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FM, Risk and Climate Change Adaptation

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ABSTRACT

Improving the sustainability of built assets in the light of uncertain futures is a major challenge facing the Facilities Management profession. A changing climate poses significant challenges to the performance of built assets in-use and could potentially render many built assets prematurely obsolete. How business clients plan for such changes formed the focus of a research project undertaken by the authors. This paper presents the findings of a 12 month Action Research project that sought to identify the impact of future climate change on the performance of a new £75m education building over the first 60 years of operation. The Action Research project involved a series of meetings and workshops between the building's design team (Architects, Engineers and Cost Consultants) and the Client's Facilities Management Department where the impact that a range of future weather scenarios could have on the buildings performance in-use were evaluated. Technical and operational adaptation solutions were developed for those scenarios that were deemed 'high impact' and selected interventions were integrated into the building life cycle as pro-active adaptation steps in the built asset management plan. This paper will describe the adaptation framework used to inform the development of the various scenarios/adaptation solutions and discuss the role of the Facilities Manager in the process. The paper concludes that the presence of the Facilities Management Department in the design team was critical to the development of viable climate change adaptation solutions.

Keywords

Risk, Adaptation, Climate Change, Resilience, Facilities Management

1. INTRODUCTION

There is a tendency in the construction industry to design and deliver new buildings based around the requirements of the 'here and now'. However, buildings are developed on a design life of 60 years plus and clients' needs from their buildings will change over time. Failure to address this issue places the building at risk of premature obsolescence (Jones, 2002). Whilst

this issue has been known for many years, it is compounded by the potential impact of climate change on the physical performance of buildings in-use, and in particular the need for building owners to consider how they might adapt their buildings to different future weather patterns. These concerns are in turn being relayed to design teams who are increasingly under pressure to consider the implications of their design decisions through the whole-life of a building. This paper presents the findings from an Action Research project that used an adaptation framework, supported by future scenarios and back-casting, to inform the development and evaluation of adaptation solutions as part of the built asset management process.

2. BACKGROUND

There is broad scientific consensus that the global climate is changing in ways that will have a profound impact on both human society and the built environment. In addition to average global temperature rise, the frequency and severity of extreme weather events are expected to increase (IPCC, 2007) and impact on the performance of buildings in-use (Jones, 2002). In response to climate change, the UK has implemented The Climate Change Act UK (2008), setting legally binding targets for the reduction of greenhouse gasses by 2050. However, even if the rest of the world follow suit, and the targets are met, there will still be a need to adapt to the consequences of inevitable climate change brought about by current Greenhouse Gas levels. Whilst adaptation does not solely affect the built environment, it does pose a major challenge to those responsible for its operation and renewal. Indeed failure to adapt buildings to climate change could render many prematurely obsolete (Jones, 2002). The challenge facing Facilities Managers is to recognise the potential impact of climate change on their built assets and develop adaptation solutions that ensure the assets continue to perform their required function. However, current approaches to asset management rarely address this issue.

Over the last decade, the UK has experienced significant increases in extreme weather events (EWEs). Heavy rainfall (Fowler & Kilsby, 2003) resulting in both localised urban flooding and more widespread fluvial flooding resulted in £500M worth of insurance claims in the UK in 2000 (RMS, 2000) and £2.2 billion in 2004 (OST, 2004). In addition to flooding the incidence of heat waves (Good et al, 2006) and associated droughts (Blenkinsop & Fowler, 2007) have increased with, in August 2003 over 2000 premature deaths being attributed to the heat wave in southern England alone (Kovats et al, 2006). As a consequence the UK Government established the Adaptation Sub-committee to undertake a UK climate change risk assessment and develop an adaptation programme for England (ASC, 2009). In an assessment of the preparedness of the UK for flooding the Committee identified the need for greater uptake of property-level measures to protect against floods both for new and existing buildings. However, the requirement to consider these issues only applies where development is planned in an existing flood plain, even though the report identified pluvial flooding as a significant problem for the future (ASC, 2012). Thus, given the risks, how should building clients address this issue?

