, and is constrained by housing and a railway embankment.	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Building is banded which restricts versatility in one direction, but is otherwise flexbile space - the library mostly	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.				4		Plantroom cladding can be demounted and moved.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Banding of building provides first floor level courtyards.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Banding using core walls interupts floor plate. Good floor to ceiling heights. Large floor plate at ground floor, although	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Exposed ceilng soffits with panelised module services. Plantroom in basement and on roof, hidden by	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Glazing faces north and south (most of it north). The gardens face east. PV is on most of the roofs.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.					5	Glazing minimized on upper levels. Banding used to shade lower levels.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Built to current best practice standards.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Mixed mode strategy. NV where possible, supplemented with mechanical assistance. Interspered open spaces	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		BREEAM Excellent rating.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Sub metering in accordance with BREEAM.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a - new build	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Designed to meld with the existing heritage street scape, while still providing a modern look.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Retail units to the front and some provision for exhibition space. Use as a university campus.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		High standard of finish within the clients budget. Consistent with a new build HE facility.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Mixed mode building, allowing some user control of environment. 9/15 Health and well-being BREEAM credits,	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Extensive and intensive green roofs cover entire area. Attenuation tank (no SUDs). Brownfield site. 7 out of 8	
The building displays a high level of community interest and political support for its future care and preservation.			3			Building is supported in that it develops a vacant plot bliighting the local landscape. As part of the university	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.			3			Sits within a world heritage area and thus as new building could be considered out of place.	

CASE 20

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			No evidence to suggest this, although PV panels were proposed for the roof.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Concrete slabs and a brickwork facade. New double glazing. Assume render to courtyard was not applied.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.		2				Building is now old and requiring refurbishment, which has only been partly completed.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.			3			Located in Doncaster.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Adjacent doncaster train station. Bus stop nearby. Car parking to rear.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Access to the plot from one point, but can gt to 3 of the buildings for sides this way. Plot is larger than the building.	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Stud partitions in one area, blockwork walls in another. Celluar spaces, but of varying sizes. Conversion from	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of specific design for disassembly.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Central courtyard has been opened back up by demolition of ramshackle buildings.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Floor to floor heights large enough to retrofit ceiling fans. Floor plates are narrow in plan and not particulary 'large'	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		No service corridors. Plant located on the roof. Suspended ceilings used to distribute services.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Glazing faces north and south mostly (short side facing east)	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.			3			No shading due to heritage issues. Internal blinds are proposed. Sensible fenestration at regular intervals.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.			3			Building windows replaced with double glazing. Solid walls without insulation.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Naturally ventilated throughout. Relatively narrow plan allowing for ventilation and daylighting.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.		2				Loss of funding means building was not BREEAM rated. EPC score of 85 (D) at sale, would have been marginally	
The building supports efficient operational and maintenance practices including effective building management and control systems.		2				Zoned controls. Local control of ventilation via windows.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			Building is within a conservation area, although not listed itself. Was previously an art college.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Building has a facade in keeping with the conservation area and the adjacent minister.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		The building is designed to house start up business, but also now provides rented space for low budget community	
The building displays a high standard of construction and finish consistent with current market expectations.		2				Low specification due to loss of funding. Some space unfinished.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		Assume building was upgrade to comply with current standards in so far as was required for occupation.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.		2				Basic accomodation. Occupant control of ventilation and heating.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Reuse of an existing building. No further ecology improvements.	
The building displays a high level of community interest and political support for its future care and preservation.		2				Building owners are committed, but have failed to obtain more funding.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.			3			No polices of note. Adjacent a church. Shopping centre nearby.	

CASE 21

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			Green roofs. No other evidence. Existing foundations have been reused but the building has been made only a little	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.			3			White render to all internal (phase 2B) elevations. Limestone is used for 2A aspects fronting the street.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Hospital, FM will have reduced maintenance profile as far as possible. Basic frame and envelope expected to be low	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.					5	Located in central London	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Near to Russell Square underground station and within walking distance of Euston and St Pancras mainline stations.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Plot is surrounded by other buildings and has no direct access to the street other than through the phase 2A	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.			3			Deep plan building, partition internal walls. Currently divided into small celluar spaces (bedrooms etc.).	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of DfD.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.		2				No atria and most of the large spaces are located within phase 2A.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		Large floor plate, although it has some awkard dimesions. Phase 2B has a slightly more regular columns pattern than	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			GLA raise concerns about access to plant rooms within the development. The engineers go some way to managing	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Building runs roughly north-south, although it will be shaded by adjacent buildings on all but the north side.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.			3			No windows on the north facade. No shading due to maintenance issues. Solar control glazing.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.			3			The phase 2a and 2b redevelopment will be designed to comply with the targets set out in the Part L2a of the 2006	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			"All the spaces in the building that are not highly serviced spaces (e.g. theatres and intensive care) are able to be	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.		2				Building is rated under NEAT rather than the more onerous BREEAM 2008. Carbon targets are mostly being met	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		"A vertical separation of different functional flows (visitor, patient, facility management, staff) is achieved across the	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.		2				Not listed. Demolition of upper floors meaning only lower floors will remain intact (but will be reclad).	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Deisgned by a leading architectural practice, the building is designed to be modern and inviting.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Children's hospital. Will increase space for parents/carers to stay over and provide cafeteria and play spaces.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		High standard of construction consistent with modern healtcare practice.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		New build on upper floors. Lower floors will be configured for better (level) access.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.					5	Better provsion of healthcare services due to better equipemnt and servicing. Better quality of care space.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.		2				Limited landscaping. Green roof and a "staff" roof garden (although it is later stated this will not be accessible). Cafe	
The building displays a high level of community interest and political support for its future care and preservation.				4		Majority funded by private donation (only part NHS/public funded). Hospital is well known throughout the UK. This	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Par tof GOSH four phase redevelopment plan. Frees up other parts of the site for redevelopemnt.	

CASE 23

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			No evidence to support this, although the foundations are found to be in good condition and could be used to support	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.					5	OCH has a bath stone facade. New foundations, although old are considered sound. Stone facades and framed	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Historic building requires maintance in keeping with its age. Windows are openable to allow for cleaning.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Located on the opposite side of the river to the town centre proper, but close by. Small town.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Located near to train station. Bus stops outside. Located south of bath, some distance from a motorway. Level car	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Large plot with space for surface car parking. Near to river Biss, in mature landscaped setting. Access all around the	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		MECH is open plan space, with cores at either end. OCH is being converted to largely open plan space by the removal	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of DfD.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Courtyard between the two buildings is infilled by this development. Potentially the space behing the OCH forms	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		Generous floor to floor heights, and a large space created by joining the two buildings. County hall has columns along	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Corridor servicing has been altered. Displacement ventilation. Plant located in basement and at roof level.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Building faces NE.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		No shading, in keeping with the historic facade of the OCH. The MECH already has some limited shading. Blinds are	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Building has been retrofitted with insulation internally in leiu of cavity wall insulation. Good BREEAM rating achieved	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			OCH is designed to be naturally ventilated, and this will be maintained in the refubishment (although some	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		See low carbon assessment (based on BREEAM score).	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Building is being designed for increased efficiency (office planning and energy) of wich control systems will play a	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.				4		"Although presently not a listed building the Old County Hall is a building of local interest." (D&A)	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			OCH is old style and attractive. MECH is a newer 1970's office block but is not the worst example of its type and sits	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.					5	Building will house new library and public access to council services.	
The building displays a high standard of construction and finish consistent with current market expectations.			3			New areas will be fit out according to local library standards and the offices will be more inkeeping with modern	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		New build will be to current standards. Assume access in the remainder of the building will be upgraded during phase	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Cooling has been introduced to combat stuffyness without opening windows and exposing occupants to train noise.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Existing building so no damage to habitat. No attempts to improve local ecology, although there is a BREEAM	
The building displays a high level of community interest and political support for its future care and preservation.			3			No particular support for or against evident. Forms part of a wider cost saving programme to reduce building stock.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Building largely maintains its original use, but brings additional services that were located nearby under its roof.	

CASE 24

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			No evidence to directly suggest this. "The existing building has significant foundations for a single storey block, approx.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Stone cladding. Concrete frame and slabs. "Robust details, materials and systems that can be afforded will be used	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		New build with durable materials commesurate with use.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.				4		Located in Sheffield, within the city centre but not centrally located.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			Tram stop nearby, considerable distance to train station. Close to ring road but limited parking.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.			3			Corner plot, sandwiched between existing buildings and used to join them. HV main and CHP cables in close	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Mix of cellular and open plan spaces. Moveable partitions. Labs configurable.	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.			3			Fume cupboard can be altered to face different directions.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Narrow atrium included along on side of the building.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		Smaller floor to floor heights on the lower floors (approx 3.5m) as a result of connecting to the old building. 4m on	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Raised access floors to the labs. Suspended ceilings. Plant located to allow entry from the courtyard. Fume cupboard	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.		2				Main elevations face north and east. Orientation dictated by desire to connect adjacent buildings and plot size.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Sun shading to the west atrium elevation. Street facing elemetns have punctuated windows with full height glazing	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Complies with Part L 2010. "While the building is being constructed under Building Regulations part L2B (as an	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Mechanically assisted natural ventilation. Facade free area maximised as far as practicable with traffic noise. Some	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		BREEAM Very Good target. University target to minimise energy consumption.	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS which controls openings for natural ventilation. Automatic lighting controls. Zoned lighting and heating.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build. Adjacent building is listed.	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Designed to complement adjacent listed building.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Ground floor lecture hall can be used for public lectures. University use (surrounding buildings include student	
The building displays a high standard of construction and finish consistent with current market expectations.				4		High standard of materials to the level the client can afford. Robust external facade in keeping with historic facade it	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		BMS to control air quality and ventilation. Mechanical ventilation supplied where NV might be insufficient.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.			3			Brownfield site. No landscaping due to completely filling the site, except for a small strip adjacent the road.	
The building displays a high level of community interest and political support for its future care and preservation.			3			University owned building.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Compatible with university campus surrounds.	

CASE 25

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				AR discusses the addition of a green roof and concludes that each structural capacity is likely to be required.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Brick facades; Metal louvres; Timber soffits; Glazed curtain walling; Zinc cladding. Following CA study detailing was	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.			3			New build. School, so designed to limit maintenance. Mixed mode strategy enforces a higher services burden	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Located int the Ebbw Vale regeneration area.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			No parking within the school grounds but a large multi-storey car park is located very nearby to serve the school.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Plot is large enough for one sports pitch of its own, but as it shares facilities with the adjacent leisure centre is smaller	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Wings can be segregated and have toilet blocks within each one. Corridors are oversized and double height allowing	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of DfD.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.					5	Entrance is atrium like, leading into a large open plan dining space. The corridors are oversized and used for open plan	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		Single height spaces 3.15m to ceiling. Structure placement unknown.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Raised access flooring. No ceilings for thermal mass. CHP located offsite at the central energy centre. Some plant is	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Classrooms face NE. Lab spaces face W.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Brise soleil is provided to some elevations. Punctated windows interspersed with double height curtain walling	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		EPC = 23 (B). LZC was largely VE's out suggesting it is thermal performance and the CHP only providing this	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Mixed mode ventilation strategy. Daylighting adequate to most spaces, with rooflights to bring daylight to corridor	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		EPC = 23 (B)	
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS controls mixed mode system. CO2 sensors. Daylight dimming. Access around the building provided.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build - n/a	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is a typical modern school aesthetic. Not unpleasing.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Designed as part of an interlinking learning campus with the primary school and learning centre. Links to leisure centre.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Subject to VE that removed much of the LZC tech (e.g. earth tubes) and presumably de-spec'd some of the finishes.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		CO2 sensors to ensure air quality. BMS controlled mixed mode environment. Large windows and roof lights for	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Ecology appears to have been mostly dealt with at the masterplan level, however the school provides a large	
The building displays a high level of community interest and political support for its future care and preservation.				4		Good political support for the regeneration.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Part of The Works masterplan.	

CASE 31

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building’s foundations and frame have capacity for additional structural loads and potential vertical expansion.					5	The building is designed with the capacity to extend the mezzanine and add extra floor space.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.					5	Cladding selected over an alternative for durability reasons. Exposed concrete finishes. Stone finished ground floor.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		Maintenance of the cladding thought through at design stage with FM team.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.					5	Located in central Manchester.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.					5	Adjacent Shudehill interchange (bus and tram) and Manchester Victoria station (which is scheduled to be	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Large plot with space for public realm to the front. Views of Manchester and out towards peak district, facilitated by	
The building’s interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.					5	Designed with three cores to enable sub division into six. Open plan space. Smart grid services planned on a 1.5m	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of specific design for disassembly, although grid pattern would allow reuse of elements within the same	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.					5	Centre of the building is a large, glazed atrium.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.				4		4m floor to floor height (2.8m floor to underside of ceiling, allowing for raised access floor). Colun grid a min of 7.5m	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			400mm raised access floors. Exposed ceiling soffits. Earth tubes are large enough to work in. CHP is located in	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Building atrium is designed to capture the sun as much as possible, with shading fins at the facade to control	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Shading fins incorporated into the double skin glazing. Trombe wall can be opened to act like a duvet, but the	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.					5	Double skin facade acts like a 'duvet'.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Building is mechanically ventilated but uses earth tubes in addition to CCHP. Daylight maximised using atria and white	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5		
The building supports efficient operational and maintenance practices including effective building management and control systems.					5	Smart grid throughout to allow management of services. Submetering. Double skin walkway can be used for	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New building (n/a)	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.		2				Building sticks out relative to its surroundings (this may change once NOMA is underway) and has not won any	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.			3			The building is designed with conference space on the ground floor and a gym for its workforce. There is some,	
The building displays a high standard of construction and finish consistent with current market expectations.					5	BCO Grade A office.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New building.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.					5	New building, commisioned by a group commited to employee welfare. Gym and cafeteria facilities. Earth tube	
The building’s design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Brownfield site. Achieved all BREEAM Ecology points. "winter gardens" on each of the upper stepped back levels.	
The building displays a high level of community interest and political support for its future care and preservation.				4		Manchester council keen for NOMA and to retain cooperative within the city. Cooperative have sold the	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Landmark building, to kick start NOMA regeneration.	

CASE 35

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	**What is the key reason that influenced your opinion?**	Valid response?
The building’s foundations and frame have capacity for additional structural loads and potential vertical expansion.			3			New build but no evidence of design for additional storeys. Roof is designed as a test bed for LZC technologies.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		aluminium rain-screen, render and slate. Concrete frame.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		New build. Render and other low maintenance envelope constructions.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	1					Rural location in cornwall.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			Adjacent to A38. Penryn has a rail station.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Located on the top of a hill, but with good views of the surrounding area. Relatively generous plot for the size of	
The building’s interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		Open plan workshop areas. Teacing spaces are provided with moveable walls to allow them to be joined and	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to support this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Two wings form a triangular open courtyard space between them. This is external space. No atria, although the	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Around 3.3m minimum clear height. Two wings are narrow but spacious enough for labs.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.							
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.						Building has mostly north and south facing elevations. North spaces have been used for areas with higher internal	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Brise soliel is provided to some facades. Fenstration is strip window type.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.					5	EPC 23.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		"The building is mainly naturally ventilated using manual and automatically opening windows and vents, with the	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.					5	BREEAM Oustanding rating.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Submetering in accordance with BREEAM.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a new build	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is not unattractive but neither is it an example of high design. Located in a prominent location it is designed	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.		2				Building is part of a university campus. No significant community facilities within the building.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Envelope specification in keeping with prominent location. Leadbitter have VE'd the building at some point.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Chilled beams for thermal comfort. Desinged to current standards. Will meet many of the BREEAM HEA credits.	
The building’s design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		"The immediate landscaping is also strongly integrated into the scheme, with proposals to use the landscape as a "living	
The building displays a high level of community interest and political support for its future care and preservation.			3			None particulary for or against.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Part of planned campus extension masterplan.	

CASE 38.1

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building’s foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				No evidence to suggest this.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Brick facade. Concrete frame.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		RSL designed and owned. High maintenance aspects (e.g. CHP) avoided.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.				4		Located in Central Brighton.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Adjacent train station. Car parking and bicycle storage located under the building (although car parking is limited	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Small, triangular shaped plot. Steep retaining wall to the rear of the site preventing use of a section of it for	
The building’s interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				Partition walls within flats, but rooms appear to have been sized for function and bathrooms are grouped together	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.			3			No evidence to support this, although the building will essentially be base and fit out to allow tenants to customise	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.		2				No atria, only shared corridors. Most of the flats have some outdoor space that could be covered over given permission.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Residental floor to floor heights. Frame does not impinge unreasonably on the plan. Flat-corridor-flat layout gives	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.		2				Underfloor heating. Only two risers per block, both adjacent one another.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Building roof covered in PV. The upper block faces east and west (west will be shaded by the train station	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Brise soleil is included (details submitted as a condition approval). Balconies will shade lower windows. Punched	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Residential level of thermal insulation, in line with Part L2A 2010.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.			3			Building is naturally ventilated , although this is only single sided. MVHR is fitted for winter use and potentially with a	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			CSH scores submitted for planning conditon approval	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Individual smart metering for all flats. Rubbish stores provided.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			n/a - new build	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is a fairly standard apartment block. Fits with surrounding NEQ architecture.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.		2				There is a small park provided in front of the building. Small retail unit may occupy the ground floor.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Different levels of finsih for the affordable and market blocks. Affordable will be a basic finsih, the market a high	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New build residential.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		New build. MVHR for air quality. Most apartments have outdoor space.	
The building’s design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Roof terraces and allotments. Rear portion of the site will be developed and maintained as a greenway. Brownfield	
The building displays a high level of community interest and political support for its future care and preservation.			3			Considerable opposition to earlier buildings proposed on the site. Difficult planning history. Will be maintained by an	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Conforms to the NEQ site masterplan.	

CASE 46

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building’s foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		Designed in two phases, building can accept the loads of the additional classrooms in the allocated positions, but would	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Render envelope and finishes commesurate with the highly exposed coastal location. Sacrifical finishes to lower floor	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		New building - would not expect an undue maintenance load, particulary as a school with relatively low servicing.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.	1					Located in shoe-bury-ness, adjacent the sea.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.			3			Building has a small staff car park, and is accessible on foot and by bus. Train station approx 1km away.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				Large plot adjacent to the sea. Site subject to flooding.	
The building’s interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.					5	Flexible walls and classrooms arranged to allow combination.	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No specific evidence of provision for DfD.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.					5	Small atria. Significant oversizing in circulation spaces and provision of a main and smaller hall which can be combined.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Residental type floor to ceiling (approx 2.7m) although the ground floor car park is taller as is the first floor in places.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.				4		Transfer slab has precut holes for services when Phase 2 is constructed. Services flow under car park roof slab making	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Orientated for views of the sea rather than solar gain, meaning the building is warmed by the sun but more	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Brise soliel provided along classroom elevations. Punctuated openings for the most part, although these are	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		High efficiency envelope in accordance with Building Regs and local planning policy requirements.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Naturally ventilated throughout, using windows (some automated) and skylights. All classrooms designed for	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4			
The building supports efficient operational and maintenance practices including effective building management and control systems.				4		BMS system to control actuated windows. Daylight sensors and controls to taps. Energy board.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build - n/a	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.			3			Building is colourful but larger than surrounding buildings (there is ongoing development in the area).	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Primary school designed with community access in mind. Funding for a swimming pool has been raised.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Some elements were removed as part of the VE exercises, but this was mostly by omitting items rather than specifying	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New building	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.			3			Conforms to BB101. Evacuation plan necessary because flood risk could not be entirely eliminated.	
The building’s design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Extensive SUDS (even post VE). Land has not previously been developed but is contaiminated. Commitment to	
The building displays a high level of community interest and political support for its future care and preservation.				4		Council supported (they self funded when they lost BSF funding).	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.				4		Area is marked for futher residential development.	

CASE 47

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.		2				No evidence to suggest this.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		"Principal materials would be brick and cement cladding panels or boarding." Committee report. Ground floor is	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.				4		New build school, not expectation of onerous maintenance requirements.	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.		2				Residential location in a London suburb.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.				4		Very close to the M4 and Heathrow airport. Underground station within walking distance.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.		2				School is the maximum size possible on the available plot, ad some doubling up of sports areas has been necessary.	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.				4		No flexbility to combine classrooms, but the circulation space has been co-opted as extra teaching space providing	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence to suggest this.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		No atria spaces but the three halls connect together to form a larger space.	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			2.7m classrooms, 3.3m (ish) to the upper floor. 8x8m grid structural frame. Narrow floor plates for the most part.	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Most of the plant is located in the roof loft, some is accessible from ground level car park.	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.			3			Classrooms face NW and NE. Ancillary spaces tend to face towards the south. "The window systems are designed to	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.			3			Ground floor is shaded somewhat by canopies (although most of these are glazed). No shading to upper storey.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.				4		Insulated from aircraft noise.	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.		2				Because of location next to airport, NV is impossible and instead earth tubes / mechanical ventilation are used.	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.				4		BREEAM Very good target. Predicted EPC A rating (meeting Part L 2010) EPC Target of 18.	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Sub metering of water. BMS system.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.			3			New build (n/a) although the old version (a temporary building) will not survive the rebuild).	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		Building is in keeping with residential setting and will be an improvement on the existing 'temporary' structure.	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Building is designed to enable the community to use parts of it out of hours, but careful location of entrances and	
The building displays a high standard of construction and finish consistent with current market expectations.				4		Standard commesurate with new build primary school.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.					5	New building.	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Air quality and protection from noise provided by use of earth tube ventilation.	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.				4		Significant outdoor landscaping including 'nature' areas.	
The building displays a high level of community interest and political support for its future care and preservation.			3			School remains at its current site. Local residents mostly object on parking grounds, not other significant objections.	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	School remains at current site, in a residential area.	

CASE 48

How do you judge the following statements for the above building/facility?	Strongly disagree	Disagree	Neutral	Agree	Stongly agree	What is the key reason that influenced your opinion?	Valid response?
The building's foundations and frame have capacity for additional structural loads and potential vertical expansion.				4		Founded on large brick arches.	
The building fabric is well constructed using durable materials, providing potential retention of existing exterior and interior finishes.				4		Brickwork base and interior. New cladding will be mostly glass with some brick. Roof will be metal.	
The building currently has a low maintenance profile with modest expected levels of component repair and replacement over its remaining lifespan.			3			Building is old and a working train station, meaning it is constantly under some sort of construction. New build	
The building is situated in a bustling metropolis comprising mixed use development and proximity to potential markets.					5	Located in central london.	
The building is located near transport facilities and provides convenience for vehicular and pedestrian mobility.					5	Building is train station (main London Interchange). Limited parking.	
The building enjoys a site with favourable plot size, access, topography, area, aspect and surrounding views.				4		Large plot, although restrictive from a transport planning perspective. Located adjacent the river in central london,	
The building's interior layout exhibits strong versatility for future alternative arrangements without significant disruption or conversion cost.		2				Concourse is open plan. Retail and arcade areas are situated within the arches with railtrack over making them	
The building has significant components or systems that support disassembly and subsequent relocation or reuse.		2				No evidence of design for disassebly.	
The building has sufficient internal open space and/or atria that provides opportunity for spatial and structural transformations to be introduced.				4		Large concourse space will be created beneath the platforms, and the circulation through the arcades will be	
The building has large floor plates and floor-to-floor heights with minimal interruptions from the supporting structure.			3			Large floor to ceiling heights, moving to double or four storey heights in places. Station retail is located in the	
The building provides easy access to concealed ducts, service corridors and plant room space to ensure effective horizontal and vertical circulation of services.			3			Retail units will be centrally serviced (because of limited plant space). High servicing to rail tracks and to support the	
The building is designed in such a way that it maximizes its orientation with good potential for passive solar strategies.				4		Building is orientated along a NW-SE axis, although the SE is partially obscured by the Shard.	
The building has appropriate fenestration and sun shading devices consistent with good thermal performance.				4		Roof designed to take advantage of North light. Glazed facades to bring in daylight to the previously gloomy space.	
The building has an insulated external envelope capable of ensuring good thermal and acoustic performance for interior spaces.			3			Building is open to the air (no attempt at air tightness due to high internal loads and acceptance of an tempered	
The building is designed in ways that maximize daylight use and natural ventilation without significant mechanical intervention.				4		Building is designed to draw in air naturally without significant mechanical assistance. Daylighting via north	
The building has low energy demand and is operating at or readily capable of achieving a 5-star Green Star® energy rating or equivalent.			3			CEEQUAL rated. Designers seem more inclined to argue the travel carbon savings rather than demonstrate efficiency,	
The building supports efficient operational and maintenance practices including effective building management and control systems.			3			Centralised services provision to retail areas. Lighting, escalator and water controls and metering.	
The building has developed strong intrinsic heritage values, cultural connections or positive public image over its life.				4		The listed part of the station is demolished by the new proposals, as is the listed office building infront of one of	
The building has high architectural merit including pleasing aesthetics and compatability with its surrounding streetscape.				4		New roof will be modern in style, but considerable effort has been expended by London planning authorities in	
The building provides relevant amenities and facilities within its neighbourhood that can add value to the local community.				4		Will inlude retail areas. Building acts as a community resource for travel.	
The building displays a high standard of construction and finish consistent with current market expectations.				4		High standard of finish to be expected of a London terminus / main line station.	
The building complies with current standards for fire prevention and safety, emergency egress and disability provisions.				4		Station will have improved DDA access (e.g. lifts and level platforms). Fire and emergency egress suitable for a large	
The building offers an enhanced workplace environment that provides appropriate user comfort, indoor air quality and environmental health and safety.				4		Improved customer safety through the provision of better access and larger spaces. Design should not overheat until	
The building's design is compatible with ecological sustainability objectives and helps minimize ongoing habitat disturbance.		2				Reuse of existing site. No landscaping beyond the provision of some planters. Green roof not adopted. Minimal SUDS.	
The building displays a high level of community interest and political support for its future care and preservation.					5	Central london transport hub. Following successful rejuvenation of St Pancras support for refurbishment of	
The building's current or proposed future use conforms to existing masterplan, zoning and related urban planning specifications.					5	Conforms to GLA plan and contributes to cross rail delievey	

