Adaptation Challenges for Healthcare Infrastructure in a Changing Climate.

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Purpose – The paper aims to discuss the relationships between the phenomenon of climate change, and the requirement for adaptation for healthcare infrastructure. It discusses the climate change debate, and demonstrates the linkages between climate change and sustainability in the context of healthcare infrastructure. Refurbishment is proposed as the only realistic opportunity to incorporate adaptation requirements within the existing healthcare estate. The paper proposes that a practical and user-friendly decision support model is required to facilitate the selection of 'best fit' options that also satisfies the mandatory requirement to demonstrate value for money in capital spending.

Design/methodology/approach – An extensive literature review was undertaken. An integrated approach to the dimensions of climate change, adaptation, sustainability, healthcare infrastructure, and decision-making requirements of the business case process has provided the contextual framework for the paper.

Findings – The paper identifies the critical requirement to understand the issues of adaptation and decision-making in the context of scale. It is discussed, that there is a lack of willingness to engage on healthcare and infrastructure projects, and that preference is given almost entirely to assets in regard to commercial evaluation, as opposed to service provision requirements, and civic functionality. The success of a high-level healthcare infrastructure scale adaptation strategy, is shown as being dependent upon the success of the design and adaption decisions taken at facility level by the relevant clinical and design team actors. A simplified and integrated decision-support model is required to identify key criteria and measure preferable options.

Research limitations/implications – Although beginning on a wider scale, the discussion narrows primarily, on the requirements of the UK NHS and the business case requirements of its capital investment process.

Originality/value – The study recognises importance of widening the debate and research in terms of healthcare infrastructure adaptation in the context of ongoing and future climate related events. It is shown; that a clear gap exists in this area. The paper also supports the development of a decision support prototype as the physical output of a three year PhD research project.

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Introduction

Regardless of the point of view taken in regards to climate change and it's causes; recent and ongoing extreme and gradually occurring weather events are clear evidence that society and the infrastructure supporting it, are being increasingly affected, and at the same time, becoming increasingly more vulnerable to its effects. For society to build resilience and adaptive capacity, decisions must be taken to modify, improve, or change the existing infrastructure. Infrastructure, in the context of the paper, is identified as the utilities and assets, which serve society as a whole. Nowhere is this felt more keenly than in the area of healthcare provision. The hospital, as the 'front line' infrastructure facility required to react to and cope with any scale of negative impact on society as a whole, is placed at the centre of the adaptation challenge. The challenge, in this context is multi-faceted, demanding that the facility as a built asset is resilient to extreme climatic effects, that it also has the ability to function in its capacity as a provider of essential healthcare services, and that it satisfies both of these requirements in a phase of economic austerity not experienced in recent times. In this context, the decision making process is key, especially in terms of finding a 'best fit' set of options that must allow for the consideration of *acceptable* 'trade offs'. This paper discusses these issues and identifies the linkages between them, before exploring the basics of a simple decision making model

Climate Change: the Argument

There is little doubt, that the issue of climate change has been an area of intense debate and argument in both scientific and political circles. This argument however, requires more detailed consideration. It is crucial to appreciate what the argument 'actually is' from the perspective of involved parties across the spectrum. These viewpoints are key to providing context on the drivers and/or barriers to the prioritisation, planning, and physical interventions to the healthcare estate.

In economic terms, and for reasons associated with national revenue creation and tax collection, it seems that the main political parties in any country, are (perhaps?) susceptible to pressure from industrialists and investors in heavy industry to adopt a laissez faire approach to the issue of climate change, and to not interfere with the status quo. At the other end of the spectrum, democratically elected governments are undoubtedly subject, through the electoral process, to the will of the people, and as such are forced to accept, or at least consider, the social zeitgeist. This apparent conflict of interest lies at the heart of the climate change argument. The argument in this context seems swayed towards the debate on whether human beings are actually responsible for the effects of a changing climate (whether wholly or partly), rather than the more fundamental and practical discussion on whether climate change as a phenomenon is *happening at all*. If, as proposed by many action groups and environmental bodies such as *Friends of the Earth, Greenpeace, Campaign Against*

Climate Change, (as representative samples) the effects of climate change *are* indeed as a result of human activities; then it would be difficult to argue against the fact, that we as a species, have a moral and sane obligation to effect changes to our social and industrial behaviors in order to mitigate the negative effects. Those who hold the belief that climate change is a wholly natural phenomenon, (Again, from groups such as *Exxon-Funded Skeptics, Heartlands Institute,* or *The Tea Party*) independent of any human activity, take the view that applying strict regulations and economic responsibilities to a naturally occurring event, is an unacceptable, or even damaging approach, especially in economic terms. This does however, highlight that the debate is a continuum, and the examples cited are selected from the opposing ends of the scale. This distance of opinion is absolutely key, as the opposition of viewpoints illustrates what is perhaps, the most basic barrier to consensus.

