Assessing the impact of risk allocation on Sustainable Energy Innovation (SEI): The case of Private Finance Initiative (PFI) school projects

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1. INTRODUCTION

It is inevitable that innovative endeavours will entail a certain amount of risk. Indeed, innovation and risk often go hand-in-hand in construction projects (Raisbeck, 2008; Barlow and Köberle-Gaiser, 2008ab). Risk is defined in the current version of the risk management standard - ISO 31000:2009 as 'the effect of uncertainty on objectives' with uncertainty arising whenever the 'understanding or knowledge of an event, its consequence, or likelihood' is inadequate or incomplete (ISO, 2009). Risk includes both opportunities and threats and therefore can create both positive and negative deviations from the expected (Hillson, 2000). To Berglund and Hellström (2002) 'risk is a factor in all innovative processes in so far as purposeful, goal-directed action is always directed towards an uncertain future with some possible reward' (Berglund and Hellström, 2002, p. 207). The strategies to identify, allocate and manage those risks depend to a great extent on the type of project, the procurement route adopted, and the contractual arrangements between project participants (Osipova and Eriksson, 2011).

The allocation of risk between the contracting parties is often seen as important factor in the creation of innovation success in complex projects (Brady and Davies, 2010; Gil *et al*. 2012; Hobday, 1998; Miller and Lessard, 2000). This is particularly in relation to the great up-front investments required and the high level of uncertainty, and therefore risk, associated with the success of innovation. The management of risk is particularly important for sustainable technologies, as the risks associated with their development and implementation are often seen as major barriers to their successful adoption (Christie *et al*., 2011; Häkkinen and Belloni, 2011).

This study sought to examine the capacity of risk allocation to encourage the implementation of Sustainable Energy Innovation (SEI). SEI is a subset of environmental innovation which has been broadly defined as “novel technological products or solutions that are successfully integrated into buildings’ design strategies in order to prevent or substantially reduce the negative impacts of energy use by increasing energy efficiency, or utilising new ways of renewable energy generation” (Badi and Pryke, 2015, p. 412). This study concentrates on risk allocation within Private Finance Initiative (PFI) project delivery model. The attention given to PFI in this study is driven by the increasing call for greater understanding of contractual drivers of innovation in complex public sector procurement models (Caldwell and Roehrich, 2008; Edelenbos and Teisman, 2008; Roumboutsos and Saussier, 2014).

The study followed a research design based on four qualitative case studies of new-build PFI schools. Our research design emphasises one key unit of analysis: how risk allocation within the PFI contract (as it was adopted within Building Schools for the Future (BSF), a UK school renewal programme) was perceived by private sector actors to influence the energy strategy during the design development stage and how this may have shaped the sustainable energy innovation implemented. Our key contribution is a conceptual understanding of the conditions under which risk allocation can support sustainable energy innovation. Our findings may also lead to a greater awareness of how complex procurement strategies, in the form of PFI, should work to support more innovative activity in the construction industry and to the growth or even creation of markets for innovative sustainable products and services (Erdmenger, 2003).

The paper begins by introducing sustainable energy innovation and explain its importance in addressing the formidable challenges associated with climate change. We then we discuss the concept of risk and how it relates to innovation. We then introduce the study’s proposition suggesting that SEI is supported by clear, appropriate and manageable allocation of the risks associated with the project's energy performance. In the following sections, we describe the methodology and report results from four PFI case studies. In the final section of the paper we discuss the findings and outline the managerial and policy implications.

2. CONCEPTUAL DEVELOPMENT

2.1 Sustainable Energy Innovation (SEI)

The study of innovation dates as far back as 1911, and Joseph Schumpeter's seminal work, 'Theory of Economic Development'. Schumpeter (1980) described innovation as a historic and irreversible change in the way of doing things. The essence of Schumpeter's definition of innovation is that it is an effort made by an entity that results in an economic gain, either by reducing cost or increasing income. Freeman and Soete (1997) defines innovation as "the actual use of a nontrivial change in a process, product or system that is novel to the institution developing the change" (Freeman and Soete, 1997, p. 11). Freeman and Soete's (1997) definition indicates that, to be considered an innovation, the change should be nontrivial, novel, and regarded as a significant improvement to existing products or practices. Innovations are 'incremental' to the extent that they reinforce existing products or processes, and are often based on current knowledge and experience (Slaughter, 1998; Taylor and Levitt, 2004) whilst 'radical' innovations are those producing disruptive changes in a specific field and result from entirely new approaches to understanding and problem-solving (Slaughter, 1998).

Sustainable energy innovation is a particular subset of environmental innovation, which has been broadly defined by Dewick and Miozzo (2002) as the use of production equipment, techniques, procedures, products, and product delivery mechanisms that are sustainable; that is, they conserve resources and energy, minimise environmental impact, and protect the natural environment. Mostly, innovation which has the effect of promoting sustainable energy involves two main strategies: energy efficiency and renewable energy. Energy Efficiency is essentially the reduction of energy inputs for a given level of service, or enhancing the services for a given amount of energy inputs (National Science Foundation, 2009). Increased energy efficiency can lead to decrease in energy costs (for suppliers and consumers), as well as reduction in CO_2 emission levels (National Science Foundation, 2009). Renewable Energy, on the other hand, is defined as ‘a flow of energy that is not exhausted by being used’ (Sørensen, 1991:386). Hence, renewable energy technologies are means by which such flows are converted into applicable devices (Sjöö, 2008). Renewable energy resources include the sun, wind, water currents, the heat of the Earth, and replaceable fuels such as from plants. As well as reducing stratospheric ozone depletion, acid precipitation, and the greenhouse effect, renewable energy resources are considered one of the most efficient and effective solutions (Dincer and Rosen, 2012). Taking the definitions of energy efficiency and renewable energy into consideration, the term SEI is used on this research to represent novel technological products or solutions that are successfully integrated into building’s design strategies in order to prevent or substantially reduce the negative impacts of energy use by increasing energy efficiency, or utilizing new ways of renewable energy generation (Badi and Pryke, 2015).