Principle	Criteria	Admiral HQ	British Trimmings	Offmore Primary	St Catherine's	Harris Academy	Technical Hub @ EBI	Edge Lane	Extracare4Exeter	LSHTM	CSM	OUP	Greenwich	Church View	GOSH	Trowbridge	Sheffield Grad School	Ebbw Vale	Co-op HQ	ESI	NEQ Site J (Resi)	NEQ Site J (NonDom)	Hinguar Primary	Westbrook Primary	London Bridge (LBSR)
Location	Good access to PT (walkable within 5 minutes (london), 10 mins elsewhere) = +1; Good access to main (A roads and motorways) roads = +1	2	0	1	0	2	1	2	1	2	2	2	2	2	2	1	1	0	2	0	1	1	1	2	1
	Central location	1	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	1
	Location suitable for a range of uses (not a mono-planning district)	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
	No nearby hostile factors	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	0
Site Access	Street frontage	1	1	1	0	0	0	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1
	No of sides accessible by vehicle	1	1	1	0	1	0	0	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	0	1
	Attached to other buildings	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	1
Site utilisation	Room for expansion within site boundary	0	1	1	1	1	1	1	1	0	0	0	0	1	0	1	0	1	1	1	0	1	1	1	0
	Space for parking	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	0	1	1	1	1	0	1	1	0
	Courtyard arrangement	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0
Occupancy	Single occupier	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	0
Building height	Not tall	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1	1	1
Storey height	Ground Floor: ≤ 2.7m (residential only) = 0	5	0	0	0	3	4	4	0	3	3	3	3	3	3	3	2	3	5	4	1	2	3	2	5
	Inclusion of mezzanies	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Plan depth	13.5 - 21m = 1 13.5 - 15m = 2	0	2	1	1	0	1	2	2	0	0	2	0	2	0	0	1	0	1	1	2	1	0	1	0
Building form	Regular shape, limited curves	1	0	1	1	1	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0
	Linear plan	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	1	1	0
Daylighting	Access to natural light on all sides = 1 Good daylighting (windows < 6m away) = 2	1	1	1	1	1	1	1	2	0	0	1	1	1	0	1	0	1	1	1	0	0	1	1	0
	With glare control/shading	1	0	1	1	1	1	0	0	0	0	1	1	0	0	0	1	1	1	1	1	0	1	0	1
Aesthetics	Listed status	n/a	n/a	n/a	n/a	0	n/a	n/a	n/a	1	1	0	n/a	0	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
Building quality	Basic finish	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0.5	0	0	1
	Quality																								
Standard components	Evidence of use of standard components	1	0	0	0	1	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0	1	0	1
Durability	Durable structure and substructure	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Loading	Office loading or above	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
	Evidence of foundations being oversized	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1
Grid spacing	Regular	1	n/a	0	1	0	1	n/a	n/a	0	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1
Span	Span ≥ 6m	1	1	1	1	1	1	1	n/a	0	1	0	1	1	0	0	1	1	1	1	1	1	0	1	1
Framed	Framed construction	1	0	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
External Walls	Non-load bearing external walls	1	0	1	1	1	1	0	1	1	0.5	1	1	0	1	0.5	1	1	1	1	1	1	1	1	1
Planning grid	Standard / repeated pattern to external facade	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1
	Evidence of use of a planning grid in positioning services and partitions	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0.5	0	0	0
	Eveness of services distribution (lighting, sprinklers etc.) and everyday connection points	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0.5	1	1	0
Separation	Services not embedded in structure	1	0	1	1	1	0	0	1	1	1	1	1	1	0	0	1	0	1	1	0	1	0	1	0
Service distribution space	Accessible horizontal service zone	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0.5	1	1	1
	Pentrable slab	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1
	Generous vertical riser provision	1	0	0	1	0	0	n/a	1	0	1	0	0	0	1	1	1	0	1	1	1	1	0	0	0
Accessibility	Plant located in an accessible location	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	1	1	1	1	0	0	0	1	0
Legible components	Exposed components	0	0	0	0	1	0	0	0	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	0
Service redundancy	Over sized distribution	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0
	Oversized or additional plant	1	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	1
	Extra connection points	1	1	1	1	0	0	1	1	0	1	1	1	1	0	1	1	0	1	0	1	0	1	1	0
Less components	Simple servicing (basic passive design)	0	1	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1
Layout	Hub and spoke arrangement of spaces	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0
	Open plan spaces	1	0	1	1	1	0	0	0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1
Internal walls	Non-load bearing internal walls	1	0	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
	Moveable walls	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0	1	0	0	1	1	0
Storage space	Generous provision of support spaces (storage areas etc.)	1	0	1	1	1	0	1	0	0	1	0	0	0	1	1	1	1	1	0	0	0.5	1	1	1
Space provision	Provision of extra space	1	1	0	0	1	1	1	1	0	1	1	1	0	1	0	0	0	1	1	1	0	1	1	0
	Circulation large enough to be used as space / no hallways	1	0	1	0	0	1	0	0	0	1	1	1	0	0	1	0	1	1	1	0	0	1	0	1
	Evidence of providing space above the minimum required, "elbow room"	0	0	1	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0.5	1	0	1
Standard spaces	Rooms demonstrate resonable standardisation in sizing	0	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	1	1	1	1	1	1	1	n/a
	Generic finish and / or fittings	1	1	1	1	0	1	1	1	0	1	1	1	0	0	0	1	1	1	0	1	1	1	1	n/a
Cores	No. of core groupings / GIFA [scoring to be determined during pilot] OR max distance	0	1	1	1	1	0	n/a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n/a
	Location of vertical cores	1	1	1	1	1	0	n/a	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	n/a
Openings	No. of openings	1	1	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1
	At least one oversize entrance	1	0	0	0	1	1	0	0	1	1	0	1	1	1	0	1	0	1	1	1	0	1	0	1
	Main entrance space central to the plan	0	1	1	1	1	1	0	0	1	1	0	0	1	0	1	0	0	1	1	0	1	1	1	1
	Provision for additional openings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Fire	Escape distance < 30m	1	1	1	1	1	1	0	1	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	0
Moveable furniture	Occupants capable of furniture arrangement (not fixed)	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0.5	1	0	0
Building service control	Occupants have some control over local servicing	0	1	1	1	1	0	1	1	1	0	1	1	1	1	0.5	1	1	0	1	1	0.5	1	1	0
	Zoned controls	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1

Case characteristics based on adaptability tactics (numbers indicate tactic counts)

		Admiral HQ	British Trimmings	Offmore Primary	St Catherine's Primary	Harris Academy	Technical Hub @ EBI	Edge Lane	ExtraCare 4 Exeter	LSHTM	UAL - Kings Cross Campus	Oxford University Press	Greenwich	Church View	GOSH 2B	Trowbridge County Hall	Sheffield Grad School	Ebbw Vale school	Cooperative HQ	ESI	SuperB	Site J Non dom	Hinguar Primary	Westbrook Primary	LBSR
Reversible	CAR1										1	1	1						1						
Moveable Stuff	CAR2	1				1	2			1	1		1				1	1			1	1	3	2	
Component Accessibility	CAR3	2	1			1	1	1			3	3	2				3	2	1	1	1		1		3
Functional Separation	CAR4	1	1								2						1		1	1				1	
Service zones	CAR5	3						1		2	1								3						
Configurable stuff	CAR6					2	1	2	1	1	3	2	4		3	2	3	2	1				4		
Multi-functional components	CAR7						1	1			2				1		1	1	1	1	1				1
Not precious	CAR8			1		1	3	1			1	1											1		
Extra components	CAR9	2	3							2	1	2	4		1		1	1			1		2	1	1
Durability	CAR10	1	1			1	2	1	1		1		1	1	1		1	3		1	2	1	1	1	3
Mature Component	CAR11		1			1																			
Efficient Services	CAR12																								
Good Craftsmanship	CAR13																								
Overdesign capacity	CAR14	3	1		1	2		3	6	1	5	7	8	2	2		2	3	1	3	2	1	3	4	5
Readily available materials	CAR15																								
Standardised components	CAR16		1			1		1			1								1						
Standard component locations	CAR17												2						1						
Off-site construction	CAR18																								
Simple construction method	CAR19			1	1									1						1					
Open space	CAR20	2	1			2					4	2	1		1	1	2	1	4			1	2	1	
Support space	CAR21	3	2	1		3	2		1		3				2		3	3	1		1	1	2	2	
Oversize space	CAR22	2	3			1	1				6	1	3	2	1		1	3	1	1		1	2		3
Typology pattern	CAR23					1		3	2						3			1							
Joinable / divisible space	CAR24	2					1			2	4		6				1	1	7	1		1	1	4	
Modular coordination	CAR25									1			2		2				1						
Connect buildings	CAR26												1				2								
Standard room sizes	CAR27	1				2		2										1							
Spatial variety	CAR28					1		3			3		2					4	1	1			2	1	1
Spatial ambiguity	CAR29	3				1	2		1		5						1	1	1			1		2	1
Spatial zones	CAR30	1				1						1	2		1		1		1				2	2	
Spatial proximity	CAR31	1									1	1	3			1							1		1
Simple plan	CAR32										1				2										
Standard grid	CAR33														1			1							
Simple form	CAR34					1							2		1										
Multiple ventilation strategies	CAR35							1	1			1	1		1			2					1		
Shallow plan depth	CAR36													2						1		1			
Passive climate control	CAR37																								
Building orientation	CAR38			1				1						1											
Good daylighting	CAR39	1						1			1	1		1											
Space to grow into	CAR40	1		1	1		1	2			1	1					1		4				2	1	1
Phased	CAR41										3			1			1		1				1		
User customisation	CAR42										5										1				
Multi-functional spaces	CAR43		2			1	1		1	1	3		2		1		3	3	1		2	1		3	
Use differentiation	CAR44										1										1	1			1
Mixed demographics	CAR45			1		2					3							1					2		
Multiple / mixed tenure	CAR46																								
Shared ownership	CAR47										1			1					1				1	3	
Isolatable	CAR48			1	2	2			1		1						1						4	1	
Multiple access points	CAR49				1	1					3								1				2		
Physical linkage	CAR50					1					3				2										
Visual linkage	CAR51					1					4						1		1			1	1		
Attitude and character	CAR52																								
Spatial quality	CAR53																				1	1			1
Building image	CAR54										1										1	1			
Quirkiness	CAR55																								
Time interwoven	CAR56																				1				
Good location	CAR57						2		1				1							1					1
Contextual	CAR58						1		1		1														1
Circulation	CAR59	1					1		1								1								
A communal place	CAR60					1	2				1										1	1			