Climate change as an issue, is a vast field in both scientific and political debate, and the very term itself is open to interpretation, or misinterpretation dependent on a wide range of opinions, beliefs, interests, or a range of other human variables. VijayavenkataRaman et al [1] identify the phenomenon as…

"…a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or more)"

The existence of such statistical variations was presented by Mann [2] in his much recognised (and itself much debated) 'hockey stick' model, which collected data from thermometers, tree rings, corals, ice cores, and historical records suggesting that over the measurement period of 1000 years, a rapid climb in temperatures has been occurring since the turn of the 20th century. The main identifiable reason for this rapid climb, has been attributed to the release into the atmosphere of *green house gases* (GHG). The Third Assessment Report on Climate Change [3] found that between the years of 1750 and 2000, carbon dioxide concentrations have increased by 31%, methane by 151%, and nitrous oxide by 17%. The Mann model however, is only one of many on the subject of atmospheric measurement. It would be remiss not to refer also, to the work of Charles Keeling [4] whose data measured the definitive increase of CO2 levels worldwide since the late 1950s (this being the start point of his measurements). Perhaps more significantly, the 'Keeling Curve' is a representation of the increase of CO2 resultant from the burning of fossil fuels, and the subsequent release of GHG into the atmosphere. This places the smoking gun, or at least part of it, at the feet of industrialised human beings. The description of these two key climate change models has been presented here in simplistic terms, and it is understood that all science and related modeling must have caveats. However, and on the face of things, the correlation between temperature rise, GHG concentrations, and the exponential increase in each models measurements and character, appear to create predictable and repeatable trends.

A simple approach to the divided views on the existence of climate change was presented within the *Report of the United Nations on Environment and Development* [5] The report officially recognised the *precautionary principle.* The interpretation of the precautionary principle in the context of climate change and its effects, were presented as…

"Where there are threats of serious or irreversible damage to the environment, lack of scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation"

It is significant to note the direct reference to the 'cost effective', or economic aspect of the climate change debate. In real-world practical terms, the structure of the worlds economies and market instruments, pose what is perhaps the greatest barrier to a *global* consensus and subsequent action, not to mention public appetite and associated political will. The 2006 Report, *The Economics of Climate Change* [6] progressed the debate, purely in terms of economics and finance. The report proposed that as…

"The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent response"

The basic ethos of the precautionary principle appears to be reiterated, although measured more quantitavely against the GDP figures of the worlds national economies. The report advises on the benefits of early action with strong political will, and recognised that although there will inevitably be costs; the potential costs of inaction are almost incomparable in scale and severity. It is thought provoking to reflect upon the timing of the Stern Report in comparison to the subsequent collapse of the Lehman Brothers Bank in 2008 [7] It is considered by many, that the collapse of Lehman Brothers was the beginning, and perhaps the catalyst, of the global economic crisis. The effects on world banking, and especially on the economic lending instruments have been powerful and rapid, and has had significant effects on the healthcare estate. Precisely the type of global participation and investment required in the recommendations of the Stern Report have, arguably, shifted on the priority list of countries and states whose immediate goal is to simply avoid national bankruptcy. In addition to this, both the precautionary principle and the findings of the Stern Review highlight *human specific* challenges, which have the capacity to prevent any real concerted action on a global scale. McGuire [8] clarifies this observation, and discusses the nature of human ability to fully comprehend dangers, which he termed 'long emergencies'. He argues that human risk assessment evolved to react to near or present dangers, such as imminent invasion or attack, but the 'hard wiring' required to identify and strategically plan for threats of a more stealthy or long term nature, are absent on a species level. He continues, using as an example, the United States reaction following the attacks on Pearl Harbour in 1941 as a measure of large-scale group action in the face of imminent threat. In a six-month period following the attacks, the entire US economy reset itself with astonishing success, on an unprecedented scale to engage in a global conflict on multiple geographical fronts. To some therefore, it may seem surprising, that given the mounting scientific evidence and predictions of irreversible natural, social, and economic change (for the worse) on a global climatic scale; the social and political will (despite the global economic challenges) remains at best 'fragmented', and at worst 'indifferent'.