The focus on SEI in this study is driven by the growing calls around the Globe for sustainable energy and CO_2 emissions reduction (Brundtland, 1987; DEFRA, 2007). Meeting the formidable challenges associated with climate change will demand substantial technical progress to deliver more sustainable energy solutions for societal needs. Among the major strategies advocated by UK government reports to meet these pressing challenges for sustainable energy and CO_2 emission reduction is technological innovation (DTI, 2007; Stern, 2006; Thalmann, 2007). Stern (2006) emphasised the point that policies to encourage innovation and the implementation of low-carbon technologies are central to mitigating climate change. Whilst the call for SEI is evident in the preceding government reports, such innovations are, however, still in their embryonic stages (Bulkeley *et al*. 2013; Kelly, 2008).

2.4. The Private Finance Initiative (PFI)

The Private Finance Initiative (PFI) project delivery model is a specific type of Public Private Partnership (PPP) (HM Treasury, 2003), where a consortium of private sector firms, known as the Project Company (ProjectCo hereafter), assumes responsibility for designing, constructing, financing, and operating an infrastructure facility. The ProjectCo is contracted to provide the public services on a long-term concession period (typically, up to 30 years) with the relevant government body (HM Treasury, 2003). It has been argued that the introduction of PFI into governments' procurement strategies has many benefits. These include control of public sector expenditure to curb inflation, overcoming the scarcity of public funds, and control over the Public Sector Borrowing Requirement - PFI contracts can be treated as 'off balance sheet' (Al-bizri and Gray, 2010; Carbonara *et al.*, 2014; McCabe *et al.*, 2001).

A major characteristic of PPP/PFI projects is the transfer of risk from the public sector to the private sector. Traditionally, construction projects entail the purchase of a product, largely governed by legal contracts, and based on fixed specifications and profit levels. The client assumes most of the risks, though risks related to the project end dates and construction methods are passed down the supply chain (Morris, 2013). A major consideration for the government in introducing PFI was the transfer of risk from the public sector to the private sector in order to introduce more discipline in risk analysis and allocation into public sector procurement (Grimsey and Lewis, 2002; Iossa and Martimort, 2012; Regan *et al.*, 2011). Therefore, appropriate risk transfer is a fundamental requirement for VfM to be achieved in PFI project delivery models. While the contractual liability for a contractor under a traditional procurement contract is limited to a shorter period, usually 12 months, under PFI the contractor is often liable for the delivery of the assets and a wide range of other services for the duration of the service period spanning 25–35 years (Gruneberg *et al.*, 2007; Robinson and Scott, 2008).

2.3 The Management of Risk in Project Environments

Construction project environments are mainly characterised by two types of risk: project-related risk and innovation-related risk (Leiringer, 2006). Project-related risk encompasses a wide range of categories all concerned with the possible events that could endanger the planned course or objectives of the project (HM Treasury, 1997; Grimsey and Lewis, 2002; Rintala, 2004). Innovation-related risk is that faced by the innovating organisation in relation to the extent to which the innovation satisfies various technical criteria without compromising cost or schedule (Keizer and Halman, 2009). This includes a number of unavoidable risks such as technical risk (Unger and Eppinger, 2011), financial risk (Nanda and Rhodes-Kropf, 2014) and capital cost risk (Intrachooto and Horayangkura, 2007). Project- and innovation-related risks are interconnected and largely affect the outcome of the attempt to innovate (Leiringer, 2006).

Risk management is widely considered as one of the most important procedures in the field of project management, principally concerned with realising opportunities and avoiding threats (Royer, 2002; Turner, 2009). Risk management involves four fundamental processes: risk identification, risk assessment, risk allocation and risk mitigation. To be managed appropriately, risk has to be clearly identified (Akintoye *et al.*, 2001). Following the identification of risk, its significance to project outcome needs to be adequately assessed. The risk assessment process may include reviewing, understanding and determining the importance of all the risks that can impact on the project and estimating the likelihood of their occurrence (Chapman and Ward, 2003). The risk impact is often estimated in terms of financial cost or completion time (Loosemore *et al*., 2006; Akintoye *et al.*, 2001). Risk allocation is the third step in the risk management process. Ideally, risk should be assigned to the party that has the greater ability to influence the probability of occurrence or the degree of consequence of the risk and has the best access to suitable mitigation techniques for the risk (Loosemore *et al*., 2006). However, as Chapman and Ward (2003) noted, this is by no means an easy exercise. In some cases the position of risk in not evident, as risks sometimes cross organisational boundaries and cannot be allocated to a single party. Following the allocation of risk, risk mitigation is concerned with the action taken by an actor to reduce the likelihood of a risk occurring as well as limiting the size of the consequence should the risk occur. There are several risk mitigation strategies such as risk avoidance/ elimination, risk reduction, risk transfer, and risk retention/ absorption (Chapman and Ward, 2003). Souitaris (2001) argues that managers of innovative firms are more favourably inclined towards risk acceptance.

2.4 Towards a Proposition: Contractual Risk Allocation, Incentives, and Innovation

In recent years, there has been an increasing amount of literature on the determinants of innovation in both main stream management studies and the specific field of construction research. A wide range of drivers has been identified, such as client requirement and involvement (e.g. Mitropoulos and Tatum, 2000; Ling *et al*., 2007; Pellicer *et al*., 2014), communication and collaboration (e.g. Nam and Tatum, 1989), contractual incentives (e.g. Bossink, 2004; Intrachooto and Horayangkura, 2007), and risk allocation (e.g. Leiringer, 2006) which underline the importance of interdependency and interaction between the different organisations involved within complex projects. Of these issues, only contractual risk allocation is relevant to this research and is reviewed further below.

Contracts are in effect a governance mechanism designed to achieve two main goals: to outline the structure of authority-responsibility, and share risk and reward among project partners (Giannoccaro and Pontrandolfo, 2004; Sen and Mitra, 2000). Contracts are safeguarding instruments against opportunistic behaviour, as they establish clear limits for breach of contractual specifications between clients and producers (Liker and Choi, 2004). In complex projects, contracts governing the relationships between producers and their upstream clients can range from traditional arms-length contracts to close cooperative relationships. Mostly, contractual incentives have their theoretical origin defined in the Principal-Agent Theory (Spence and Zeckhauser, 1971; Ross, 1973). The

Principal-Agent Theory mainly addresses the relationship between two contracting actors—the Principal and the Agent. The theory is primarily concerned with the difficulties that arise under conditions of imperfect and asymmetric information when a Principal appoints an Agent to pursue the Principal's interests. The theory's central assumption is that both actors will pursue their own objectives. Thus, it assumes that the Agent will adopt a strategy with which he will receive the maximum reward for the minimum effort (Milgrom and Roberts, 1992; Douma and Schreuder, 2008). Therefore, incentive-based contracts are designed to align the Agent's objectives with those of the Principal.