Case	Tactic	Why	Resolved Characteristic(s)	Installed
1	Large open plan office space which is designed to be sub-divided should the need arise	Sub-let a portion of the building to a different occupant	Joinable / divisible space	y
1	Central core option provides ultimate flexbility (floor plate planning)		Open space Spatial zones	y
1	High provision of riser and service spaces	Will ensure that a wide range of office uses can be accomodated from open-plan call centre operations to individual cellualr offices and meeting rooms	Oversize space	y
1	Raised access flooring		Component accessibility	y
1	Suspended ceilings		Component accessibility	y
1	Trees will be placed in containers		Moveable stuff	y
1	Steel beams will span from the perimeter columns back to the concrete core	effectively providing a flexbile column-free arrangement	Functional separation Open space	y
1	Generous floor to ceiling height (2.8m clear - exc ceiling and floor void space = 3.2 total?)		Oversize space	y
1	Heating and cooling systems will have zoned controls local to the space that they serve		Service zones	y
1	Merged distinction between public and private space - allow public access to ground floor		Spatial ambiguity Circulation (neighbourhood scale)	y
1	Double height breakout spaces at one end of each floor.	Provision of breakout space and better daylighting.	Support space Good daylighting	y
1	Electrical rising busbar to be provided with 25% spare capacity	Tenant's brief	Spatial proximity Standardised interfaces Overdesign capacity	y
1	Incoming services to be provided with 10% spare capacity	Tenant's brief	Overdesign capacity	y
1	External recreational space - sheltered areas within the curtailage of the building	To allow space to move away from their desks during breaks	Spatial ambiguity Support space	y
4	Piled foundation	allow better access beneath the ground floor slab for any future excavation and service connection works	Component accessibility	y
4	Underfloor heating	Allows for flexibility in space planning compared to traditional radiators	Open space	y
4	Suspended ground floor slab	allow better access beneath the ground floor slab for any future excavation and service connection works	Component accessibility	y
4	Use of the sloping site to make space with reasonable head room below the building on the south side	Additional service space, plant rooms, water treatment plant as required.	Support space	y
4	Small study	Could be used as a separate dining space or other function	Multi-functional spaces	y
~~4~~			~~DELETED~~	
4	Patios and balconies large enough to provide a private outdoor sitting space and table		Oversize space Support space	y
6.1	Bulk of the building is a relatively simple duo pitch two storey block, of steel frame construction	Making adaptation to other uses possible	Simple construction method	y
6.1	Position of the hall wing at the front	Helps it be accessible for community use without having to open up the rest of the school	Isolatable	y
6.1	Catering kitchen for after school club use		Mixed demographics	y
6.1	Temporary mobile classrooms	Accommodate extra year groups as a result of school system restructuring while awaiting rebuild.	Not precious	y
6.2	Bulk of the building is a relatively simple duo pitch two storey block, of steel frame construction	Making adaptation to other uses possible	Simple construction method	y
6.2	Last block can be separated off from the rest of the school	To allow for extended school activities	Isolatable	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
6.2	Access to this block for out of hours use is provided by a separate entrance at the south end		Multiple access points Isolatable	y
7	Addition of dance and activity studios alongside a new gym room	Encourage community use	Mixed demographics	y
7	Locate sports facilities so as to allow closing down the rest of the school	Allow use of part of the building only out of hours	Isolatable	y
7	Legible entrance to the sports facilities	Encourage community use	Multiple access points Visual linkage	y
7	Inclusion of a meeting / refreshment area	Encourage community use and bolster school income	Support space	y
7	Externally accessible storage space for the MUGA pitches		Support space	y
7			Standardised components	y
7	Minimise fixed furniture	Maximise the number of possible teaching and learning configurations	Moveable stuff	y
7	Specify furniture to British standards and Euro Norms		Durability Mature component	y
7	Consolidate levels		Simple form	y
7	More legible internal circulation		Physical linkage	y
7	ICT and business suite located adjacent main entrance at ground floor.	Allow community access to IT suite	Isolatable Mixed demographics Spatial zones	y
7	Large enterprise zone: open plan group work and independent learning areas		Open space	y
7	Ground floor offers optimum opportunity for a variety of uses and provides a central space with community and educational facilities		A communal place	y
7	External spaces that are sufficiently flexible to offer different curricular activities at different times of the school day		Multi-functional spaces	y
7	Floor to floor heights are relatively generous (3250?)	Allows the possibility in terms of space planning to introduce low carbon plant and mechanical cooling in future if and when required	Oversize space	y
7			x	
7	Provision of temporary accommodation during the demo + build		Not precious	y
7	Ensure the layout of the different departments will allow for some departments to expand and some to contract over time without remodelling		Standard room sizes Spatial ambiguity	y
7	Lighting designed to change the character of key areas at different times of day depending on their different functions e.g. when used by the		Configurable stuff	y
7	Repetitive programme of spaces gathered around larger assembly spaces		Standard room sizes Spatial variety Typology pattern	y
7	ICT infrastructure to be easily accessible		Component accessibility	y
7	It is important that the services and security systems are designed to allow changes of use and long term expansion		x	y
9	Light bulbs replaced every 3 - 5 years at end of life	Upgrade lighting efficiency	Not precious	y
9	Equipment changes happen relatively frequently	Opportunity to upgrade equipment efficiency	Not precious	y
9	Market square with grassed features	Overspill dining space and outdoor seating in good weather (pedestrian route at other times)	A communal place Circulation (neighbourhood scale)	y
9	Informal meeting rooms link with the tea point	to provide breakout space and collaborative working for staff	Support space Spatial ambiguity	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
9	Modular project team studios	To accommodate teams that can range from 3 to 20 people depending on the nature and stage of the projects	Joinable / Divisible space Moveable stuff	y
9	The furniture configuration is flexible to accommodate user preference		Moveable stuff	y
9	The phase 2 innovation centre is designed to plug into the phase 1 works	(i.e. it uses the existing phase 1 infrastructure and facilities)	Contextual	y
9	Physical layout of the new development, delivery of site infrastructure works in phase 1 and the retention of 'temporary' construction	Later phases can be added with little disruption	Not precious	y
9	Site has been planned with expansion of south fields campus in mind		Space to grow into	y
9	Pathway around the building for cherry picker access	Access for cleaning and maintenance	Component accessibility Support space	y
9	Courtyard garden at the lower level	Will function as an informal amphitheatre, garden, gathering and events space and paved break-out space for the basement	Multi-functional spaces A communal place Spatial ambiguity	y
9	Typical floor to floor heights are in the range of 4.5 - 5m	in order to accommodate engineering services appropriate for laboratory spaces, and allowing for distribution in ceiling voids	Oversize space	y
10	pre fabricated timber frame	Provide flexibility	Standard room sizes	y
10	Variant sizes of rooms are accommodated	To support broad activity ranges such as group rooms, offices	Spatial variety	y
10	Design manual	Help clients and users understand the design intent…can deviate knowingly from the way in which the building was conceived originally, or can enhance	Information provision	y
10	Every courtyard has a mains tap provided for irrigation purposes	the infrastructure would allow some future features to be added to assist with cooling or transpiration	Component accessibility	y
10	Blinds		Configurable stuff	y
10	Spare structural capacity	Allow future imposed loads of sedum planted roofs or renewable technologies	Overdesign capacity	y
10	Site for future expansion. For the foreseeable future this zone is absorbed within the overall landscape framework as part of the entrance		Space to grow into	y
10	Standardised single bedrooms with ensuites	Adaptable for non medical and other medical uses with different care methods	Typology pattern Standard room sizes	y
10	ward buildings follow a similar template [to other sites]	increase flexibility and adaptability, even across different site	Typology pattern	y
10	Layout is organised to address a range of service configurations	services need to be adaptable	Typology pattern Spatial variety	y
10	Flat, accessible and well orientated roof	Retrofit green roof / PV	Space to grow into Building orientation	y
10	Insulated fabric of timber framed wards	External fixings for additional elements easily provided at a later date	Not precious	y
11	Awareness of peripheral development and future access requirements		Contextual Circulation (neighbourhood scale)	y
11	Flexible use activity rooms		Multi-functional spaces	y
11	50+ units in scheme (to make extracare viable). - Block size	Design the affordable housing to allow flexibility for conversion to an extra care scheme in due course (55+ community, want them to be able to age in situ)	Typology pattern	y
11	Provide units as flats - unit type	Provides a greater degree of management control and flexibility for an RSL (conversion to extracare - residents age in situ)	Typology pattern	y
11	All properties are built to the lifetime homes standard		Overdesign capacity	y
11	Cafe is designed to open up to the outer environment to merge with the external green space		Spatial ambiguity	y
16	Missing ceiling where services were to be concealed		Component accessibility	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
16	generous workshops behind glazed walls of the central street	Avoiding barriers between zones	Oversize space Spatial ambiguity Visual linkage	y
16	Providing extensive bookable accommodation		Shared ownership Support space	y
16	Concrete warehouse shell with large floor plates and generous floor to ceiling heights		Functional separation Oversize space Open space	y
16	Standard steel sections and no special extrusions		Standardised components	y
16	Generous wide bridges, spanning and animating the street; bridges link the various cores and workspaces cross it; Wide bridges across the	Encourage student interaction; offering breakout space for meeting, relaxing and people watching; Alternately promote movement and contemplation	Oversize space Physical linkage Visual linkage	y
16	The street space is large and flexible enough to accommodate a range of activities (large enough to accommodate pavilions)	Accommodate fashion shows, exhibitions, social areas	Multi-functional spaces Open space A communal place	y
16	280 people main theatre (up to), 100 studio and foyer bar	Flexible performance, rehearsal and exhibition spaces	Spatial variety	y
16	A continuous light gantry (within the street) installed under the roof to enable it to be transformed into a performance stage as	Street conceived as a space of theatre and collaboration; "it needs a level of infrastructure. It's quite difficult to put stuff in it, because it's so	Multi-functional spaces	y
16	Triple height rendered walls	Can have films / images projected onto them	Multi-functional components	y
16	Rails behind the courtyard's several glazed openings	Enable students to hang installations	User customisation	y
16	Ground floor openings (to the street) large enough to permit a vehicle through	Street conceived as a space of theatre and collaboration	Multiple access points Overdesign capacity	y
16	Informal arrangement of teaching areas	Enable all manner of functions and activities to take place within	Spatial ambiguity Spatial variety	y
16	Turnstiles that stop the public at the point where the internal street begins	Allow public access; removes need for more significant structural barrier (e.g. a wall)	Mixed demographics Spatial ambiguity	y
16	Plain concrete floors, all those rough and ready timber partitions, plus the exposed ductwork		Component accessibility User customisation	y
16	Walls of most of the classrooms are faced with plywood boards	Encourage students to constantly change their environment by adding or removing installations, presentations and colour	User customisation	y
16	Stepped back mezzanine can incorporate cut-backs	Strong visual linkages between levels	Visual linkage	y
16			Joinable / divisible space	y
16	Spare capacity is designed in from the start and empty ductwork will be available for IT providers	will allow buildings simply to plug in to all required utilities…there will be no need to dig up pavements and close roads for future upgrades	Overdesign capacity Extra components	y
16	With the exception of the structure and concrete frame, other building elements can be easily replaced		Reversible	y
16	Studio risers contain additional space for use as part of the UAL fit out		Oversize space	y
16	Hinged doors and panels to risers	Accessible installation and maintenance	Component accessibility	y
16	350 seat theatre has its own entrance	Useable by the public for events	Multiple access points	y
16	As the underground duct system is the only connection between risers space ducts will be provided where practical	For future fit out use	Extra components	y
16	Bus bar within selected cores of the building		Spatial proximity Standardised interfaces	y
16	Four dedicated goods lifts, enhanced to allow for passenger use		Overdesign capacity Physical linkage	y
16	Assemblage of flexible spaces; decision was taken to make all workshops shared, and to distribute them throughout the building	For changing patterns of use, can be orchestrated and transformed by space over time	Spatial variety	y
16	Restrained backdrop; "it wasn't about the building making a statement. It needed to leave space for people inside it to make the	Allow personalised spatial identities (e.g. the textile workshop - enables rows of wonderfully intricate loom machines to take centre stage)	User customisation	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
16	Uniformity, grid like, rectilinear form of the street		Simple plan	y
16	sliding doors and sliding / folding partitions to sub-divide areas	in order to sub-divide the space as required; sudivide display areas within the western transit shed and granary offices	Configurable stuff Joinable / Divisible space	y
16	Large, uninterupted spaces	Cubitt designed a building that was remarkably flexbile in its operation. The spacing of the column grid did not interupt the operation and symetry of	Open space	y
16	Constructed of robust materials; invest in long life fabric components and structures	Gives the building a robust character that "lend themselves to this addition" and reduces EE (as a result of degradation necessitating replacement)	Durability	y
16	Space tall enough to allow the insertion of mezzanines: "insert new first floor in each transit shed"		Oversize space	y
16	easily moveable partitions within offices	enable changes to be made in response to the needs of occupiers	Joinable / divisible space	y
16	great vertical loading slots at ground level have been opened up at ground level	to allow a new restaurant / cafe to spill out into the square	Spatial ambiguity	y
16	Multi-storey development: "it is not felt possible to reuse the assembly shed because as a single storey building in this location	it …is an inefficient use of the land.	Contextual	y
16	the fountains can be turned off; fountains will have a number of programmed displays	the space can be used for a range of events	Configurable stuff	y
16	The building's robust character	lend themselves to this [the LED facades] addition	Building image	y
16	The complex will provide a variety of uses	allowing for maximum utlilisation of the space available in a sustainable way	Mixed demographics Use differentiation	y
16	remainder [of the disable seating in the theatre] as removeable	to follow AD M guidance on disable provision	Moveable stuff	y
16	The shell arrangement allows there to be access provided at both ground and first floor level to both theatre spaces	this will aloow there to be level access to any hihger level seating provided in the fit out.	Multiple access points Physical linkage Phased	y
16	Four levels of fit out provided to UAL: shell, studio, head office and full fit out	UAL will complete further fit out works in due course; with the exception of the structure and concrete frame ... the other building elements can be easily	Phased	y
16	a subtle curve in their profile [each concrete bench]	provides varying seating heights	Multi-functional components	y
16	There will be no physical doors on the elevation at the public route…sliding metal screens mounted on the rear, inner wall face will make	encourging public entry; seeks to blur the boundaries between inside and out, public and private	Mixed demographics Spatial ambiguity	y
16	Cast reglit glazing at the upper level	allows north light to penetrate ad expose ghostly figures and performers from street level whilst offering a degree of privacy	Visual linkage	y
16	The Granary building [at the front of the development] is mostly given over to the library	placed here so students could gain round the clock access	Isolatable	y
16	The lighting control for the UAL covered street will be separated from the general facilities lighting control system	to enable UAL staff to adjust the lighitng in this area	Service zones Configurable stuff	y
16	Studios should be like warehouses, heavy loadings, big floor plans, daylight wherever possible	The scheme was predicated on the college coming in, inhabiting the building, and continuing to change. The architectural framework fixes certain things, but	Overdesign capacity Oversize space Open space	y
16	The system [BMS] will have 25% spare capacity	to allow for future fit out of shell areas	Overdesign capacity	y
16	The application proposes separate storm and foul drainage within the development, only combining these discharges at the point of	[maximise future flexbility]	Functional separation	y
16	Areas on the roof have been identified for additional plant for use by UAL fit out	to allow for future fit out of shell areas	Space to grow into Phased	y
17	Very generous floor to ceiling height on the ground floor		Oversize space	y
17	Fire escape stairs, toilet, lifts, plant rooms and service risers have been grouped together in two service cores	To maintain the flexibility of the floor plates	Spatial zones Open space	y
17	New raised access floors at all levels		Component accessibility	y
17	Modular carpet tiles, raised floor systems, light fittings, ceiling panels	Incorporate materials / elements that will be simple to reuse / recycle at the end of the building life	Reversible	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
17	Demolition to bring daylight to all floors	Increasing the potential to provide flexible office space	Good daylighting	y
17	Main rising busbar		Spatial proximity Standardised interfaces	y
17	2 No. chillers sized at 66% of the load	Designed for resilience (over design)	Overdesign capacity	y
17	Space capacity in the substation	No need to build additional sub stations for extensions	Overdesign capacity	y
17	Provision of recessed compact fluorescent luminaires to denote notional corridors		Open space	y
19	Graining or banding of the facade / plan	Gives a logic to the organisation of the internal spaces within the building by creating adaptable spaces that allow different configurations for	Modular coordination	y
19	(Green) roof design for maximum (intensive) soil depth	Allows for an increase in flexibility of substrate and the use of the roof over time	Overdesign capacity	y
19	Ground floor (of the library) is a high space and the upper floors of the library have a flexible layout	Providing an adaptable structure that can accommodate varying uses and teaching over the life of the building	Oversize space Spatial variety	y
19	All high level services are exposed internal	Done to reduce floor to floor height	Component accessibility	y
19	Raised floor system	Allows for flexible services distribution	Component accessibility	y
19	Grid of lighting forming a continuous strip of lighting	Provide maximum flexibility	Joinable / divisible space Spatial proximity Standard component locations	y
19	Repeating pattern of cores to distribute services vertically and allow horizontal service spines to distribute horizontally at regular intervals	Provide maximum flexibility	Spatial zones Spatial proximity	y
19	Windows will be openable	in order to provide users with the option to benefit from natural ventilation	Configurable stuff	y
19	Mixed mode HVAC	Maximum flexibility in environmental control	Multiple ventilation strategies	y
19	Library structure designed to accommodate additional load of compact shelving in library	to allow for future flexibility	Overdesign capacity	y
19	Building has been designed on a modular grid	To allow for future reconfiguration of partitions and services	Modular coordination Standard component locations	y
19	High level network connectivity and wireless access		Spatial proximity Extra components	y
19	Space has been allowed within the plant room, in proximity to the main street, to allow a heat exchanger with a district scheme	Allow later connection to a district heating scheme should one become available in the area	Oversize space	y
19	PV connection point to be included in a nearby distribution board for more future PVs	Allow more PV is planning restrictions relaxed	Extra components	y
20	Wheelchair accessible vehicle parking	More flexible that standard parking bays	Overdesign capacity	y
20	Develop a flexible allocation strategy for communal rooms	So for instance some spaces in 'cold' areas of the building can be used in times of high thermal stress as alternative meeting spaces when some in 'hotter'	Shared ownership	y
20	Functional but basic accommodation (some of the view was not completed to a high contemporary standard due to budget cuts)	Space for activities that don't need high end interior design - yoga, art classes and music rehearsal rooms	Phased	y
20	High ceilings, high thermal mass, shallow floor plates, good natural daylight penetration, potential for increasing natural ventilation	Inherently sustainable' building features that make it easier to adapt for climate change	Simple construction method Shallow plan depth Oversize space	y
20	B1 office and workspace use with flexibility for ancillary use within classes A3 and D1		Planning classification	y
20	Higher ceiling levels to 2.7m minimum	Allow for retrofitting ceiling fans	Oversize space	y
21	Rationalise the floor levels, vertical and horizontal circulation between buildings on the campus		Physical linkage Simple form	y
21	Hybrid angiography suite	Provides a versatile treatment room that adapts to a range of treatments and surgeries. This means a patient needing multiple operations will not need to	Configurable stuff	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
21	Phase 2Bs frontage has projecting fully glazed windows in a contemporary arrangement (i.e. it replicates the publically visible facades)	Future proof the design in the event of the phase 3 elevation becoming visible from a new visitor entrance or public realm	Overdesign capacity	y
21	Conceived as general, flexible, clinical floors that can accommodate ward layouts, theatres and other functions		Typology pattern Simple plan	y
21	Locating the main vertical cores and fire escape stairs at the extremities of the building.	Provide maximum flexibility in the floor plate arrangement	Open space Spatial zones	y
21	Conceptualised around the provision of 2 similar shaped buildings	Providing the template for standardisation of clinical and support accommodation	Typology pattern	y
21	Create a procedure pathway floor at level 3 across the heart of the hospital	The premier inn clinical building facilities at level 3 will link to the Morgan Stanley clinical building and the variety club building to provide this	Physical linkage	y
21	Spacious bedrooms and bedbays with sofa beds and ensuites	To allow a parent / carer to stay overnight	Oversize space Configurable stuff Support space	y
21	7.8m planning grid for cladding panels	Can accommodate 2 bedrooms per grid.	Standard grid Modular coordination	y
23	Remove some of the existing partitions	Create a flexible, open plan working environment	Open space	y
23	Wi-Fi		Spatial proximity	y
23	Flexible exhibition digital display system	Enable a programme of temporary exhibitions	Configurable stuff	y
23	Intelligent ETFE inflatable (fritted) roof covering to courtyard	Vary shading depending on weather	Configurable stuff	y
24	Line building floor levels with the adjacent building	Allow to link through the gable end of the adjacent building	Connect buildings	y
24	Raised access flooring	Facilitate flexible servicing	Component accessibility	y
24	2 (of 3) labs have loose central benching		Moveable stuff	y
24	Extensive provision of network access, interactive whiteboards and projectors	Allow the majority of rooms to accommodate most subject areas	Multi-functional spaces Extra components	y
24	Laboratories designed to facilitate various uses		Multi-functional spaces	y
24	Provision has been included in layout and floor structure for a store cupboard to become a future riser provision as required		Overdesign capacity Support space	y
24	2 No. wet labs have 12 No. fume cupboards that can be connected to either lab as required		Configurable stuff	y
24	A social area is provided adjacent the lecture theatres	Provide a crush space for lecture changeover times	Support space	y
24	Infilling the site up to the height of the adjacent block; being linked though to all adjacent facilities on both the Hadfield / chemical	Provides maximum connectivity between the departments / buildings giving the faculty greater flexibility	Connect buildings Circulation (neighbourhood scale)	y
24	Ceiling baffles and higher, acoustically absorptive partition screens	Reduce speech transmission levels for privacy and concentration	Open space	y
24	Moveable walls	When fully opened up spaces are able to accommodate the same number of people as the lecture halls - flexibly for a group to move from one	Joinable / Divisible space Configurable stuff	y
24	Two generous meeting rooms	Size allows flexibility for them to used as further PGR/PDRA space if required	Oversize space	y
24	Breakout / brainstorming areas of the main circulation space	Allow larger groups to filter out across the building; atrium spaces also allowing flexibility in how the space is temporarily divided and functions	Support space Spatial ambiguity	y
24	Lift will be a passenger and fire fighting lift with beneficial use	Allowing the building to be kitted out using the lift in the first instance	Multi-functional components	y
24	Locate open plan spaces within the larger floor to floor heights	To enable provision of raised access flooring = facilitates flexible servicing	Component accessibility Open space	y
24	Fans and operable vents in areas where acoustics prevent full NV	Give end users a greater degree of control to open vents when traffic noise is low / don't need perfect quiet	Configurable stuff	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
24	Internal partitions to be stud partitions		Functional separation	y
24	Align sill heights to 1150mm above finished floor level	For laboratory and teaching flexibility	Multi-functional spaces	y
24	Heat exchangers (no boilers on site, served by CHP)	Effectively infinitely modulable	Component accessibility Space to grow into	y
24	Pushed circulation (to) the outside of the ground floor	Animates the ground floor, provide possibility of managing the lower floors to operate independently for the rest e.g. evening lectures accessed directly	Isolatable Visual linkage	y
24	Locate laboratories in the space where NV won't work	Allows upper floors to be naturally ventilated, labs have option to have a/c added if required.	Spatial zones	y
25	Energy centre has space within it for future technology e.g. a fuel cell		Oversize space	y
25	Energy supply located in a central energy centre	Easier to scale up the capacity more efficiently and quickly in order to adapt to potential climate change or reduced availability of fossil fuels	Component accessibility	y
25	IT and hub rooms cooling sized for 25% future expansion		Overdesign capacity	y
25	Organisation arrangement (learning clusters of a number of classrooms, studio/lab space around a core area)	Selected because it is flexible and can accommodate a faculty based arrangement	Spatial variety Standard room sizes Typology pattern	y
25	Main hall is elevated above the open plan ground level (heart)	Ensure the space below is generous and fully accessible; a variety of functions will take place in the Heart some formal and regular, others more informal	Open space Multi-functional spaces	y
25	Each cluster to have a number of classrooms varying in size		Spatial variety	y
25	Class partitions removable	joining classrooms into one large space or to allow the classes to spill out into the circulation space	Joinable / Divisible space	y
25	Generous circulation spaces	Allow the classes to spill / break out	Oversize space Support space	y
25	Light-practical studios	allow some of the space from the specialist areas to be located in each cluster, providing diverse learning areas to assist daily lessons	Support space Spatial variety	y
25	Studios will vary in character	To allow for varying functions (at ground level there will be the possibility of black-out and 'lecture' projection, while at first floor level the studio will be	Spatial variety	y
25	Outdoor dining break out space: size and setting	make it ideal for accommodating outdoor events, gatherings and exhibitions	Multi-functional spaces Spatial ambiguity	y
25	Spaces outside Resistant Materials lab designed with low seating walls and benches	Act as breakout space, accommodate classes	Support space	y
25	Fully accessible floor void	A flexible future proof solution to changes in future or floor plan layout; enables change of use, expansion and adaptation of spaces as the user	Component accessibility	y
25	Building and systems based around a mixed mode approach	Will initially maximise the passive operation but can in time the systems are adaptable to deal with higher temperature or gains	Multiple ventilation strategies	y
25	Floor plan grids (column arrangements)	Arranged to allow a range of space configurations	Standard grid	y
25	Generous floor to ceiling height	Allow retrofit of additional servicing	Oversize space	y
25	Moveable outdoor furniture elements		Moveable stuff	y
25	Small performance hub terminating the northern end of the building will be a multi use space		Multi-functional spaces	y
25	Access will be down a series of stepped terraces / ramps	will function as a large Seating Terrace for the covered performance space at the base	Multi-functional components	y
25	Lighting to all weather basket ball court	Allow access by community and out of (school) hours	Mixed demographics Extra components	y
31	Every pane of glass in the building can be cleaned on both sides and replaced with fully range if fully integrated and safe methods of		Component accessibility Reversible	y
31	Designed to have the ability to plug-in to, or provide, future innovative energy solutions such as district heating systems etc		Configurable stuff Space to grow into Standardized interfaces	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
31	Cafe within the atrium can be reconfigured as a 400 conference facility		Multi-functional spaces	y
31	Plan form (3 sided continuous floor plate with 3 independent cores)	enables maximum flexibility of departmental divisions whether physical or implied being possible at any point around the perimeter with all	Joinable / divisible space	y
31	Building cores located in the corners	To enable the space to be subdivided on a floor by floor or part floor basis; 28,000 sq. ft. floor plates can be easily subdivided into 5,000 sq. ft. units with	Joinable / Divisible space Multiple access points	y
31	Planning grid of 1500mm is employed throughout (1.5 x 3m)	enabling coordination of structural components and servicing and allowing for maximum flexibility for partitioning of internal areas	Modular coordination Standard component locations	y
31	Use of mechanical ventilation strategy via an underfloor plenum	flexibly in office spaces	Open space Joinable / Divisible space	y
31	Speculative approach to the base build	Allow scope for changing future demands / occupants	Phased	y
31	State of the art Smart Grid	To enable the management change (to hot desking) to be readily implemented	Service zones	y
31	Open plan floors / minimise individual offices		Open space	y
31	Column free floor plates	Maximise subdivision options on a 3 x 1.5m grid	Open space Joinable / Divisible space	y
31	Services designed to be isolated and controlled separately		Service zones	y
31	Expansion space built in at roof level behind the double skin facade		Space to grow into	y
31	Double height ground floor allows later insertion of mezzanine floor space		Oversize space Space to grow into	y
31	Variety of work settings and furniture options are offered	Provide greater diversity of how, and where, to work	Spatial variety	y
31	hybrid steel and pre cast concrete superstructure	Provided a slender floor build up that maximises floor to ceiling height whilst spans uninterrupted across the 16.5m floor plate	Functional separation Open space	y
31	Personal lockers for everyone	Allow hot desking	Shared ownership	y
31	Building is highly glazed and transparent allowing the activities of the clients business to be open and visible to one another	Removes the current silo nature of the business and promotes a shared and flexible workspace	Visual linkage	y
35	Plan depths and widths	Support future adaptation of building use	Joinable / divisible space Shallow plan depth	y
35	High ceilings	To accommodate services; allows future installation of ceiling fans	Oversize space	y
35	A simple layout of hard and soft spaces	Allows for change of usage as required and provides the opportunity for gatherings of various sizes	Spatial variety	y
35	Some areas have raised access floors		Component accessibility	y
38.1	Use of appropriate materials	The proposed design seeks to be exemplar in quality and to maintain it for the duration of the building's lifespan	Durability Spatial quality Building image	y
38.1	Mixed use development	Ensure a lively and animated area - office and retail uses day, hotel and residential night.	Use differentiation	y
38.1	Moveable coffee bar		Moveable stuff	y
38.1	Layout of the square and staircase	will lend itself to use by artistic performances and offer potential use by a local produce farmers market / Christmas market	Multi-functional spaces A communal place	y
38.1	Illuminated shade sail	extend the usability of the courtyard play space during both wet periods and into the evenings	Extra components	y
38.1	More informal play features (such as mounding, a play tunnel and boulders)	Provide a range of play experiences that may also appeal to older children, promoting a degree of multi-functionality within the residential context and	Multi-functional components	y
38.1	Provision of space for a home office	Lifetime homes standards	Multi-functional spaces	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
38.1	Units below the residential benefit from planning permission that will permit uses within A1, A2, A3 or B1, with the flexibility to move		Planning classification	y
38.1	Area for PV panels based on 9m2/kWh	Not based on most efficient panel to ensure developer would have a wide range of options when procuring the panels (planning requires a set	Overdesign capacity	y
38.1	apartments at SuperB have a neutral but bold palette	the canvas is kept bank so you can create your own interior to suit your lifestyle.	User customisation	y
38.1	The residential building blocks are all proposed to be of a uniform light coloured pre-aged brick.	This will give a consistency and solidity to the forms. These are meant to be comfortable generic buildings, which could even be renovated to different uses over	Time interwoven	y
38.2	Ground floor ceiling heights raised	Allow higher windows (active frontage)	Oversize space Visual linkage	y
38.2	Building width 5 -7 m or multiples thereof (planning checklist)	Optimum adaptability of commercial units to future use changes	Joinable / divisible space	y
38.2	Floor to floor heights of commercial units to allow for vertical segregation of mixed uses and provide adaptability for change of use		Spatial ambiguity	y
38.2	Building depth 9 - 13m (planning checklist)	Optimum adaptability of commercial units to future use changes	Shallow plan depth	y
38.2	Innovation style flexible office space		Open space	y
38.2	Sufficient back of house and plant space	Allow to operate as an upmarket hotel (as opposed to original budget chain)	Support space	y
46	Sliding / folding partitions	Allow spaces to work independently or as one large space (e.g. main and small hall, classrooms, classroom and breakout space); offer the flexibility to	Joinable / divisible space	y
46	Open plan studio space, open plan library / IT space		Open space	y
46	Classroom clusters and other learning spaces supported by breakout spaces with glazing for observation	For smaller group learning activities	Visual linkage Spatial variety Support space	y
46	Retractable seating to main hall		Configurable stuff	y
46	Mobile storage units	Storage of class specific resources in a flexible teaching approach	Moveable stuff	y
46	Catering facilities, lift and toilets located so as to allow community use of building facilities	allow independent use of facilities to support an extended curriculum	Isolatable Spatial zones	y
46	Inclusion of learning support spaces (hall, kitchen, food lab, internet cafe, sports pitch) that are attractive to community use		Mixed demographics	y
46	Class bases generously proportioned	Allow loose furniture and storage to be arranged in new layouts.	Oversize space	y
46	Good mix of room sizes		Spatial variety	y
46	Classrooms will not contain a teacher's desk, a teacher's workspace and a locate for each class teacher will be located in the breakout areas	To support the flexible teaching approach (no one 'owns' a classroom?)	Shared ownership	y
46	Area identified and all necessary service connections installed for later construction of a pool	All school to expand as funds allow	Space to grow into Extra components	y
46	Underfloor heating	Frees up wall space from radiators	Open space	y
46	Undercroft parking area has sufficient height to accommodate high top mobility vehicles		Oversize space	y
46	Height adjustable tables	DDA	Configurable stuff	y
46	Full (insitu transfer) structural slab, capable of taking the loading of future classrooms constructed [but only a lightweight steel frame]	Playdeck now, allows the planned addition of extra classrooms at second floor	Space to grow into	y
46	Services / drainage runs for the future extension will also be 'designed in' to Phase 1 - sacrifical holes	Facilitate a quick and easy extension	Phased	y
46	WIFI coverage to external areas by mounting outlets on the underside of covered play area	Make us of external IT devices possible	Spatial proximity	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
46	Stack seating system to sports hall	Allow for a variety of uses including sports, theatre, larger meetings, and assemblies for the whole school.	Moveable stuff	y
46	Raised transfer slabs means rainwater pipes are easily accessible beneath it	Flood defence (i.e. unintended benefit)	Component accessibility	y
46	Independent access bridge serving the nursery	Allowing it to operate independently from the main school if necessary	Multiple access points Isolatable	y
46	"Tents"	Used for shading (in place of fixed external shades) to provide different external teaching environments	Moveable stuff	y
46	Open weave dark coloured internal roller blind	Allow occupants maximum adaptability and control to suit external lighting conditions	Configurable stuff	y
47	Position of existing school on the site allows new school to be constructed next to it		Space to grow into	y
47	All weather pitch type 4 with recessed goal cages and pitch markings for multiple sports use		Multi-functional spaces	y
47	Outdoor dining space	Adaptable and can be used for teaching as well as for cooking and eating.	Multi-functional spaces	y
47	All toilets to be unisex		Shared ownership	y
47	Locating the main hall next to one of the smaller halls	To create a larger space when required	Joinable / divisible space	y
47	Classroom cluster arrangement with shared flexible teaching space		Shared ownership Spatial zones	y
47	Multi functional group rooms		Multi-functional spaces	y
47	Shared spaces linked by folding sliding screens	Spaces big enough to hold a key stage assembly can be created	Joinable / divisible space	y
47	Open plan zones with potential for partitions or screens to be retrofitted	If central spaces are required to be used by multiple teachers independently in future	Open space Joinable / divisible space	y
47	Framed structure	Allowing the internal walls to be easily reconfigured in future years	Functional separation	y
47	Storage a combination of lockable cupboard, shelving and mobile storage including pupil tray units		Shared ownership Moveable stuff	y
47	Mobile teaching stations for each classroom rather than a teacher desk		Moveable stuff	y
47	Main hall has a partition to divide the space for dual use when required		Joinable / divisible space	y
47	Library and all three halls located near to the main public entrance (controlled space) and isolated from the classrooms	Facilitate use by the community out of hours	Isolatable Spatial zones	y
47	Specialist areas added to the circulation zones	More area given over to teaching than traditional BB99 approach, more opportunity for different types of learning	Spatial ambiguity Support space	y
48		Design structures to accommodate retrofits	Durability	y
48	5.5m floor to ceiling height in concourse area (max 8.5m)	Natural daylight, generously proportioned spaces, clearer spatial links to platforms	Oversize space	y
48	Centralised plant for retail areas	Compatible with future connection to an external heat network should one become available in future	Spatial proximity Component accessibility	y
48	Number of escalators, lifts and stairs within the station increased in line with anticipated passenger growth		Extra components	y
48	Concourse is sized to allow a 66% increase in capacity		Oversize space	y
48	Column width adequate to house platform equipment such as fire extinguishers and train dispatch plungers in a coordinated and coherent	Minimise the accretion of visual clutter over time	Multi-functional components Spatial quality	y
48	Considerably greater number of cycle parking spaces than required by TfL guidelines (after allowing for passenger growth)	Station can accommodate an increase in the % of passengers choosing to cycle as well as a general increase in passengers	Overdesign capacity	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
48	Removable soffit panels (to canopy roof)	Allows access to CCTV and other roof level services	Component Accessibility	y
48	Service void / zone along the side of the track with space to accommodate additional cabling		Oversize space Component accessibility	y
48	Cycle space provision designed to be provided incrementally with demand		Space to grow into	y
48	Supported by a lively mix of uses (within the station and under its arches)		Use differentiation	y
48	Build on the unique townscape opportunities of density and height that the development pattern in the conservation affords	Success of modern design in conservation areas	Contextual Good location	y
1	Internal climate being wholly maintained by mechanical HVAC systems, sized to accommodate significant temperature changes	Building's HVAC strategy (too noisy / pollution and building's internal gains too high)	Overdesign capacity	Already
1	Relaxation areas not only inside the building but also linking into the public space outside. Here a tall, colonnaded walkway running down the		Spatial ambiguity	Already
1			Durability	Already
1	Roof terrace	provide useful amenity space for employees	Support space	Already
1	Water usage sill be monitored throughout the building using several strategically located water meters . These will be linked to the Building	Meet BREEAM requirements for water efficiency	Information provision	Already
4	Smoke clearance system incorperating window actuators as AOV's will be linked to temperature and rain sensors	To assist in providing natural ventilation for comfort purposes to communal and circulation areas	Configurable stuff Multi-functional components	Implemen
4	Identifying plantroom space for future water treatment plant; plantroom size should however cater for this additional plant	Retrofit RWH; space for GSHPs and a back up boiler	Oversize space	Implemen
4	Allowing service distribution space for a future installation of dual water (potable and non potable) supply system	Allow RWH retrofitting	Oversize space	Implemen
4	Fixing positions for future external structures should be provided from the outset	to futureproof against potentially damaging retrofit of external elements such as shading devices; make it easier and safer to install	Extra components	Implemen
4	Levels for all the proposed housing are set a minimum of 150mm above surrounding finished ground level	To protect against potential overland flows and surcharging of the existing drainage system in the event of heavy and prolonged storms	Overdesign capacity	Already
4	Passive first - ensuring the fabric performs well without technological assistance	ensuring the fabric performs well without technological assistance	Mature component	Already
4	Operating temperatures on the heating system must be around 45C	Retrofit ground source heat pumps to serve the existing underfloor heating	Standardised components	Already
4	Corridor doors will have magnetic hold open devices (linked to fire alarm)	to provide better cross ventilation on each floor level	Extra components Passive climate control	Already
4	Piled foundation	would allow better access beneath the ground floor slab for any future services (.e.g GSHPs); founds the building beneath the effect of any soil volume	Component accessibility Open space x	Implemen
4	oppourtunites for multi- use shared spaces e.g. low usage access roads shared with footpaths, vehicular turning heads used also for communal	creation of external spaces that can enhance health and facilitate increase active and passive use by residents in summer	Multi-functional spaces	Implemen
4	introduction of some non-native but resilient plants	the extent and range of some native species will enevitably change	Durability	Implemen
4	Dual water supply system	required for the use of water for non potable uses; would allow some non potable uses without treatment and would reduce the treatment load	Extra components Functional separation	Implemen
4	Using a sectional tank	to allow for future split of potable and non-potable water distribution [for RWH]	Functional separation Extra components	Implemen
4	Increasing the calculated rainfall intensities by 20-30% depending on the life of the development	current practice is to make some provision in the drainage design	Overdesign capacity	Already
6.1	North-Eastern aspect	gives good daylighting whilst avoiding overheating from the south; control of solar gain removes the need for energy using mechanical ventilation	Building orientation	Already
6.1	Large roof overhangs	give shade to south facing nursery and reception classrooms and provide outside teaching space	Support space	Already
6.1	decision to arrange most of the classrooms on the north elevation	to minimise summertime overheating	Spatial zones	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
6.2	water will overflow into the upper playing field; schemes have been designed to flood playing fields or drain to supplementary storage basins	Overflow storage as rainfall intensity and duration increase	Multi-functional spaces Space to grow into	Already
6.2	The storage requirement for the 1 in 100 year return period with a 30% allowance for climate change is 77mm for every m2 of developed	Climate change has been allowed for in the Modified Rational Method by addition of 30% to the 1 in 100 year rainfall depth and in the Institute of Hydrology	Overdesign capacity	Already
7		Night ventilation systems rely on fitted actuators	Configurable stuff	Already
7	The project is located next to a large open space	protection from localised floods	Good location	Already
7	clear specification for sealant between boards and external insulation, face fix and glued system [changed from 'carrier system']	longevity of an air tight envelope	Durability	Implemen
7	design incorporates a courtyard plan	providing self shaded areas externally	Support space	Already
7	Category 2 rainfall; 150mm pipes were specicifed as an uplifted enhancement	allows for a 30% increase in rainfall as per climate change scenarios; increasing the rainwater design capacity to deal with future scenarios	Overdesign capacity	Implemen
7	Recommend dowmnstand to allow for future retrofit cooling if required	for future retrofit cooling if required	Open space	Implemen
7	F2F heights was an issue at planning stage in terms of resulting building heights.	Depth reduced slightly though still generous at 3250 to u/s slab to assit with thermal strategy.	Multiple ventilation strategies Oversize space	Already
7	top opener to 400mm was adopted, whilst 250mm was ensured to the lower windows	increases the potential for external air to replace internal air at times when the external dry-bulb temperature is lower than the internal air	Multiple ventilation strategies Configurable stuff	Implemen
7	full height internal roller blind		Configurable stuff	Already
7	Design roofscape has PV panels throughout	roof surface 100% shaded this helps reduce exposure and thus improves the performance of insulation is keeping cold out and reducing overheating in hot	Extra components Multi-functional components	Already
7	The soakaways have also been sized on 1 in 100 year storm plus 20% climate change	EA rules	Overdesign capacity	Already
7	Principle of careful location of IT and managing these areas individually	Naturally ventilate the majority of the building	Service zones	Already
9	Surrounded by a large amount of mostly green space	Enhance external microclimate	Good location	Already
9	Fingers' built form with green space between	To allow green landscaped space to appear between units…helping to improve air flow and reduce heat build up in paved and built structures	Support space	Already
9	BMS controls can adjust the start time [of cooling]	Starting cooling earlier would aloow early morning solar heat to be alleviated before occupants turn up for work	Configurable stuff	Already
9	Drought tolerant planting	Site in an area of drought (SE)	Durability	Already
9	Basic design choices e.g. selection of resilient materials		Durability	Already
9	Internal blinds	mostly to avoid glare and meet a planning requirement to limit the impact of internal lighting on the landscape during twilight hours	Configurable stuff	Already
9	A flood level of 31.1m AOD within the site has been agreed with the Environment Agency. No built development or land-raising will take place	No impact of the function of the existing flood plain	Good location	Already
9	Fortunate location (which meant low flood risk)		Good location	Already
9	large, overhanging roofs (portal frame on east and west facades)	Provide shelter to pedestrian circulation, as well as shading the elevations from solar gain	Multi-functional components	Already
9	Tiered curving ramps link the Plaza Level with the Lower Level and create an outdoor amphitheatre	for use as an outdoor meeting environment. The arrangement, scale and size of the Technical Hub building arrangement on the site will allow the sun to	Support space	Already
9	good spatial planning as the majority of the east side of the building consists of circulation spaces and plant rooms	prioritise locating productive areas in the best locations in the building taking into considerations such as access to daylight, view to outside and	Spatial zones	Already
10	The internal courtyards are a vital part of the building design	Good natural daylight and ventilation; to provide relief from overheating to the patients and staff. Extensive planting will provide shade and	Multiple ventilation strategies Good daylighting Spatial variety	Already
10	finished floor levels will be set at least 150mm above external ground levels	to ensure reduced risk of damage as a result of overland flows	Overdesign capacity	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
10	high parapet roof upstands	to safely accommodate additional renewable energy systems out of sight; Renewable strategies should be sought to deal with the additional energy load of the	Overdesign capacity	Implemen
10	individual controls of heating, ventilation and water fo each bedroom	will be useful in heatwave conditions later in the life of the building; benefit to patients of feeling a breeze and being able to directly affect their environment	Service zones	Already
10	Manually openable windows to the bedrooms	provide the patient with supplementary ventilation and give them an element of control over their environmental conditions; conditional windows	Configurable stuff	Already
10	The chosen Envirowall render wall system	is anti-crack and high impact resistant...very high resistance to environment pollutants and is weatherproof, rot resistant, non swelling, low stress	Durability	Already
10	flat roofs with additional loading capacity for sedum planting or additional renewable energy systems	remains with the intention that it may be added at a later date; a green roof allows 40%-60% attenuation of the thermal gain entering the space beneath	Overdesign capacity Space to grow into	Already
10	flat roofs with additional loading capacity for sedum planting or additional renewable energy systems	Renewable strategies should be sought to deal with the additional energy load of the cooling requirement	Overdesign capacity Space to grow into	Already
10	under-floor heating that can be used for summer cooling		Multi-functional components	Already
10	The attenuation volume required in order to restrict the proposed development to 98 l/s at Mill Lane for the critical 1 in 100 year storm	esign requirement is that flooding may occur during events in excess of the 1 in 30 year storm, as long as the water is retained on the site without affecting	Overdesign capacity	Already
10	Use of water meters throughout the development;	in line with BREEAM requirements, water management	Information provision	Already
10	Every courtyard has a mains water tap provided for irrigation purposes	infrastructure would allow some future features to be added to assist with cooling or transpiration	Component accessibility	Already
11	Maximise the amount of accessible outdoor space: balconies, roof garden, and courtyard		Support space	Implemen
11	A centralised hot water system linked into plate heat exchanger technology system	reduce standing losses from hot water pipework in the flats and standing losses associated with hot water cylinders	Service zones	Already
11	Enclosed secure courtyard design	provides secure means for occupants to open windows and ventilate during the day and at night	Isolatable Multiple ventilation strategies	Implemen
11	Use of smart meters	to make tenants aware of their energy use and internal heat gains	Extra components	Already
11	No finished levels will be less than...he 1 in 100 year flood level (including 20% for cliamte change) + a 600mm freeboard allowance	Flood risk mitigation strategy	Overdesign capacity	Already
11	wind loads would be increased by 10% from that required by the codes	in the absence of future wind speed data	Overdesign capacity	Implemen
11	Actuated window system	intelligent ventilation control [shut when hotter outside]; to shut down in the event of a fire for some flats	Configurable stuff	Implemen
11	No residential development is proposed within the high risj area [flood zone 3]	Flood risk mitigation strategy	Good location	Already
11	assumption that all windows are openable	allow for cross ventilation.	Configurable stuff	Implemen
11	increase this capacity by approximately 50% ... by utilising 250x200 box section gutter in conjunction with 15 x 100mm downpipes	to discharge peak flow rates from the roof under a climate change scenario	Overdesign capacity	Implemen
11	provide species that can cope with challenging conditions		Durability	Implemen
11	Design the structure (foundations, columns, roof structure) to accommodate the extra load of water storage tanks located on the adjacent	Allow retrofitting of RWH if not installed now	Overdesign capacity	Implemen
11	Flats were orientated so that some of the bedrooms were located on relatively cooler northern facades and living rooms on southern		Spatial zones	Implemen
11	1 in 100 year event plus 30% for climate change	sufficient storage for the most severe design event. (i.e. 1 in 100year event plus 30% climate change	Overdesign capacity	Already
16	Internal blinds	may also be required as part of the environmental strategy	Configurable stuff	Already
16	A sumptuous decked roof terrace		Support space	Already
16	DEFRA recommends a 20% increase in rain intensity be assumed for worst case storm events	[planning] officers would expect the site wide strategy referred to, to take into account the anticipated effects of climate change	Overdesign capacity	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
16	Tenant sub metering	reduce demand for mains water consumption. Water efficiency leads to reduced impacts assocaited with its supply and disposal, including energy	Extra components	Already
17	Control will be automatic based on measured internal temperatures but with the capability for occupants to override	HVAC mixed mode strategy	Configurable stuff	Already
17	pipework and power provided for future external drinking points	to allow drinking points to be easily installed when required	Extra components	Implemer
17	Deeper [door] frames in the basement	to allow for future fitting of door dams	Overdesign capacity	Implemer
17	The inclusion of empty PVC ducts between the pub and the basement plantroom	for future plant connection [of thermal store etc.] to pub basement	Extra components Component accessibility	Implemer
17	Chillers / cooling coils "slightly oversized"	due to the use of standardized manufacturers components which when examined provide sufficient capacity until at least 2040	Overdesign capacity	Already
17	Maximise the amount of storage available in addition to this [for basic attenuation and RWH]	for attenuation of [storm] flows	Overdesign capacity	Already
17	proposed to enhance cooling through an incremental increase of mechanical system control	Building HVAC strategy; there will be periods of the year when this [NV] will not be sufficient to overcome excessive heat loads	Multiple ventilation strategies Configurable stuff	Already
17	the high and low level windows will open to enable cross flow air movement	HVAC strategy (NV); for continued use of the building in the event of a power faliure	Configurable stuff	Already
17	Increase the diameter of the rainwater downpipes	overcome possible damage caused by rainwater downpipes insufficient to cope with the increase in stormwater	Overdesign capacity	Implemer
17	increase the strenght of the roof design under this potential mezzanine; increase the pile depth to allow for future plant to be	allow space for an additional single chiller based on the size of the currently specified units which worked out to be at least 15m2	Overdesign capacity	Implemer
17	installing 'knock-out' panels next to each riser	Could easily be removed to allow the exisiting risers to be exteneded without damaging or effecting the structure	Not precious Space to grow into	Implemer
17	current stormwater design allows for an increase in storm conditions due to climate change		Overdesign capacity	Already
17	the window surrounds are to allow for future fitting of insect mesh		Component accessibility	Implemer
19	Greenwich Park is next to the site	the main reason for extending the use of the roof to building users would be if the Park were ever developed	Contextual	Already
19	include adaptable door frames for door dams, addition of a slot within the door frame to accommodate a door-dam	should drainage fail to prevent water energy the workshops etc.	Extra components	Implemer
19	The external materials are predominantly stone and glass	which are extremely robust to high temperatures	Durability	Already
19	chillers in this situation have been sized three chillers at 40% - each at 532kW each. However, chillers come in standard sizes and the selection	additional capacity in the chillers	Overdesign capacity	Already
19	Extensive planting - designed to be self sustaining and requiring minimum maintenance	will delay the discharge of surface water and reduce the load on local surface water drains during peak flow storm periods; ill also help to minimize the	Durability	Already
19	Intensive planting - roof gardens	environmental wind and ameliorate downdrafts; help reduce the local heat island effect	Support space	Already
19	implementation of a user controlled shading system	Glare will be minimised	Configurable stuff	Already
19	building is on an elevated ground level to a street that slopes away from the main entrance	therefore there is not deemed to be any risk to the occupants over escaping during a flood situation	Good location	Already
19	mechanical ventilation supplying tempered air will also be provided, with cooling provided by efficient chillers	Where natural ventialtion is not sufficient	Multiple ventilation strategies	Already
19	openable windows	will provide supplementary outside air to the space to assist in preventing overheating	Configurable stuff	Already
19	the roof designed has been upgraded (structure and thought about space and demountable screening for reuse when it's moved, see AP	to allow for the installation of future plant	Overdesign capacity Reversible	Implemer
19	includes an allowance for 30% increase in the rainfall intensity	in order to take into account the effects of climate change in line with Planning Policy Statement 25.	Overdesign capacity	Already
19	metering for each building, and sub-metering for large water consuming plant and/or areas,	Water use will also be reduced	Information provision	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
20	Install ceiling fans		Extra components	Implemen
20	Low irrigation plants are specified		Durability	Already
20	Incorperate higher ceiling levels raised to 2.7m minimum	To allow for ceiling fans	Oversize space	Already
20	Plan depth between 10 metres, and in a few places only increasing to 16 - 18 m	light and ventilate naturally	Shallow plan depth	Already
20	Drainage includes a consideration of climate effects	Drainage has been resigned to current standards	Overdesign capacity	Already
21	Central courtyard provides a naturally shaded external space	Reduce radiant heat gain and the liklihood of heat stress to the individual	Support space	Already
21	design a green roof which can accommodate the collection of water	Roof loading for predicted increase in rainwater Reduce the amount of run off generated by the building	Extra components Overdesign capacity	Already
21	Privacy blind and black out fabric; thermally efficient internal blind	can siginificantly reduce resultant temperatures	Configurable stuff	Already
21	will utilise mixed mode ventilation in non-critical areas	to provide free comfort to complement to installed a/c system	Multiple ventilation strategies Configurable stuff	Already
21	Implementation of separate foul / surface water systems	Reduce the probability of polluted flood water flooding the lower areas of the hospital	Functional separation	Already
21	The underfloor heating in the restaurant, lift lobbies and floor landings can also be used in reverse	To provide cooling	Multi-functional components	Already
21	Select materials based on good UV resistance properties	Improved durability and appearance	Durability	Already
21	Sub-metering systems in place	monitoring of water consumption	Information provision	Already
23	Design shading layer within the ETFE roof for good UV blockage	to protect furnishings below	Multi-functional components	Implemen
23	Water metering; Leak detection system	targetting a minimum BREEAM very good rating	Extra components	Already
24	The building and site have been designed to incorporate an improvement over the pre-development condition of 30%	drains have been sized to cope with increased rainfall event	Overdesign capacity	Already
25	First and second floor automated windows	are used for night purging	Configurable stuff	Already
25	Energy centre located centrally to the masterplan	easier to scale up capacity more efficiently and quickly in order to adapt to potential climate changes	Component accessibility	Already
25	Drought tolerance plants	to minimise the need for irrigation	Durability	Already
25	We have worked with Ibstock to select two bricks that are classified as F2 to meet the aesthetic intentions	Protect against permeability, frost damage, water ingress	Durability Overdesign capacity	Implemen
25	profiled bricks	allowing us to add relief to the façade whilst using a durable facing brick	Durability	Implemen
25	Internal blinds	Keeping cool for internal spaces	Configurable stuff	Already
25	building systems based around a mixed mode approach	will initally maximise the passive operation but can in time the systems are adaptable to deal with higher temperatures	Multiple ventilation strategies Configurable stuff	Already
25	Opening windows	psychological effect of having control over your environment is a significant factor in occupant satisfaction	Configurable stuff	Already
25	designed to have separate foul and surface water drainage piped networks	ideal solution to avoid surcharging combined sewers and sewerage treatment works during storm events	Functional separation	Already
25	considered a “climate change” flows increase of +20% as part of the design process	drainage network has been designed and sized so that no out-of-pipe flooding should occur in storm return periods of ... 1:100 years all with an increased	Overdesign capacity	Already
31	A walkway exists between the inner façade and exterior façade panels	for maintenance and solar shading	Multi-functional components	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
31	Sized to accommodate the 1 in 100 year return period…with an 30% allowance for climate change		Overdesign capacity	Already
31	Metering and leak detection;	Managemnt of water resource on site [required to minimise building SW run off by planning]	Information provision	Already
35	Rainfall in excess of the 1 in 100 year event could be stored in a more informal manner above ground by selectively flooding areas		Space to grow into Multi-functional spaces	Already
35	is at the top of a hill, over 10m above any exisitng level of flood risk	Development has sought to use the areas of the site at the lowest probability of flooding	Good location	Already
35	not formal gutters as such; rather they form the lowest part of the roof and the area to which rainwater gather	envisaged to be adapted to the climate change projections [peak rainfall increases]	Multi-functional components Simple construction method	Already
35	Increasing the size of the rainwater harvesting tanks	rainwater tank sized such that the same proportion of rainwater would be met [recycled] under future climates	Overdesign capacity	Implemer
35	blockwall with stone rainscreen, or steel framing system with a rainscreen render; the constructions separate the thermal and	There is a cavity behind the rainscreen reducing the risk of driving rain damage	Functional separation	Already
35	Revising the landscaping to include wildflower planting areas more suitbale to the climate of the day; alternative tree species	Species chosen for their resilience rather than cooling effect of transpiration	Durability	Implemer
35	The onsite drainage will consist of separate systems for foul and surface water	will avoid overloading the foul sewers or treatment facilites with surface water	Functional separation	Already
35	design will be checked against a 1 in 100 year storm event +30% for climate change	SUDs design in line with good practice	Overdesign capacity	Already
38.1	drainage design for a 1 in 100 year storm 'plus 30% for climate change' approach		Overdesign capacity	Already
38.1	All roof gardens will have a water point	[watering the plants; but by implication fo the other projects could also be used to provide water features]	Component accessibility	Already
38.1	Many properties have private gardens and roof terraces	provide amenity use for residents	Support space	Already
38.1	The hardwood chosen for the balustrades will be iroko or similar	so that it won't rot in the wetter climate.	Durability	Already
46	Passivent ventilation louvres (linked to the BMS); automatic opening windows; small high level window openings in the north facing	allow for secure night time ventilation	Configurable stuff Multiple ventilation strategies	Already
46	marine grade finsih to galvanised and powder coated elements, durable UV stable cladding materials	owing to the location of the site in an exposed coastal environment	Durability	Already
46	Raising all habitable spaces by one storey, above the flood level (incl. climate change allowance); by providing car parking under the building;	to mitigate the flood risk and the impact of climate change	Overdesign capacity Spatial zones	Already
46	30 % increase for global warming	limiting the surface water run off	Overdesign capacity	Already
46	Finsihes to GF rooms have been specified as easily replaceable (painted plasterboard, rubber sheet flooring)		Not precious	Already
47	the exposure category for the design to be increased by one level, from Level 1 sheltered to level 2 moderate e.g. maintaining the cavity	Design facades to increased rainfall quanities	Overdesign capacity	Already
47	building…is being raised above the level of the surrounding area	mitigates that surface water would tend to run towards the building in an exceedance event	Overdesign capacity	Already
47	System will be designed to current British standard…include a climate change allowance of 20%	Roof will be … able to deal with the climate change related 17% increase of peak rainfall	Overdesign capacity	Already
47	the U shaped layout creates a series of useable outdoor spaces directly accessible from the classrooms		Support space	Already
47	provide sufficient structural capacity in current design to allow green roof retrofit		Overdesign capacity	Already
47	difference between the ground level of the soakaway and the FFL of the school	means that there is no risk of the soakaway backing up if the drainage fails	Overdesign capacity	Already
47	Soakaways have been designed to accommodate the 1 in 100 year storm plus 30% for the climate change storm event	Designing surface water drainage to accommodate future increases [in rainfall intensity]	Overdesign capacity	Already
47	overall metering and submetering of specific areas within the school		Information provision	Already