Climate Change and the Built Environment

Mirroring the climate change argument itself, the relationships and subsequent effects of changing weather patterns and temperature fluctuations in regards to the built environment, are inevitably an issue of *scale*. On the macro scale, societal infrastructure is placed in an increasingly vulnerable position due (in part) to the high population densities of the modern worlds cities. In the foreword to the book *Resilient Cities* [9], Zimmerman presents the stark projection that the current city dwelling populations of the planet (whom are measured at almost half), is set to rise by 2050 to a statistical projection of 70%. Given that the majority of these figures refer to the rapidly expanding 'urban poor' population, especially in developing countries, it follows that those most affected by extreme weather or climate related events (again, in regards to scale), are likely to be those least able, geographically and economically, to deal with or recover from them. Extreme weather events are by no means restricted to the developing world however, as the 2012 Hurricane Sandy has demonstrated in New York [10] Infrastructure was paralyzed, and tens of thousands of city residents were placed in a vulnerable housing situation. It should be borne in mind that this particular 'event' was fully expected and preparatory procedures were put in place on a mass scale, and yet the effects were still devastating. Compare this also to Hurricane Katrina; again, a devastating major weather event affecting one of the most developed and affluent countries on the planet. Focusing still, on the macro scale, extreme weather events have been commonly expected on practically an annual basis in many parts of the world, although the increased urban density and expanding population have the exponential capacity to affect more people and the infrastructure supporting them. A recent example, close to the time of writing, is the devastating 'Typhoon Bhopa' in the Philippines island of Midanao [11] which is projected to have destroyed up to 80% of the agricultural capacity, with an economic cost of circa $98m. On the other end of the spectrum (or the micro scale) the observer can see immediately, the level of destruction caused to individual properties and public buildings. In human terms, disruption or contamination to vital infrastructure services, such as the water supply, or transport networks, introduces the potential to promote the spread of infectious diseases or food shortages, respectively. Both of these examples ultimately place pressure on the infrastructure 'cornerstone' of *healthcare provision.* It may be argued that damaged or destroyed social infrastructure (in the form of built assets) are capable of contingency planning, but the hospital, and the healthcare function are perhaps the last, and most critical, line of defence.

Climate change effects are not however, restricted to such extremes as *catastrophe scale* events. As discussed in the Mann [2] *hockey stick* model, one of the most noticeable effects of a changing climate, is the measured and recorded rise in global temperatures. Short et al [12] provide one of the more explicit examples of temperature related effects in discussing the 15,000 "excess" deaths from the effects of a heatwave in Northern France in 2003. In the summer of 2006, the increase in heatwave related deaths in the UK was measured as adding an increase to the baseline mortality rate of 4%. It is emphasized here, that these deaths are not the result of a geographically targeted event, but measured on a national scale. Aside from the obvious observation that the death rate spikes dramatically, potentially from the effects of changes in the climate; as with the 'last line of defence' analogy given above in relation to large scale events, it is the existing healthcare infrastructure which is the ultimate institutional body on the front line of the society's situation management. The 2005 Report *Measuring Progress: Preparing for climate change through UKCIP* [13] identified the major predicted effects that climate change may have, specifically related to the built environment. As with many other aspects of this issue, these must also be viewed in the context of scale, although the primary areas of potential danger are recognised as thermal discomfort in buildings (which, if related to the previous example, affect the practical requirements for an increased demand in summer cooling), storm damage and flood damage, alongside the regional shortages of water supply. These examples are far from exhaustive, and it is impractical to identify and address a single specific occurrence or effect. The nature of the built environment, the infrastructure supporting it, and the behavior and demographic patterns of human beings, demand that an integrated approach be taken.

The Requirement for Adaptation

It has been identified that the issues of climate change, and the potential effects of the phenomena on the built environment, must be considered as a continuum or scaled process. The understanding and placement of context is critical to the identification of a problem goal, which itself is a fundamental requirement for the successful implementation of the decision making activity. Decision making in these terms is a critical process and will be explored in a subsequent section of the paper. When considering *adaptation*, a similar 'scaled' approach must be undertaken. In terms of both climate change and the built environment, the contextual positioning of adaptation requires clarification, again, on a macro and micro level. In the context of 'a' facility or building, Douglas [14] defines adaptation as…

"…any major works to adjust, reuse or upgrade a building to suit new conditions or requirements"

This is a very 'asset specific' description. A purely physical activity is described that may be planned, designed, and constructed within the normal parameters of the 'standard' project management and procurement processes. Adaptation of a single facility however, has the capacity to fail on an infrastructure basis, when measured as part of an integrated approach as described previously. Boyd and Tompkins [15] illustrate this potentially myopic approach with the example of a property owner constructing a seawall to protect their facility against 'wave attack'. This is measured as a success in terms of a singular project, however the redirection of tidal energy may have the effect of increasing the severity of erosion further down the coast on multiple facilities or properties. From an integrated and sustainability focused standpoint; could the original adaptation project still be considered as a success?