Several studies, adopting a system-oriented approach to innovation, have emphasised the importance of risk allocation among the contracting parties in determining innovation success (Hobday, 1998; Miller and Lessard, 2000). This is particularly in relation to the substantial investment required and the high level of uncertainty, and therefore risk, associated with the success of innovation. Thus, Hobday (1998) maintains that contractual incentives are needed for sharing project risks among clients and their producers. Construction-related studies of innovation equally underlined the importance of risk allocation in decision making associated with innovation (Akintoye *et al*., 2001; Loosemore *et al*., 2006; OECD, 2005). In their study of technology adoption decisions in mega infrastructure projects, Gil *et al*. (2012) identify that technological decisions are greatly affected by the project stakeholders' attitude towards risk. Miozzo and Dewick (2002), explored the innovation drivers amongst the largest contractors in Europe, and concluded that innovative activities are often promoted by parties with both the incentive and the ability to allocate resources to investments with uncertain and irreversible outcomes.

Three characteristics of risk allocation are considered important for innovation: clarity, appropriateness and manageability. In his study of technological innovations in PPPs, Leiringer (2006) maintains that greater clarity over the assumed risks, due to more explicit risk transfer under a PPP, might benefit innovative activities as it allows the innovating organisation to make rational decisions. Barlow and Köberle-Gaiser (2008b) also argue that the financial and legal uncertainty faced by the ProjectCo may be reduced by clear allocation of risk. In addition, government guidelines often use the maxim that risk should be allocated to the party best placed to control and manage it (UNIDO, 1996; HM Treasury, 2003). Ideally, risk should be assigned to the party that has the greater ability to influence the probability of occurrence or the degree of consequence of the risk and has the best access to suitable mitigation techniques for the risk (Loosemore *et al*., 2006). However, Thomas *et al*. (2003), in their survey of risk allocation strategies in BOT road projects in India, have found that this principle is rarely observed due to the differences in the perception of risk among the project participants. Ng and Loosemore (2007) also underlined the problems associated with inappropriate risk allocation on PPP projects, such as cost and time overruns and failure to deliver value-for-money objectives. They concluded that the risks allocated should not only be considered clear, but also appropriate and manageable.

Following the arguments above, it can be proposed that:

Clear, appropriate, and manageable allocation of the risks associated with the project's energy performance can support innovative effort in the PFI project delivery model.

The energy performance of buildings is associated with several types of risk such as regulatory, energy consumption and planning approval risks. For the ProjectCo to be innovative, the assumed risks associated with the project's energy performance should be considered clear, appropriate and manageable. Greater clarity over the assumed risks will allow the innovating organisation to make rational decisions, which may benefit innovative activities. Greater appropriateness and manageability will support the equitable allocation of risk among project participants, thus encouraging innovative efforts. In the next section, we describe the methodology adopted to examine the three issues within the context of the UK government Building Schools for the Future' (BSF).

3. METHODS

3.1 Context of the Study

The study focused on schools delivered within the context of the UK government's Building Schools for the Future (BSF) programme. BSF was an immensely ambitious programme designed to rebuild or refurbish all secondary schools in England over 15 years at a cost of £45 billion. As well as being a project to improve radically the fabric of school buildings and transform the educational experiences of pupils, it has been actively seeking to embed sustainability (House of Commons, 2007). The need for SEI in BSF schools was reinforced by the fact that school buildings are responsible for about 2% of greenhouse gases emissions in the UK, the equivalent to 15% of the national public sector emissions (DCSF, 2010). In order to address this challenge, the Department for Children, Schools and Families (DCSF) announced in 2007 that £110 million would be allocated for sustainable school buildings and set the ambitious target that all new-build schools should be 'zero-carbon' by 2016 (DCSF, 2007[i]). The target was subsequently delayed to 2019 to match the EU Energy Performance of Buildings Directive. PFI was the government's preferred project delivery model for 132 new-build BSF schools.

3.2 The Case Studies

A qualitative approach was considered the best-suited for this research, given the exploratory nature of the study (Yin, 2014). Four new-build BSF PFI school projects were selected for investigation following set criteria to ensure comparability and to maximise what could be learned from the study. Three case studies were selected on the grounds that they showed at least one significant SEI (Case Studies 1, 3 and 4), and one case study was selected on the grounds that it showed no evidence of SEI

(Case Study 2). This was pursued to facilitate a heterogeneous sample; the technique also termed 'maximum variation sampling' in qualitative enquiry (Patton, 2005). This enabled the researcher to capture of a wide range of perspectives relating to the conditions under which SEI is implemented, or otherwise, and helped in highlighting common themes that held consistent across the case study projects. Literal replication was sought on the three innovative projects, while theoretical replication was tested on the project where no innovation was implemented (Yin, 2014). Literal replication in a case study, tests precisely the same outcomes, principles, or predictions established by the initial case study. Thus, it must be selected so that it predicts similar results. In contrast, a theoretical replication, is a case study that produces contrasting results but for predictable reasons. Under the development of a conceptual framework, literal replication can explain the conditions under which a particular phenomenon is likely to be found, whereas a theoretical replication can explain the conditions when it is not likely to be found (Yin, 2014)

Identifying projects with evidence of implementing sustainable energy innovation was challenging. Extensive review of the national press and trade journals was undertaken to verify the nature of the solutions implemented and whether or not they could be considered innovative. In addition, so as to confirm the findings arising from the interview data, the case study projects and their innovative solutions were described to an independent heating and ventilation (HV) design expert. This confirmed that the sustainable energy innovations implemented could be considered a novel change from standard practice. Table 1 lists the pseudonym used to represent each of the case study projects and provides a brief outline of the location, value and the main sustainable energy innovations implemented.