Case	Tactic	Why	Resolved Characteristic(s)	Installed
47	upper level state structure have been secured	in regards to high wind occurrences	Overdesign capacity Durability	Implemer
48	colonnade will provide a useful extension to the narrow pavement width along Tooley St	providing some shelter	Spatial ambiguity Spatial variety	Already
48	Highest form of lightning protection	station has been classed as lightning risk category 1 which is the highest risk category	Overdesign capacity	Already
48	additoonal allowance for temperature increase, being sized to a peak of 35C	climate resilience in the cooling capacity	Overdesign capacity	Already
48	extensive free area opening to the outdoors	Concourse is completely naturally ventilated	Passive climate control	Already
48	leak detection equipment	to prevent water wastage through leaks in the system	Information provision	Already
48	passengers will wait below the platforms until there train is announced	passengers are not expected to spend extended periods of time on the platforms [i.e. away from "the elements"]	Spatial zones	Already
48	system within the station will be a separate foul / surface water system	help prevent any flooding of the internal foul water system as a result of intense rainfall	Functional separation	Already
48	proposed drainage network designed to discharge at a discounted rate for a 1 in 100 year return period rainfall event including a 30%		Overdesign capacity	Already
48	material selection is primarily uncoated kalzip canopy panels, glazing and brick facades	Are very resistant to UV radiation	Durability	Already
48	Installation of water meters for washrooms areas, for each retail area and other key uses	water efficiency measures which are currently being proposed as part of the design	Information provision	Already
24	Load bearing brick	Cladding choice as result of planning process	Durability	Implemer
48	Maintain design to exposure category 2 (one higher than required)	inkeeping with the strategy for at least one catergory higher [than the facade exposure cat required by the brief]	Overdesign capacity	Already
47	The EPDM roof membrane is found to be of very good UV resistance	will be durable even under increased UV radiation.	Durability	Already
47	External area adjoining each classroom to incorperate a canopy	providing shelter during inclement weather, "enabling year round activity" (D&A)	Extra components Spatial ambiguity Spatial variety	Already
35	Setting external threshold and internal floor levels with a minimum 600mm freeboard above the 1 in 100 year flood risk level, including 20%	Flood mitigation	Overdesign capacity	Already
19	Open spaces…it's not designed with lots of walls in it		Open space	y
19	develop the furniture so there is a mixture of spaces..Thre needs to be thinking spaces, writing spaces, quiet spaces		Spatial variety	y
19	Structure allows for a glazed link to be introduced at second floor level	if the building should change from being the two separate uses it is now	Connect buildings Overdesign capacity	y
19	This light is effectively applying to the whole building. Services distribution design for multifunction spaces	It creates a singular type of space..you can move whatever you want underneath it. IT's not a bespoke design, so this is not designed for office work, and	Multi-functional spaces	y
19	Water tap allocated to every roof	So roof can be converted from sedum to PV (water tap for cleaning)	Extra components	y
19	Single tap wash basins	If we decided in ten years' time we were only ever going to have cold water for people to wash their hands then we really only need a single hole basin	Configurable stuff	y
19	Plasterboard paritions, not structural	could be taken out if required.	Joinable / divisible space	y
19	Double height crit spaces with structural capacity to insert a floor		Joinable / divisible space Overdesign capacity	y
19	Light on both sides of larger spaces	so it can be halved if needed later on	Joinable / divisible space	y
19	Overprovision of IT tray infrastructure	To allow for retroffiting of additional IT etc. if spaces were to change use	Overdesign capacity	y
19	600mm service space where everything is hung	Prevent adhoc solutions to wiring etc. that ruin design intent	Spatial zones Oversize space	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
19	One degree fall to roofs	Similar to internal slabs. Allows things to be grown on it (water doesn't run away too quickly)	Simple form	y
19	Lecture theatre floor flat not raked	Allows conversion from tiered seating to flat floor or insertion of a mezzanine later if required.	Simple form Multi-functional spaces Moveable stuff	y
1	Two independent risers facing opposite sides of the core	To allow subdivision	Extra components Service zones	y
1	Floor plates are identical on each floor		Standard room sizes	y
1	Atria could be filled in	Additional floor space	Space to grow into	y
46	Transfer slab provides covered play area	Outside everyday as protected from the weather	Support space	y
46	Additional doors	To secure school for out of hours community access	Isolatable	y
46	Community room has an outside door	To secure school for out of hours community access	Multiple access points	y
46	Ensuring that the football field is sized for a junior team	Useable by community / for hire	Overdesign capacity Mixed demographics	y
46	Provision of separate changing rooms beneath the school	Useable by community / for hire	Isolatable Extra components	y
6.1	No earth tubes	Restrict future site development	Space to grow into	y
6.2	No earth tubes	Restrict future site development	Space to grow into	y
16	Pair of lecture theatres that turn into an in the round flat performance space		Multi-functional spaces Joinable / divisible space	y
31	Winter gardens can be filled in	Creation of additional floor space without losing breakout spaces	Space to grow into	y
31	Zoned public (ground floor double height) and no public (upper storeys) spaces	Subdivision	Spatial zones	y
31	Ventialtion designed to work when the atrium is glazed over	Subdivision	Joinable / divisible space Service zones	y
31	Floor plate divides into saleable portions	Subdivision	Joinable / divisible space	y
31	Outdoor terraces have WIFI	Allow working outside	Spatial ambiguity	y
31	The rafts are designed so that when you put up a partitiion there is a prefabricated bulkhead"	Subdivision locally	Joinable / divisible space Standardised components	y
24	Store / Future riser	Extend existing riser size	Phased	y
31	Location of future cleaners store	To allow subdivision of the floor plate	Support space	y
38.2	Use of appropriate materials	The proposed design seeks to be exemplar in quality and to maintain it for the duration of the building's lifespan	Durability Spatial quality Building image	y
38.2	Mixed use development	Ensure a lively and animated area - office and retail uses day, hotel and residential night.	Use differentiation	y
38.2	Moveable coffee bar		Moveable stuff	y
38.2	Layout of the square and staircase	will lend itself to use by artistic performances and offer potential use by a local produce farmers market / Christmas market	Multi-functional spaces A communal place	y
38.2	drainage design for a 1 in 100 year storm 'plus 30% for climate change' approach		Overdesign capacity	Already
1	Each floor is submetered and can be controlled independently.	BREEAM (although would permit subdivision by floor)	Extra components Joinable / divisible space Service zones	y

Case	Tactic	Why	Resolved Characteristic(s)	Installed
1	the lighting is all controlled by floor or by zone. Heating and ventilating is controlled by floor and by zone. The sub-division works on Cat A only	BREEAM, local control	Service zones	y
19	Demountable walls to basement archive	Allow conversion to plantrooms when transition to ele	Joinable / divisible sapce	Already

	CAR1 Reversible	CAR2 Moveable Stuff	CAR3 Component Accessibility	CAR4 Functional Separation	CAR5 Service zones	CAR6 Configurable stuff	CAR7 Multi-functional components	CAR8 Not precious	CAR9 Extra components	CAR10 Durability	CAR11 Mature Component	CAR12 Efficient Services	CAR13 Good Craftsmanship	CAR14 Overdesign capacity	CAR15 Readily available materials	CAR16 Standardised components	CAR17 Standard component locations	CAR18 Off-site construction	CAR19 Simple construction method	CAR20 Open space	CAR21 Support space	CAR22 Oversize space	CAR23 Typology pattern	CAR24 Joinable / divisible space	CAR25 Modular coordination	CAR26 Connect buildings	CAR27 Standard room sizes	CAR28 Spatial variety	CAR29 Spatial ambiguity	CAR30 Spatial zones
1 Admiral HQ		1	1	1	1				1	1		1	1	1		1	1	1		1	1	1		1	1		1	1	1	1
4 British Trimmings		1	1	1					1	1	1	1		1		1			1	1	1	1							1	
6.1 Offmore Primary		1						1				1							1		1									1
6.2 St Catherine's Primary		1										1		1					1					1						
7 Harris Academy		1	1			1		1		1	1	1		1		1				1	1	1	1	1			1	1	1	1
9 Technical Hub @ EBI		1	1			1	1	1		1		1				1	1	1			1	1		1	1	1	1		1	1
10 Edge Lane			1		1	1	1	1		1		1		1		1		1					1		1		1	1	1	
11 ExtraCare 4 Exter		1				1				1		1	1	1							1		1						1	
14 LSHTM		1			1	1			1	1				1							1			1	1					
16 UAL - Kings Cross Campus	1	1	1	1	1	1	1		1	1				1		1				1	1	1		1		1		1	1	
17 OUP	1	1	1			1		1	1			1		1		1	1			1		1		1	1	1			1	1
19 Greenwich	1	1	1			1			1	1		1	1	1		1	1	1	1	1	1	1		1	1	1		1	1	1
20 Church View		1								1				1					1			1		1				1		
21 GOSH 2B						1	1		1	1		1		1		1	1			1	1	1	1	1	1	1	1			1
23 Trowbridge County Hall						1				1		1								1					1	1			1	
24 Sheffield Grad School		1	1	1		1	1		1	1		1		1						1	1	1		1	1	1	1	1	1	1
25 Ebbw Vale 11-16 Phase school		1	1			1	1		1	1		1		1						1	1	1	1	1	1		1	1	1	1
31 Cooperative HQ	1	1	1	1	1	1	1			1		1	1	1		1	1			1	1	1	1	1	1		1	1	1	1
35 ESI			1	1			1			1		1		1				1	1			1		1	1			1		
38.1 SuperB		1	1				1		1	1		1		1		1					1					1				
38.2 Site J Non dom		1								1		1		1						1	1	1		1		1			1	
46 Hinguar Primary		1	1			1	1	1	1	1		1		1					1	1	1	1		1				1	1	1
47 Westbrook Primary		1		1			1		1	1		1		1						1	1			1			1	1	1	1
48 LBSR			1				1		1	1		1	1	1			1	1		1	1	1			1			1	1	1

	CAR31 Spatial proximity	CAR32 Simple plan	CAR33 Standard grid	CAR34 Simple form	CAR35 Multiple ventilation strategies	CAR36 Shallow plan depth	CAR37 Passive climate control	CAR38 Building orientation	CAR39 Good daylighting	CAR40 Space to grow into	CAR41 Phased	CAR42 User customisation	CAR43 Multi-functional spaces	CAR44 Use differentiation	CAR45 Mixed demographics	CAR46 Multiple / mixed tenure	CAR47 Shared ownership	CAR48 Isolatable	CAR49 Multiple access points	CAR50 Physical linkage	CAR51 Visual linkage	CAR52 Attitude and character	CAR53 Spatial quality	CAR54 Building image	CAR55 Quirkiness	CAR56 Time interwoven	CAR57 Good location	CAR58 Contextual	CAR59 Circulation	CAR60 A communal place	TOTAL
1 Admiral HQ	1	1	1	1			1	1	1	1	1			1		1	1				1			1			1	1	1	1	39
4 British Trimmings												1	1		1	1	1	1	1	1	1									1	24
6.1 Offmore Primary		1	1	1		1	1	1	1	1		1			1			1	1												18
6.2 St Catherine's Primary		1	1	1		1	1		1	1		1			1			1	1												16
7 Harris Academy				1	1		1		1			1	1		1		1	1	1	1	1	1								1	32
9 Technical Hub @ EBI		1	1	1		1			1	1			1			1	1		1	1	1		1	1			1	1	1	1	36
10 Edge Lane					1	1		1	1	1			1								1			1	1		1				25
11 ExtraCare 4 Exter	1				1	1	1	1	1			1	1		1	1	1	1	1		1				1		1	1	1	1	28
14 LSHTM		1	1	1			1						1		1								1	1	1	1	1				20
16 UAL - Kings Cross Campus	1	1	1	1			1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	44
17 OUP	1	1			1		1		1	1							1			1	1		1				1				28
19 Greenwich	1			1	1		1			1			1	1	1	1	1		1	1	1		1		1		1	1			39
20 Church View		1			1	1	1	1	1		1	1	1	1		1	1		1				1		1	1	1				24
21 GOSH 2B		1	1	1	1								1							1		1					1				25
23 Trowbridge County Hall	1				1				1					1	1		1	1	1				1	1	1		1				19
24 Sheffield Grad School		1	1	1	1		1		1	1	1		1				1	1		1	1			1			1		1		35
25 Ebbw Vale 11-16 Phase school	1		1		1		1		1			1	1		1			1	1			1									29
31 Cooperative HQ		1	1	1			1		1	1	1	1	1				1		1		1	1	1	1			1				39
35 ESI		1	1	1	1	1	1		1																		1				20
38.1 SuperB				1		1			1			1	1	1	1	1			1				1	1		1	1		1	1	25
38.2 Site J Non dom		1	1	1	1	1			1		1		1	1	1	1					1		1	1			1		1	1	27
46 Hinguar Primary	1			1	1		1		1	1	1	1			1		1	1	1	1	1	1		1							33
47 Westbrook Primary		1	1	1	1	1	1		1	1		1	1		1		1	1	1		1					1					30
48 LBSR	1				1		1		1	1	1			1	1	1	1	1	1	1			1	1	1		1	1		1	35

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AdaptSTAR total	Pearson Correlation	.669**	1	.012
	Sig. (2-tailed)	.000		.955
	N	26	26	26
March et al. (2011) total	Pearson Correlation	.311	.012	1
	Sig. (2-tailed)	.122	.955	
	N	26	26	26
RSiiiExpert	Pearson Correlation	.543**	.583**	.205
	Sig. (2-tailed)	.006	.003	.337
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TacticCounts	Pearson Correlation	.491*	.639**	-.068
	Sig. (2-tailed)	.015	.001	.752
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Correlations