In the context of infrastructure, and accepting that regardless of the argument on the *causes* of climate change and extreme weather events, the definition and understanding of adaptation must be 'up-scaled'. Various definitions exist in the literature, however the following, taken from the *Organisation for Economic Co-operation and Development* [16] are suggested as identifying and encompassing the main aspects.

1. *Adjustment in natural human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory or reactive adaptation, private and public adaptation, and autonomous and planned adaptation* [3]
2. *…a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented* [17]

Adaptation in these terms is a far more strategic endeavor. The adaptation of the stand alone facility or building as described by Douglas [14] is critical, and yet, as with the issue of healthcare provision in 'infrastructure stressed' scenarios, it is the 'downstream' or 'end' aspect of the greater whole. Despite this linear seperation, there is no significant distance between the strategic adaptation requirements, and the physical adaptation methods employed at facility level. Figure 1 shows Boyd and Tompkins [15] 'eight elements' of an adaptation strategy. When these are considered against the 'usual' requirements and processes involved within the construction (or adaptation) of a major public infrastructure project such as an acute hospital, it can be seen that the differences are in fact slight, and only differ on most elements in regards to scale.

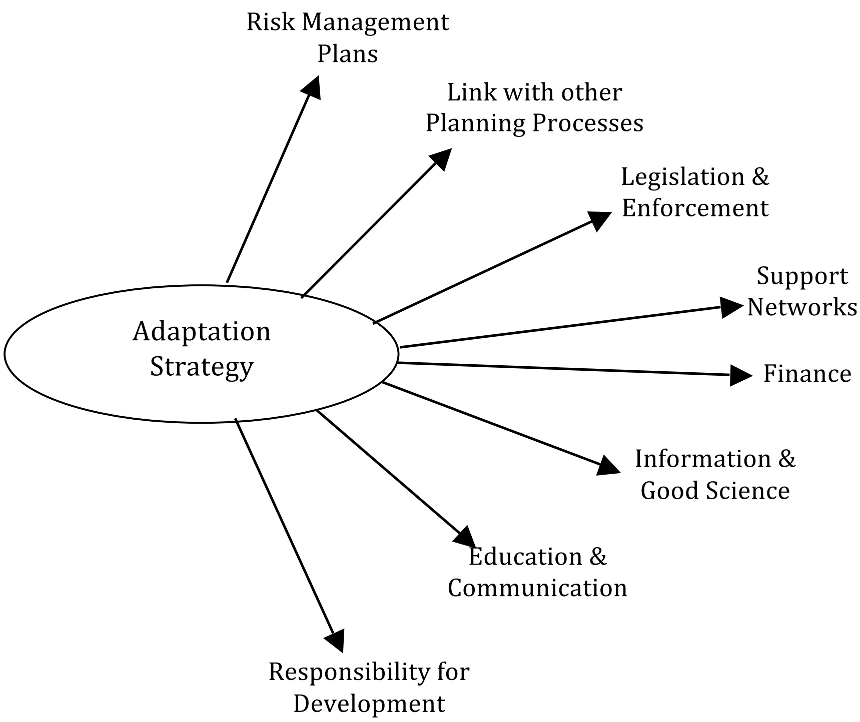

Figure 1. The eight elements of an adaptation strategy (Adapted from Boyd and Tompkins 2010 pp. 85)

Linking Climate Change to the Sustainability model

Climate change and sustainability are both issues relating to environmental concerns. The much-recognised sustainability Venn diagram shows ‘environment’ to be only one dimension of a triple dimensional model, which also incorporates ‘social’ and ‘economic’ aspects. The environment in respect of climate change may be perceived as the complete atmospheric system in which humans reside. Sustainability by its very nature, is targeted strongly towards the reduction and/or replacement in use of the earths natural resources and fossil fuels. This applies to both finite resources such as oil and coal, but also replaceable resources such as timber or (arguably) water. It could be debated that given these ‘on the earth’ and ‘around the earth’ distinctions, that sustainability and climate change are in fact two completely separated paradigms.

However, the paper challenges this separation and it is suggested that in considering the potential adaptation requirements of the urban condition, then it is not only desirable, but essential to consider climate change and sustainability as two interlinking approaches. Figure 2 models this integration and shows the cyclic and connected nature of the main activities and problem areas.