********INSERT TABLE 1 ABOUT HERE ********

Furthermore, to control as much as possible for the impact of contextual factors on innovation outcomes, the four case studies were early BSF schemes. This was to ensure that the projects were subjected to the same policy and economic environment, and followed the same BSF documentation and national legislation. This was the case with the first three case studies (Case Studies 1, 2 and 3), which were expected to offer insight into how the BSF PFI project delivery model, as it was during this initial period, influenced the pursuit of innovation for sustainable energy. Case Study 4 further benefited from the introduction of the government's Carbon Funding and was awarded the extra funding of £50/m^2 to meet the operational carbon target of 27Kg CO_2/m^2/yr. This case study may presented a special regulatory context and was included to maximise what could be learned from the research study.

3.3 Data Collection

Data collection for this research study was largely based on primary data, thus data gathered and assembled specifically for the research project at hand (Yin, 2014). The unit of analysis in this research study is the BSF PFI project and the key project actors involved served as the primary sources of data. Data was collected through semi-structured interviews with ProjectCo representatives from each case study. Interviewees included the ProjectCo's Special Purpose Vehicle (SPV) bid managers, architects, M&E engineers, building contractors and facility managers. In total, 26 interviews were conducted. Table 2 outlines the interview participants from each case study.

********INSERT TABLE 2 ABOUT HERE ********

A Case Study Interview Protocol was developed to guide the interview process. Interviewees were asked about their perception of the clarity, appropriateness and manageability of risk allocation associated with the project's energy performance. The developed qualitative definitions of the conceptual constructs are outlined in Table 3.

********INSERT TABLE 3 ABOUT HERE ********

Particularly, the following items were examined:

1. **Clarity of risk allocation:** Participant's perception of the extent to which the allocation of the risks associated with the energy strategy is free from confusion, uncertainty, ambiguity, or doubt.
2. **Appropriateness of risk allocation:** Participant's perception of the extent to which the allocation of the risks associated with the energy strategy is fitting for a particular entity or situation.
3. **Manageability of risk allocation:** Participant's perception of the extent to which the allocation of the risks associated with the energy strategy can be managed or controlled.

All interviews were recorded and later transcribed. Data collection took place between April 2009 and May 2010. Three of the case study projects, i.e. Case Studies 2, 3 and 4, were on-site when the researcher established first contact with the projects. Case Study 1 had been operational for a few months.

3.4 Data Analysis

The analysis of the transcribed interviews started by building chronological stories for each case study, triangulating the interpretations from the multiple ProjectCo respondents. Within-case analysis was then conducted using tabular displays to cluster and process the interview data. The within-case analysis helped to develop preliminary understanding of the main issues affecting risk allocation and innovation across the interdependent actors. Cross-case comparative analysis was then conducted using tabular displays as shown in Table 4 which helped identify the main issues that would hold consistently across the units of analysis. In addition, cross-case analysis follows the advice of Yin (2014) in adopting an analytical strategy based on literal and theoretical replication. In this research study we aimed for literal replication between three innovative cases (Case Studies 1, 3 and 4) and theoretical replication in the case where no innovation was implemented (Case Study 2).

********INSERT TABLE 4 ABOUT HERE ********

4. FINDINGS

The findings indicate that the energy strategies developed on the four case study projects were influenced by the allocation of two types of risk to ProjectCo actors: project-related risk, and innovation-related risk. Project risks, as they relate to the energy strategy, are those assumed by ProjectCo actors in relation to the project meeting agreed environmental and energy performance standards. Innovation-related risks are those assumed by the innovating organisation in relation to the extent to which the innovation satisfies various technical criteria without compromising the project's budget and schedule. The interplay between those two types of risk shaped the energy strategies and the innovations implemented on the case study projects. Figure 1 outlines the main identified risks associated with the energy strategy, while Table 5 provides brief definitions of the main risks involved and the parties to whom the risks are allocated under the BSF PFI contract. The findings are presented under three headings: (1) clarity of risk allocation; (2) appropriateness of risk allocation; and (3) manageability of risk allocation.

********INSERT FIGURE 1 ABOUT HERE ********

********INSERT TABLE 5 ABOUT HERE ********

4.1. Clarity of Risk Allocation

In the literature, greater clarity of risk allocation is seen to reduce the financial and legal uncertainty faced by the innovating organisation and support rational decision making, which may benefit innovation (Barlow and Köberle-Gaiser, 2008b; Leiringer, 2006). ProjectCo actors on the innovative projects agreed that the risks associated with the project's energy performance were generally made clear early in BSF documentation. This potentially benefitted innovation efforts. However, the situation was different on SVC (Case Study 2), the project where no innovation was implemented. The building contractor lacked adequate understanding of the BREEAM 'Excellent' requirement[ii] and its implications on the project's costs and time constraints. Indeed, post financial close, as there were penalties associated with meeting the requirement, the amount of time and resources needed to achieve it was a considerable challenge to the building contractor. This lack of understanding was explained by the newness of the requirement itself to the building contractor. As the project was the first BSF project to the building contractor, the environmental requirements associated with it, including BREEAM, were clearly underestimated. The requirement was eventually met but at a considerable cost, in terms of time and resources. The newness of some environmental requirements to firms, such as BREEAM, demands sufficient assessment of their impact on the planned course and objectives of the project. Without such assessment, it is likely that adequate understanding of what is needed to deliver the requirements, and manage the associated risks, will be weak.

4.2. Appropriateness of Risk Allocation

Most government guidelines advocate that risk should be allocated to the party best placed to control and manage it (HM Treasury, 2003; UNIDO, 1996). Blayse and Manley (2004) and Leiringer (2006) also stress the need for equitable allocation of risk among project participants. ProjectCo actors across the four case studies perceived the risks associated with the project's energy performance to be mostly appropriately allocated. However, concerns were raised with regards to the building contractor assuming the initial energy consumption risk. This was explained by the difficulty to accurately predict energy consumption targets during the design process; the long period of time buildings need to settle into their natural level of performance; and the significant influence of end-user behaviour on energy consumption as opposed to the actual building itself. In addition, the government's carbon target of 27kg $CO_2/m^2/yr$ was seen to be onerous and difficult to completely close down. The success of any mitigation strategy was seen to be difficult to predict and can only be clear after the building is operational for a period of time. This perceived inappropriateness of risk allocation is potentially damaging as the OECD (2005) considers excessive perceived risk as one of the main barriers to innovation.