The ability to effectively respond to an EWE depends upon the vulnerability, resilience and adaptive capacity of the building under threat. Whilst there is considerable debate over the precise definitions of the terminology (Gallopín, 2006), from a built environment perspective: vulnerability is normally considered to be the likelihood of exposure to hazards (EWEs) and the adverse consequences resulting from them; resilience, as the ability of the building to

prevent, withstand and recover from the impacts of the hazard; and adaptive capacity, as the ability of the building to change (adapt) to meet the new conditions brought about by any permanent changes to the original operating conditions (Jones & Few, 2009). However, organisations find it difficult to recognise their vulnerabilities let alone assess the resilience of their buildings and develop adaptation solutions to address them (Berkhout, 2004). Organisations need to consider the likelihood of an EWE occurring and the impact that it could have if it does occur. Also, hazards need to be interpreted relative to a frame of reference that the individual and business can relate to and solutions need to be measurable against clear operational indicators.

Assessing the impacts of hazards on an organisation normally involves the assessment of the risk of an event occurring and the development of contingency plans to deal with the consequences. Whilst risk based assessments are not new to Facilities Managers, using them as part of future climate change scenario planning is. Whilst generic climate change risk assessment models have been developed (Willows & Connell, 2003; UKCIP, 2008; Sustainable Homes, 2012) they are primarily awareness tools that assess whether a management action has been taken, rather than providing practical guidance on how to assess vulnerability, resilience and adaptive capacity. This paper addresses this shortcoming by describing the development of a series of practical steps that can be used to ensure that new buildings are designed in a way that allows for future adaptation to climate change.

3. A CLIMATE CHANGE ADAPTATION FRAMEWORK

There are a number of risk models (UKCIP, 2010; BCI, 2007) currently available to assess vulnerability, resilience and adaptive capacity to EWEs. Whilst each model addresses the problems of risk in slightly different ways, they all follow the same generic methodology. An initial scoping exercise contextualises the system being studied and identifies system boundaries. Once the system boundaries are established, the types of risk (what is at risk, whom is at risk, the causes of the risk, the impacts of the risk, and the threshold levels at which the risk becomes unacceptable) that can affect the system are identified. For each identified risk, a risk appraisal is undertaken where the consequences of the threshold being exceeded are examined and strategies for managing the consequences considered. This process invariably involves the use of scenarios to both identify the potential consequences and evaluate alternative management strategies. Once the risk appraisal is complete, a risk evaluation takes place where the various options are prioritised. Finally the highest priority options are instigated and their performance is monitored. Unfortunately, whilst this generic approach to risk assessment is fairly well understood, its application, particularly in the UK, is patchy and its use at the design phase of new buildings is largely missing. In this paper the generic approach is combined with future climate change scenarios to develop an adaptation framework for assessing the impact of EWEs on the performance of existing buildings and integrating this into the built asset life cycle (Figure 1).

The first Stage of the framework establishes the impact of antecedent EWE hazards on the inherent vulnerability of the building. This should ensure acceptance of the risks by the organisation as they will have first-hand knowledge of the impacts. The second Stage of the model extends the range of EWEs to take into account the impact of future climate change on the type, nature and intensity of events. This phase inevitably involves the use of future scenarios to develop a range of weather patterns that can be superimposed onto the building and its surrounding area to allow specific hazard impacts to be developed for each scenario (e.g. flooding, etc.). These impacts can then be related in relative terms to the antecedent

assessments carried out in Stage 1. In this way stakeholders can assess the relative significance of an EWE scenario against a frame of reference that they are familiar with. Once the currency of the scenarios has been established, the impacts of each EWE on the building can be assessed and those components which are highly vulnerable and have low inherent resilience (coping capacity) can be identified. For each of these components adaptations can be developed, either to reduce the vulnerability of the components or improve coping capacity. These can then be prioritised and introduced into the design, at either the initial design phase, or where the impact is expected to be delayed (e.g. not expected to occur until 20 years into the life cycle), as part of the built asset management plan. The operationalization of the adaptation framework model and its ability to integrate effectively with the building life cycle was examined in this study.