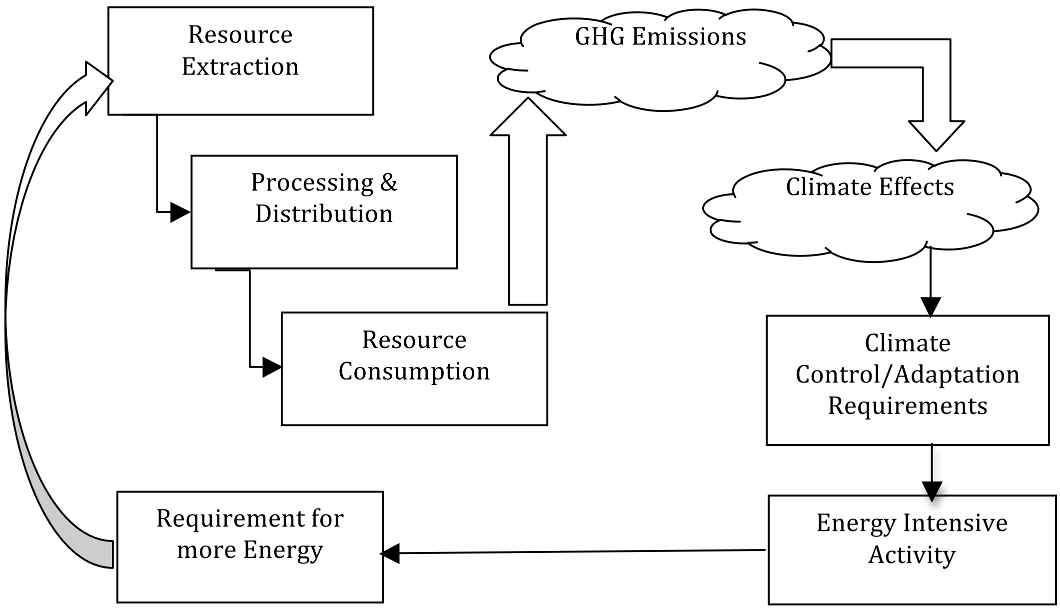

Figure 2. The climate change/sustainability link.

The model in Figure 2 is simplistic in its representation of the closed loop process inter-linking sustainability with climate change, yet it provides immediate opportunities to, firstly; identify the main interface points between sustainability and climate change issues, and secondly; to break the loop into distinct dimensions. This allows the observer the opportunity to identify optimal intervention points, designed to break or minimize the effects *and* impacts associated with each issue. Therefore, in addition to understanding adaptation in terms of scale, as previously discussed, adaptation *as an approach*, must also sit astride and incorporate both sustainability and climate change as an integrated process or phenomenon.

Healthcare Infrastructure and Adaptability

It was suggested previously that the hospital is the 'key' physical asset representing one of the main infrastructure services (i.e. Healthcare). What places the hospital within a demanding league of its own, and sets it apart from other infrastructure assets, are the 'functional requirements'. These requirements differ from the majority of infrastructure networks in the sense that the pressures placed upon healthcare facilities are multi-faceted, whether in the context of an extreme weather event or the susceptibility to the more gradually evolving effects of a changing climate. This is most clearly understood by the appreciation that in the first instance (and shared with all other infrastructure assets), the building itself is vulnerable to the effects of changes in climate and weather patterns. These effects are both external and internal in nature (for example, building fabric performance and indoor environmental quality) but are broadly driven by the same factors identified by Oven et al [18] of heatwaves, coldwaves, floods, and storms. Secondly, and uniquely, the hospital by its nature must have the capacity to treat those affected by climate related effects. This itself is a double-edged sword, in the sense that the built asset must have the capability to provide a clinical or recuperative environment (such as cooling for heat related injuries), and also that the clinical *models of care* are flexible and resilient enough to deal with medical situations as they arise. This demands that the hospital as an asset, and the provision of effective healthcare as a service, presents a critical requirement to model the integrated nature of both in the face of complex adaptation requirements. Given the number of variables associated with the hospital, and the rapidity of changes in both treatments and conditions, it is therefore surprising that the challenge of adaptation to date, has largely focused on domestic or commercial premises [19] [20] driven primarily in terms of economic evaluation. This also contrasts with Boyd and Tompkins [15] eight required elements for an effective adaptation strategy shown in Figure 1. Carter [21] takes a wider view, and suggests that across Europe, adaptation requirements present a 'very low priority' for city planners and governors. There are of course, regional exceptions such as Madrid, Manchester, Basel, Freiburg et al, but given the fact that circa 75% of Europeans live in urban areas, a figure predicted to rise to 80% by 2020 [22], this apparent reluctance to engage on a city or national scale is perplexing.