Furthermore, an important issue that was highlighted by ProjectCo actors across the four case studies was the conflicting environmental requirements that needed to be met under the BSF PFI contract. The ProjectCo was required to balance the 'Availability Clause' which requires teaching spaces not to exceed 28°C for more than 120 hr/yr during core summer hours, whilst meeting agreed standards for maximum annual energy consumption in the PFI contract. The strategies adopted to achieve these conflicting requirements were mainly to reduce the demand for the energy required to cool those spaces through passive design principles, whilst maintaining the efficiency of the supply as much as possible. However, ProjectCo actors across the four case studies argued that the Availability Clause and temperature tolerances forming part of its criteria were potentially harmful to the energy efficiency and CO_2 reduction objectives. Excessive perceived availability risk may force contractors to install carbon-intensive technologies, such as heating, ventilation, and air conditioning systems (HVAC), to ensure teaching spaces do not exceed 28°C and safeguard their long-term investment in the project. This is particularly detrimental in situations where penalties for non-availability considerably exceed penalties for not meeting annual energy consumption targets. Indeed, it can be argued that the temperature tolerances forming part of the Availability Clause may represent a considerable challenge to achieving the government's target of zero-carbon schools by 2019 through PFI contracts.

4.3. Manageability of Risk Allocation

The manageability of the risks allocated to ProjectCo actors was an important criterion across the case study projects. Importantly, the allocation of several types of risk to ProjectCo actors was found to have encouraged the pursuit of sustainable energy innovation as the innovations implemented were largely developed as strategies to manage several types of risk allocated to ProjectCo actors. This will be discussed below:

- Perceived availability risk was a major consideration across the three innovative projects. Not meeting the availability criteria exposes the ProjectCo to payment deductions as part of performance monitoring linked to the Payment Mechanism. Availability risk was particularly a major consideration on BEC (Case Study 1), where the risks associated with the availability criteria were identified, evaluated, and the related financial penalties were deemed significant enough to influence the design process. The risk-averse attitude of the ProjectCo and its desire to protect its investment in the long-term resulted in setting challenging environmental targets for the design team to meet. In order to reach an extremely robust and safe design, teaching spaces were designed so as not to exceed 28°C for more than 20 hr/per year rather than the allowed 120 hr/yr under the BSF PFI contract. This was a highly ambitious target at the time and was pushing the boundaries of what could be achieved for sustainability. The design team needed to meet the target, whilst maintaining agreed standards for maximum annual energy consumption in the PFI contract. The target led to the development of the innovative ventilation chimney which ensured excellent air flow across the classrooms, minimising the need for mechanical ventilation and significantly reducing energy consumption during operation.

- Perceived energy consumption risk was a major consideration across the three innovative projects. Not meeting energy consumption targets exposes the ProjectCo to payment deductions as part of performance monitoring linked to the Payment Mechanism. On HGS (Case Study 3), energy consumption risk was particularly a major consideration. The design team was presented with challenging site constraints, mainly the adjacency of the site to a busy emergency route, which meant that 70% of the building needed to be mechanically ventilated. The team evaluated several energy strategies in order to increase the likelihood of meeting the energy consumption targets, while providing an internal environment comfortable to the school. The strategy adopted was to minimise the demand for energy, by increasing the building's thermal mass and improving air leakage rates and U-values, as well as maintaining the efficiency of the supply as much as possible. The innovative energy supply strategy was a new combination of best available sustainable technologies in the market (mini-Combined Heat and Power Plant, Ground Source Heat Pump, Earth Tubes, and mini-Wind Turbine) to spread the risk across several technologies, energy providers, and users within the school.

- Perceived operational carbon target risk encouraged the pursuit of innovation on BWS (Case Study 4). BWS was among the first BSF schools to bid for and be successfully awarded the DCSF additional funding of £50/m² to achieve the challenging target of 60% reduction in carbon emission (compared to a school being constructed to the energy efficiency standards set out in the 2002 Part L Building Regulation). The target was translated into an operational carbon target of no more than 27kg $CO_2/m^2/yr$ emission during core hours, which is a contractually binding operational obligation placed on the building contractor and linked to the payment mechanism. The innovative biodiesel Combined Heat and Power (CHP) solution was implemented to ensure that the building meets this operational target, significantly reducing the school's dependence on electricity from the national grid.

Two key observations could be made from the above findings. First, the allocation of long-term energy performance risks to ProjectCo actors was successful in encouraging sustainable energy innovation. On PFI projects, the two specific mechanisms the Local Authority used to achieve this risk allocation are the Output Specification and the Payment Mechanism (Rintala, 2004). As the Local Authority cannot readily measure the amount of resources the ProjectCo requires producing the service, it heavily relies on measuring the output of the service provision and linking the Unitary Payment the SPV will receive from the Local Authority for providing the service to that output (Douma and Schreuder, 2008; Grout and Stevens, 2003). In the case of the building's energy performance, the Local Authority measures the energy consumption of the building, and links the Unitary Payment to that performance. Not meeting energy consumption and CO_2 targets exposes the ProjectCos to payment deductions as part of performance monitoring linked to the Payment Mechanism. Therefore, the ProjectCo is incentivised to avoid penalties for non-compliance and are, thus, likely to ensure that the building meets agreed energy performance standards. This study finding provides empirical evidence to the importance of risk allocation as a driver for sustainability innovation. Indeed, our findings suggest that contract practices that allocate long-term energy performance risks to private sector actors may support innovation effort. Innovations for energy efficiency are directly linked to the ProjectCo future revenue as a result of the ProjectCo responsibility for meeting agreed energy consumption and CO_2 emission targets in the duration of the concession period. Energy efficiency also implies future financial savings and returns by reducing the cost of building operation. Therefore, sustainable energy innovations are directly linked to the long-term profitability of the ProjectCo and are, thus, favourably perceived.