		RSiiiExpert	TacticCounts
Generic Assessment total	Pearson Correlation	.543**	.491*
	Sig. (2-tailed)	.006	.015
	N	24	24
AdaptSTAR total	Pearson Correlation	.583**	.639**
	Sig. (2-tailed)	.003	.001
	N	24	24
March et al. (2011) total	Pearson Correlation	.205	-.068
	Sig. (2-tailed)	.337	.752
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RSiiiExpert	Pearson Correlation	1	.762**
	Sig. (2-tailed)		.000
	N	24	24
TacticCounts	Pearson Correlation	.762**	1
	Sig. (2-tailed)	.000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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		Sig. (2-tailed)	.
		N	26
	AdaptSTAR total	Correlation Coefficient	.591**
		Sig. (2-tailed)	.001
		N	26
	March et al. (2011) total	Correlation Coefficient	.165
		Sig. (2-tailed)	.421
		N	26
	RSiiiExpert	Correlation Coefficient	.462*
		Sig. (2-tailed)	.023
		N	24
	TacticCounts	Correlation Coefficient	.407*
		Sig. (2-tailed)	.048
		N	24

Correlations

			AdaptSTAR total
Spearman's rho	Generic Assessment total	Correlation Coefficient	.591**
		Sig. (2-tailed)	.001
		N	26
	AdaptSTAR total	Correlation Coefficient	1.000
		Sig. (2-tailed)	.
		N	26
	March et al. (2011) total	Correlation Coefficient	-.015
		Sig. (2-tailed)	.940
		N	26
	RSiiiExpert	Correlation Coefficient	.570**
		Sig. (2-tailed)	.004
		N	24
	TacticCounts	Correlation Coefficient	.687**
		Sig. (2-tailed)	.000
		N	24

Correlations

			March et al. (2011) total	RSiiiExpert
Spearman's rho	Generic Assessment total	Correlation Coefficient	.165	.462*
		Sig. (2-tailed)	.421	.023
		N	26	24
	AdaptSTAR total	Correlation Coefficient	-.015	.570**
		Sig. (2-tailed)	.940	.004
		N	26	24
	March et al. (2011) total	Correlation Coefficient	1.000	.189
		Sig. (2-tailed)	.	.377
		N	26	24
	RSiiiExpert	Correlation Coefficient	.189	1.000
		Sig. (2-tailed)	.377	.
		N	24	24
	TacticCounts	Correlation Coefficient	-.067	.731**
		Sig. (2-tailed)	.754	.000
		N	24	24

Correlations

			TacticCounts
Spearman's rho	Generic Assessment total	Correlation Coefficient	.407*
		Sig. (2-tailed)	.048
		N	24
	AdaptSTAR total	Correlation Coefficient	.687**
		Sig. (2-tailed)	.000
		N	24
	March et al. (2011) total	Correlation Coefficient	-.067
		Sig. (2-tailed)	.754
		N	24
	RSiiiExpert	Correlation Coefficient	.731**
		Sig. (2-tailed)	.000
		N	24
	TacticCounts	Correlation Coefficient	1.000
		Sig. (2-tailed)	.
		N	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

```
PPLOT
  /VARIABLES=GenericTotal AdaptSTAR MarchTotal TacticCounts RSiiiExpert
  /NOLOG
  /NOSTANDARDIZE
```

```
/TYPE=P-P
/FRACTION=BLOM
/TIES=MEAN
/DIST=NORMAL.
```

PPlot

```
[DataSet1] \\hs1.lboro.ac.uk\cvrcg2\Chapter 5\Chapter 5 Data final.sav
```

Model Description

Model Name		MOD_1
Series or Sequence	1	Generic Assessment total
	2	AdaptSTAR total
	3	March et al. (2011) total
	4	TacticCounts
	5	RSiiiExpert
Transformation		None
Non-Seasonal Differencing		0
Seasonal Differencing		0
Length of Seasonal Period		No periodicity
Standardization		Not applied
Distribution	Type	Normal
	Location	estimated
	Scale	estimated
Fractional Rank Estimation Method		Blom's
Rank Assigned to Ties		Mean rank of tied values

Applying the model specifications from MOD_1

Case Processing Summary

		Generic Assessment total	AdaptSTAR total
Series or Sequence Length		26	26
Number of Missing Values in the Plot	User-Missing	0	0
	System-Missing	0	0

Case Processing Summary

		March et al. (2011) total	TacticCounts	RSiiiExpert
Series or Sequence Length		26	26	26
Number of Missing Values in the Plot	User-Missing	0	0	0
	System-Missing	0	2	2

The cases are unweighted.

Estimated Distribution Parameters

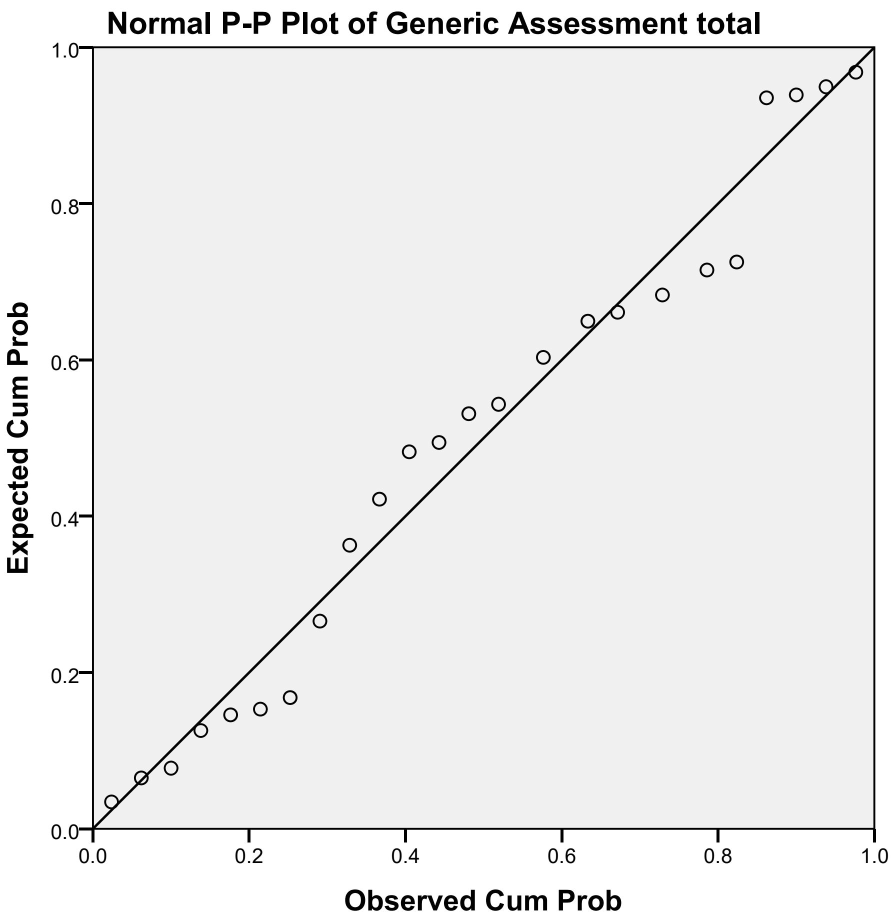
		Generic Assessment total	AdaptSTAR total	March et al. (2011) total	TacticCounts
Normal Distribution	Location	30.89231	69.30769	.44351	19.16667
	Scale	6.534641	7.423041	.043998	11.040111

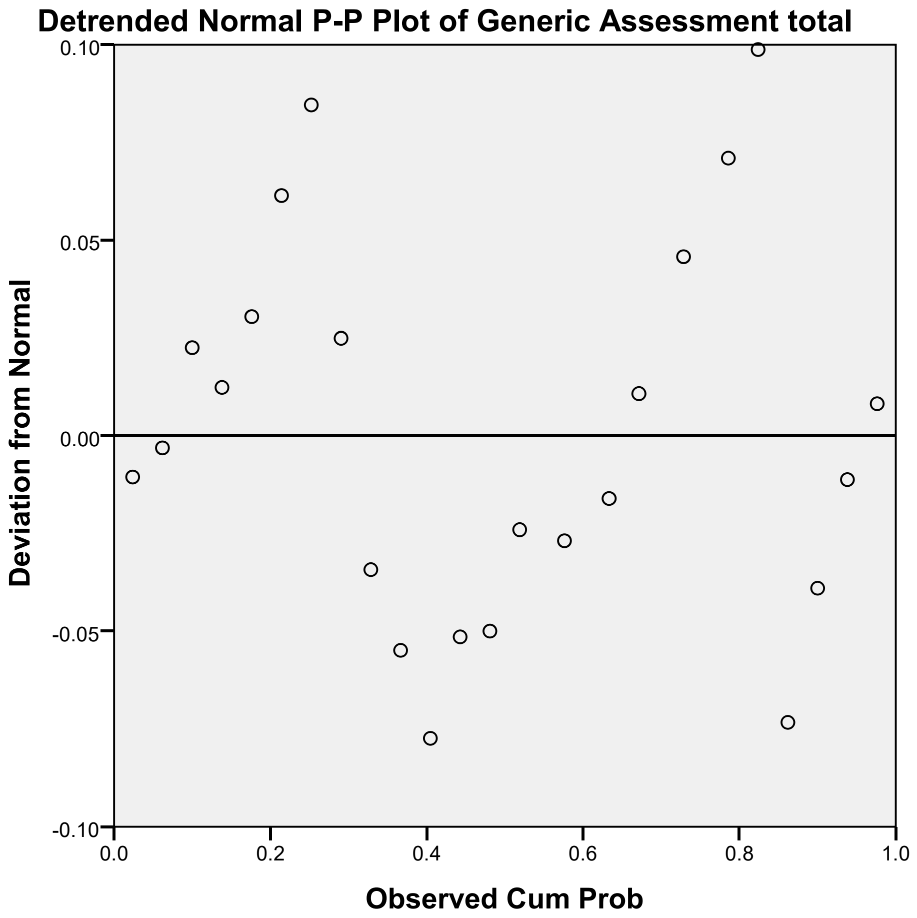
Estimated Distribution Parameters

		RSiiiExpert
Normal Distribution	Location	2.37500
	Scale	1.951866

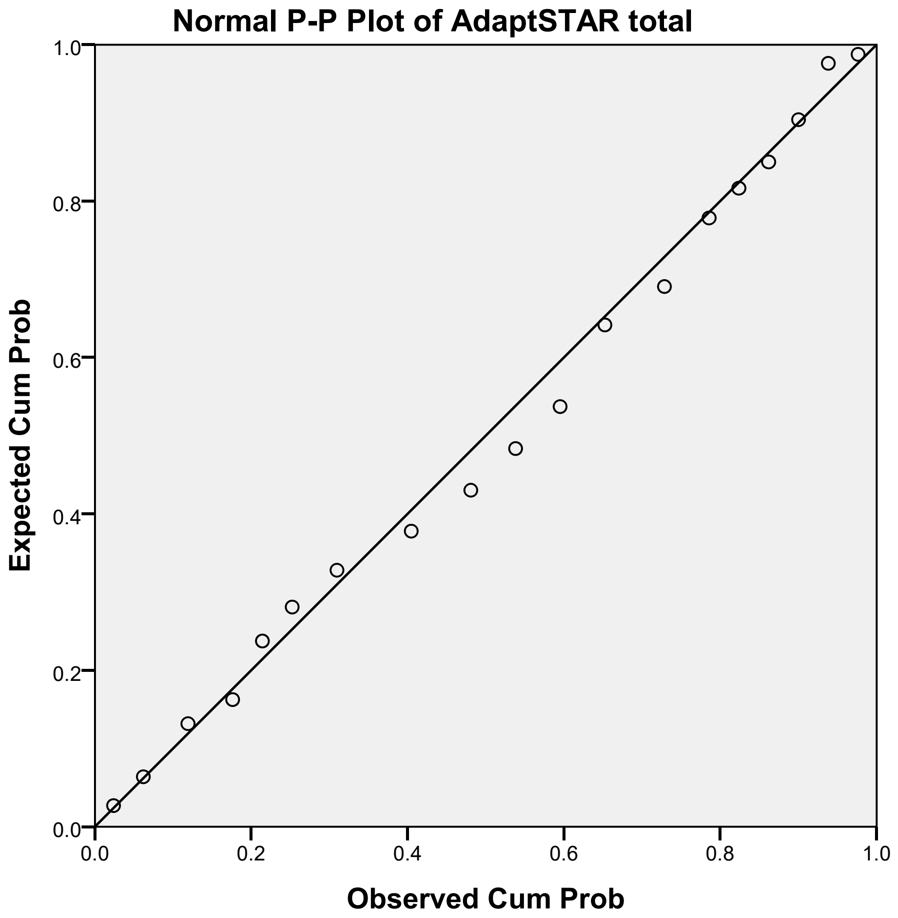
The cases are unweighted.

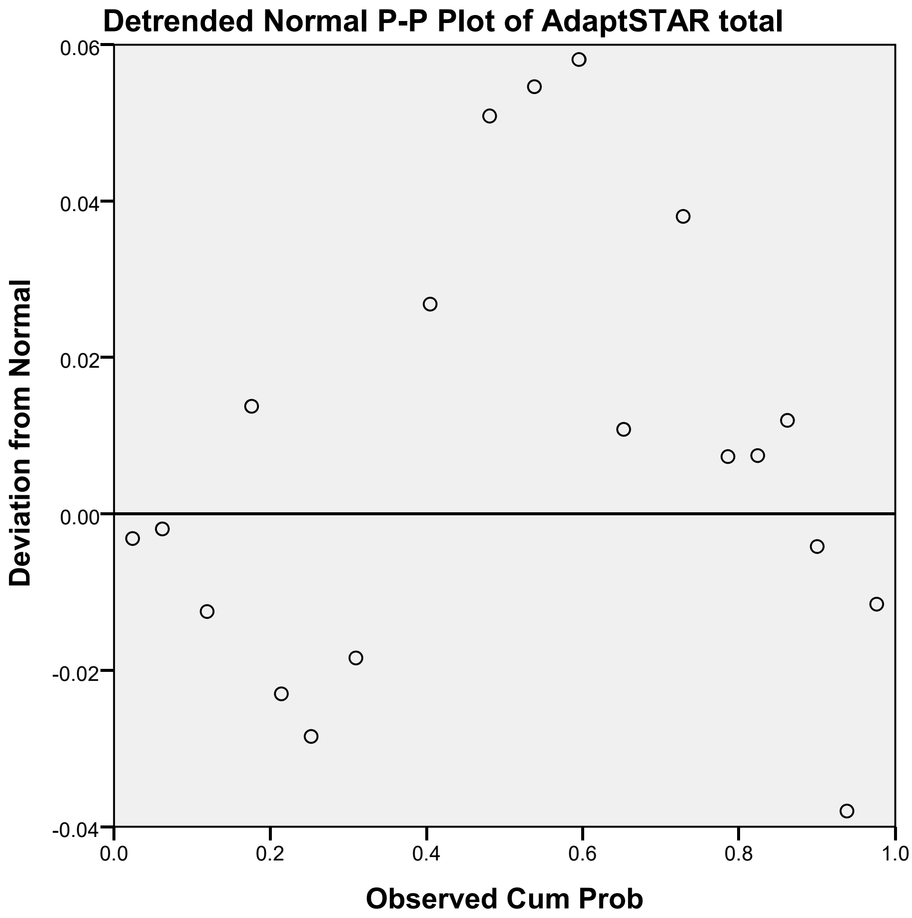
Generic Assessment total



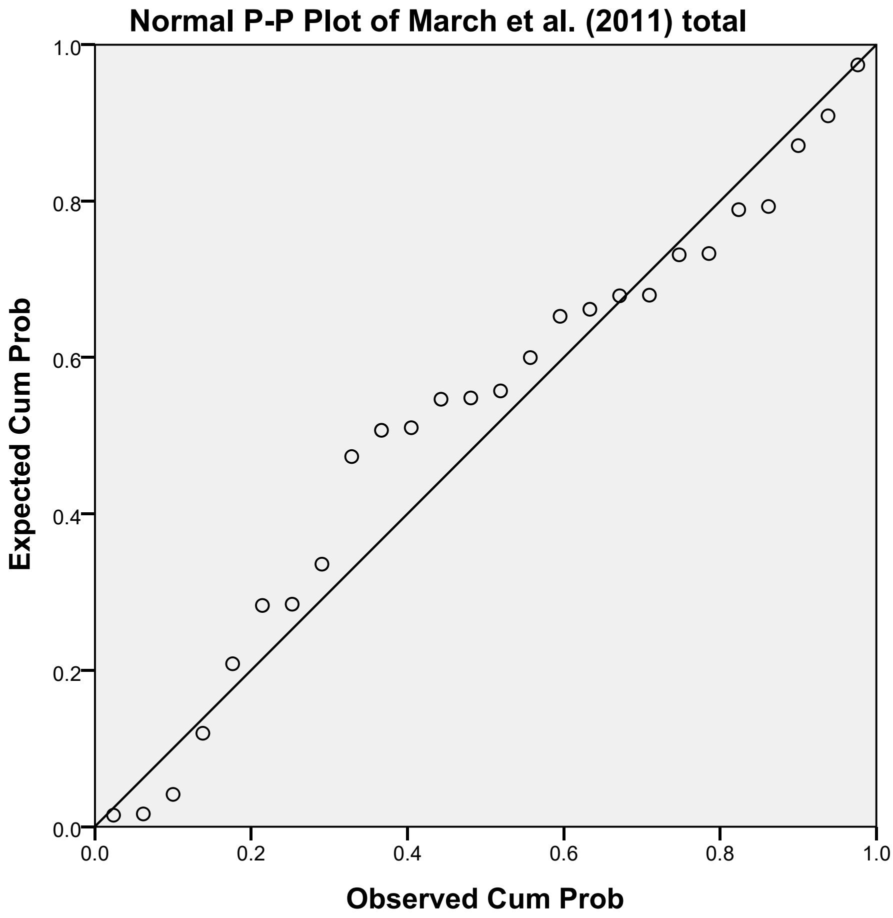


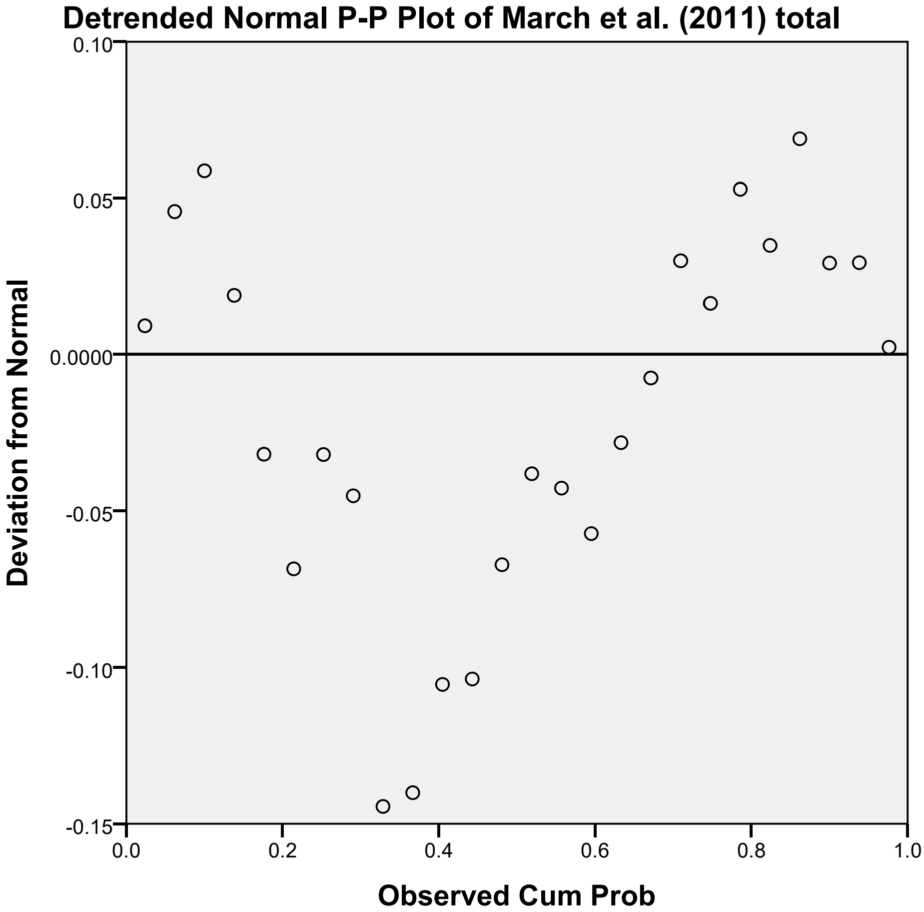
AdaptSTAR total


Normal P-P Plot of AdaptSTAR total
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

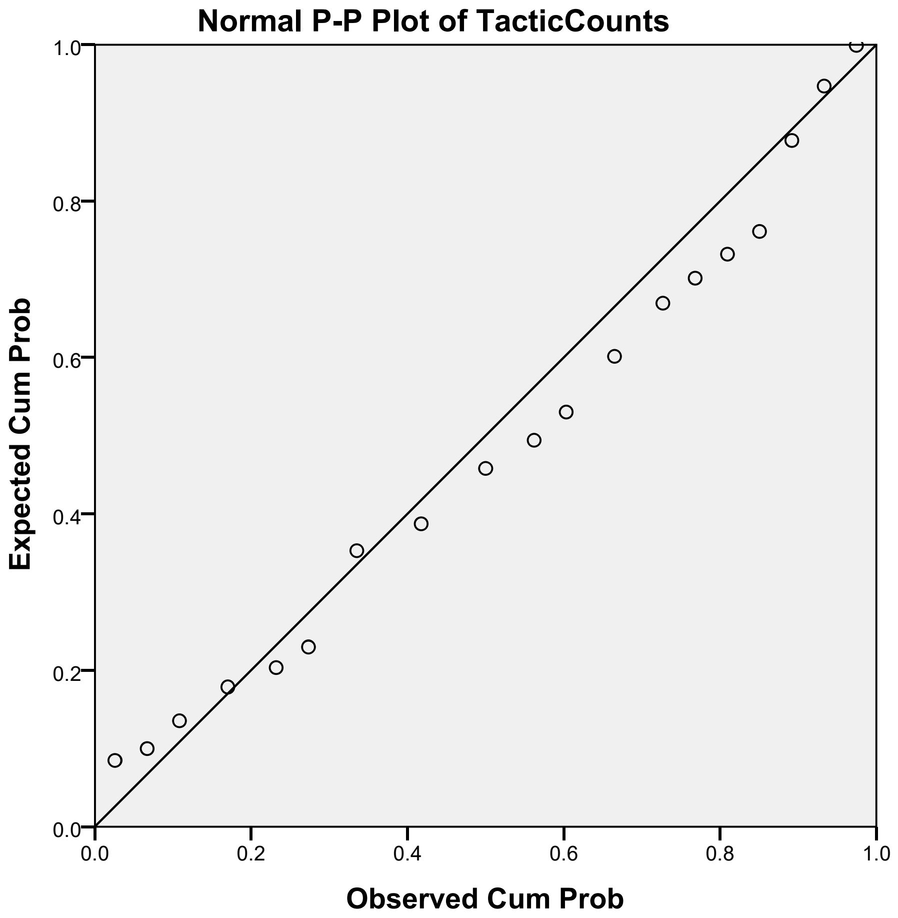


March et al. (2011) total

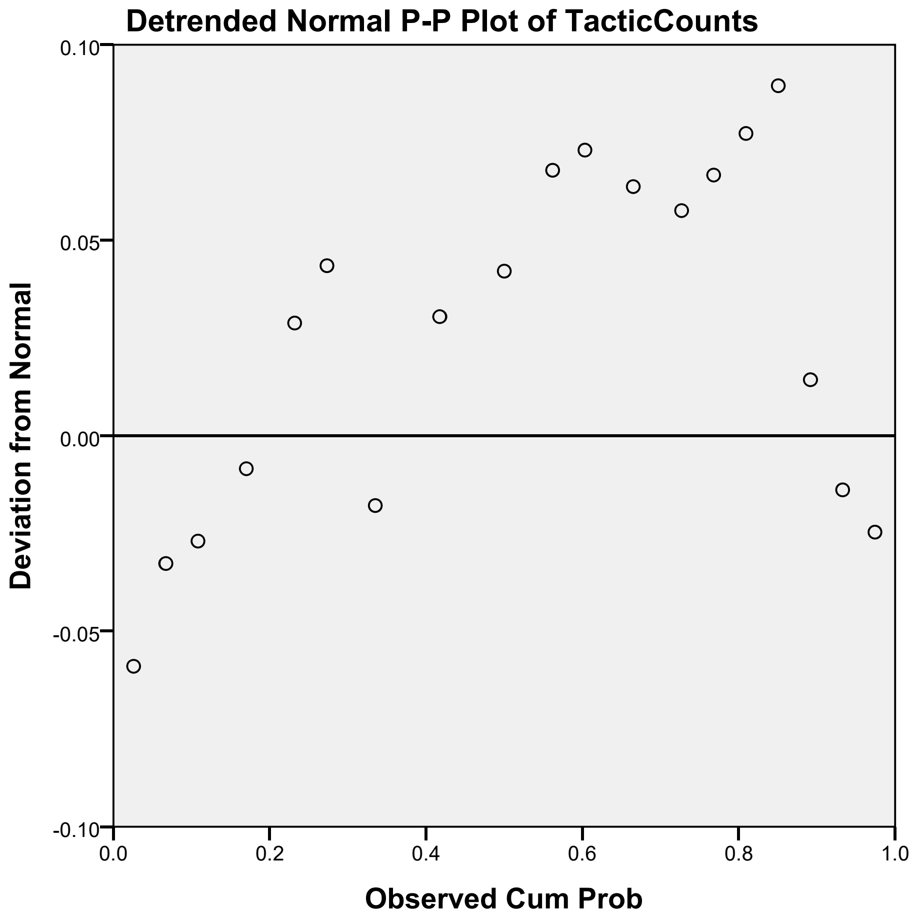

Normal P-P Plot of March et al. (2011) total
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0