The Role of Refurbishment

Adaptation of the healthcare estate has been considered so far, mainly in the context of strategic planning requirements. However, referring back to Douglas's [14] definition of adaptation specifically in the sense of the physical built asset, it naturally follows that strategic plans must ultimately equate into physical works or actions. An understanding of the relationship between adaptation and refurbishment is a key point, and Douglas [14] recognises this in placing refurbishment as a 'level of intervention' within the overall adaptation process. Markus [23] highlighted the …'unhappy confusion' of terms used interchangeably when considering building adaptation, refurbishment, alteration, or maintenance. At face value, this distinction might be considered as merely an exercise in semantics, however the legislative, regulatory, and funding requirements of capital release on hospital refurbishment projects (certainly within the United Kingdom) are highly prescriptive in nature. The current assessment model used (predominantly) in the UK, is the BREEAM assessment tool currently addressing what it terms 'major refurbishment' projects. The criteria identifying a major refurbishment are offered as…

"For the purposes of a BREEAM assessment, a major refurbishment project is a project that results in the provision, extension or alteration of thermal elements and/or building services and fittings. Thermal elements include walls, roofs and floors. Fittings include windows (incl. rooflights), entrance doors. Building services include lighting, heating and mechanical ventilation/cooling" [24]

There are a number of factors which need considered in regards to the refurbishment activities described within the BREEAM assessment (and guidance) In the first instance, the fact that the UK Government has legislated to demand a BREEAM assessment as a mandatory design and construction consideration may be justifiably viewed as a welcome step in the right direction. The other side of the argument however, also has merit in viewing the success of BREEAM application as part of the problem rather than solution. Stringent legislation and inflexible prescriptive requirements within the assessment methodology impress many practitioners and user groups with the emergence of additional layers of bureaucracy and cost which, when measured against wider sustainability aims, provide negligible effect when viewed through the lens of value versus cost. Implementing adaptability-focused changes to the refurbishment process of an existing facility requires an understanding of the pro-active/reactive connections between the activities and drivers of adaptability, refurbishment, resilience, and vulnerability. Figure 3 shows the characteristics of these connections.

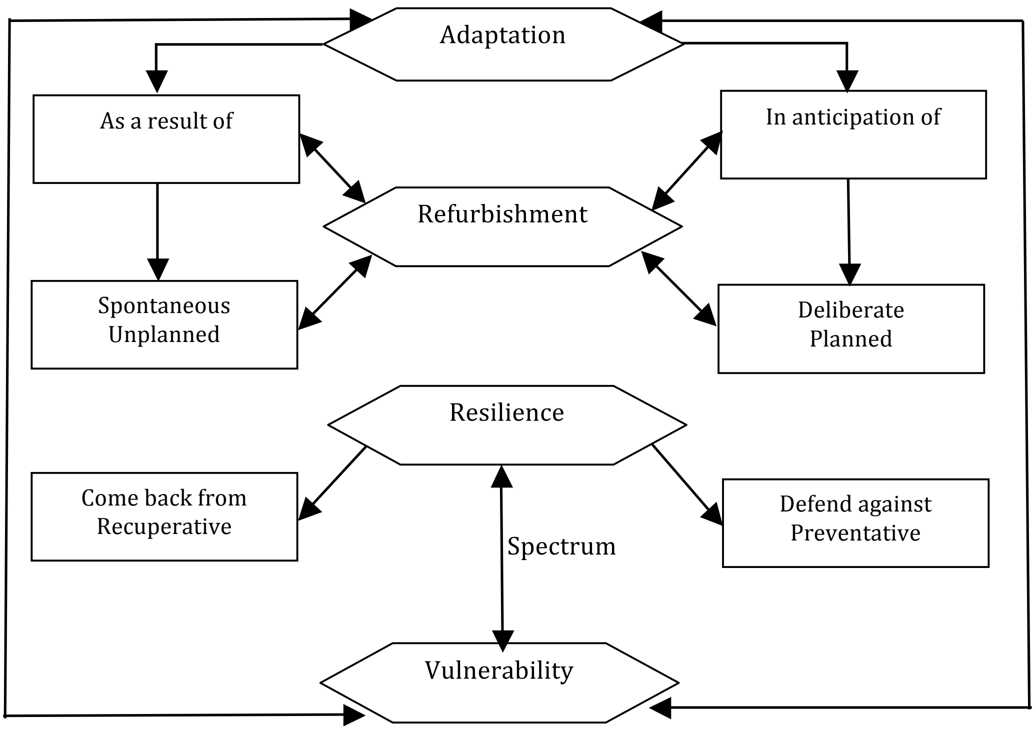

Figure 3. The proactive and reactive relationships of the structural/facility adaptation process