Second, ProjectCo actors on the three innovative projects were inevitably faced with innovation risks that needed to be managed. The findings underlined several strategies adopted by ProjectCo actors to manage those risks. Technical risks arising from innovation were managed across the multiple case studies by improving the technical knowledge base of the team. The experienced design teams of

BEC (Case Study 1) and HGS (Case Study 2) as well as the appointment of an energy consultant on BWS (Case Study 3) provided assurance to the ProjectCo that the developed innovations were well-resourced. Therefore, the development of sustainable energy innovation in our case studies required sufficient technical and sustainability knowledge within the team for the ProjectCo to innovate successfully. In addition, the findings highlighted that the innovations implemented were closely following best practice. The chimney design in BEC (Case Study 1) was a combination of tried and tested technologies. HGS's (Case Study 3) energy supply strategy was based on a new combination of best available technologies. BWS's (Case Study 4) Biodiesel CHP plant, although new in UK school buildings, was a well-known technology and was purchased from an established German manufacturer. In all three case studies there was existing evidence to suggest that these technologies could be successfully implemented. Reliability of the technology was an important criterion as it reduced the uncertainty associated with the innovation and provided further assurance to the ProjectCo. Indeed, as our study suggests, the nature of the PFI contract often drives ProjectCo actors to adopt tried and tested technologies in order to minimise their risk exposure. Therefore, it can be argued that innovation for sustainable energy within PFI projects are more likely to be incremental (Lutzenhiser and Biggart, 2003; Slaughter, 1998) and exploitative (Holmqvist, 2004; March, 1991) rather than radical (Slaughter, 1998) or explorative (Holmqvist, 2004; March, 1991). However, this bias towards incremental innovation may weaken the capacity of PFI contracts to deliver the government's zero-carbon objectives as more radical and system innovations are required to deliver such significant reductions in carbon emissions (Enkvist *et al*., 2008; Huesemen, 2003).

Finally, the findings call attention to the negative effect of excessive perceived capital cost risk on the adoption of high-cost technologies with extended payback periods. Across the four case studies, the long-term commitment of the ProjectCos to the projects did not justify investment in high-cost technologies because payback periods were equally important. Being in a competitive bidding process, affordability was also a major consideration. In fact, the biggest challenge for sustainability was seen to be cost and trying to achieve it within the allocated 'Financial Envelope'. The study findings suggest that the need for the ProjectCo to reduce costs to match the approved affordability limits established by the Public Sector Comparator (PSC) could result in low levels of sustainability innovation on PFI projects. The limitations brought in by perceived capital cost risk is particularly damaging to sustainable energy innovation as the nature of the technology requires additional upfront cost and design time to develop energy-efficient buildings. Therefore, the limited acknowledgment of the need for such initial investment within BSF is potentially detrimental to innovation efforts.

7. CONCLUSION

Innovation and risk go hand in hand in complex projects. The purpose of this study was to examine the influence of risk allocation on sustainable energy innovation within the context of the PFI project delivery model. The study responds to an important gap in knowledge as there has been no attempt to explore the relationship between PFI and sustainability innovation, including those for sustainable energy. Therefore, the descriptive case studies, and their subsequent analysis and findings should prove valuable to both public and private sector actors interested in the delivery of sustainable buildings, not only within BSF but for the PFI sector at large.

The study of four new-build BSF PFI school projects provided compelling evidence to the importance of greater clarity, appropriateness and manageability of energy-related risks in order to support sustainable energy innovation. In fact, the main sustainable energy innovations were largely in order to manage long-term energy performance risks allocated to ProjectCo actors and safeguard their long-term commitment to the project. In addition, the study drew attention to the incremental nature of the innovations implemented. Indeed, reliability of the technology was an important criterion and the nature of risk allocation in the PFI contract forces private sector actors to adopt tried and tested technologies in order to reduce their risk exposure. However, this preference to incremental innovation weakens the capacity of PFI contracts to deliver the government's zero-carbon objectives as more radical and system innovations are needed to meet such significant reductions in carbon emissions (Enkvist *et al*., 2008; Huesemenn, 2003).

The study may have several important implications for policy makers and public authorities concerned with the procurement of public sector assets. Importantly, the research study highlights the importance of appropriate risk allocation on PFI projects. The allocation of long-term energy performance risks to ProjectCo actors was underlined as a successful contractual arrangement in providing the ProjectCo with the incentive to improve the energy performance of the project. However, risk management should not stop at this point. Demaid and Quintas (2006) emphasized the need for formal procedures for risk management to be built into the management processes for major projects to allow sustainability issues to be integrated into core procedures, rather than being considered as additional, secondary constraints. In the case of PFI projects, efforts to address the conflicting requirements placed on the ProjectCo and to reduce the perceived limitations of other risks, such as capital cost risk, may work to induce further innovation for sustainable energy.

The study also called attention to the detrimental impact of perceived capital cost risk as a major inhibitor for innovation. This accentuate the need for the sustainable energy requirement to be clearly reflected in the Public Sector Comparator (PSC). Our findings indicate that many of the conflicts of interest among the different parties on PFI project arrangement would be reconciled if there was more specific funding channelled toward integrating sustainable energy innovations. Indeed, the method by which the PSC is calculated is crucial if sustainable buildings are to be delivered through PFI. For example, if the PSC has considered the fact that the scheme must produce 20% of its own energy on site from renewable sources; the ProjectCo would have the incentive to include it in their proposals. Akintoye *et al*. (2003) equally emphasise that 'best value' in the VfM assessment should take into account wider policy objectives. It can thus be argued that delivering the Local Authority's sustainable energy objectives can form an important assessment of 'best value' in the PSC's VfM assessment. Therefore, a vital aspect to obtain more sustainability in PFI would be to build more sustainable features into the PSC model. In fact, failing to build sustainable energy into the PSC may result in sustainable energy innovations being abandoned as being ‘unaffordable’.

The study has stimulated a number of research questions in need of further investigation. First, the examined risks associated with the energy strategy are mostly project-related risks that affect the realisation of the project objectives; how these risks may translate into business risks for the risk-taker, such as uncertainty in profits, threat of loss or business failure, is a research area worthy of future exploration. In addition, an important issue in the achievement of sustainable energy that was beyond the scope of this research is whether a sustainable school building produces the desired effect, i.e. sustainable behaviour in end-use. Future research could build on this study’s findings and further explore PFI school projects in their operational stages. An interesting research question would be whether the espoused sustainable energy design objectives correlated with experienced sustainable energy performance in operation. Future research could also focus on how risk allocation through the output specification, payment mechanism and performance-monitoring mechanisms work together during the operational stages of PFI projects to ensure that the schools remain energy-efficient during operation.