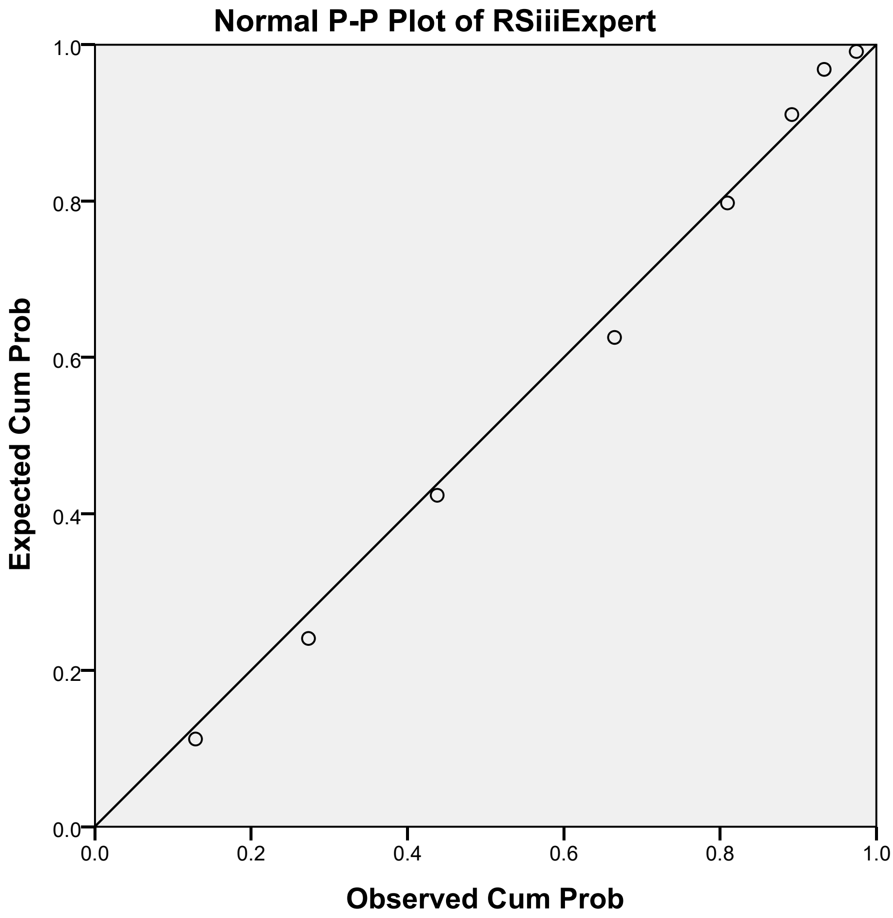
TacticCounts

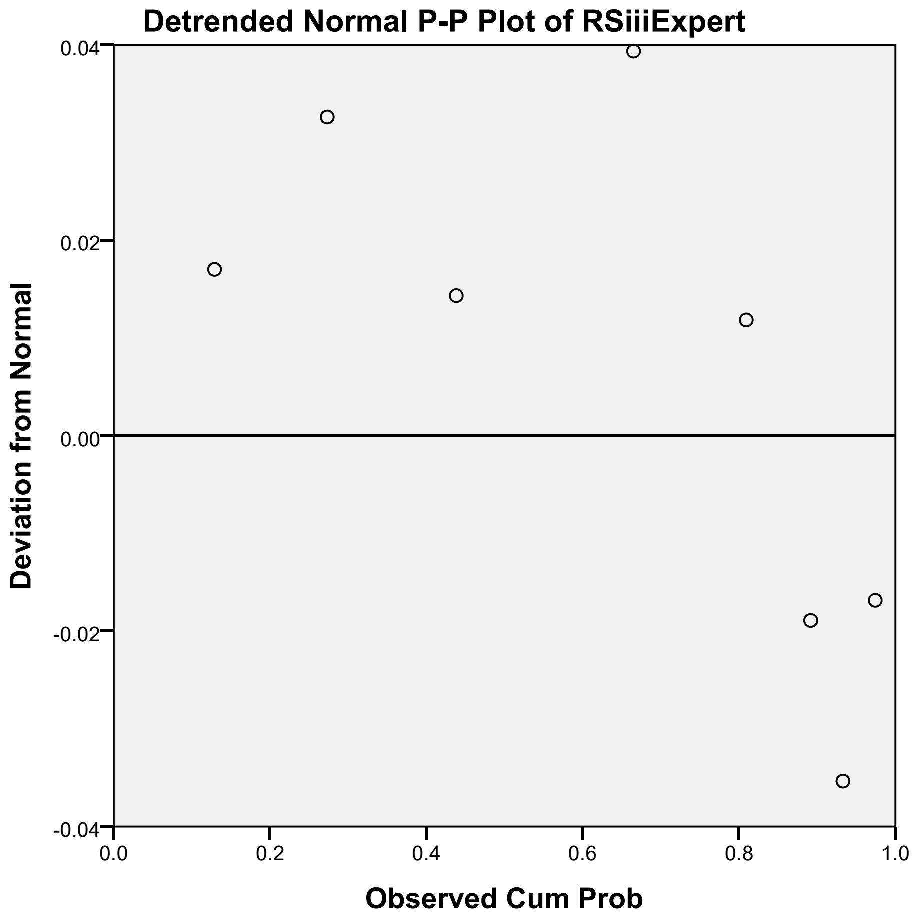


Normal P-P Plot of TacticCounts
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0



RSiiiExpert


Normal P-P Plot of RSiiiExpert
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0




```
EXAMINE VARIABLES=GenericTotal AdaptSTAR MarchTotal TacticCounts RSiiiExpe
rt
  /ID=CaseNo
  /PLOT BOXPLOT HISTOGRAM NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES EXTREME
  /CINTERVAL 95
  /MISSING PAIRWISE
  /NOTOTAL.
```

Explore

[DataSet1] \\hs1.lboro.ac.uk\cvrcg2\Chapter 5\Chapter 5 Data final.sav

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Generic Assessment total	26	100.0%	0	0.0%	26	100.0%
AdaptSTAR total	26	100.0%	0	0.0%	26	100.0%
March et al. (2011) total	26	100.0%	0	0.0%	26	100.0%
TacticCounts	24	92.3%	2	7.7%	26	100.0%
RSiiiExpert	24	92.3%	2	7.7%	26	100.0%

Descriptives

			Statistic	Std. Error
Generic Assessment total	Mean		30.8923	1.28155
	95% Confidence Interval for Mean	Lower Bound	28.2529	
		Upper Bound	33.5317	
	5% Trimmed Mean		30.8726	
	Median		31.5000	
	Variance		42.702	
	Std. Deviation		6.53464	
	Minimum		19.00	
	Maximum		43.00	
	Range		24.00	
	Interquartile Range		9.65	
	Skewness		.061	.456
	Kurtosis		-.558	.887
AdaptSTAR total	Mean		69.3077	1.45578
	95% Confidence Interval for Mean	Lower Bound	66.3095	
		Upper Bound	72.3059	
	5% Trimmed Mean		69.1624	
	Median		68.5000	
	Variance		55.102	
	Std. Deviation		7.42304	
	Minimum		55.00	
	Maximum		86.00	
	Range		31.00	
	Interquartile Range		8.75	
	Skewness		.377	.456
	Kurtosis		.158	.887
March et al. (2011) total	Mean		.44351	.008629
	95% Confidence Interval for Mean	Lower Bound	.42574	
		Upper Bound	.46128	
	5% Trimmed Mean		.44441	
	Median		.44934	
	Variance		.002	
	Std. Deviation		.043998	

Descriptives

			Statistic	Std. Error
	Minimum		.348	
	Maximum		.529	
	Range		.181	
	Interquartile Range		.052	
	Skewness		-.648	.456
	Kurtosis		.441	.887
TacticCounts	Mean		19.1667	2.25355
	95% Confidence Interval for Mean	Lower Bound	14.5048	
		Upper Bound	23.8285	
	5% Trimmed Mean		18.2685	
	Median		18.0000	
	Variance		121.884	
	Std. Deviation		11.04011	
	Minimum		4.00	
	Maximum		53.00	
	Range		49.00	
	Interquartile Range		14.50	
	Skewness		1.266	.472
	Kurtosis		2.628	.918
RSiiiExpert	Mean		2.38	.398
	95% Confidence Interval for Mean	Lower Bound	1.55	
		Upper Bound	3.20	
	5% Trimmed Mean		2.26	
	Median		2.00	
	Variance		3.810	
	Std. Deviation		1.952	
	Minimum		0	
	Maximum		7	
	Range		7	
	Interquartile Range		4	
	Skewness		.607	.472
	Kurtosis		.042	.918

Extreme Values

			Case Number	Case Number	Value
Generic Assessment total	Highest	1	18	31	43.00
		2	10	16	41.60
		3	1	01	41.00
		4	25	00	40.80
		5	19	35	34.80
	Lowest	1	8	11	19.00
		2	2	04	21.00
		3	9	14	21.60
		4	21	38.2	23.40
		5	24	48	24.00
AdaptSTAR total	Highest	1	25	00	86.00
		2	18	31	84.00
		3	10	16	79.00
		4	12	19	77.00
		5	24	48	76.00
	Lowest	1	26	00	55.00
		2	2	04	58.00
		3	21	38.2	61.00
		4	9	14	61.00
		5	8	11	62.00
March et al. (2011) total	Highest	1	1	01	.529
		2	13	20	.502
		3	5	07	.493
		4	6	09	.479
		5	15	23	.479
	Lowest	1	20	38.1	.348
		2	21	38.2	.349
		3	14	21	.367
		4	8	11	.392
		5	10	16	.408
TacticCounts	Highest	1	10	16	53.00
		2	12	19	37.00
		3	22	46	32.00
		4	18	31	27.00
		5	17	25	26.00
	Lowest	1	15	23	4.00
		2	4	06.2	5.00
		3	3	06.1	7.00
		4	13	20	9.00
		5	9	14	9.00
RSiiiExpert	Highest	1	10	16	7
		2	16	24	6

Extreme Values

		Case Number	Case Number	Value
	3	22	46	5
	4	12	19	4
	5	13	20	4[a]
Lowest	1	20	38.1	0
	2	14	21	0
	3	9	14	0
	4	8	11	0
	5	4	06.2	0[b]

a. Only a partial list of cases with the value 4 are shown in the table of upper extremes.

b. Only a partial list of cases with the value 0 are shown in the table of lower extremes.

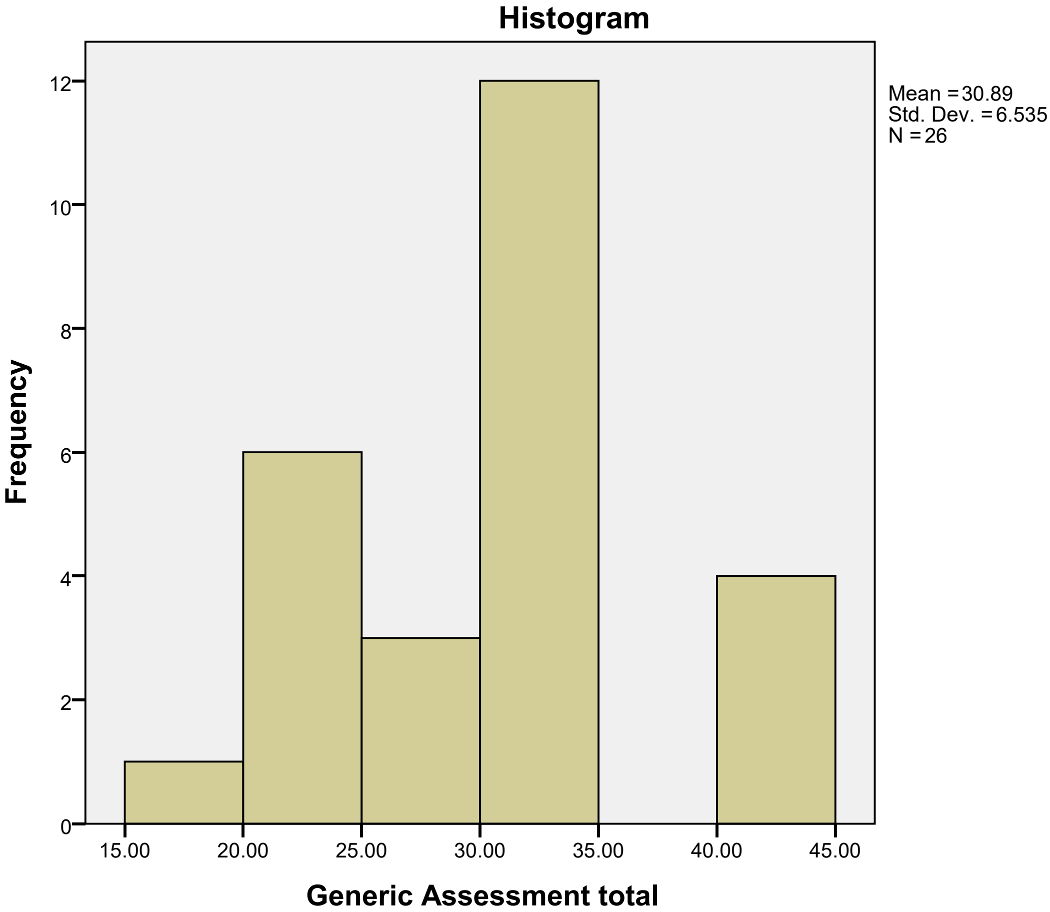
Tests of Normality

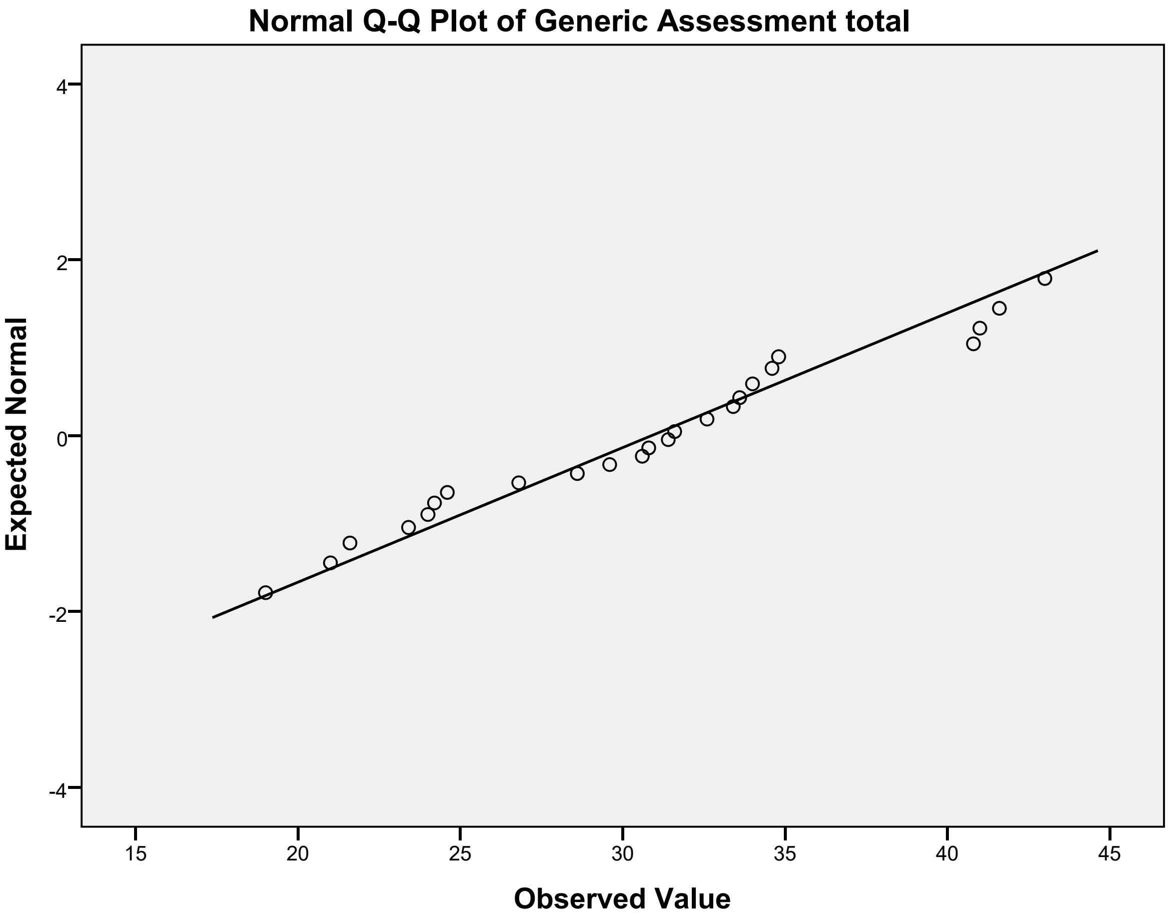
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Generic Assessment total	.121	26	.200*	.959	26	.378
AdaptSTAR total	.093	26	.200*	.982	26	.906
March et al. (2011) total	.165	26	.065	.946	26	.182
TacticCounts	.114	24	.200*	.916	24	.048
RSiiiExpert	.160	24	.117	.914	24	.043

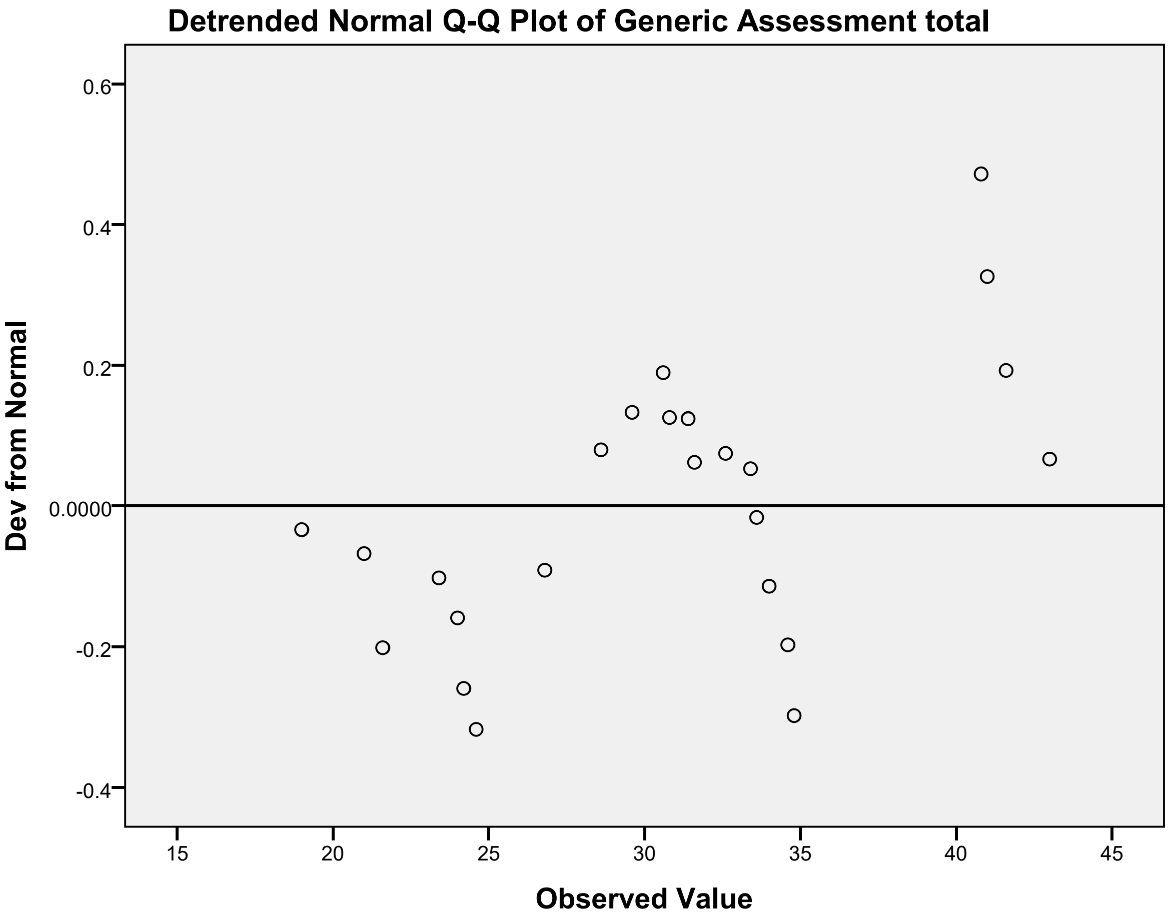
*. This is a lower bound of the true significance.

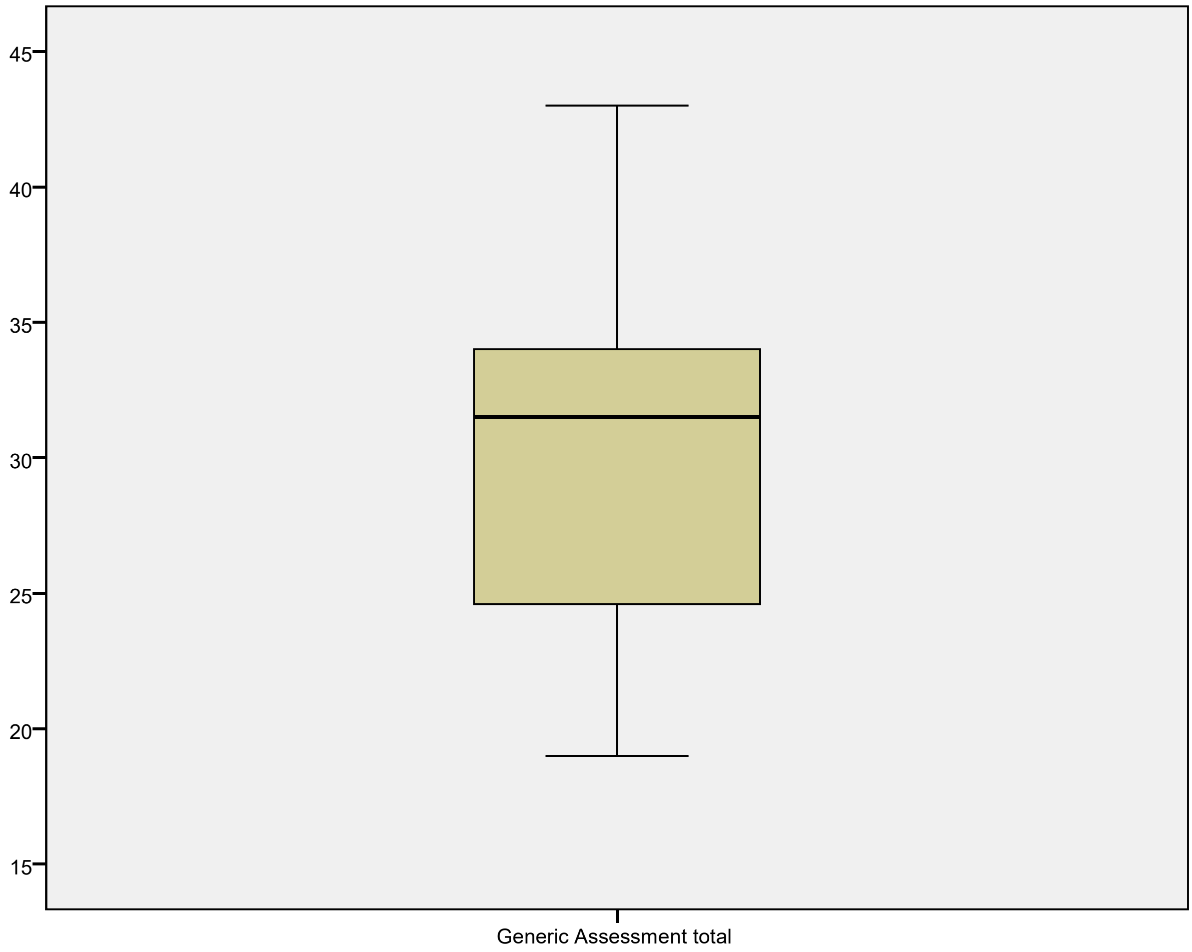
a. Lilliefors Significance Correction

Generic Assessment total

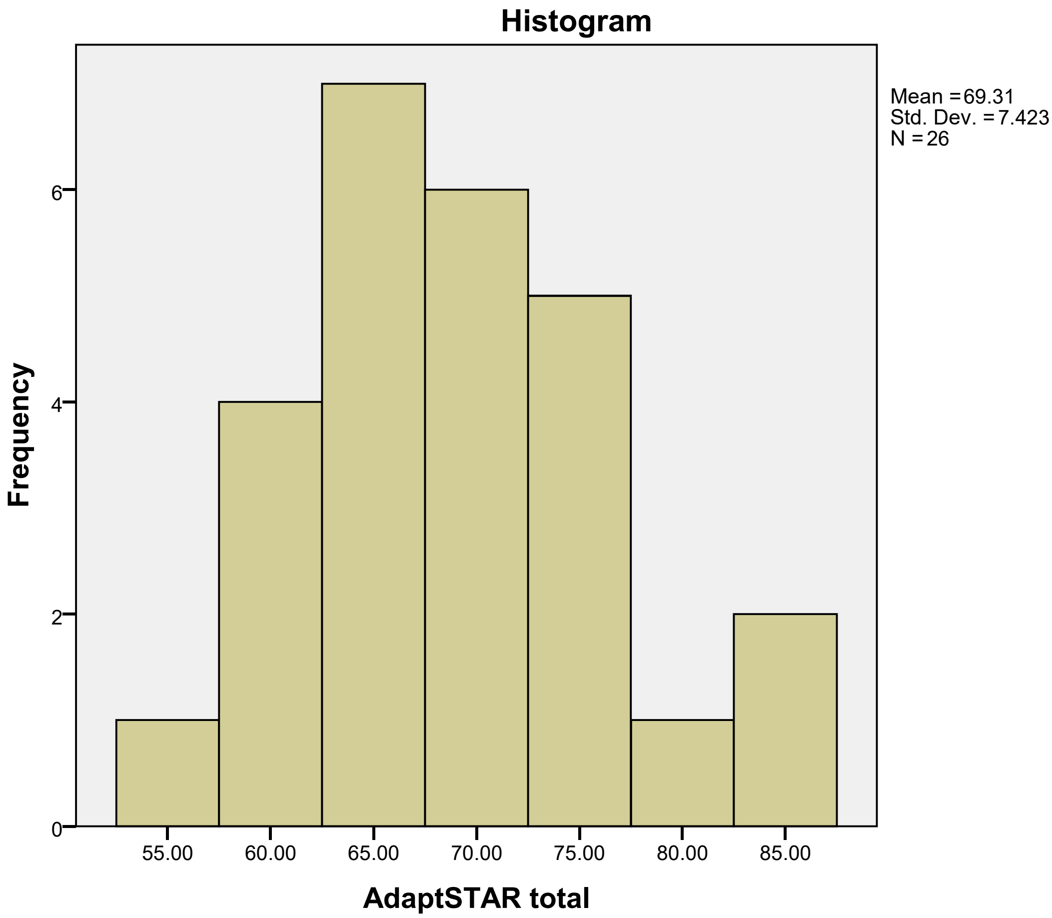

Histogram
Mean = 30.89
Std. Dev. = 6.535
N = 26
Frequency
0
2
4
6
8
10
12
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Generic Assessment total