In terms of finance and resource, it is unrealistic to consider a complete new-build of the existing healthcare infrastructure within an adaptation strategy. Similarly, it is not feasible to carry out adaptive works on every hospital or healthcare facility without the already existing drivers encountered for commissioning a 'standard' healthcare refurbishment project. This suggests that refurbishment may be the only *realistic* physical opportunity for adaptive capacity to be designed and built into existing facilities. Again; using the BREEAM assessment as an exemplar, adaptation does feature through credits such as 'Potential for Natural Ventilation' and 'Flood Risk' but adaptive structural capacity as a *targeted activity* is not recognised as a stand-alone section or set of criteria. Many of the credits within this (and other) assessments, can be placed within the climate change/sustainability loop shown in Figure 2, but does this target the adaptive requirements specifically enough?

Notwithstanding Markus's [23] observations on the myriad and often mixed definitions between adaptation and refurbishment et al; in practical terms of securing money from the public purse to carry out adaptive capacity works, and to place criteria within a regulatory framework for Facilities Managers and Contractors, it seems most logical and least complicated to insert adaptation more prominently within the existing processes and methodologies. This approach is clearly discernible within Boyd and Tompkins [15] 'eight element' requirements for an effective adaptation strategy, most notably against the elements of linking with other planning processes, legislation & enforcement, and finance. This is not to say, that the issue of adaptation of the built environment and its relationship to climate change is being ignored. On the contrary, there is a great deal of consultation and discussion ongoing across departments. The Scottish Government (as an example) is arguably one of the most pro-active in their policy commitments, evidenced by publications such as the *Built Environment Sector Action Plan* [25] or exampled more specifically within the healthcare sectors key guidance documents such as the *Property Appraisal Guidance for NHSScotland* [26]. This last, categorically states that it is a mandatory aspect of the guidance for a climate change impacts and 'suitable' adaptation strategy, to be included as part of the overall environmental management process. How well the individual Health Boards respond to this remains to be seen, however, a common thread throughout the guidance and publications, is the identification of 'the problem', and the identification of the 'requirement' to evaluate and plan for the problem. However no clear strategy or integrated methodology that facilitates the decision making process in selecting and implementing cost effective, and real 'physical interventions' to the existing built healthcare estate, exists (in a formalised and measurable form)

The Importance of Decision-Making

The process, or activity, of decision making, is all around us. In reference to the earlier discussion identifying the importance of 'scale' in regards to climate change and adaptation, this is no different for the decision maker (DM) when faced with the requirement to find a 'best fit' solution. Bouyssou et al [27] define the decision and evaluation models (within the context of formal techniques) as:

"A set of explicit and well-defined rules to collect, assess and process information in order to be able to make recommendations in decision and/or evaluation processes"

Loken [28] clarifies this further in identifying the DM (at the most fundamental level) as being concerned with attaining what he terms the "optimal solution". This is highly significant and again, revisiting earlier discussion in the paper, a common understanding of the semantics and linguistic framing of the issue under consideration is vital. De Boer et al [29] present this in the context of the climate change 'mitigation' versus 'adaptation' argument. Mitigation in this sense, being the endeavor of reducing the source reasons for proposed climate change, and adaptation accepting that climate change events are occurring and taking physical actions as necessary. Historically viewed as two completely separate issues, the growing frequency of extreme weather or climate related events seems to have forced these two issues together. Skirting the climate change argument, the undeniable fact is that these extreme weather events 'are' happening and as such, decisions in regard to adaptation strategies are becoming far more mainstream. There is an irony in the field of decision making however, and this is recognised within the *Encyclopedia of Decision Making and Decision Making Technologies* [30] in that, the rapid growth and vast expansion of techniques in the decision making field, have presented the DM with an intimidating range of options on methodology choice. In essence; the decision to select an appropriate decision making process, in itself requires a decision making process for the decision *maker*.

In application to the adaptation of the healthcare infrastructure, the DM is immediately confronted with the need to consider the issue in the context of scale. Governmental and institutional policy and guidance are becoming increasingly familiar to the Facilities Managers, Estates Managers, Healthcare Practitioners, and Design Teams associated with the physical interventions to the built asset. However, in practice, these may be viewed as merely identifying the high level issues associated with climate change and adaptation, without any 'facility specific' direction on 'how' to best proceed. Morrisey et al [31] agree with this perspective, suggesting that there is a noticeable weakness in the integrated decision making process for infrastructure projects, specifically at the 'micro' level. In terms of the actual realization of adaptive benefits to the facility, the decision making process itself is only part of the process. The NHS, as a publicly funded body, is subject to strict controls and requirements as evidenced (for examples sake) by the *Scottish Capital Investment Manual* [32] which clearly states the 'duty' of the decision makers to demonstrate that 'Value for Money' has been achieved. This is arguably, an extremely challenging task in terms of provenance, unless the decision making process can be measured and quantified. How could the observer know, that the decisions undertaken within the early design and specification stages address both the adaptive requirements of the facility in terms of extreme weather resilience, whilst also demonstrating that this has met the mandatory 'duty' to demonstrate that Value for Money has been achieved?