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Figure 1: Main identified risks associated with the energy strategy

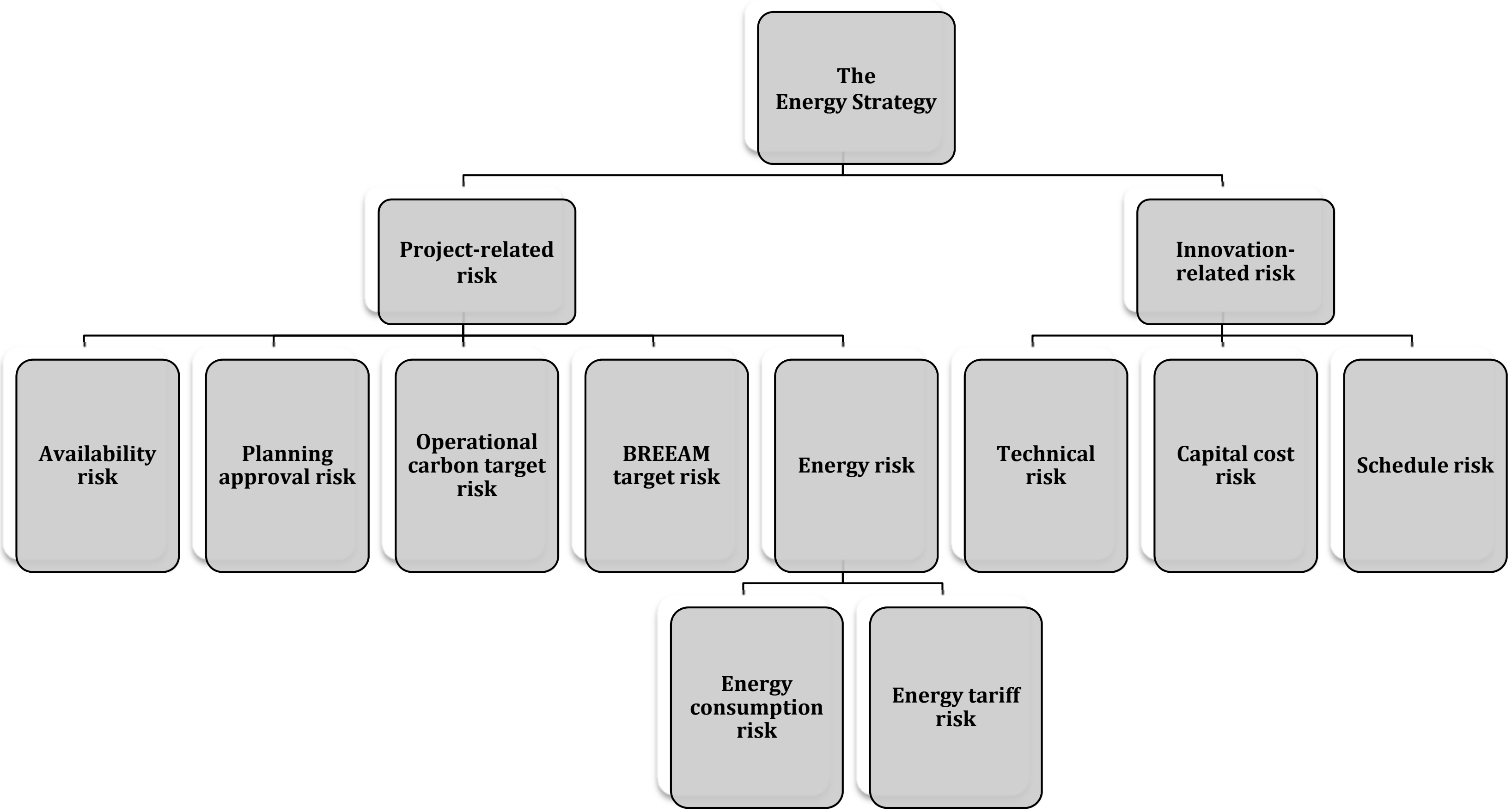

Table 1: The case Studies

Case Study	pseudonym	Location	Value (£)	Main SEI(s) Implemented
1	BEC	South West	£34m	The design utilises an innovative ventilation chimney in every classroom. The innovative chimneys provide outstanding cross air flow across the classrooms, minimising the need for mechanical ventilation. The school design achieved 40% reduction in CO_2 emission against Part L 2002 Building Regulation.
2	SVC	East Midlands	£21.5m	No SEI was implemented.
3	HGS	South East	£30m	The design adopts an innovative sustainable energy supply strategy utilising high-end technologies (mini-Combined Heat and Power Plant, Ground Source Heat Pump, Earth Tubes, and mini-Wind Turbine) to offset and reduce carbon emissions and provide micro-generation. This led to a 61% reduction in CO_2 emissions against Part L 2002 Building Regulation and 25.3% reduction against Part L 2006 Building Regulation.
4	BWS	East Midlands	£20m	The design is based on an innovative energy supply solution with an Energy Centre housing a biodiesel Combined Heat and Power (CHP) plant, the first to be implemented in a school in Britain. The CHP plant provided heating and electricity. It also substantially offset the demand for grid energy, leading to a dramatic CO_2 reduction of 60% against Part L 2002 Building Regulation.

Table 2: Case Study Participants

Team	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Bid Management Team	Bid Manager	Bid Manager	Assistant Bid Manager Whole Life Cost Director	Bid Director
Architect	Project Director (Principal Architect) Project Director (Development Architect)	Project Director 1 Project Director 2	Project Director	Project Architect
M&E Engineer	Project Leader Project Engineer	Project Engineer	Project Engineer	Project Engineer
Building Contractor	Design Manager	Operations Manager	Operations Manager	Operations Manager Education Director
Facility Manager	General Manager	Design Co-ordinator	Operations Manager	Contract Manager
Energy Consultant	-	-	-	Project Manager

Table 3: Qualitative measurement of conceptual constructs

Concept	Key Construct(s)	Measurement	Corresponding Interview Question(s)
Risk allocation	(1) Clarity of risk allocation	Participant's perception of the extent to which the allocation of the risks associated with the energy strategy is free from confusion, uncertainty, ambiguity, or doubt.	How clear was the allocation of the risks associated with the energy strategy on this project?
	(2) Appropriateness of risk allocation	Participant's perception of the extent to which the allocation of the risks associated with the energy strategy is fitting for a particular entity or situation.	In your opinion, was the allocation of the risks associated with the energy strategy appropriate? What, if any, risks were non-negotiable? Were there any specific risks associated with the energy strategy that should have been allocated differently? Do you think that the affected actors were/are clear over the risks that they were taking on?
	(3) Manageability of risk allocation	Participant's perception of the extent to which the allocation of the risks associated with the energy strategy can be managed or controlled.	In your opinion was the risk allocated to your organisation manageable? What were the most probable risks to materialise for your organisation? How did the innovation influence these probabilities? What were the most probable risks to materialise for the project as a whole? How did the innovation influence these probabilities? What were the most significant risks for your organisation should they materialise? When were you clear that you had to take those risks? How did the innovation impact (positive or negative) on the way you handled these risks?