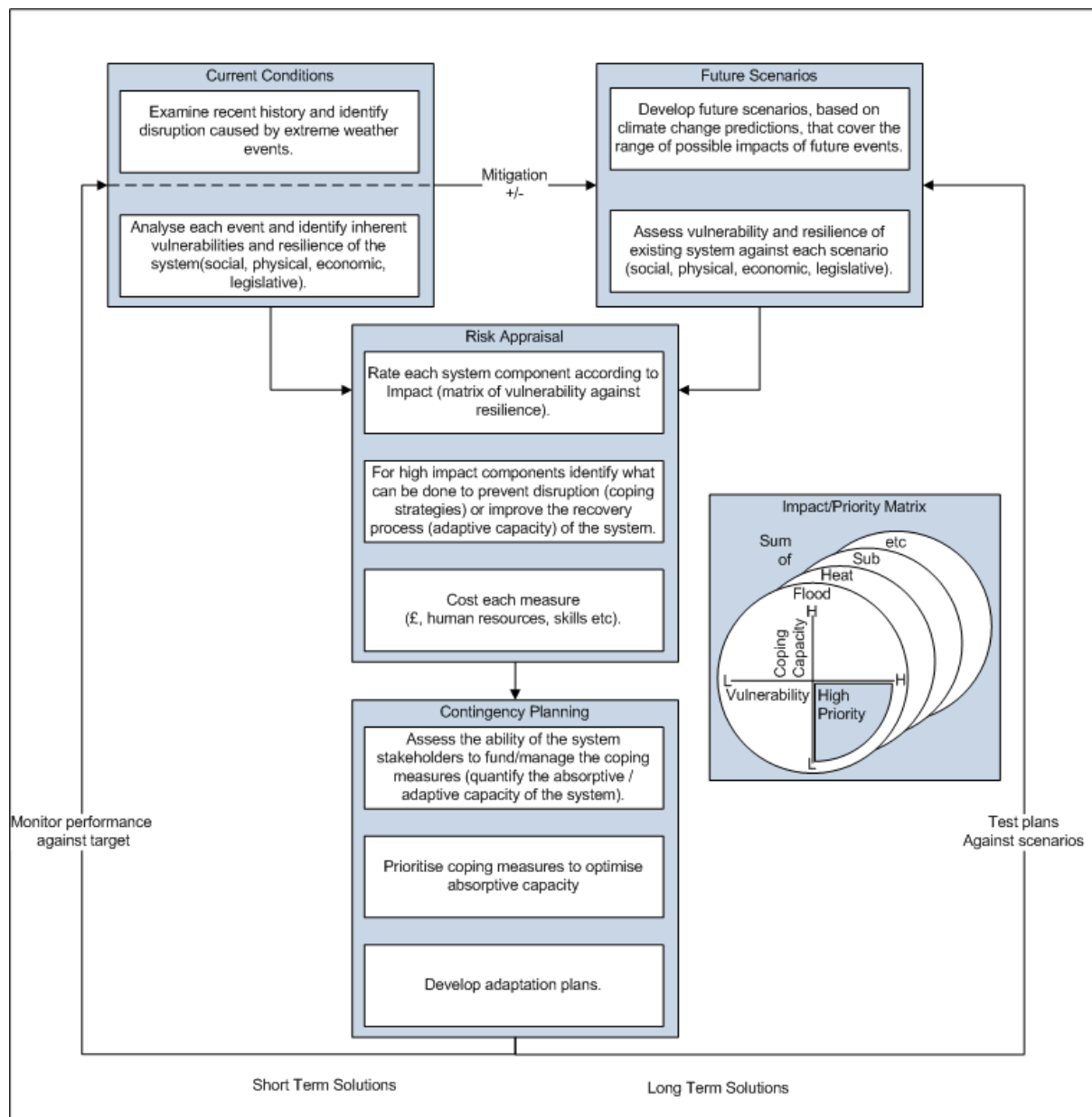


Figure 1. Climate Change Adaptation Framework Model

4. RESEARCH METHODOLOGY

This project applied an Action Research methodology that involved a team of researchers and practitioners examining the issues associated with the implementation of the climate change adaptation framework model to the design phase (RIBA Stage D) of a new £75m educational building being developed by the University of Greenwich. Action Research seeks to use theory to drive changes in practice by studying the impact that context has on the journey towards an end-goal. Through a series of iteration cycles (Planning; Implementation; Reflection; Review) the impact of theory is assessed and refined until the end-goal is achieved or the journey is abandoned. (Lewin & Cartwright, 1975; Heron & Reason, 2001). This approach fitted well with the research challenge of this project.

The Action Research project commenced in October 2010 and was completed in June 2011. The Action Research team comprised representatives from the Architects; Building Services Engineers; Structural Engineers; Quantity Surveyors; the Client (represented by the Facilities Management Department); and the authors to this paper. In addition, specialist input to the project was provided by a climate change expert who developed the climate impact models. The Action Research team met formally on 4 occasions. Each of these meetings was in the form of a 1 day workshop. Between workshops members of the team worked in small groups to develop, test and refine their inputs. The first meeting established the focus for the project; developed a set of questions for the partners to investigate; agreed procedures for data gathering/analysis; and outlined a set of deliverables for the second meeting, which were mainly concerned with an assessment of the antecedent EWEs (Current Conditions in Figure 1) and the identification of future climate change risks (Future Scenarios in Figure 1).

At the second meeting the Action Research team received a climate change risk report that identified current and expected risks aligned to the predicted first and second refit of the building (2020 and 2040) and design life (2080). The risk reports were generated using the UKCP09 (median prediction emissions scenarios) to produce likely weather scenarios and associated building impacts on: Internal Comfort & Building Façade; External Comfort; Structural Stability; Infrastructure; Water Supply; Drainage & Flooding; Landscaping; and the Construction Process. Although a wide range of EWEs were examined, due to limitations in national data sets the final analysis was limited to issues of thermal performance, where a 3.8-4.8°C rise in annual mean temperature above the control period was predicted by 2080 and pluvial flooding, where an increased risk was identified to the basement areas and attenuation tank capacity.

Once the weather data had been presented, the Facilities Management members of the Action Research team developed performance specifications, in terms of operational expectations for 2020, 2040 and 2080, and the design members analysed how their design solutions would perform against each specification (Risk Appraisal in Figure 1). In particular 4 questions were considered: 1) Would rooms overheat in the future? 2) What will be the impact on the annual energy loads? 3) Can the chiller specification cope with the increased load? 4) How will solar gain change in the future? These analyses were presented to the whole Action Research team at the third workshop. As this project was solely concerned with the impact of climate change no account was taken of other future scenarios (e.g. economic, political etc).

The third Workshop examined the design implications of the questions outlined above. The performance specifications provided the 'operational targets' from which costed adaptation solutions were 'back-cast' to ensure that the building would meet its targets over its life-cycle

(Risk Appraisal in Figure 1). This process identified twenty five adaptation measures which were tagged as ‘do now’, ‘2020’, ‘2040’ or ‘2080’. Each adaptation was evaluated against the following principles:

1. Measures that required structural alteration were recommended to be undertaken immediately irrespective of their actual required implementation time.
2. Measures that required changes to system or component capacity were only to be implemented when required but consequential structural and space planning issues were implemented (as 1)
3. Each measure was considered in terms of its impact on the current design and modifications introduced to facilitate a future retrofit.
4. Those measures that were identified but for which the UKCP09 weather data provided no firm direction were assessed on their merits. This particularly applied to the risk of flooding where preparation was undertaken even though the likelihood of future events was uncertain.