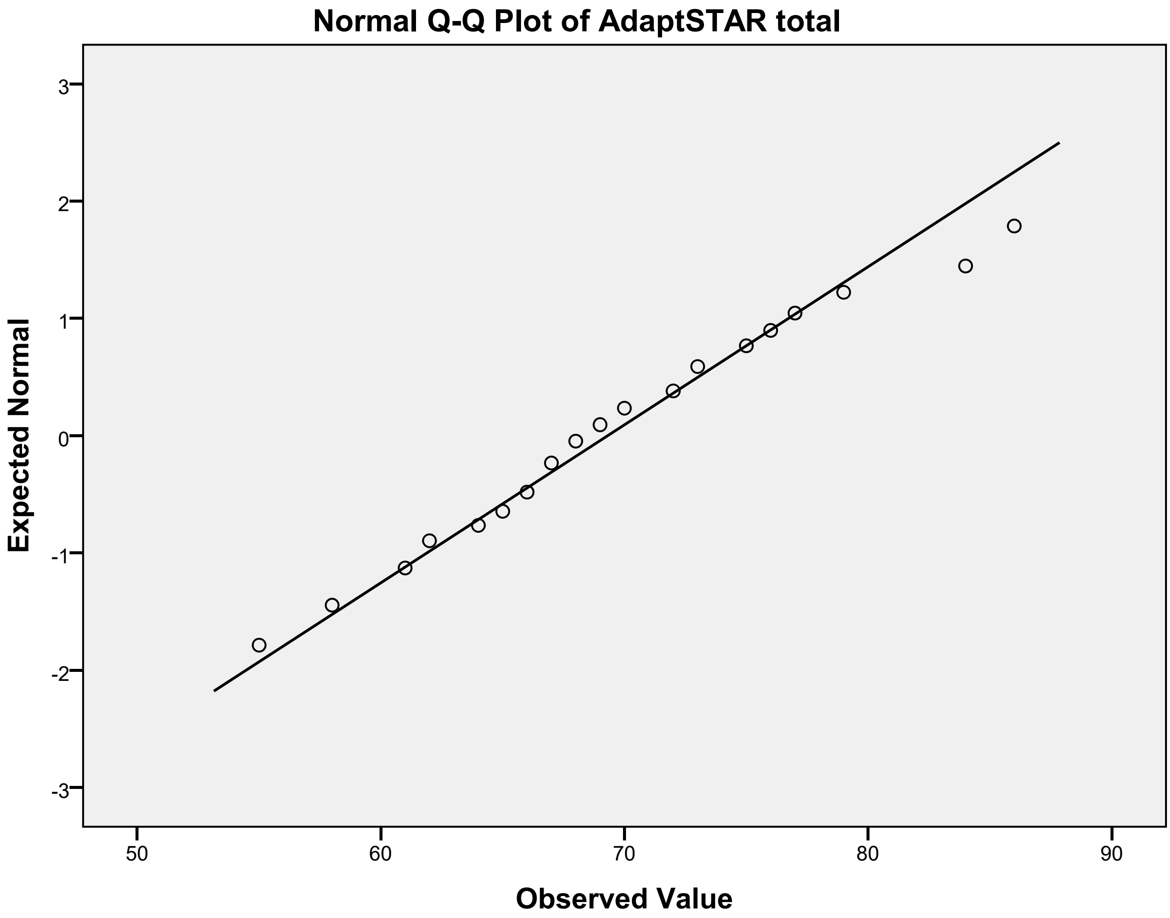

Normal Q-Q Plot of Generic Assessment total
Expected Normal
Observed Value
4
2
0
-2
-4
15
20
25
30
35
40
45

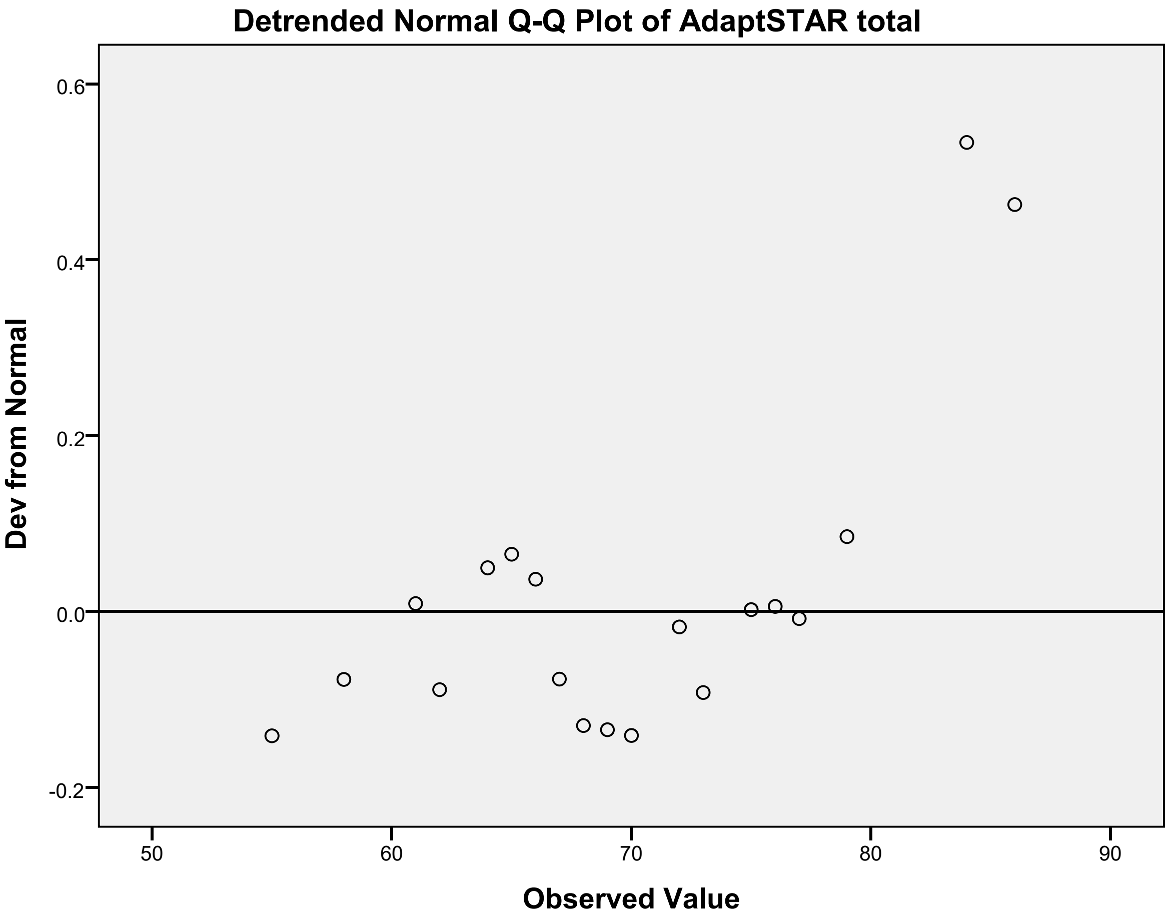

Detrended Normal Q-Q Plot of Generic Assessment total
Dev from Normal
0.6
0.4
0.2
0.0000
-0.2
-0.4
15
20
25
30
35
40
45
Observed Value



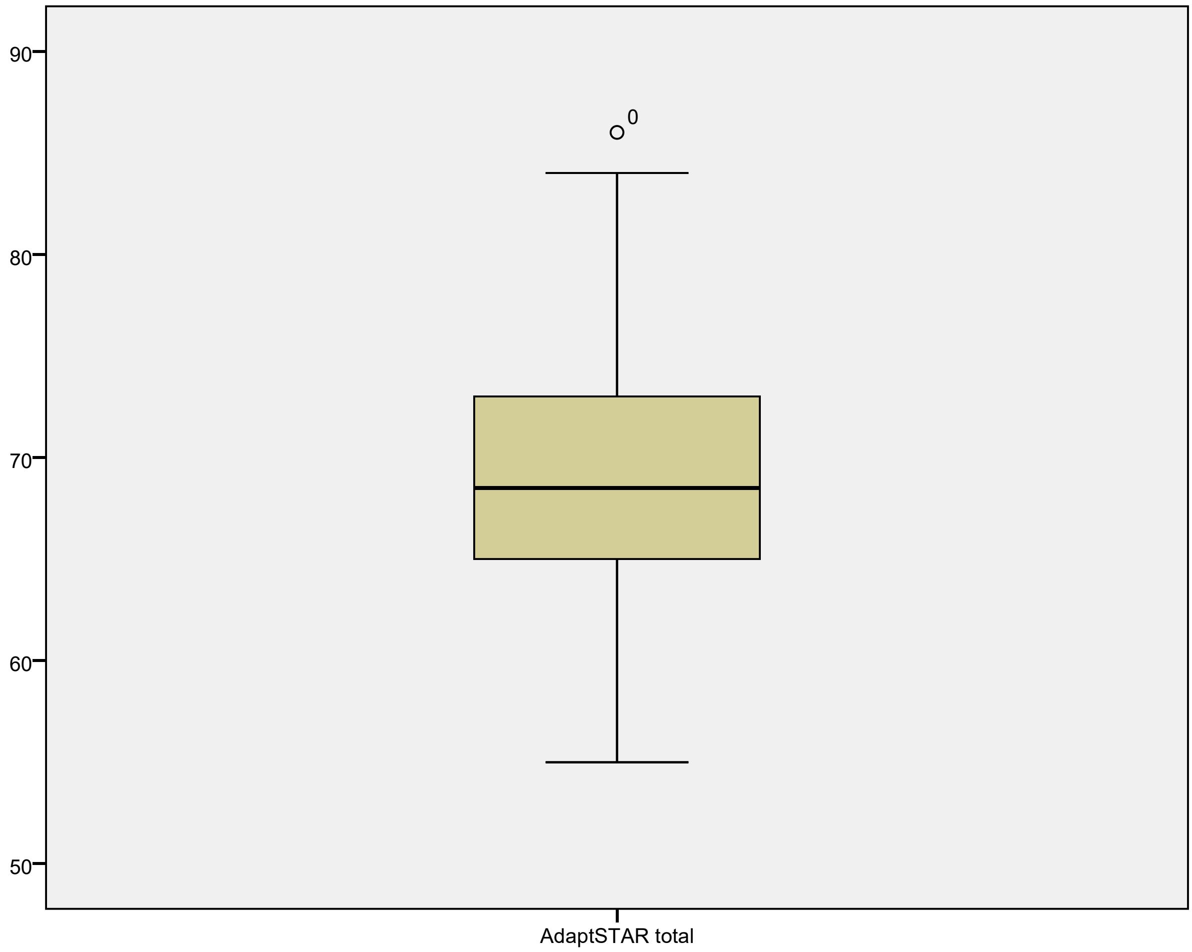
AdaptSTAR total


Histogram
Mean = 69.31
Std. Dev. = 7.423
N = 26
Frequency
0
2
4
6
55.00
60.00
65.00
70.00
75.00
80.00
85.00
AdaptSTAR total

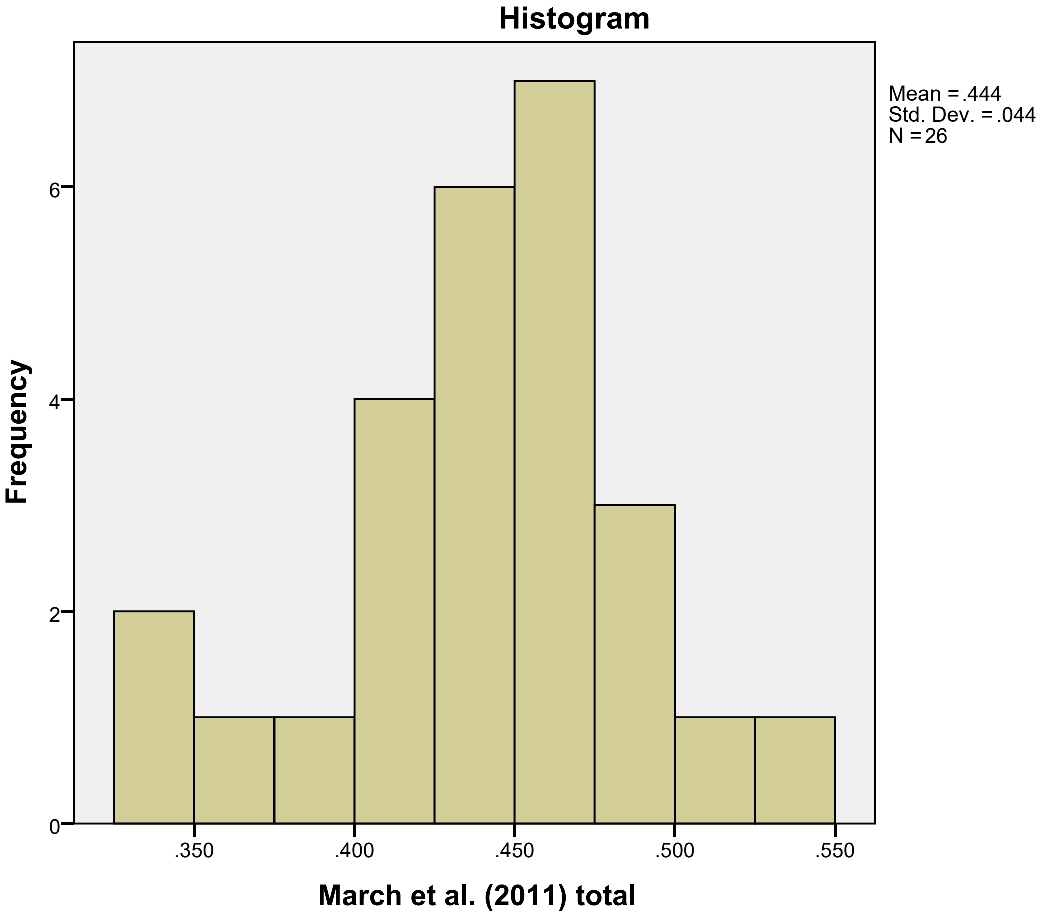

Normal Q-Q Plot of AdaptSTAR total
Expected Normal
3
2
1
0
-1
-2
-3
50
60
70
80
90
Observed Value

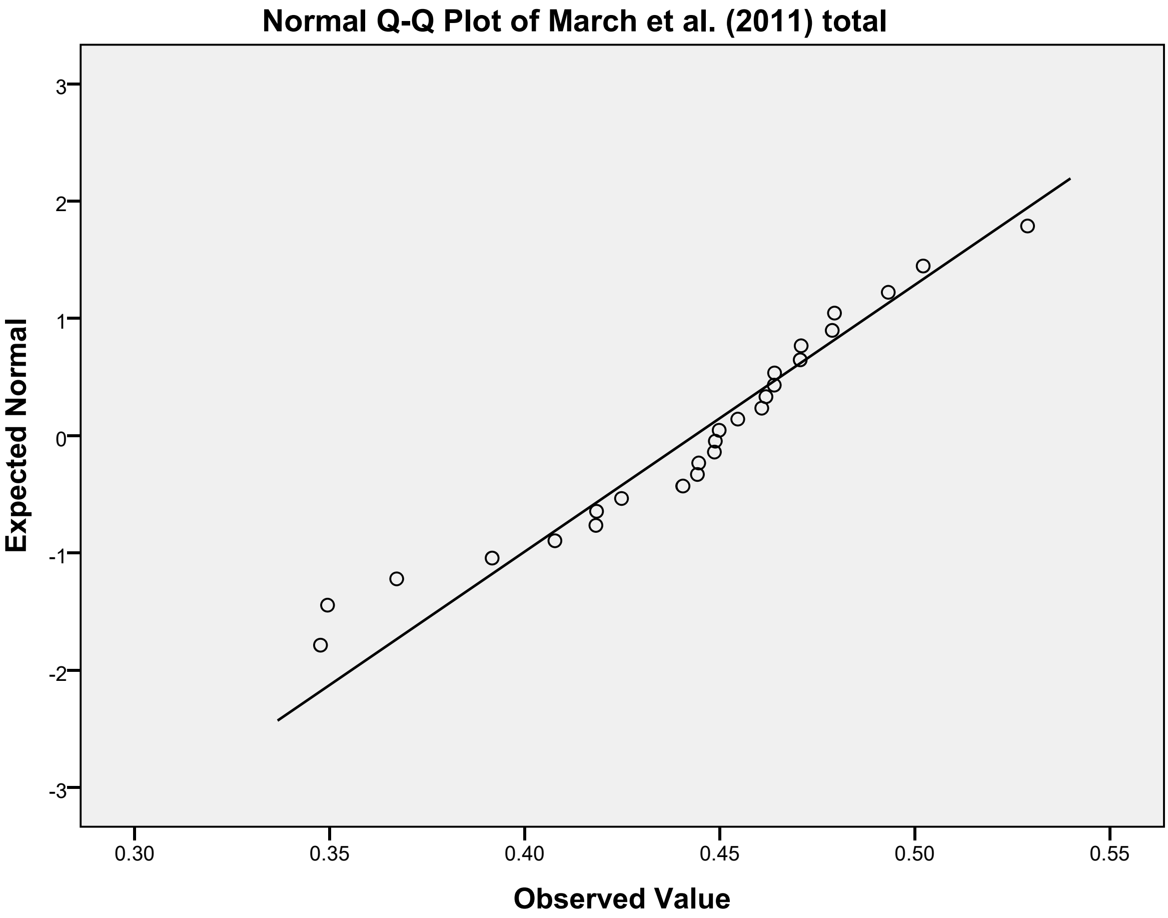


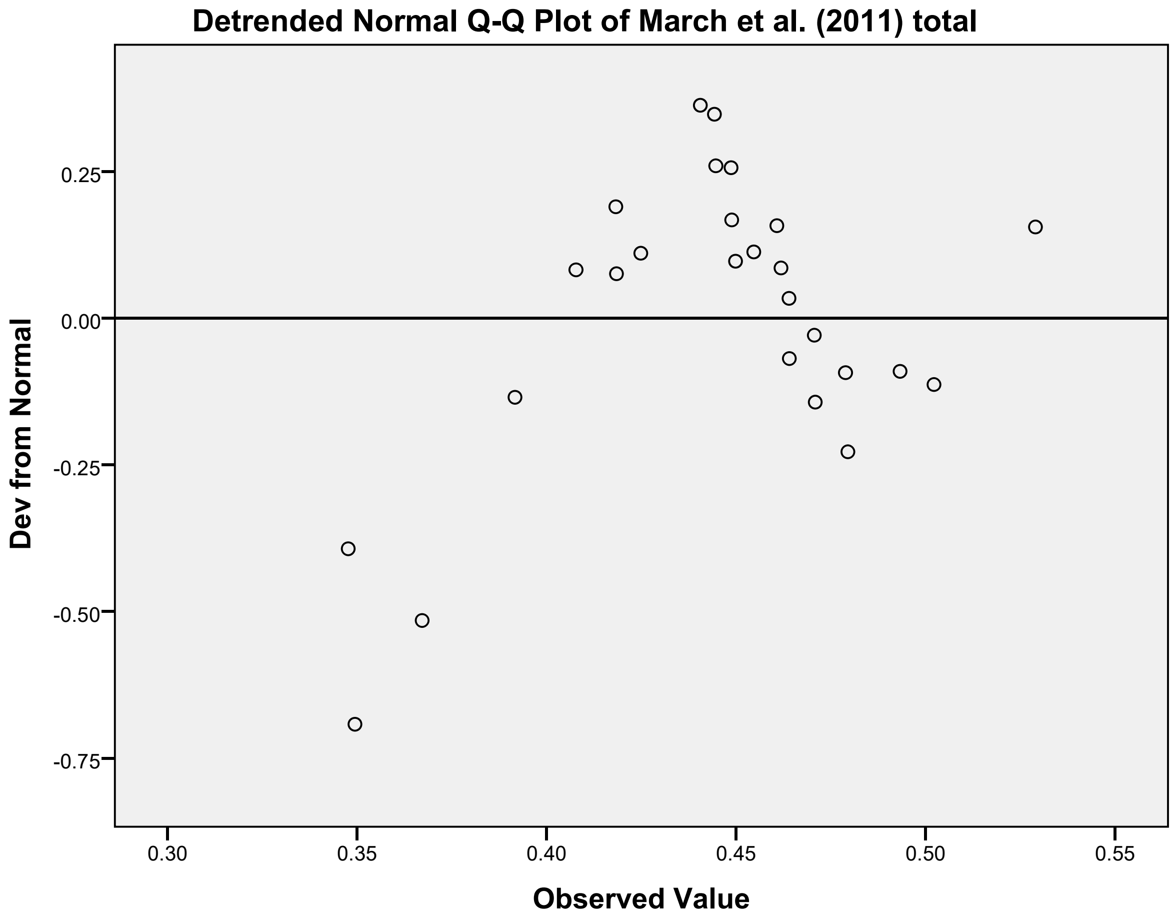
Detrended Normal Q-Q Plot of AdaptSTAR total
Dev from Normal
0.6
0.4
0.2
0.0
-0.2
50
60
70
80
90
Observed Value

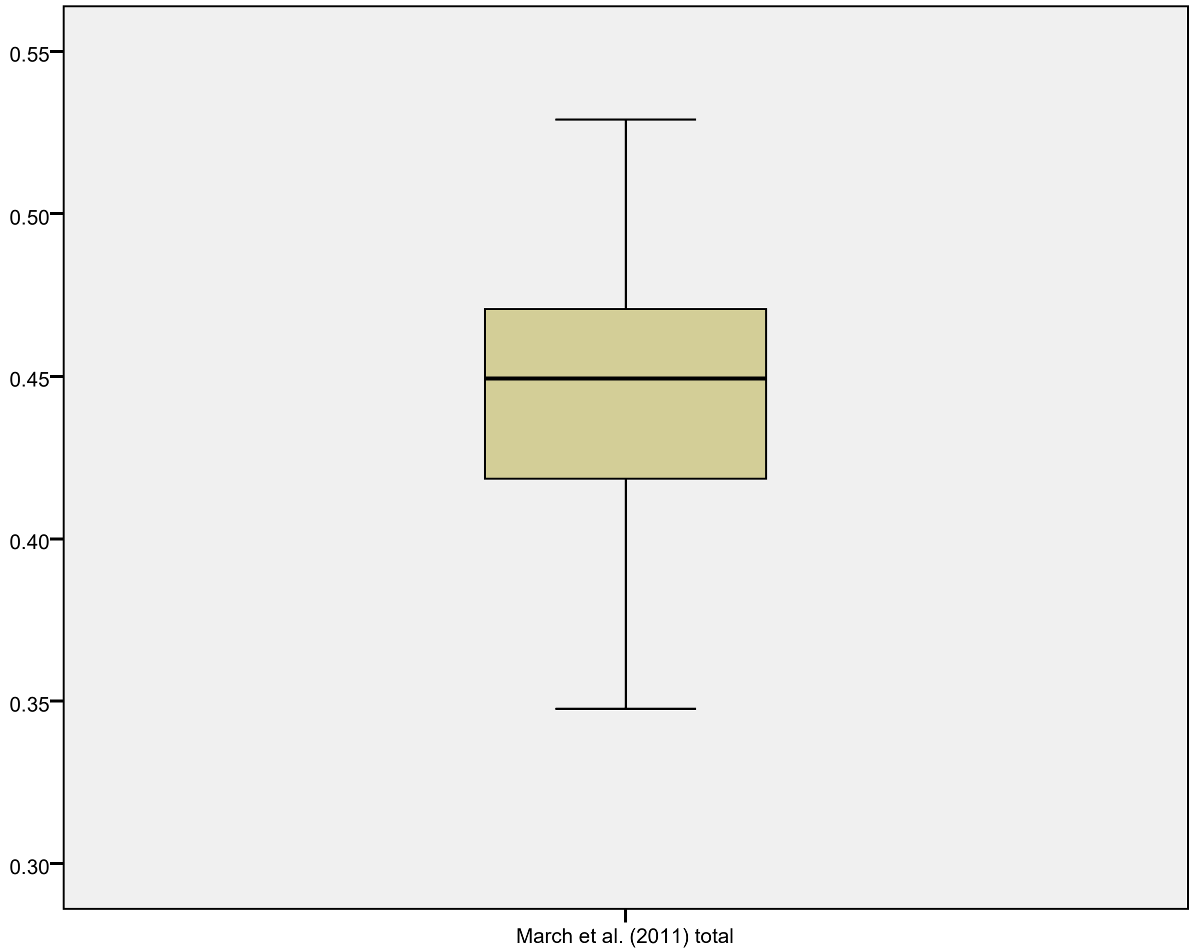


March et al. (2011) total

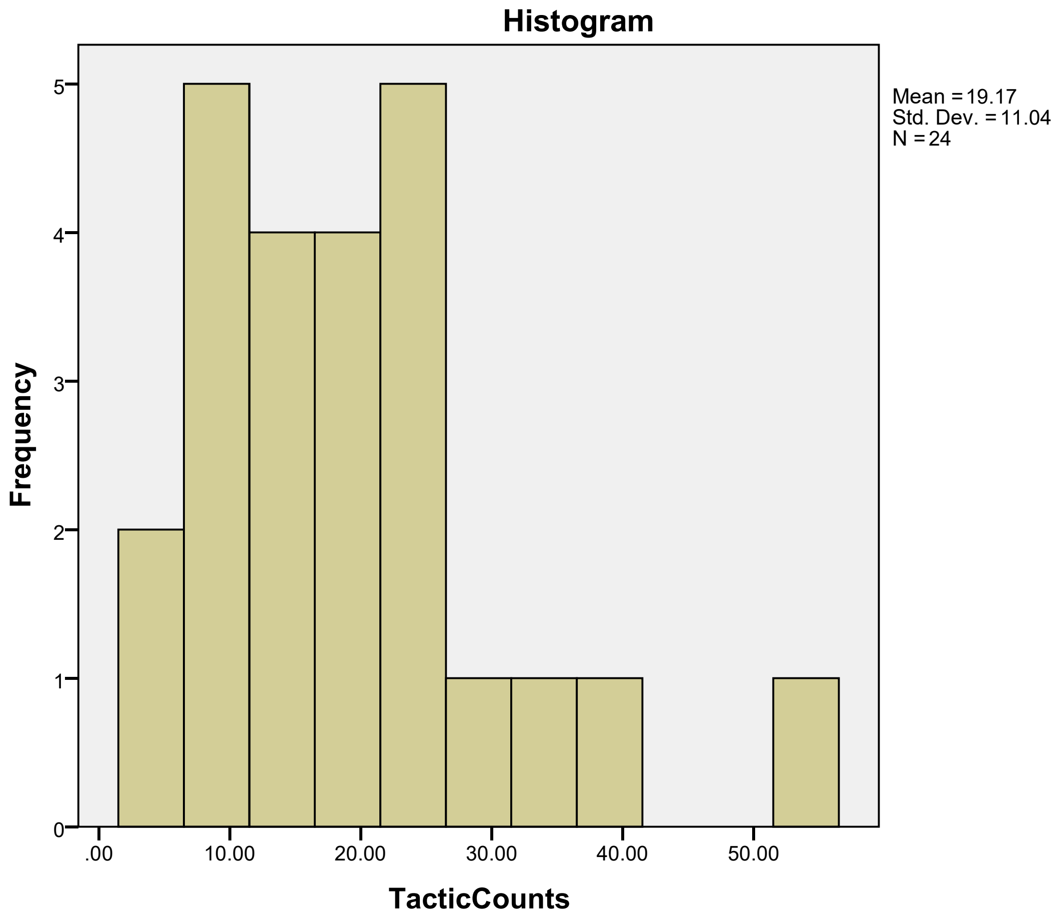

Histogram
Mean = .444
Std. Dev. = .044
N = 26
Frequency
0
2
4
6
.350
.400
.450
.500
.550
March et al. (2011) total