Table 4: Risk allocation and implication for sustainable energy innovation: summary of key findings

Key Constructs	Emergent Issues	Case study 1 Findings	Case study 2 Findings	Case study 3 Findings	Case study 4 Findings
Clarity of risk allocation	Clarity of Energy-related Risks	Risk allocation clear on BSF documentation (+)	Building Contractor's limited understanding and assessment of BREEAM risk complicated design process (-)	Risk allocation clear on BSF documentation (+)	Risk allocation clear on BSF documentation (+)
Appropriateness of risk allocation	Appropriateness of Energy-related Risks	Risk allocation fair and acceptable (+) Conflicting requirements and excessive perceived availability risk damaging to energy efficiency (-)	Risk allocation fair and acceptable (+)	Risk allocation fair and acceptable (+) Allocation of initial carbon target risk to Building Contractor seen by ProjectCo WLC Director to be somewhat unfair (-)	Risk allocation fair and acceptable (+) The 27kg $CO_2/m^2/yr$ target seen by Education Director to be onerous and difficult to close out (-)
Manageability of risk allocation	The Management of Energy-related Risks as a Driver for SEI	Availability risk was main driver for innovative chimney design (+)	-	Energy consumption risk, availability risk and planning approval risk drove innovative design (+)	Operational carbon target risk main driver for innovative CHP solution (+)
	Strategies to Manage Innovation-related Risks	Perceived technical risk managed by undertaking numerous prototyping and simulation tests Chimney design not to be 'too experimental' to safeguard investment and long-term commitment to project Chimney design predominantly new combination of tried and tested technologies	-	Energy simulation models were critical to ensure targets are met and minimise risk Perceived planning approval risk managed by discussions with planners Innovation is new combination of best available technologies in market	Technical risk managed by appointing an Energy Consultant Bid Director was instrumental in overcoming resistance to innovation Innovation not necessarily 'risk-taking' and CHP purchased from well-known manufacturer Perceived planning approval risk managed by discussions with planners
	Unmanageability of Innovation-related Risks as Barrier to Innovation	Perceived technical risks led to adoption of a new combination of well-known technologies (-) Perceived capital cost risk inhibited adoption of high-cost technologies with long payback periods (-) Perceived planning approval risk restricted installation of a wind turbine (-)	Perceived technical risks led to adoption of safe and robust technology (a biomass boiler) (-) Perceived capital cost risk inhibited adoption of high-cost technologies (-) Perceived planning approval risk restricted adoption of a wind turbine (-)	Perceived capital cost risk inhibited adoption of high-cost technologies with long payback periods (-) Perceived off-take and construction risks associated with energy supply networks restricted their development (-)	Perceived capital cost risk inhibited adoption of high-cost technologies with long payback periods (-)

Note: (+) indicate that the issue has a positive effect on construct, (-) indicate that the issue has negative effect on construct.

Table 5: Main identified risks and the party assuming the risk

Risk	Definition	Risk Allocation
Project-related risks:		
Availability risk	The risk that the building's environment fails to meet agreed environmental criteria and, thus, incurring availability penalties.	ProjectCo SPV
Energy risk	Energy Consumption Risk: the risk that the building's operational energy consumption is beyond agreed standards for maximum annual energy consumption in the contract.	ProjectCo SPV/ FM
	Energy Tariff Risk: the risk of fluctuations in the market price of energy.	ProjectCo SPV/ FM for the first three years. Subsequently retained by the Local Authority
BREEAM target risk	The risk that the building fails to achieve the BREEAM target and, hence, incurring penalties.	Building Contractor
Operational carbon target risk	The risk that the building fails to meet the operational carbon target of 27kg $CO_2/m^2/yr$ and, hence, incurring penalties.	Building Contractor
Planning approval risk	The risk that the building specification/energy strategy adopted fails to achieve the terms of planning permission.	Building Contractor
Innovation-related risks:		
Technical risk	The risk that the innovative solution adopted fails to meet technical criteria set by the innovating organisation and/or the contract.	The innovating organisation
Capital cost risk	The risk that the innovative solution adopted fails to meet project budget and, hence, rejected as being unaffordable.	The innovating organisation
Schedule risk	The risk that the innovative solution adopted fails to be delivered to schedule.	The innovating organisation

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[i] In the DCSF (2010) Report 'Road to Zero-Carbon, Final Report of the Zero-Carbon Task Force', a 'zero carbon' building was defined as that with "a net zero carbon emissions over the course of a year [..] after taking into account (a) energy consumption and related CO2 emissions of the fixed building services (i.e. heating, ventilation, hot water, lighting, and appliances) and (b) energy exports and imports from the development (and directly connected energy installations) to and from centralised energy networks". However, this definition is yet to be finalized, according to the UK Green Building Council Task Group report (2014) titled: 'Building Zero Carbon – the case for action'.

[ii] BREEAM 'Building Research Establishment Environmental Assessment Method' is used in the measurement and labelling of a building's environmental performance. It sets the standards for best practice in building design, specification, construction and use. The measures evaluate performance against a wide range of environmental and sustainability issues and consequently provide an environmental label for the building in a scale of 'Pass', 'Good', 'Very Good', 'Excellent' and 'Outstanding'. In our four case studies, the client requirement for Case Study 1, as specified in the output specification, was to achieve BREEAM for Schools' 'Very Good', while the other three schools were delivered to a requirement of 'Excellent' BREEAM rating.