At the final workshop each of the detailed adaptations were considered and either adopted or rejected by the client team (Contingency Planning in Figure 1). Of the 25 detailed adaptations developed through this process, seven were adopted immediately and included in the final detailed design. The remainder formed part of the future asset management plan. The full list of adaptation measures can be seen in Table 1.

Table 1. Adaptation measures and implementation schedule

Risk	Adaptation/ Comment	Implementation			
		Now	2020	2040	2080
Overheating	Alter the current glazing system to allow for openable windows to be easily installed in future			•	•
	Install additional chillers on the roof		•	•	
	Future thermal design modifications should be based on an adaptive comfort model		•	•	•
Overheating and Energy Use	Introduce a ‘siesta’. Behavioural adaptations were seen as beneficial and could limit the predicted thermal issues. However it would impact on the usability of the building.	•		•	•
Reduced Heating Load	Replace boilers with an increased number of smaller sized units			•	
Insufficient comfortable external areas	Allow all building users to access the roof areas	•			
	Introduce shading to external spaces				
	Introduce external water features				
Increase in cooling load	*Allow for an increase in plant and riser space	•			

Infrastructure failure (electric)	*Add access control to the standby generator	•			
Infrastructure failure (gas)	Include for an electric back-up form of heating (GSHP)			•	
	Increase hot water storage			•	
Infrastructure failure (water)	Increase the cold water storage			•	
Infrastructure failure (drainage)	Increase size of Attenuation tank				•
Increase in storm activity	Increase capacity of rainwater pipes & drainage				•
	Increase roof capacity to store rainwater				
	*Permanent flood protection measures to basement areas *Include adaptable door frames for door dams Increase the height of the retaining walls	•			
Failure of drainage system	*Connect drainage system to the BMS	•			
Increase in groundwater level	*Provide adequate build-up above the tank to avoid flotation	•			
Increase in water costs	Introduce waterless urinals			•	
	Add a rainwater recycling system				
Waste from refurbishments	Upgrade facade systems with recyclable materials	•			
Insufficient cycle storage spaces	*Increase the cycle store capacity	•			
*denotes that the adaptation identified was approved and preparatory work was implemented at the design stage to allow future upgrade when the need became critical (e.g. in 2020, 2040 or 2080)					

The adaptations generally fell into three categories; immediate implementation of the adaptation solution as part of the original build; implementation of preparatory work as part of the immediate build to allow for a planned future upgrade; or operational changes to the building. An example of an immediate implementation was the inclusion of a backup generator to run essential services in the event of a flood. Although the building was not currently at risk of flooding, the future flood risk assessment had identified a potential risk to the critical power infrastructure that supplies the building. This risk, whilst unquantifiable at present, was never the less considered serious enough for the Facilities Management team to advise the client of the need to build in a contingency against this possibility as part of the initial design solution. Examples of preparatory work include an increase to the plant and riser space within the building to accommodate a future increase in chiller capacity for

cooling (circa 2020) and allowance for a change to a modular based boiler installation to accommodate a reduction in installed heating capacity as demand reduces over time. Examples of operational changes were adopting a relaxed dress code (staff) and not programming classes for the middle of the day to encourage behavioural adaptations to the thermal environment within the building. The changes were expected from 2020 onwards.

5. DISCUSSION

There is an emerging body of work considering the likely impact of climate change on building performance that are based on simulated predictions and risk based decision making. This study outlines how such an approach could be applied in a systematic manner and embedded in the building design/asset management process. The study aimed to consider the likely climate change impacts to the building on a whole-life basis, identifying adaptations that could be included in the original design, or/and implemented with the 2020, 2040 or 2080 interventions. Such an approach will help to produce a more realistic picture of the buildings likely resilience to climate change. The focus of this paper was to test an adaptation framework and identify the barriers to its application in the design/built asset management process. An Action Research approach was used to refine the original theory in light of the barriers encountered.