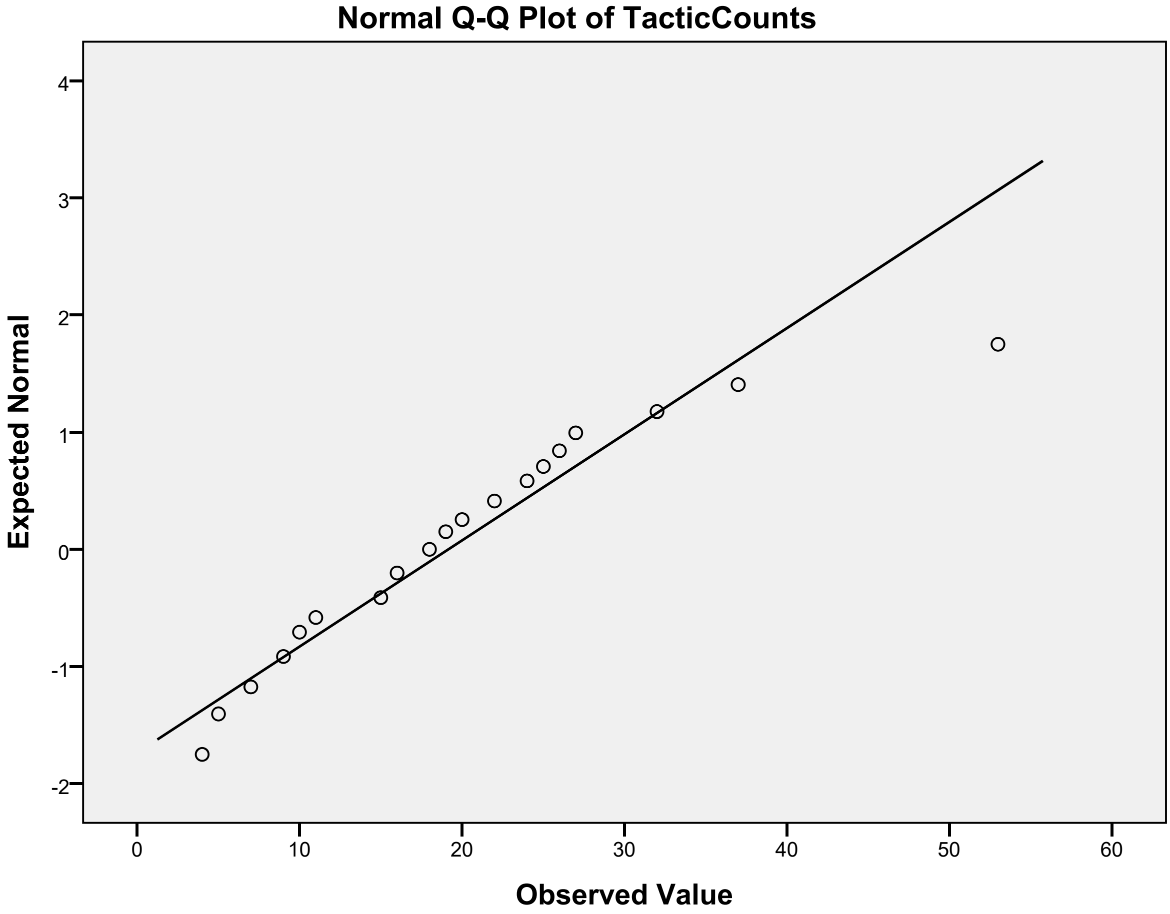

Normal Q-Q Plot of March et al. (2011) total
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
0.30
0.35
0.40
0.45
0.50
0.55

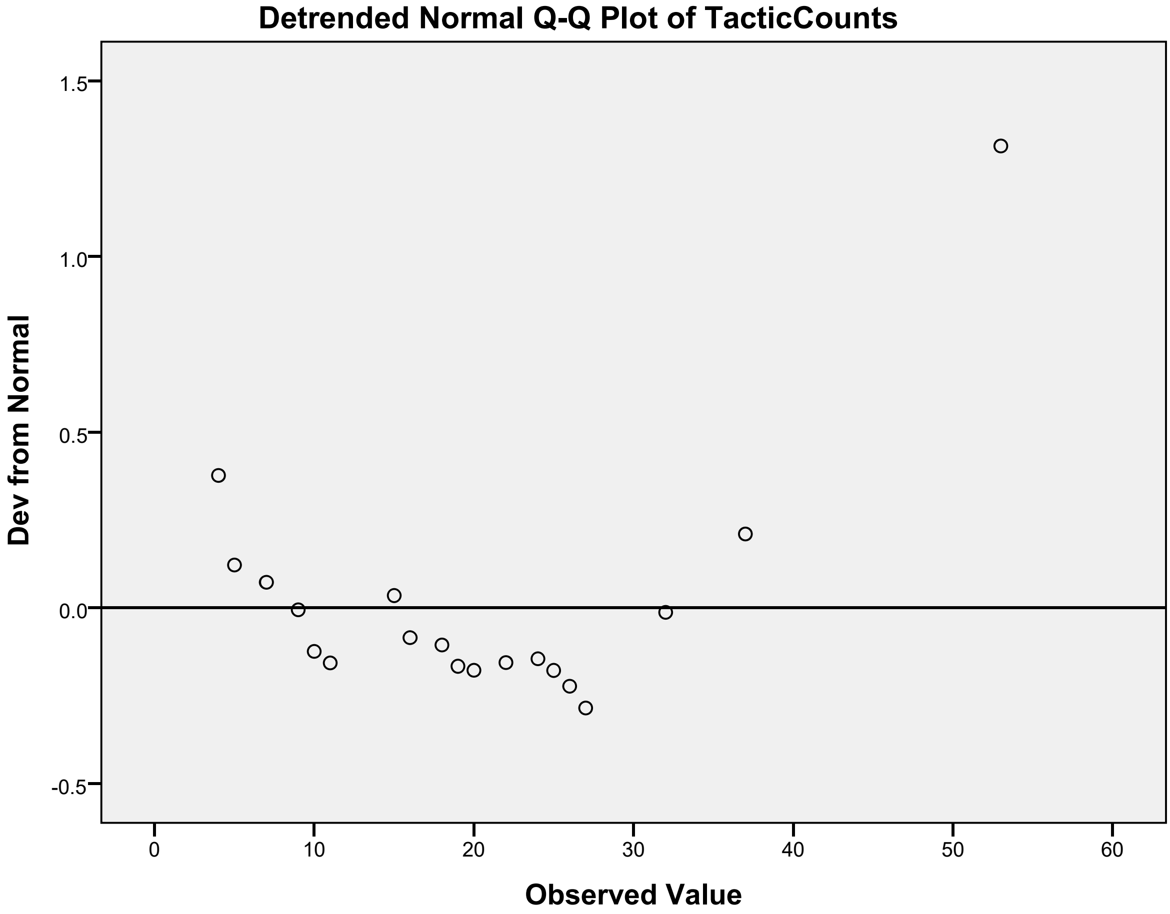

Detrended Normal Q-Q Plot of March et al. (2011) total
Dev from Normal
0.25
0.00
-0.25
-0.50
-0.75
0.30
0.35
0.40
0.45
0.50
0.55
Observed Value



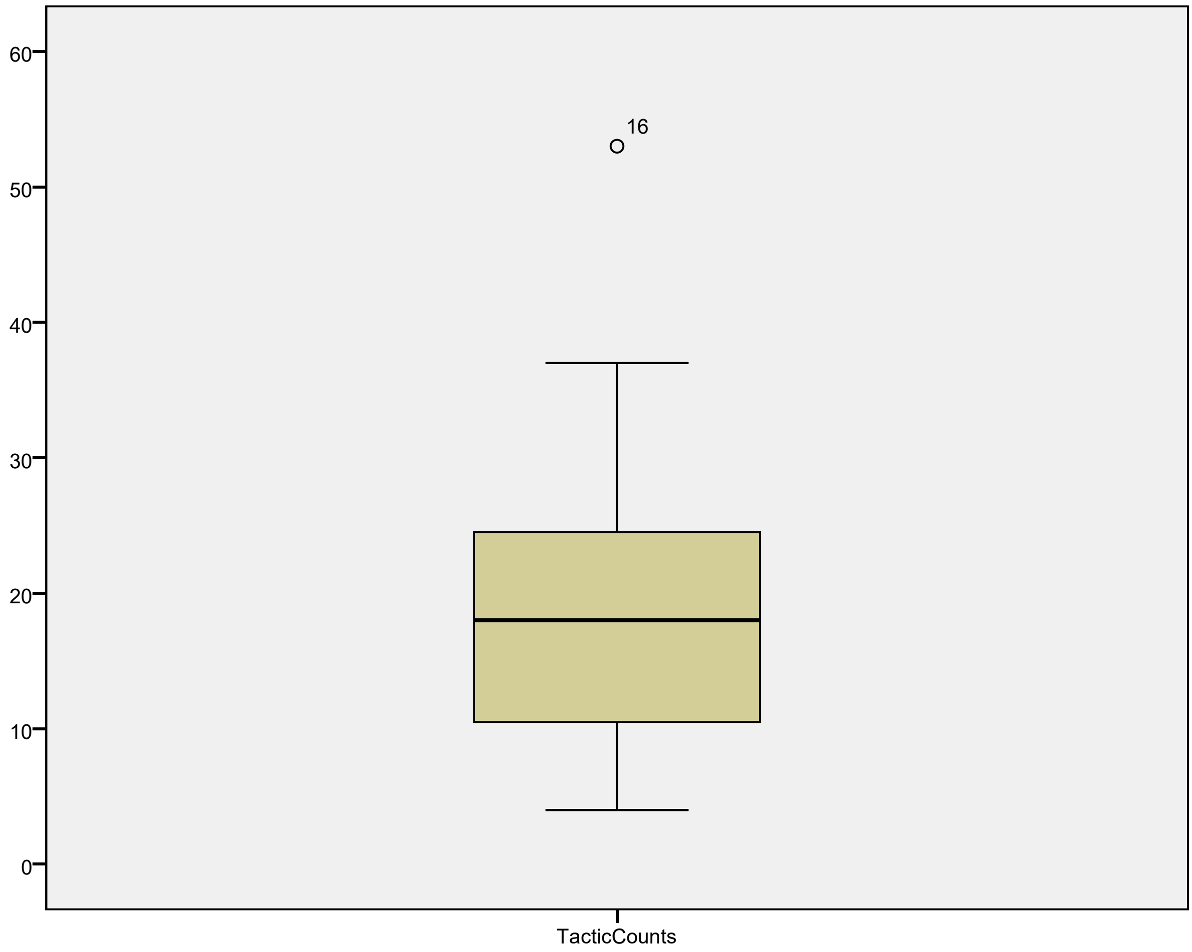
TacticCounts


Histogram
Mean = 19.17
Std. Dev. = 11.04
N = 24
Frequency
0
1
2
3
4
5
.00
10.00
20.00
30.00
40.00
50.00
TacticCounts

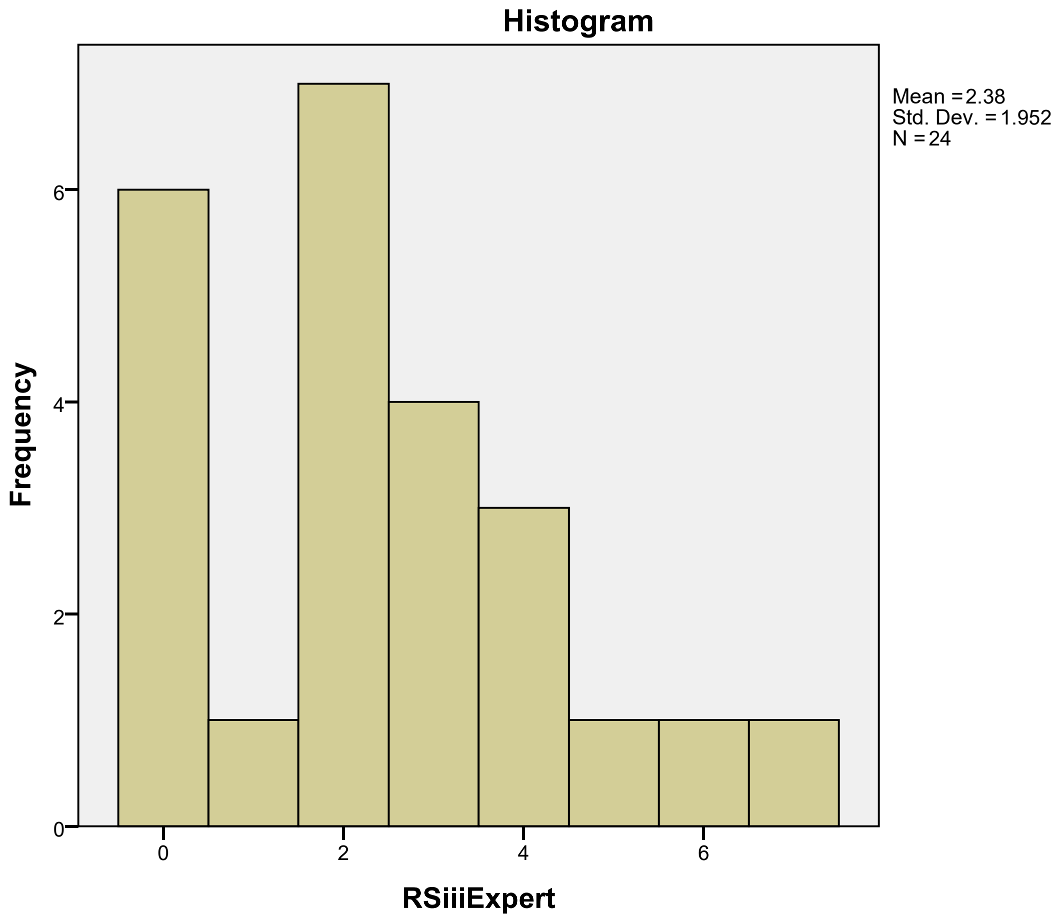

Normal Q-Q Plot of TacticCounts
Expected Normal
4
3
2
1
0
-1
-2
0
10
20
30
40
50
60
Observed Value

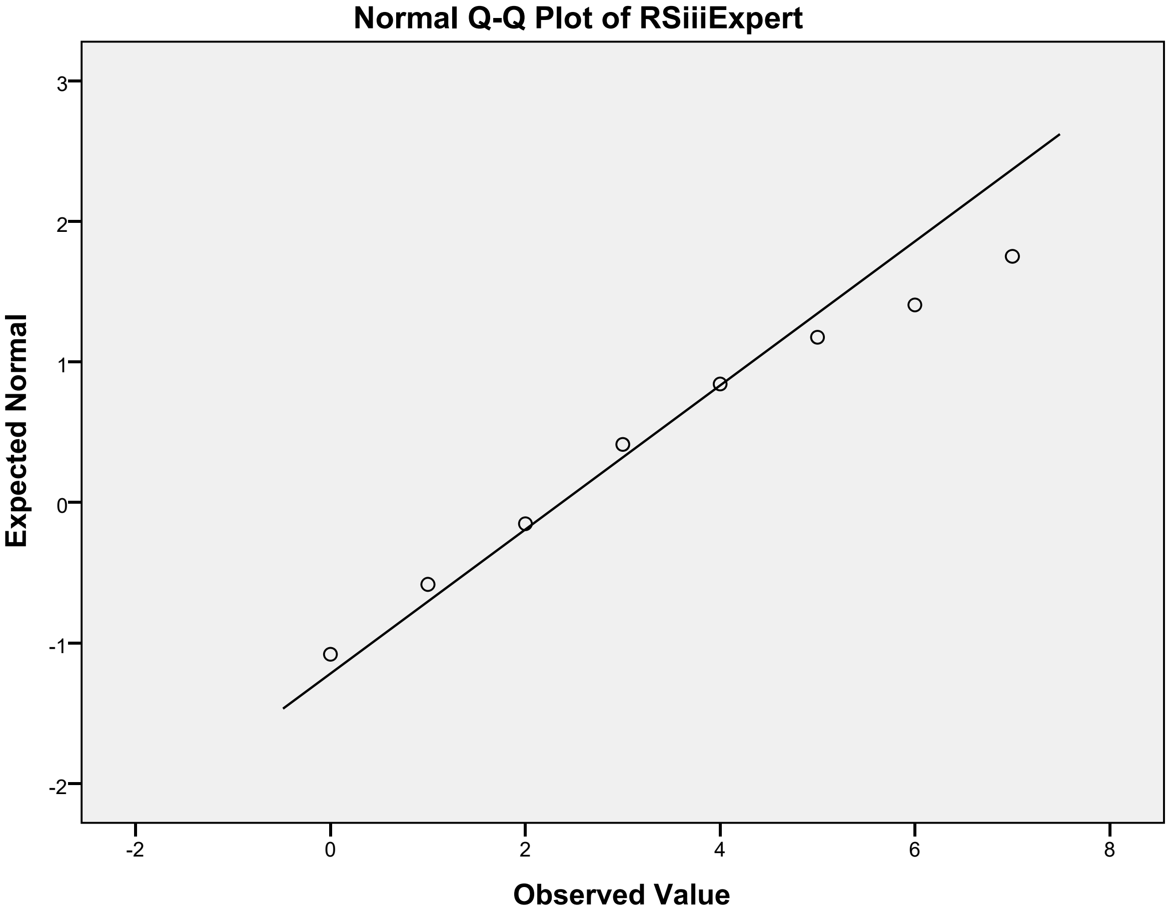


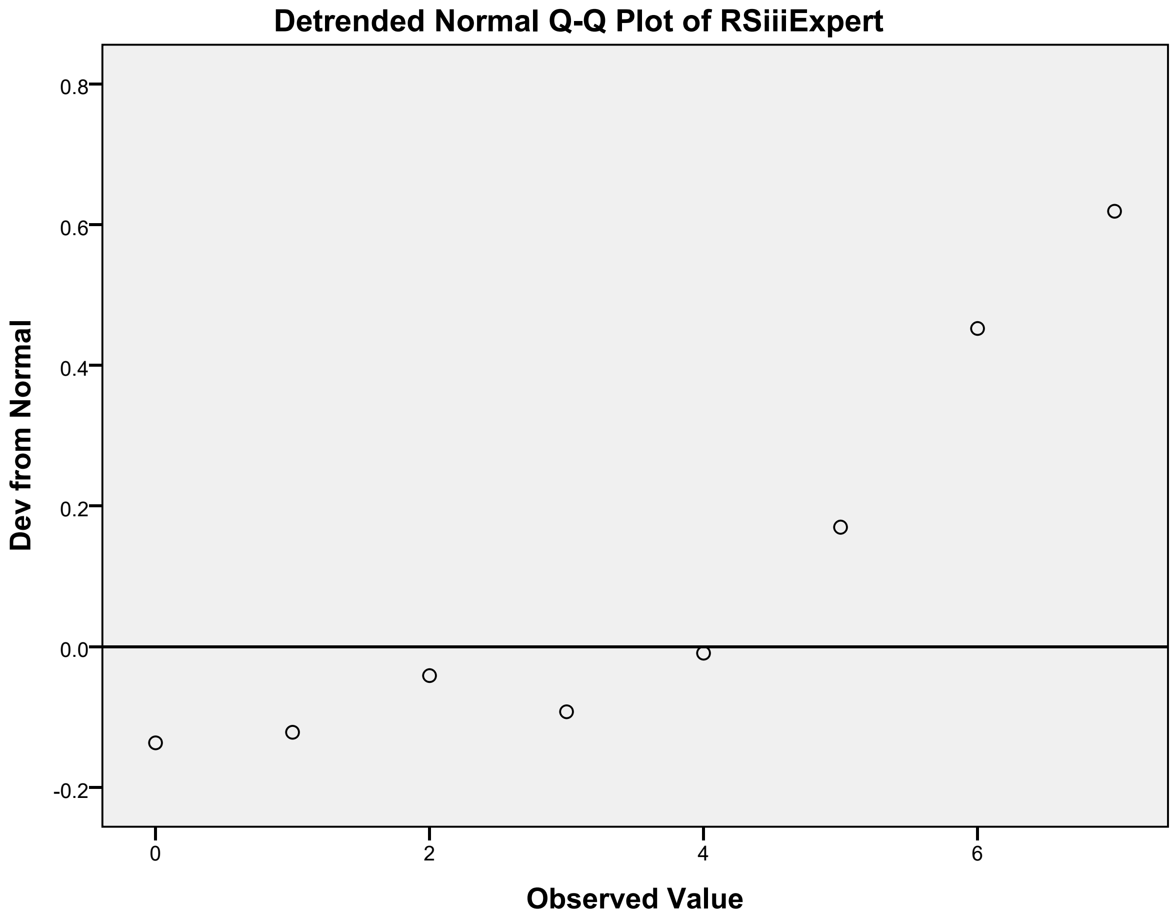
Detrended Normal Q-Q Plot of TacticCounts
Dev from Normal
1.5
1.0
0.5
0.0
-0.5
0
10
20
30
40
50
60
Observed Value

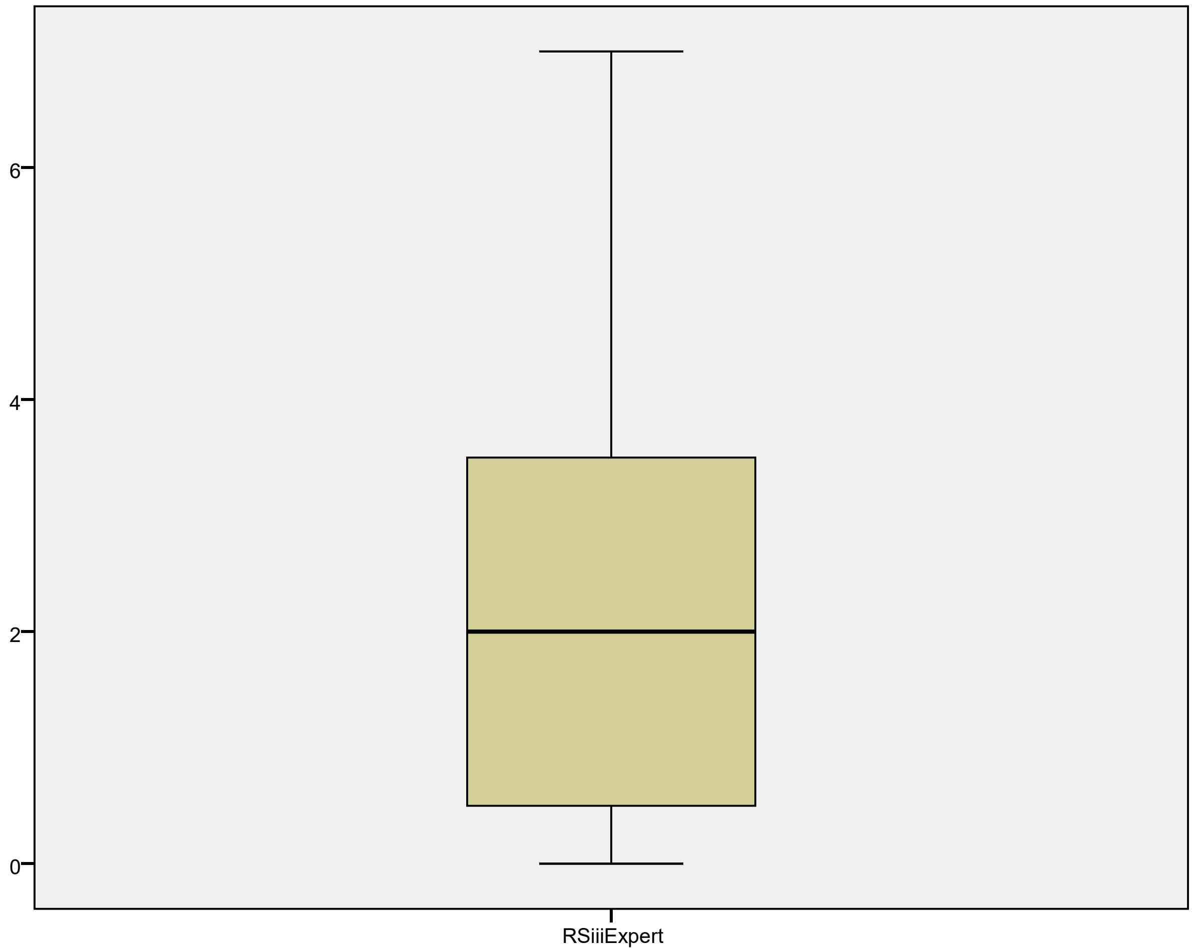


RSiiiExpert


Histogram
Mean = 2.38
Std. Dev. = 1.952
N = 24
Frequency
0
2
4
6
0
2
4
6
RSiiiExpert


Normal Q-Q Plot of RSiiiExpert
Expected Normal
Observed Value
3
2
1
0
-1
-2
-2
0
2
4
6
8


Detrended Normal Q-Q Plot of RSiiiExpert
Dev from Normal
0.8
0.6
0.4
0.2
0.0
-0.2
0
2
4
6
Observed Value


6
4
2
0
RSiiiExpert

FULL TRUTH TABLE

change	settingexample	ownership	budget	statobj	trusting	number	outcomebp	raw consist.	PRI consist.	product
0	0	1	0	0	0	3	0	0	0	0
0	0	1	0	0	1	2	0	0	0	0
0	1	1	0	0	0	2	0	0	0	0
0	0	0	1	1	1	1	0	0	0	0
0	0	1	0	1	0	1	0	0	0	0
0	0	1	1	0	0	1	0	0	0	0
0	0	1	1	0	1	1	0	0	0	0
0	1	1	0	1	0	1	1	1	1	1
0	1	1	0	1	1	1	1	1	1	1
0	1	1	1	0	1	1	1	1	1	1
1	0	0	0	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1	1	1	1
1	0	1	1	1	0	1	1	1	1	1
1	1	0	0	1	0	1	0	0	0	0
1	1	1	0	0	0	1	1	1	1	1
1	1	1	0	0	1	1	1	1	1	1
1	1	1	0	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0				
0	0	0	0	0	1	0				
0	0	0	0	1	0	0				
0	0	0	0	1	1	0				
0	0	0	1	0	0	0				
0	0	0	1	0	1	0				
0	0	0	1	1	0	0				
0	0	1	0	1	1	0				
0	0	1	1	1	0	0				
0	0	1	1	1	1	0				
0	1	0	0	0	0	0				
0	1	0	0	0	1	0				
0	1	0	0	1	0	0				
0	1	0	0	1	1	0				
0	1	0	1	0	0	0				
0	1	0	1	0	1	0				
0	1	0	1	1	0	0				
0	1	0	1	1	1	0				
0	1	1	0	0	1	0				
0	1	1	1	0	0	0				
0	1	1	1	1	0	0				
0	1	1	1	1	1	0				
1	0	0	0	0	1	0				
1	0	0	0	1	0	0				
1	0	0	0	1	1	0				

FULL TRUTH TABLE

change	settingexample	ownership	budget	statobj	trusting	number	outcomebp	raw consist.	PRI consist.	product
1	0	0	1	0	0	0				
1	0	0	1	0	1	0				
1	0	0	1	1	0	0				
1	0	0	1	1	1	0				
1	0	1	0	0	1	0				
1	0	1	0	1	0	0				
1	0	1	0	1	1	0				
1	0	1	1	0	0	0				
1	0	1	1	0	1	0				
1	0	1	1	1	1	0				
1	1	0	0	0	0	0				
1	1	0	0	0	1	0				
1	1	0	0	1	1	0				
1	1	0	1	0	0	0				
1	1	0	1	0	1	0				
1	1	0	1	1	0	0				
1	1	0	1	1	1	0				
1	1	1	0	1	0	0				
1	1	1	1	0	0	0				
1	1	1	1	0	1	0				
1	1	1	1	1	0	0				