There is no simple solution, nor (and mirroring the general ethos of all multi-criteria decision making techniques) is there necessarily an absolutely right solution. In this context, the DM is presented with the challenge of finding a 'best fit' solution, which is subject to compromise and trade off, dependent upon the unique specifics of the facility and business case in question. Zarghami & Szidaroszky [33] capture the main dimensions of the decision making process in suggesting five step process (Table 1)

Step	Activity
1	Identify Goal (and Objectives)
2	Identify Criteria
3	Identify Alternatives
4	Alternatives/Criteria Evaluation
5	Make Decision

Table 1. 5 Step decision making process (adapted from Zarghami & Szidarovszky 2011)

The decision making process is fundamentally a human endeavor, and as such it is argued that the process can only be automated to a degree. This is more prevalent the more detailed the issue becomes in regards to scale. Morrissey et als [31] identification of the weakness in this 'micro' scale is reiterated. Regardless of the high level commitments and political rhetoric in regards to the dangers, wants, and needs of issues relating to climate change and adaptation; it is at the point of Client/Design-Team/Stakeholder interface, where the 'real' physical interventions are made; these being in turn, as the result of 'some form' of decision making process.

The Basic Characteristics of an Integrated Decision Making Model

The paper has reviewed the context for a decision making model, and also highlighted the basic steps required throughout the decision making process. It is important however, to highlight the essential characteristics of a decision model in terms of the identified decision makers' themselves, and the parameters and limitations of the models design. Primary research has overwhelmingly recognised the need for simplicity and familiarity for use by a decision making team which encompasses both clinical and design oriented backgrounds. An uncomplicated, and navigable graphical user interface is key to this process. Clear guidance and direction on identifying a discrete (or workable) range of criteria and options is a critical aspect of the models design. To this end, the research has identified that the models prototype development, must allow for a process of discussion and consensus between the assorted professional disciplines, and allow also, for the quantification and measurement of subjective values by means of simple weighting and comparison calculations. Additionally, a clear visual representation of the models results, with the inbuilt ability for non-financial and financial sensitivity analysis, is ultimately the key (stakeholder oriented) objective of the completed prototype. Finally, and of especial significance in considering healthcare infrastructure, any model must have the flexibility to pursue 'best fit' solutions in the context of scale, from the wdier healthcare infrastructure on national or regional basis, down to the specific requirements of the individual hospital or healthcare facility.

Conclusions and the Way Ahead

The connections between climate change and the requirement for adaption to the healthcare infrastructure have been discussed. It has been proposed that regardless of 'whom' or 'what' is the cause of global climate change, extreme and gradually occurring weather events are here, and they are a fact. The hospital especially has been discussed as being a hub facility, but prone also to multi-faceted pressures and effects. It is a highly complex building, vulnerable to the same structural effects as any other building, and if anything, even more so, by virtue of its 24/7 requirement and significant energy requirements. Added to this, in the event of an extreme weather event (either catastrophic or gradual), the service provision which the built asset houses, is the first and last line of defence for the modern society, especially perhaps, those in urban areas. An overly prescriptive or dogmatic set of assessment tools and guidance documents etc, must be integrated within a simplified, effective, and time horizoned decision making process. This paper has discussed all of these issues in context, and recognised the foundation requirements for a logical and formalised approach to identifying adaptation requirements, and implementing them by a process of prioritised decision making. Integrating the clinical, functional, and maintenance needs of the hospital as a built asset, is identified as fundamental to the adaptive and cost effective requirements across the entire healthcare estate. The background and the context of this paper, support a PhD research programme that seeks to develop and test a simple and integrated decision support prototype, for the sustainable refurbishment of hospitals and healthcare facilities. The wide, and often restrictive, parameters and variables associated with the physical and administrative aspects of works to the NHS Estate, themselves support the requirement for a facilitated and user friendly system to be developed. The use of the sustainability model as the basis for criteria selection, allow for the social, environmental, and economic dimensions to be considered from the outset. The over-arching driver for this, being the clearly evident pressures placed upon the healthcare sector through climate related effects. This approach in turn, intends to encourage closer integration between the requirements of the built asset in capital spending terms, and the real non-financial benefits associated with public health provision in the context of patient and practitioner satisfaction.

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