The original theory envisaged a 4 stage model to assess and plan building level adaptations to climate change. A number of difficulties/issues arose at each stage of the model.

At Stage 1: There was limited information available to assess the current impact of EWEs on the performance of the building. As such, creating a realistic frame of reference from which to explore the impact of future climate change proved difficult. Indeed, there was considerable scepticism amongst the design team as to the impact that future climate change would have on the building and resistance to considering these impacts at the design stage. These concerns were heightened at Stage 2 of the model where the inability of the UKCP09 projections to produce quantifiable weather patterns at the building scale (UKCP09 is based on a 5km² grid and scaling this down to a particular site is difficult) made it difficult for design professionals to develop specific adaptation solutions. This was especially true of predictions relating to rainfall intensity and flood risk which potentially will have greatest impact on the usability of the building going forward. At both these Stages it was the presence of the Facilities Management team in the group that drove the project forward, constantly reinforcing the importance of this project from the client's perspective and ensuring that the design team took the scenarios seriously and didn't simply play lip-service to the development of adaptation solutions. To reinforce the scenarios the Facilities Management team developed a series of future performance specifications for the building that required detailed adaptation solutions to be developed, tested and programmed into the built asset management strategy. These specifications effectively set the end point (e.g. system requirement in 2020, 2040 or 2080) from which the various design teams had to work their adaptation solutions back from. In this way interim solutions that would be required on the adaptation journey could be clearly identified and, where necessary, changes made to the initial design to accommodate the adaptation solution. This approach represents a change to the traditional forecasting model of built asset management.

At Stage 3 of the model the main issue to arise was timing of adaptations. The professional design team working on the research project were also working on the main building project. As such, they had a detailed understanding of the building and were able, once they had accepted the climate change projections, to develop technical adaptation solutions (although

there was some resistance when their previous decisions were revisited or called into question). What the design team found more difficult was to visualise how these adaptations would be implemented at the 2020, 2040 and 2080 points of the buildings life-cycle. This was particularly true where future adaptations required preparatory work to be included at the initial design stage. For example, the potential need for a larger attenuation tank by 2080 was identified but providing the infrastructure for this at the design stage would significantly increase building cost. The members of the design team responsible for this area did not want their solutions to appear expensive and were very reluctant to change their design to accommodate a future upgrade. Again, it was the presence of the Facilities Management team, and the reassurance this gave to the design team that the increased costs would not be held against them should they bid for future work, that insured the design team took the issue seriously and developed a planned upgrade route should a larger attenuation tank ever be required.

Stage 4 of the model proved the least problematic (probably because the decisions could not be tested until the adaptations were required), with the Facilities Management team able to identify those adaptations which they believed would have the greatest potential impact on the building. Those measures that would not have an immediate impact were scheduled for later building upgrades unless other steps were needed to enable the later adaptation. In addition, a series of thresholds were identified as triggers for inclusion of adaptations into built asset management plans. Whilst quantifiable triggers were not set as part of this project, the built asset management strategy that will inform future maintenance and refurbishment planning does contain specific upgrade routes that can be followed should the climate impacts be realised.

6. CONCLUSIONS

This project tested an incremental approach to developing building adaptation plans that address future climate change. An Action Research approach was used to test and refine the theoretical model underpinning the approach and to identify practical barriers to the application of this approach at the design stage of a new building. The project confirmed the applicability of the approach and identified the proactive role that the Facilities Manager played in ensuring the project success. The Facilities Manager ensured that whole-life considerations overrode the short term considerations of the design team. Without the Facilities Managers setting future performance targets it is unlikely that the design team would have produced detailed adaptation based solutions for 2020, 2040 or 2080. Whilst this may not be a traditional role for a Facilities Manager, if adaptation to climate change is to be taken seriously then the authors would suggest that they should be key members of the design team.

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